REGIONAL TSP STANDARDS AND IMPLEMENTATION GUIDELINES

FOR THE

REGIONAL TRANSIT SIGNAL PRIORITY IMPLEMENTATION PROGRAM (RTSPIP)

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DOCUMENT VERSION TRACKING TABLE

Version	Date	Description of Changes	Changes Made By:
0.1	08/02/13	Initial draft for RTA Review and Comment	
1.0	08/09/13	First draft for TSP Working Group Review and Comment	URS
1.1	08/28/13	Second draft for TSP Working Group Review and Comment	URS / TSP Working Group
1.2	08/30/13	Third draft for TSP Working Group Review and Comment	URS / TSP Working Group
1.3	09/17/13	Final draft document for TSP Working Group Review	URS / TSP Working Group
1.4	09/30/13	Final draft document for TSP Working Group Review	URS / TSP Working Group
1.5	05/08/14	Revisions made after review of RFI Responses in April 2014	URS
1.6	12/21/15	Updated URS to AECOM on document (transition effective as as of Jan. 1st, 2015). Change log added to Appendix A TSP Message Set). Added Standard Message Dialogs developed in August 2014 to document as new Appendix B. Previous Appendix B is now labeled as Appendix C.	AECOM

DOCUMENT STATEMENT OF LIMITATIONS

This Regional TSP Standards and Implementation Guidelines document presents standards and guidelines for the proposed Transit Signal Priority (TSP) system to be implemented under the Regional Transit Signal Priority Implementation Program (RTSPIP). This report is a living document and 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 during the Preliminary and Design Engineering phases of the RTSPIP to be utilized during the TSP Implementation phase of the RTSPIP.

LIST OF DOCUMENT ACRONYMS

ASN.1 -- Abstract Syntax Notation One
AVL – Automatic Vehicle Location
CDOT – Chicago Department of Transportation
CMAP – Chicago Metropolitan Agency for Planning
CMAQ -- Congestion Mitigation and Air Quality
ConOps – Concept of Operations
CTA – Chicago Transit Authority
FTA – Federal Transit Administration
I-2-C – Intersection-to-Center
I-2-I – Intersection-to-Intersection
IDOT – Illinois Department of Transportation
IP – Internet Protocol
MIMO – Multiple-Input and Multiple-Output
NEMA – National Electrical Manufacturers Association
NTCIP – National Transportation Communications for ITS Protocol
PMP – Program Management Plan
PRG – Priority Request Generator
PRS – Priority Request Server
RTA – Regional Transportation Authority
RTSPIP – Regional Transit Signal Priority Implementation Program
SAE – Society of Automotive Engineers

SEMP – Systems Engineering Management Plan
SNMP – Simple Network Management Protocol
TSP – Transit Signal Priority
V-2-I – Vehicle to Intersection

1. Introduction

This Regional TSP Standards and Implementation Guidelines document has been developed to provide detailed guidance on 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 document is to define Regional TSP Standards that must be followed by TSP Implementers as they proceed through the TSP Design Engineering phases of the program. These standards will include, among other items, the formatting of the Regional TSP message set defined previously in the Technical System Requirements document.

In addition, Implementation Guidelines are presented in this document for Pace and CTA to consider in deploying TSP systems under the program, including among other items, guidelines for installing communications equipment to maximize the efficiency of vehicle-to-intersection communications. This is a living document that will be updated based on feedback from TSP Implementers as they proceed through the TSP Preliminary Engineering, TSP Design Engineering, and TSP Implementation phases of the RTSPIP.

1.2. Project Background

Expansion of TSP systems throughout the region is anticipated in the coming years through federal Congestion Mitigation and Air Quality Improvement (CMAQ) funding programmed by the Chicago Metropolitan Agency for Planning. 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 TSP program supports the goals of GO TO 2040 and improves air quality.

The RTA is following the Systems Engineering process in planning for the implementation of a regionally interoperable TSP System throughout the Chicago region. This Regional TSP Standards and Implementation Guidelines document builds upon the Concept of Operations (ConOps) and Technical System Requirements documents previously developed. Further detail on the TSP System Components can be found within these separate documents. Further detail on the Systems Engineering process and subsequent steps to be taken by the RTA are contained in another separate document called the Systems Engineering Management Plan (SEMP).

Further detail on the roles and responsibilities of TSP Implementers can be found within the Program Management Plan (PMP) also previously developed. Pace and CTA are referred to as the Primary TSP Implementers within this document. They will be leading the efforts of TSP Preliminary Engineering, TSP Design Engineering, and TSP Implementation. Further details on these activities are contained within the separate PMP document.

1.3. Intended Audience

The intended audience for this document is the TSP Working Group, whose review and input on the Regional TSP Standards and Implementation Guidelines is important for ensuring that a regionally interoperable TSP System is deployed in the region. The TSP Working Group includes representatives from the RTA, CTA, Pace, the Chicago Metropolitan Agency for Planning (CMAP), the Federal Transit Administration (FTA), the Chicago Department of Transportation (CDOT), the Illinois Department of Transportation (IDOT), and the Lake County Division of Transportation. Further detail on the roles and responsibilities of all members of the TSP Working Group can be found in the PMP previously developed.

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
- Section 2 – Regional TSP Standards – Details the Vehicle-to-Intersection (V-2-I) TSP message set and the communications frequency used for V-2-I communications
- Section 3 – Regional TSP Implementation Guidelines – This section provides TSP implementation guidelines with respect to vehicles, intersections, and backhaul of TSP data to a central server for reporting and analysis
- Appendix A – Contains the V-2-I TSP Message Set that is to be sent from vehicles to intersections as part of the RTSPIP
- Appendix B – Defines the exchange of messages between the Vehicle and Intersection devices, and some of the actions to be taken by the devices in response to messages received through the TSP Message Set. This will reduce the potential for misinterpretation by equipment vendors regarding the intended usage of the TSP Message Set in device interaction.
- Appendix C – Contains the Technical System Requirements and the proposed Verification Methods to be used in verifying that requirements are met during TSP Implementation

1.5. Referenced Documents

1. Program Management Plan for the Regional Transit Signal Priority Implementation Program (RTSPIP). Prepared by URS for the Regional Transportation Authority (RTA). Version 1.2. March 25, 2013.
2. Systems Engineering Management Plan for the Regional Transit Signal Priority Implementation Program (RTSPIP). Prepared by URS for the Regional Transportation Authority (RTA). Version 1.2. March 7, 2013.

3. Concept of Operations (ConOps) for the Regional Transit Signal Priority Implementation Program (RTSPIP). Prepared by URS for the Regional Transportation Authority (RTA). Version 1.3. April 29, 2013.
4. Technical System Requirements for the Regional Transit Signal Priority Implementation Program (RTSPIP). Prepared by URS for the Regional Transportation Authority (RTA). Version 2.3. June 30, 2013.
5. "System Engineering Guidebook for ITS", version 3.0 dated November 2009. Available at: http://www.fhwa.dot.gov/cadiv/segb/
6. Northeastern Illinois Regional ITS Architecture. Available at: http://data.cmap.illinois.gov/ITS/Default.aspx
7. Regional Transportation Authority Mapping and Statistics (RTAMS) – Transit Signal Priority. Available at: http://www.rtams.org/rtams/home.jsp
8. NTCIP 1202:2005 – Object Definitions for Actuated Traffic Signal Controller (ASC) Units – version 02. Available at: http://www.standards.its.dot.gov/fact_sheet.asp?f=89
9. NTCIP 1211 version v01 – Object Definitions for Signal Control and Prioritization. Available at: http://www.standards.its.dot.gov/fact_sheet.asp?f=89
10. Chicago Metropolitan Agency for Planning (CMAP) GO TO 2040 Comprehensive Regional Plan. Available at: http://www.cmap.illinois.gov/2040/download-the-full-plan
11. The Way Forward: RTA Strategic Plan 2012-2016. Available at: http://www.rtachicago.com/images/stories/About_the_RTA/Strategic%20Plan/The%20Way%20Forward-Small.pdf
12. Manual on Uniform Traffic Control Devices (MUTCD). Available at: http://mutcd.fhwa.dot.gov/
13. Illinois Manual on Uniform Traffic Control Devices (IMUTCD). Available at: http://www.dot.state.il.us/mutcd/utcdmanual.html
14. Transit Signal Priority (TSP): A Planning and Implementation Handbook. Harriet R. Smith, Brendon Hemily, PhD, and Miomir Ivanovic, Gannett Fleming, Inc. May 2005.
15. CTA Transit Signal Priority Initiative: Evaluation Report for Western Avenue TSP Demonstration, September 2010.
16. Pace Transit Signal Priority Initiative: Evaluation Results for the Harvey Transportation Center TSP Demonstration Corridor, October 2011.

2. Regional TSP Standards

The Regional TSP Standards that are defined for the RTSPIP include the following two standards: 1) the Vehicle-to-Intersection (V-2-I) TSP message set, and 2) the communications frequency used between vehicles and intersections. These two standards will enable regional TSP interoperability between Pace and CTA buses and intersections throughout the region at which TSP equipment has been deployed through the RTSPIP.

2.1. V-2-I TSP Message Set Definition

A complete draft of the RTSPIP message set definition, which is a result of discussion, research and analysis by the project team, is available in Appendix A in Abstract Syntax Notation One (ASN.1) format. This draft meets the parameter requirements of the RTSPIP project, and is based from the NTCIP 1211 standard, version 1.38. In order to meet the project requirements, custom parameters are included, in addition to those already defined by NTCIP 1211. Custom parameters leverage the SAE J2735 standard, version 2009 r036, where applicable, in order to maximize the use of existing standards. Note: The message set definition is for private use only, since the proposed customization of the NTCIP 1211 standard was not registered or coordinated with NEMA.

The NTCIP 1211 standard, entitled “Object Definitions for Signal Control and Prioritization”, provides guidelines for 6 message types to be transmitted between the Priority Request Generator (PRG) and the Priority Request Server (PRS). The PRG refers to vehicle-based equipment that includes the existing Automatic Vehicle Locator (AVL) system and any additional equipment needed to send a V-2-I TSP Message Set. The PRS refers to intersection-based equipment that includes the existing traffic signal controller and any additional equipment needed to receive and process V-2-I TSP Message Sets.

The 6 message types that make up the V-2-I TSP Message Sets are as follows:

1. <u>Priority Request Message</u> – This is the core request message from the PRG to the PRS.
2. <u>Priority Update Message</u> – This is used to update the original Priority Request Message from the PRG to the PRS. Contents are similar to the original message, minus a few static parameters.
3. <u>Priority Status Control Message</u> – This is used for the PRG to request status of its request from the PRS.
4. <u>Priority Status Buffer Message</u> – This is used to define how the PRS will respond with the request status back to the PRG.
5. <u>Priority Cancel Message</u> – This is used to cancel an active request.
6. <u>Priority Clear Message</u> – This is used to manually clear a non-active request.

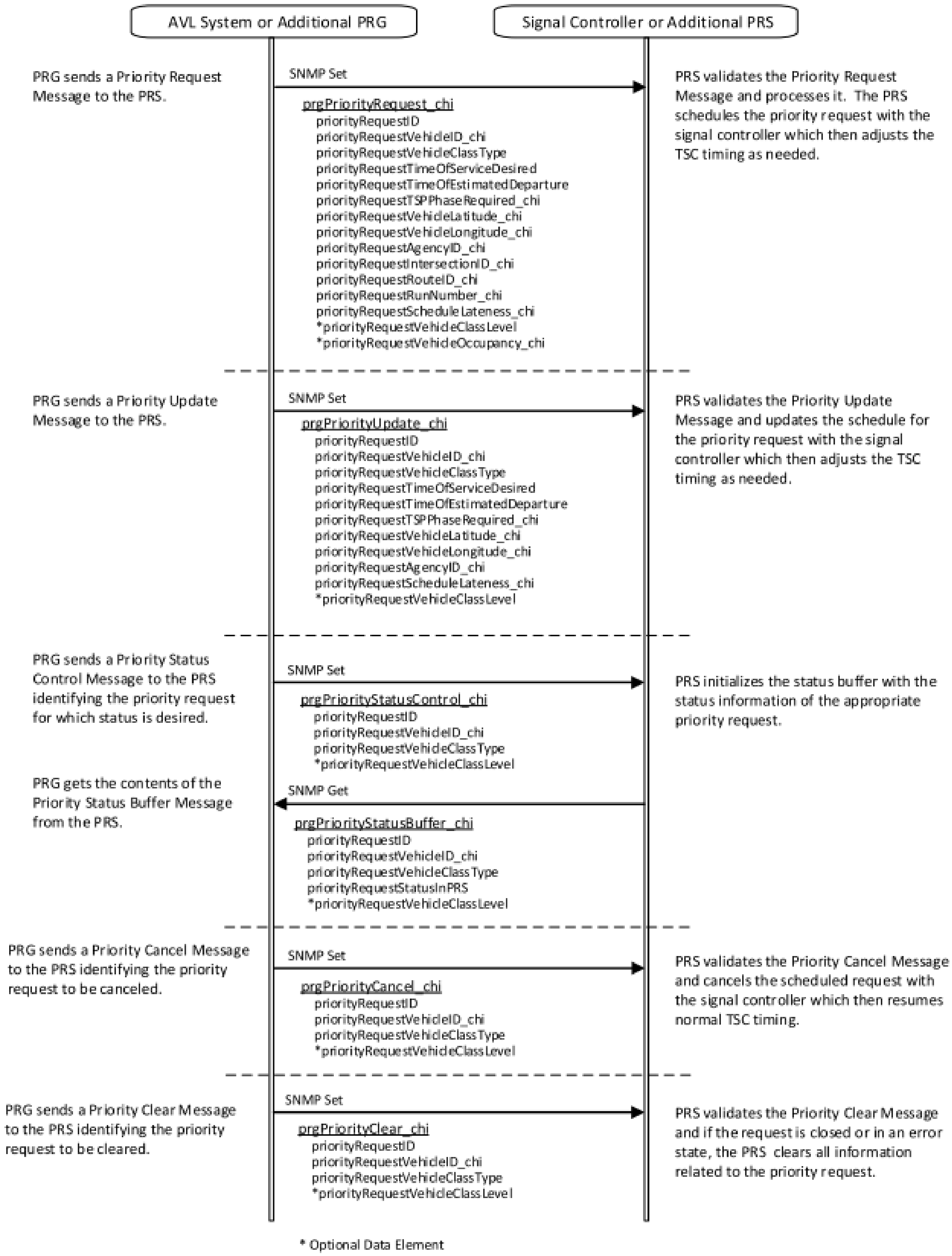
A Priority Request Message will initiate the TSP request process, and a PRG may send a Priority Update Message during the bus’ approach to the intersection, should an update be required for the original request. The Priority Status Control Message and Priority Status Buffer Message set can be used at any point during the bus' passage near or through the intersection to retrieve request status from the PRS. Also, the PRG may cancel a request using the Priority Cancel Message, if no longer required. A TSP request can be automatically cleared after a configurable amount of time has passed, but there is also an option to use the Priority Clear Message to manually clear a request.

Figure 2-1 below shows the 6 message types and the direction of flow for data. All messages, except the Priority Status Buffer Message, involve transfer of data from the PRG to the PRS, via Simple Network Management Protocol (SNMP) Set commands. The Priority Status Buffer Message contents are requested by the PRG from the PRS via an SNMP Get command, and the PRS responds with the data defined by that message type. Parameters shown below in black are mandatory, while those shown in light grey are optional and are used for logging purposes.

It should also be noted that Appendix B to this document contains a set of standard message dialogs for implementation by the Priority Request Generator (PRG) and the Priority Request Server (PRS) devices. The standard message dialogs define the exchange of messages between the PRG and PRS, and some of the actions to be taken by the PRS in response to messages from the PRG. This will reduce the potential for misinterpretation by equipment vendors regarding the intended usage of the TSP Message Set in PRG and PRS interaction.

Virtual PRG and PRS testing tools will be provided to Contractors responsible for designing and developing the PRG and PRS devices of the RTSPIP. The testing tools will verify the correct usage of data objects within the TSP Message Set in Appendix A, as described by standard dialogs defined in Appendix B. The testing tools will also be used during bench testing activities to confirm that the PRG and PRS devices being developed are interoperable with one another, prior to proceeding with field testing activities and implementation of the PRG and PRS devices.

Figure 2-1. RTSPIP Message Set Summary



2.1. FREQUENCY STANDARD FOR V-2-I COMMUNICATIONS

The RTSPIP TSP Working Group has previously agreed upon a recommendation of Wi-Fi technology (5 GHz) as the regional standard for V-2-I communications technology. The 5.0 GHz band and, at a minimum, the 802.11n Wi-Fi standard will be specified in individual TSP corridor designs. Given that upgrades to Wi-Fi protocols are backwards-compatible with previous protocols, newer protocols, such as 802.11ac, have the potential to improve V-2-I communications over an 802.11n protocol and are acceptable. Figure 2-2 contains a high-level summary of the regional standard for V-2-I communications.

As noted in a previous assessment of various V-2-I communications options, the 5 GHz band was recommended over the 2.4 GHz band given the reduced chance of interference from other Wi-Fi radios that may be operating on the same band along a corridor. The desire to implement projects quickly and be able to realize “early winners” and benefit from the deployed TSP system as quick as possible was a strong factor in the decision as well. This was also one of the reasons in not selecting DSRC communications which is still considered developing technology. The selection of a Wi-Fi solution in the 5 GHz band provides the fastest route to an interoperable TSP deployment under the RTSPIP.

It should be noted that many equipment vendors currently provide 5.0 GHz radios in the marketplace and maintenance personnel have become comfortable with installing and maintaining the equipment. Pace and CTA also have projects that currently are deployed or being deployed using Wi-Fi hardware. There are also routers installed in a number of Pace and CTA buses that will directly accept Wi-Fi devices operating in the 5.0 GHz frequency. The use of MIMO (Multiple-Input, Multiple-Output) radios and antennas are recommended to overcome many line of sight issues for the 5 GHz band.

Figure 2-2. RTSPIP Regional Standard for Frequency of V-2-I Communications

Communications Item	RTSPIP Standard	Description
Technology	Wi-Fi and MIMO Radios	Technology utilized in sending V-2-I TSP Message Set from buses to intersections. MIMO radios and antennas can overcome line-of-sight issues for the 5 GHz band
Frequency	5.0 GHz	Frequency for communications between buses and intersections
Protocol	802.11n (minimum)	Wireless networking standard that governs wireless transmission of V-2-I TSP Message Set. 802.11n is set as a minimum, as newer protocols, such as 802.11ac, are backwards compatible with 802.11n

3. Regional TSP Implementation Guidelines

The Regional TSP Implementation Guidelines will be discussed in the following categories: 1) Vehicles, 2) Intersections, 3) I-2-I Communication, and 4) I-2-C Communication. The Implementation Guidelines provide TSP Implementers with some flexibility in performing detailed design based on the existing conditions of AVL systems, corridors/intersections, traffic signal controllers and signal interconnects.

3.1. Vehicle Implementation Guidelines

Pace / CTA vehicles will generate the V-2-I TSP Message Set through the following equipment:

1. Existing on-board AVL Systems, which will need to be modified to send the required V-2-I TSP Message Set on TSP Corridors
2. Additional PRG equipment (if necessary) to supplement the AVL System and provide additional information for the TSP Message Set.
3. A 5.0 GHz radio compliant with Regional TSP Standards used to send V-2-I TSP Message Sets to corresponding 5.0 GHz radios at intersections

The following sub-sections present Implementation Guidelines with respect to vehicle equipment. Other guidelines discussed in this section include the use of schedule adherence threshold as a condition for TSP operations and AVL-TSP equipment integration guidelines.

3.1.1. Integration with On-board AVL Systems

As part of the TSP Preliminary Engineering activities, Pace and CTA should plan to work with their respective AVL vendors to identify necessary hardware and software upgrades/modifications required for the V-2-I TSP Message Set. Feedback from the AVL Vendors will help to form an initial order of magnitude cost estimate for TSP implementation. It may also be determined at this early stage that additional PRG equipment may be required to supplement the AVL System until future AVL enhancements are developed.

3.1.1.1. Schedule Adherence for Conditional TSP Operations

It is a requirement for TSP System operations that schedule adherence as measured by the existing on-board AVL System be utilized to initiate TSP requests on TSP Corridors whenever buses are running behind schedule. Pace and CTA can determine the appropriate schedule adherence threshold for the TSP Corridors that are implemented under the RTSPIP based on an analysis of transit on-time performance and through agreement with the DOTs. Pace and CTA should also review the schedule adherence values on an on-going basis to determine whether or not adjustments could be made to improve on-time performance.

Pace and CTA should work with AVL vendors to determine at an early stage if multiple schedule adherence thresholds can be established for different TSP Corridors.

3.1.1.2. AVL-TSP Equipment Integration Guidelines

Given the potential for integration that will be needed between on-board AVL and TSP System equipment, a listing of equipment integration guidelines is presented below for AVL Vendors, TSP System Vendors, and Pace / CTA.

3.1.1.2.1. AVL Vendor Integration Guidelines

1. Develop and send V-2-I TSP Message Set according to the Regional TSP Standards presented in this document
2. Connect AVL equipment to on-board 5.0 GHz radio equipment for its use in communicating V-2-I TSP Message Sets to 5.0 GHz radio equipment at the roadside.
3. Test TSP Message Set transmission from buses to multiple intersections on a TSP Corridor
4. Ensure that TSP Message Set transmissions do not conflict in any way with any other existing on-board vehicle systems.
5. Facilitate distribution of any needed AVL system updates to Pace / CTA fleet
6. Develop procedure for sending TSP Log Files from AVL equipment to 5.0 GHz radio equipment at transit garages for data evaluation.
7. Work with TSP Vendors / Installers (if necessary) in transmitting information to the additional TSP equipment for its use in sending the V-2-I TSP Message Set
8. Install equipment required to interface with additional TSP equipment (if necessary) on the bus

3.1.1.2.2. TSP System Vendor Integration Guidelines:

1. If necessary, install TSP System equipment on buses at proper locations that have been approved by Pace / CTA.
2. Work with AVL Vendor on AVL-TSP integration and testing of AVL-TSP interface.
3. Install TSP System equipment on Pace / CTA buses
4. Use approved Pace / CTA-designed wire harness and PRG equipment mounting brackets.
5. Connect TSP System equipment to on-board 5.0 GHZ radio equipment for its use in communicating with 5.0 GHz radio equipment at the roadside.
6. Develop procedure for sending TSP Log Files from TSP System equipment to 5.0 GHz radio equipment at transit garages for data evaluation (if necessary)

3.1.1.2.3. Pace / CTA Integration Guidelines:

1. Work with TSP Vendors / Installers to test and evaluate the settings and orientation of the TSP equipment (if installed on the bus).
2. Work with AVL and TSP Vendors / Installers to test TSP Message Set transmission from bus to intersection on site with AVL / TSP Vendors / Installers and other stakeholders as necessary.
3. Develop TSP equipment mounting brackets (if necessary) to secure the equipment at the proper location on the vehicle.
4. Develop 5.0 GHz radio mounting brackets to secure the radio at the proper location on the vehicle.
5. Develop a wiring harness to provide the required power and J1708 connectivity for the TSP System equipment (if necessary).
6. Develop procedure for receiving TSP Log Files from AVL or TSP System equipment at transit garages if necessary for data evaluation.
7. Supply TSP Log Files from AVL System or TSP System equipment to evaluation contractor and monitor data for defective AVL and/or TSP System units.
8. Conduct or assist with before and after evaluation of TSP deployment as necessary

3.1.2. Additional PRG Equipment (As needed)

It is anticipated that current vendors of on-board TSP System equipment could provide the additional PRG equipment if the AVL Systems cannot generate all the required information for the V-2-I TSP Message Set. TSP equipment vendors will likely need to modify their on-board equipment to generate the information required within the TSP Message Set.

If necessary, it is recommended that the additional PRG equipment from TSP System vendors be responsible for sending the V-2-I TSP Message Set to the intersection via the 5.0 GHz frequency established as a Regional TSP Standard. As part of the TSP Design Engineering activities, Pace and CTA should coordinate with their respective AVL vendors on determining what pieces of information can be transmitted from the AVL System to additional PRG equipment that would be responsible for sending the V-2-I TSP Message Set. Additional TSP equipment installation and wiring plans can also be prepared and approved by Pace / CTA mechanics as part of the TSP Design Engineering activities prior to TSP Implementation.

Additional PRG equipment from current vendors of on-board TSP System equipment may also be able to communicate additional data from the vehicle to the intersection beyond the standard TSP Message Set. This would likely require corresponding TSP equipment at the intersection from the same vendor providing the vehicle equipment. The additional TSP data could provide value in terms of functional capabilities beyond the Technical System Requirements that have been defined by the TSP Working Group for the program. Additional data communicated from the vehicle to the intersection is allowable, provided that the

TSP Message Set is communicated to all intersections and the base system requirements are met by the TSP vendor.

3.1.3. Vehicle 5.0 GHz Radio Implementation Guidelines

This section provides physical installation and design considerations to be made by Pace and CTA in the planning and deployment of 5.0 GHz radios on buses for the purpose of sending V-2-I TSP Message Sets to corresponding 5.0 GHz radios at intersections.

3.1.3.1. Physical Equipment Installation Guidelines

1. Use factory terminated jumper cables of the shortest length possible to have known loss for the system. This also reduces the chance for installation mistakes.
2. Choose high gain bus antennas with multiple elements for the various bands required. Consider a custom bus antenna design for mobile application.

3.1.3.2. Design Considerations and Guidelines

1. Perform field testing at installation sites using temporary radios to measure signal strength in the desired area.
2. The use of MIMO radios and antennas will help to overcome many line of sight issues for the 5 GHz band.
3. As much as possible, standardize the installation to simplify maintenance and reduce spare part inventory needed.
4. Wi-Fi radios used in a mobile environment:
    a. Provide a base configuration for the radios on the project to simplify integration
    b. Mobile Wi-Fi requires configuration knowledge specific to a mobile application and require a minimum level of technical expertise as a part of the bid package for each project
    c. Consider bringing in a specialized networking consultant in the design or implementation side of the contract for the network configuration
5. Provide a detailed security and authentication scheme designed for a mobile application.
    a. Use certificates for authentication that can be easily tracked and managed
6. Define a detailed network architecture and IP scheme for the system.
    a. Consider data flow and reduce overhead where possible.
    b. Use small broadcast domains
7. Utilize SNMP Version 2 for intersection radio health monitoring.

3.2. Intersection Implementation Guidelines

Intersections along TSP Corridors that receive the V-2-I TSP Message Set will include the following equipment:

1. Existing traffic signal controllers to process TSP requests from buses along TSP Corridors.
2. Additional PRS equipment (if necessary) to receive and process V-2-I TSP Message Sets from buses
3. A 5.0 GHz radio compliant with Regional TSP Standards used to receive V-2-I TSP Message Sets from corresponding 5.0 GHz radios on buses

The following sub-sections present Implementation Guidelines with respect to intersection equipment. Other guidelines to be discussed in this section include guidelines on the use of TSP strategies and signal timing parameters and the installation / configuration of 5.0 GHz wireless radios used in vehicle-to-intersection communications.

3.2.1. Controller Upgrades at TSP Intersections

This section includes a summary of different controller types and firmware throughout the Chicago region, including replacements needed to ensure the intersection is capable of TSP operations.

3.2.1.1. Econolite and Eagle Signal Controllers

After consultation with local Econolite and Eagle signal vendors, the following guidelines in Figure 3-1 and Figure 3-2 were developed for upgrades required to the traffic signal controllers and cabinets to allow for TSP operation. These controllers are primarily installed outside City of Chicago limits in the suburban areas of the region.

The signal controllers in Figure 3-1 have varying degrees of compatibility with the NTCIP 1211 standard as proposed for the TSP Message Set described in Appendix A of this document. Also noted in Figure 3-1, Econolite ASC/2 and ASC/2S and Eagle M40 series signal controllers will require replacement with either an Econolite ASC/3 or Eagle M50 series controller to have the functionality required for TSP operations.

Figure 3-1. Summary of Econolite and Eagle Signal Controller Modifications

Existing Controller Types	Compatible with NTCIP 1211?	Replacement Needed?	Controller Modifications
Econolite ASC-2	No	Yes	Replace ASC-2 Controller with ASC-3 model. See modifications for ASC-3 controller below.

Figure 3-1. Summary of Econolite and Eagle Signal Controller Modifications

Existing Controller Types	Compatible with NTCIP 1211?	Replacement Needed?	Controller Modifications
Econolite ASC/2S	No	Yes	Replace ASC-2 Controller with ASC-3 model. See modifications for ASC-3 controller below.
Econolite ASC-3	Yes	No	Install TSP Data Key Upgrade for ASC-3. Will require firmware upgrade for NTCIP 1211 communications or separate PRS.
Eagle M40 series	No	Yes	Replace M40 series controller with Eagle M52 model with SEPAC 3.52 and SEMARC 4.0 Firmware. See notes below.
Eagle M50 series	Yes	No	Local Controller Firmware Upgrade to SEPAC 3.52 firmware. Master Controller Firmware Upgrade to SEMARC 4.0 firmware. Requires use of a separate PRS to receive TSP Message Set.

Field checks are required at locations with Econolite ASC-2 or Eagle M40 series controllers to determine if the traffic signal cabinets are the NEMA TS1 or TS2 standard. As noted in Figure 3-2, if the cabinet is NEMA TS1, a cabinet replacement would likely be required when upgrading the controller to Econolite ASC-3 or Eagle M50 series. It is recommended that the inventory of signal controllers and cabinets be confirmed in the preliminary engineering phase before the design engineering phase begins.

Figure 3-2. Summary of Signal Cabinet Modifications

Cabinet Type	Replacement Needed?	Cabinet Modifications
TS-1	Yes	Replace NEMA TS1 Cabinet with NEMA TS2 cabinet and new controller
TS-2	No	None

3.2.1.2. PEEK CONTROLLERS

Peek traffic signal controllers are primarily installed within the city limits of City of Chicago. Peek ATC-1000 controllers are being utilized with an existing demonstration of TSP operations on the CTA's Jeffery Jump corridor and receive TSP request messages directly from CTA buses without additional PRS equipment within the signal cabinet.

As noted in Figure 3-3, older versions of Peek controllers will need to be replaced with either a Peek ATC-1000 model controller or other approved ATC model controller for TSP operations.

Figure 3-3. Summary of Peek Signal Controller Modifications

Existing Controller Types	Compatible with NTCIP 1211?	Replacement Needed?	Controller Modifications
Peek ATC-1000	Yes	No	Modify how controller reacts to proposed regional TSP Message Set
Peek LMD	No	Yes	Replace with ATC-1000 or other approved ATC model controller
Peek 3000E	No	Yes	Replace with ATC-1000 or other approved ATC model controller

3.2.1.3. TSP Strategies and Signal Timing Parameters Considerations

As part of the TSP Preliminary Engineering activities, Pace and CTA will need to develop appropriate TSP strategies and traffic signal timing parameters in coordination with CDOT, IDOT, and local DOT’s. These will vary based on the ability of the signal controller to modify the signal cycle to provide signal priority.

In general, TSP Strategies should focus on either a green extension or early green that minimizes general traffic disruption and does not require the traffic signal controller to skip any phases within a signal cycle. TSP signal timing parameters for those respective TSP Strategies should be developed by traffic signal timing consultants pre-qualified and approved to work on signals by CDOT, IDOT, and local DOT’s.

During the TSP Implementation activities, TSP Strategies and signal timing parameters should also be reviewed to verify that TSP is operating as intended on the signal controllers. A modification of signal timing parameters at some locations may be required to either minimize traffic impacts and/or improve transit operations on the corridor.

3.2.2. Additional PRS Equipment (As Needed)

It is anticipated that current vendors of intersection-based TSP System equipment could provide the additional PRS equipment if the traffic signal controller cannot receive and process the entire V-2-I TSP Message Set. TSP equipment vendors will likely need to modify their intersection equipment to receive and process the information required within the TSP Message Set, as well as interface with traffic signal controllers to initiate TSP strategies for Pace / CTA buses.

The V-2-I TSP Message Set as detailed in Appendix A provides the messages that will be required to be received and processed by the PRS, as well as information to be retrieved from the signal controller on whether or not TSP requests were granted or denied. TSP equipment vendors that will provide the PRS equipment will need to properly configure the equipment to receive and log the information sent within the V-2-I TSP Message Set.

During the TSP Implementation activities, Pace and CTA should consider a bench test and/or field test of PRS equipment and its interface with the signal controller to verify that the V-2-I TSP Message Set is being implemented as designed. The bench test could include monitoring of the PRS and its receipt of V-2-I TSP Message Sets from Pace and CTA buses. This bench and/or field testing is important to ensure that regional interoperability will be achieved as additional TSP Corridors proceed through the TSP Implementation phases.

Additional PRS equipment from current vendors of TSP System equipment installed at intersections may also be able to receive additional data from the vehicle beyond the standard TSP Message Set. This would likely require corresponding TSP equipment on the vehicle from the same vendor providing the intersection equipment. The additional TSP data could provide value in terms of functional capabilities beyond the Technical System Requirements that have been defined by the TSP Working Group for the program. Additional data communicated from the vehicle to the intersection is allowable, provided that the TSP Message Set is communicated to all intersections and the base system requirements are met by the TSP vendor.

3.2.3. Intersection 5.0 GHz Radio Implementation Guidelines

This section provides physical installation and design considerations to be made by Pace and CTA in the planning and deployment of 5.0 GHz radios on TSP Corridors for the purpose of receiving V-2-I TSP Message Sets from buses.

3.2.3.1. Physical Equipment Installation Guidelines

1. Use cantilever arms to place the antennas for the radios out over the center of the roadway for better line of sight to vehicles.
    a. If cantilever arms are not feasible consider line of sight to the travel path of the bus, mount antenna in a location that has best line of sight. Highest location on the pole may not always be the best location.
    b. Place radios near the antennas to reduce system loss.

2. Use factory terminated jumper cables of the shortest length possible to have known loss for the system. This also reduces the chance for installation mistakes.
3. Use directional antennas to focus the signal only on the roadway where it is needed. This will increase range and reduce the chance for interference.
    a. The use of MIMO radios will help to establish multipath signals and create a more reliable connection.
4. If desired, use dual radios along the corridor, in which one radio is utilized for vehicle-to-intersection communications, and another is utilized for backhaul intersection-to-center communications purposes.
5. If desired, use a radio that can be software-upgradeable to communicate via Dedicated Short Range Communications (DSRC) with vehicles on the corridor.

3.2.3.2. Design Considerations and Guidelines

1. Perform field testing at installation sites using temporary radios to measure signal strength in the desired area.
2. The use of MIMO radios and antennas will help to overcome many line of sight issues for the 5 GHz band.
3. Require spectrum analysis in each project area to identify potential interference problems prior to installation.
4. Require a demonstration test using an exact replication of a corridor.
    a. Use the same network IP scheme, channels, and configuration as will be deployed in the field. Use attenuators and exact switch configurations in the demo test to work out bugs prior to deploying the system.
5. As much as possible, standardize the installation to simplify maintenance and reduce spare part inventory needed.
6. Design a robust surge suppression system and detail out the installation.
7. Wi-Fi radios used in a mobile environment:
    a. Provide a base configuration for the radios on the project to simplify integration
    b. Mobile Wi-Fi requires configuration knowledge specific to a mobile application and requires a minimum level of technical expertise as a part of the bid package for each project
    c. Consider bringing in a specialized networking consultant in the design or implementation side of the contract for the network configuration
8. Provide a detailed security and authentication scheme designed for a mobile application.
    a. Use certificates for authentication that can be easily tracked and managed
9. Define a detailed network architecture and IP scheme for the system.
    a. Consider traffic flow and reduce overhead where possible.

   b. Use small broadcast domains
10. Utilize SNMP Version 2 for intersection radio health monitoring.

3.3. Intersection-to-Intersection (I-2-I) Communication Guidelines

I-2-I Communications along TSP Corridors refers to the transfer of TSP data logged by the PRS through existing wired or wireless signal interconnect to one central location on the corridor, such as the intersection where the master controller resides. The use of wired signal interconnects is preferable to a wireless signal interconnect which may require the installation of additional wireless equipment that would need to be managed by either the transit agency or DOT responsible for traffic operations.

3.3.1. Use of Existing Communications Equipment on TSP Corridors

As part of the TSP Preliminary Engineering process, Pace and CTA should determine the potential to utilize existing wired and wireless communications equipment along TSP corridors to enable I-2-I communications. This could include spare pairs of existing fiber or twisted pair cable infrastructure installed as part of existing signal interconnects along TSP Corridors. This may also include the use of wireless signal interconnects used to relay signal information along a corridor. Either type of communications would need to support the transfer of V-2-I TSP Message Sets logged by PRS devices to a single location along an interconnected signal system.

The TSP Preliminary Engineering process would determine which type of interconnect exists along TSP corridors, and a potential preference for the type of interconnect to be used in I-2-I communications.

The TSP Design Engineering process would focus on more technical details of how to utilize existing communications equipment and infrastructure. If a wired signal interconnect is used on the TSP Corridor, this would involve the evaluation of fiber capacity for transmitting V-2-I TSP Message Set data, as well as the identification of spare pairs of existing fiber or twisted-pair cables for use by TSP Vendors / Installers in establishing I-2-I communications.

It should be noted that it is unlikely that existing spare IDOT fiber will be available for I-2-I communications. The state of Illinois is currently in the process of mapping fiber installed by various state agencies, including IDOT, so that in-ground fiber can be utilized by other state agencies, or perhaps leased to private companies. As a result, any existing IDOT fiber availability for I-2-I communications cannot be assured.

3.3.2. Installation of New Signal Interconnect

If there are any gaps in existing wired or wireless signal interconnects at intersections where it would be desired to implement TSP operations, Pace and

CTA should coordinate with traffic agencies on the potential to install new signal interconnect for the purposes of I-2-I communications along the TSP Corridor.

The TSP Preliminary Engineering process would determine which type of interconnect could be used on TSP corridors, and a potential preference for either a wired or wireless interconnect to be used in I-2-I communications. As part of the TSP Design Engineering process, Pace and CTA could focus on more specific details regarding the installation and configuration of the new signal interconnect in coordination with the respective DOT responsible for traffic operations.

3.4. Intersection-to-Center (I-2-C) Communication Guidelines

I-2-C Communications refers to the backhaul of TSP data from a central intersection along a TSP Corridor to a central server that would reside at either a Pace or CTA transit management center. The use of a wired connection for I-2-C communications is preferable to a wireless or cellular connection, which may require the installation of additional wireless equipment and ongoing communications costs that would need to be managed by the transit agency.

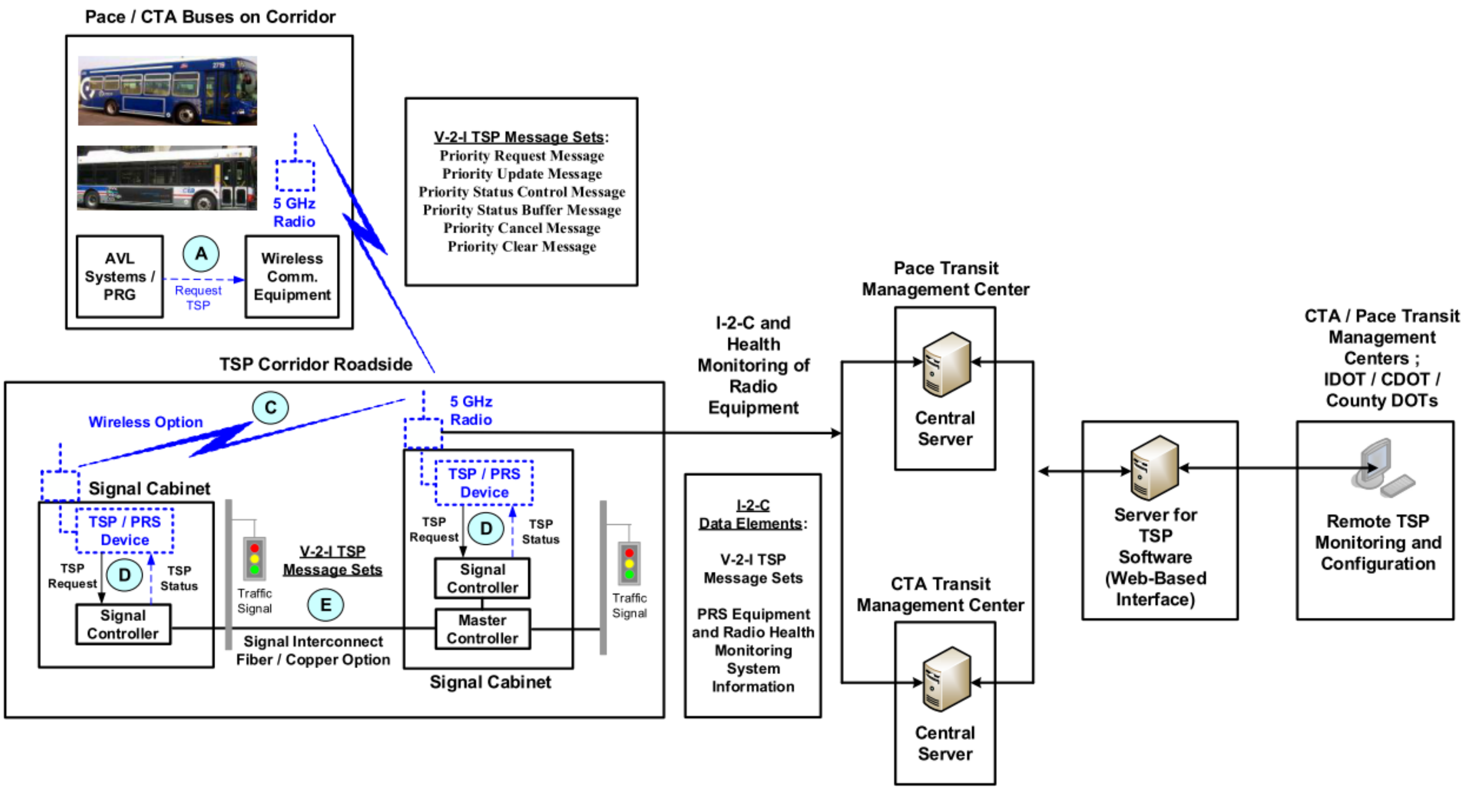
3.4.1. I-2-C Communications Guidelines

Figure 3-4 illustrates one option of data elements being transmitted from intersections along a TSP corridor to Pace and CTA transit management centers. This includes data recorded by the PRS within the signal cabinet, as well as health monitoring system information from 5.0 GHz radios and PRS equipment along the TSP corridor. These data elements would be transmitted along existing interconnect between traffic signals, or via new interconnects that may be needed to transfer data to a signal cabinet including a master signal controller.

Backhaul of the data elements from the master controller cabinet to Pace and CTA transit management centers could occur over a wired or wireless connection depending on the communications infrastructure available. It should be noted that this option allows for real-time monitoring of TSP activity by the PRS, as transit and traffic agencies would be able to monitor and review the most recent TSP activity recorded along TSP corridors.

Part of the TSP Design Engineering process should also consider the health monitoring of 5.0 GHz radios and PRS equipment along the TSP Corridor. This is accomplished through the use of SNMP Version 2 protocols for remote health monitoring and configuration management of the 5.0 GHz radios and PRS devices.

Figure 3-4. Intersection-to-Center Backhaul of TSP Data from TSP Corridors



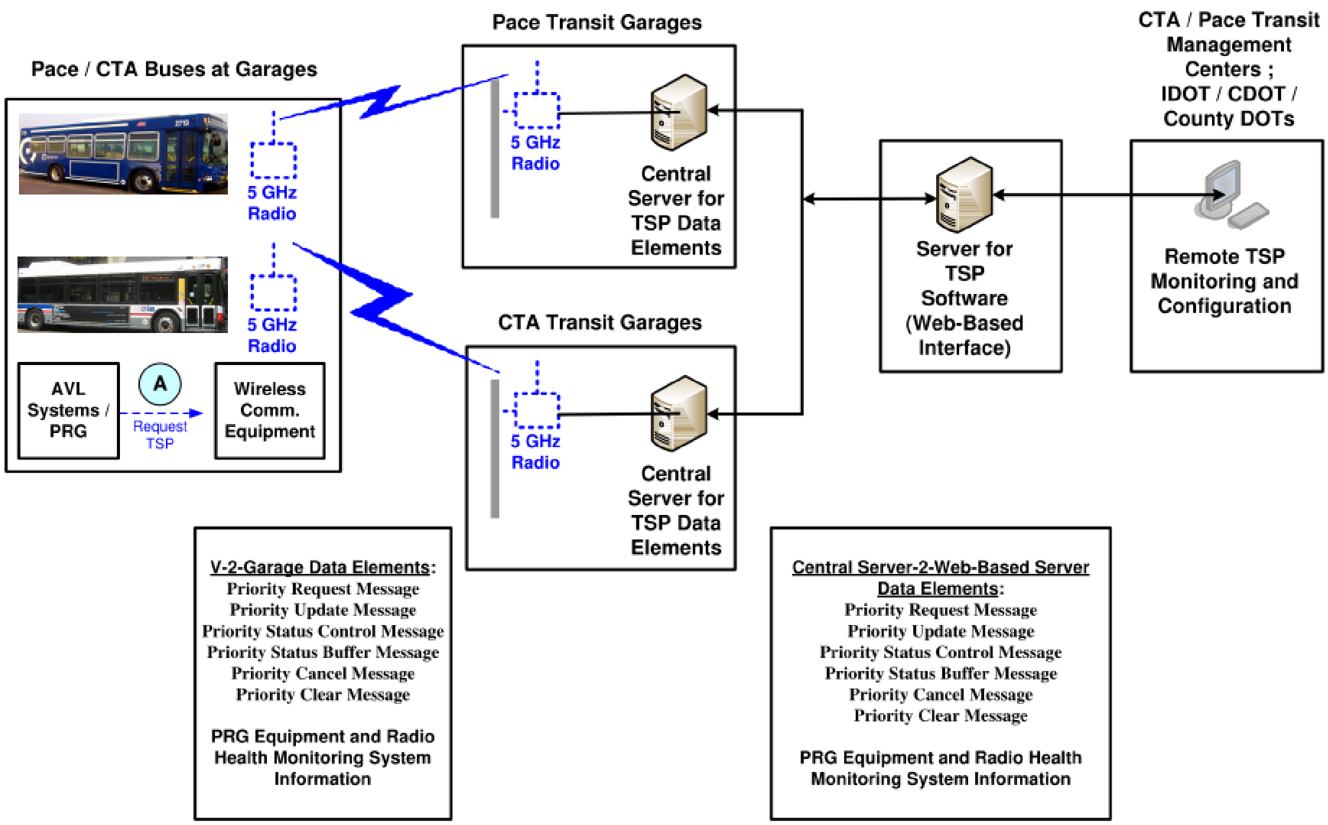
3.4.2. Vehicle-to-Garage Communications

In the event that establishing I-2-C communications for backhauling TSP data along TSP corridors is not feasible, Pace and CTA should consider the alternative option of retrieving TSP data from vehicles as they return to transit garage facilities.

The detailed design of retrieving TSP data from buses would be part of the TSP Design Engineering process for transit agencies.
Figure 3-5 illustrates the alternative option of buses sending recorded TSP Message Sets from the buses to Pace and CTA transit management centers for monitoring and review by transit and traffic agencies.

Pace and CTA may also want to consider installing a TSP system test site within the garage for equipment health monitoring purposes. Depending on the design of the system, buses could send test TSP requests as they either leave from, or return to, the transit garage. The test requests would be designed to provide an indication to bus drivers or to other transit staff that TSP equipment needs to be repaired or replaced.

Figure 3-5. Vehicle-to-Garage Backhaul of TSP Data from Vehicles



3.4.3. Central Server for Web-Based Interface

In both options of TSP data backhaul, there is an additional server that will host a web-based interface for analyzing V-2-I TSP Message Sets that are backhauled to Pace and CTA transit management centers. The web-based interface will be accessible to all transit and traffic agencies interested in analyzing TSP data and its effectiveness in meeting performance measures and targets discussed in the following section.

3.5. General TSP Implementation Guidelines

This section will include general implementation guidelines relating to TSP operations for consideration by Pace / CTA. This includes the re-location of near-side bus stops to far-side stops where feasible, as well as information relating to performance targets for evaluating TSP system operations before and after deployment.

3.5.1. Convert Near-Side Stops to Far-Side Stops

As part of the TSP Preliminary Engineering phase, Pace and CTA should consider the re-location of bus stops from the near-side of an intersection to the far-side in order to maximize the potential benefits of TSP System operations. A majority of the benefit to TSP operations is realized with green extension TSP strategies that allow buses to travel through an extended green signal. Bus stops at the near-side of the intersection prevent the bus from traveling through an extended green light if passengers are requesting to stop from the bus or waiting at the near-side bus stop. Far-side bus stops allow the bus to clear through the intersection and better take advantage of the green extension TSP strategy prior to stopping.

One of the recommendations noted in the evaluation of the CTA Western Avenue TSP System was the relocation of near-side bus stops to the far-side of the intersection if land use allows. As buses stopped at near-side bus stops, they lost the ability to utilize a green extension provided by the signal controllers along the corridor.

3.5.2. Prioritize Corridors Based on Signal Controllers / Interconnect

Prior to nominating TSP corridors for the RTSPIP, Pace and CTA should consider corridors that feature signal controllers as shown in Figure 3-1 and Figure 3-3 that enable TSP System operations while minimizing impacts to general traffic and side street traffic. In addition, recommending corridors with existing signal interconnect might facilitate I-2-I and I-2-C communications as discussed in Sections 3.3 and 3.4 of this document.

Pace and CTA should coordinate where possible with CDOT, IDOT, and other local DOTs to understand future plans for signal controller and / or interconnect upgrades along a potential TSP Corridor. In the event that controller replacement and signal interconnects are programmed for installation by the DOTs, this may reduce the overall cost of TSP System installation.

3.5.3. Use TSP to Achieve Operational Objectives

Important operational objectives that can be achieved by implementing TSP systems include increasing on-time transit performance and reducing transit travel times along a major transit corridor. These objectives can be measured by tracking performance measures before and after TSP Implementation.

Pace and CTA should determine at an early stage of TSP Corridor deployment which transit-related performance measures should be observed to assess how well the TSP System is meeting the operational objectives. In instances where TSP is the primary improvement to transit operations along a corridor, a measurement of on-time performance can indicate how successful TSP has been at improving schedule adherence. In instances where TSP is one of many transit improvements to a corridor, a measurement of transit travel times can indicate how TSP is contributing to improving travel times along the corridor.

Performance measures to be utilized by TSP Implementers in evaluating the benefits of TSP operations should be consistent with the goals and objectives of the RTSPIP and the CMAQ Program. As such, the primary performance measures will focus on:

1. Headway or schedule reliability
2. Travel time improvements
3. Fuel efficiency
4. Additional performance measures for individual TSP corridor projects (as needed)

Figure 3-6 contains the performance measures and anticipated sources of data for those measures. The performance targets presented in the right column indicate the percentage changes anticipated before and after TSP System deployments. These performance measures trace back to the goals and objectives of the RTSPIP as defined within the Concept of Operations (ConOps) developed for the program. While the overall amount of travel time savings from previous TSP Deployments throughout the country have varied significantly, general travel time savings on the range of 5% to 15% have been observed with minor impacts on the overall intersection operations.

Supplemental performance measures may be proposed for individual TSP corridor projects as long as the measurements can be calculated based on data from the AVL Systems or from other means of data collection. More specific measures that can reveal the success of TSP operations include:

- Reduced traffic signal delay experienced by buses at signalized intersections due to red signals
- Reduced number of stops due to red signals while traveling through a section of the TSP corridor

These performance measures would require a more intensive field data collection and analysis process. Trained staff would need to be able to consistently measure signal delay along a TSP Corridor, as well as record the number of stops on the TSP corridor that are due to red signals.

The following sub-sections provide further details on how performance measures should be collected by TSP Implementers and evaluated before and after TSP System Deployments.

Figure 3-6. Summary of Proposed RTSPIP Performance Measures and Targets

Objective	Performance Measure	Source	Description	Performance Targets
Improve transit schedule (or headway) adherence / reliability	Increased schedule adherence / “on-time” performance	Pace / CTA AVL Systems	Improvement of bus schedule adherence, or “on-time” performance. “On-time” is generally defined as less than 5 minutes behind schedule and no more than 1 minute ahead of schedule. This measure applies to TSP Corridors in which TSP is the primary improvement to transit operations along a corridor.	Increase in percentage of buses “on-time” between 5% and 10% along TSP Corridor
Improve transit travel times along TSP Corridors without skipping signal phases or interrupting of signal system coordination	Reduction in transit travel times	Pace / CTA AVL Systems	Improvement in transit travel times along corridors where traffic signals have been equipped with the TSP system. This measure applies to TSP Corridors in which TSP is one of many improvements to transit operations along a corridor.	Reduction in transit travel times along TSP Corridor between 5% and 15% along TSP Corridor
Improve traffic signal operations and minimize negative impacts of TSP to private vehicles on arterials and cross streets	Reduction in general vehicle travel times	Travel Time Runs (As necessary)	Reduction in general vehicle travel times along corridors where traffic signals have been equipped with the TSP system and traffic signal timing plans have been optimized..	Reduction in general travel times along TSP Corridor between 5% and 10% along TSP Corridor
Reduce signal delay to buses at red signals on TSP corridor	Reduction in signal delay	Bus ride-alongs / bus shadowing	Reduction in traffic signal delay along corridors where traffic signals have been equipped with the TSP system.	Reduction in signal delay between 5% and 10% along TSP corridor
Reduce number of stops due to red signals on TSP corridor	Reduction in number of stops at red signals	Bus ride-alongs / bus shadowing	Reduction in the number of stops along corridors where traffic signals have been equipped with the TSP system.	Reduction in number of stops at red signals between 5% and 10% along TSP corridor

3.5.4. Project-Level Data Collection and Evaluation Plans

Evaluations of the performance measures will require data collection to be performed by Pace / CTA through retrieving data from their AVL Systems, and potentially from travel time runs along a TSP corridor. It is anticipated that AVL System timepoints near the beginning and end of each TSP Corridor will serve as the boundaries for data collection purposes.

Data collection should occur over a two week period during the following three phases of a TSP deployment:

1. Phase One: Before Traffic Signal Timing Optimization
2. Phase Two: After Traffic Signal Timing Optimization
3. Phase Three: After TSP System Deployment

It is expected that the performance targets presented in the far right column of Figure 3-6 would be observed when comparing data collected from Phase Two to the data collected during Phase Three, which would indicate the improvements made due to TSP System operations. A comparison of Phase One and Phase Two would reveal improvements made due only to traffic signal timing optimization.

The following three sources of data should be utilized to collect the relevant performance measures as indicated below:

1. Transit Data Measurements from AVL Systems
    a. Average Schedule Adherence Values Along TSP Corridor at Timepoints
    b. Average Transit Travel Times Along TSP Corridor
2. Transit Data Measurements from Field Data Collection
    a. Traffic signal delay due to red signals
    b. Number of stops due to red signals
3. Data Measurements from Vehicle Travel Time Runs
    a. General Vehicle Travel Times Along TSP Corridor

It should be noted that reported travel time savings could vary significantly because TSP systems can often be deployed with other transit service changes, such as schedule updates, route changes, and operational policy changes. Pace and CTA should attempt to isolate the impact of TSP operations on travel time savings as much as possible along a TSP Corridor. In the project-level evaluation reports, Pace and CTA should note any changes that may have a factor in the travel time savings experienced during TSP implementation.

3.5.5. Summary of TSP System Evaluation Best Practices

This section provides a summary of best practices with respect to gathering data listed above regarding the evaluation of TSP Systems efforts.

3.5.5.1. MVTA Cedar Avenue TSP System Evaluation

The Minnesota Valley Transit Authority (MVTA) in Apple Valley, MN recently had a TSP System installed as part of a larger Bus Rapid Transit (BRT) project. New transit service was implemented on the Cedar Avenue corridor extending between the Mall of America in Bloomington, MN and the Apple Valley Transit Station. TSP equipment was installed on all seven BRT buses, as well as at 6 intersections spanning a two-mile stretch of Cedar Avenue. The Cedar Avenue corridor was also widened significantly along the stretch of intersections at which TSP System equipment was installed.

Given the transit and roadway changes implemented, baseline data from the on-board AVL system was gathered at two points in time:

1. While the TSP System was activated for a period of time
2. While the TSP System was de-activated for a period of time

The AVL system was configured to generate timestamps of events when the bus arrived within, and departed from, pre-configured zones established along the TSP corridor. Transit travel times between zones were calculated by subtracting the bus departure time at one zone from the bus arrival time at the next zone in that direction of travel. Vehicle ID numbers were gathered from the AVL data to verify that calculated travel times applied to the same bus that generated the arrival and departure events.

Zones were established in the AVL system to divide the corridor into two segments. Transit travel times for each segment, and the corridor as a whole, were then calculated based on the departure and arrival times within zones. In addition, values of schedule adherence were also reported with each event that was generated in the system.

Given that TSP is only requested from the bus when it is behind schedule by at least 3 minutes, travel times were only calculated for the corridor when the bus was behind schedule. These travel times along the corridor with the TSP System activated were compared against travel times with the system de-activated to measure the travel time savings due to the TSP System.

Field travel time runs were also conducted to collect travel time data for general traffic by using "floating car" methods along the TSP corridor while the TSP System was activated and de-activated over the same period of time.

3.5.5.2. CTA Western Avenue TSP System Evaluation

The CTA and CDOT installed a TSP System to improve bus schedule adherence and transit operational efficiency at 10 TSP intersections along Western Avenue for Route X49 buses and Route 49 buses. Given that traffic signal timings were being optimized prior to TSP System installation, evaluation data were collected during the following three stages:

1. Stage 1: Existing - before traffic signal optimization
2. Stage 2: Optimized - after traffic signal optimization but before TSP implementation
3. Stage 3: TSP - after traffic signal optimization and after TSP implementation

The field data were collected during the three stages using the following three approaches:

1. Field Travel Time Runs: Field travel time runs were conducted to collect travel time and delay data for buses and general traffic by using “bus shadowing” and “floating car” methods respectively.
2. AVL System Data: AVL data included trip information, timestamps (both arrival and departure times), bus headways, schedule deviations, bus identification numbers, and bus position coordinates at each time point along the bus route. Bus travel time and schedule deviation were derived from the AVL data to assess bus operational performance and schedule adherence improvement after the signal timing optimization and TSP implementation.
3. Field TSP Data: TSP records were collected from the TSP phase selectors installed inside the traffic control cabinets at the TSP intersections.

Figure 3-7 summarizes the evaluation data used to assess each goal and objective for X49 and local 49 bus routes respectively in the analysis.

Figure 3-7. Summary of CTA Data Used to Assess Project Goals and Objectives

Goal	Objective	Evaluation Data	Bus Route
1: Improve Transit Mobility	1-1: To reduce bus travel time	Field travel time runs data	X49
		CTA bus data	X49
	1-2: To reduce bus delay	Field travel time runs data	X49
	1-3: To reduce bus intersection waiting time	Field TSP data	Local 49
2: Improve Transit Reliability	2-1: To reduce bus travel time variance	CTA bus data	X49
	2-2: To reduce time deviated from the schedule	CTA bus data	X49
	2-3: To number of delayed buses at bus stops	CTA bus data	X49
3: Improve General Traffic Mobility	3-1: To reduce car travel time	Field travel time runs data	X49
	3-2: To reduce car delay	Field travel time runs data	X49
4: Reduce Energy Consumption and Pollutant Emissions	4-1: To reduce bus fuel consumption	Field TSP data	Local 49
	4-2: To reduce bus emissions	Field TSP data	Local 49
	4-3: To reduce car fuel consumption	Synchro modeling data	X49
	4-4: To reduce car emissions	Synchro modeling data	X49

Synchro modeling was used to assess energy consumption and emission reductions for general traffic at a network level. TSP data were used to assess fuel consumption and emission reductions due to engine idling for buses at intersection and segment levels.

The evaluation analysis was conducted by comparing the MOEs between Stage 1 (Existing) and Stage 2 (Optimized) and between Stage 2 (Optimized) and Stage 3 (TSP). Percentage differences were used as the measurement to quantify the comparison results.

Evaluation results indicate that both mobility and reliability were improved for Route X49 buses, Route 49 buses and general traffic on a directional basis during the peak periods for the one-mile long studied segment (between Lyndale and Diversey Avenues) after TSP implementation.

3.5.5.3. Pace Harvey Transportation Center TSP System Evaluation

Pace installed a TSP System to improve bus schedule adherence and transit operational efficiency at 20 TSP intersections operated by IDOT surrounding the Harvey Transportation Center (HTC) and on 50 buses traveling to and from the HTC. Similar to the CTA Western Avenue project, evaluation data was collected during the following three stages:

1. <u>Stage 1</u>: Existing - before traffic signal optimization
2. <u>Stage 2</u>: Optimized - after traffic signal optimization but before TSP implementation
3. <u>Stage 3</u>: TSP - after traffic signal optimization and after TSP implementation

The field data were collected during the three stages using the following three approaches:

1. <u>Field Travel Time Runs</u>: Field travel time runs were conducted to collect travel time and delay data for buses and general traffic by using a "floating car" method.
2. <u>Pace AVL System Data</u>: AVL data included trip information, timestamps (both arrival and departure times), bus headways, schedule deviations, bus identification numbers, and bus position coordinates at each time point along the bus route. Bus travel time and schedule deviation were derived from the AVL data to assess bus operational performance and schedule adherence improvement after the signal timing optimization and TSP implementation.
3. <u>Pace Bus Ride Along Data</u>: Bus travel time and delay data was collected by individuals that used a JAMAR travel time unit while riding the buses traveling in the project area.

Figure 3-8 summarizes the evaluation data used to assess each goal and objective for the Pace HTC TSP Demonstration.

Figure 3-8. Summary of Pace Data Used to Assess Project Goals and Objectives

Goal	Objective	Evaluation Data
1: Improve Transit Mobility	1-1: To reduce bus travel time	Pace AVL System Data, Pace Bus Ride Along Data
	1-2: To reduce bus delay at intersection level	
	1-3: To reduce bus delay at corridor level	
2: Improve Transit Reliability	2-1: To reduce bus travel time variance	AVL System Data, Pace Bus Ride Along Data
	2-2: To reduce time arrival/departure times deviated from the schedule at bus stops	
3: Improve General Traffic Mobility	3-1: To reduce car travel time	Field travel time runs

Overall, bus travel times were reduced by a range from 2% (25 sec) to 15% (3.3 min). In addition, bus travel time variations were reduced by a range of 14% (12 sec) to 66% (4 min).

4. TSP System Verification and Acceptance Testing

As part of the Systems Engineering process in TSP System deployment, the Verification Plan is intended to verify that the TSP system being built meets the specified System Requirements. Specific procedures are defined that can be traced back to the System Requirements as a means of verifying that the TSP System complies with the applicable system requirements.

TSP System Acceptance Testing is anticipated to be completed by TSP Vendors / Installers hired by Pace and CTA during the TSP Implementation stage of the RTSPIP. The Verification Plan can be utilized as an outline for how System Acceptance Testing can be conducted by TSP Vendors / Installers.

There are four general verification methods used to verify System Requirements:

1. Inspection – This method uses direct observation to verify that deployed system components conform to those specified requirements. Inspection can be applied to the verification of component features, workmanship, dimensions, and physical characteristics. Inspection could also be conducted by verifying the specifications provided by the manufacturers for some work products in the system.
2. Demonstration – This method requires test personnel to witness actual system operations, adjustment, or re-configuration. The demonstration verifies system requirements by providing evidence that the designed functions are accomplished under specific scenarios or in the expected environments without need for measurement data. Demonstrations are typically applied to the verification of system operational capabilities at component, subsystem and overall system levels
3. Analysis – This method uses established simulations and procedures to provide quantitative evidence that stated requirements are met.
4. Test – This method uses direct measurement of system operation and typically includes some level of instrumentation. The test method verifies requirements by providing defined inputs and measuring the outputs from the system. This method is applied to the verification of system functional operations and involves the application of established scientific principles and procedures.

Appendix C to this document assigns one of the four verification methods defined above to each of the Technical System Requirements. A majority of the Technical System Requirements can be verified through a demonstration of TSP System operations after the system has been installed. Subsystem testing pertaining to TSP System equipment installed on vehicles and intersections should be completed prior to a complete, end-to-end TSP System test.

TSP Vendors / Installers will be required to develop System Acceptance Tests that illustrate how a demonstration of TSP System operations can satisfy those requirements that should be verified with a demonstration as defined above.

Appendix A – Regional TSP Message Set Definition

REGIONAL TSP MESSAGE SET DEFINITION TRACKING TABLE

Version	Date	Description of Changes	Changes Made By:
1.3	02/20/15	Updated draft with correction to length of octet strings for the prgPriorityStatusControl_chi, prgPriorityStatusBuffer_chi, prgPriorityCancel_chi and prgPriorityClear_chi objects.	IBI Group / AECOM
1.2	07/31/14	Data objects were re-ordered by IBI Group to ease the overall testing of the messages later on in the project	IBI Group / AECOM
1.1	05/08/14	Changes to TSP Message Set made after review of RFI Responses from vendors	Battelle / AECOM
1.0	09/30/13	Updated draft included with updated Regional TSP Standards and Implementation Guidelines	Battelle / AECOM
0.1	08/02/13	Initial version for TSP Working Group review and comment	Battelle / AECOM

```
PRS-MIB1 DEFINITIONS ::= BEGIN

-- This group of objects represents the data elements for priority service requests communication exchange
between a Priority Request Generator (PRG) and a Priority Request Server (PRS).
IMPORTS
OBJECT-TYPE
FROM RFC-1212

devices
FROM TMIB-II;

scp OBJECT IDENTIFIER ::= {devices 11}

-- This group of objects represents the data elements used in the Priority Service Request Messages.

priorityRequestServer OBJECT IDENTIFIER ::= {scp 1}

priorityRequestTable OBJECT-TYPE
        SYNTAX SEQUENCE OF PriorityRequestTableEntry_chi
        ACCESS not-accessible
        STATUS optional
::= { priorityRequestServer 1 }

PriorityRequestTableEntry_chi OBJECT-TYPE
        SYNTAX PriorityRequestTableEntry_chi
        ACCESS not-accessible
        STATUS optional
        INDEX { PriorityRequestTableEntryNumber }
::= { priorityRequestTable 1 }

PriorityRequestTableEntry_chi ::= SEQUENCE
        {
        PriorityRequestTableEntryNumber         INTEGER (1..10),
        priorityRequestID                       INTEGER (1..255),
        priorityRequestVehicleID_chi            OCTET STRING (SIZE (6)),
        priorityRequestAgencyID_chi             INTEGER,
        priorityRequestVehicleClassType         INTEGER (1..10),
        priorityRequestVehicleClassLevel        INTEGER (1..10),
```

```
        priorityRequestTimeOfServiceDesired            INTEGER (1..65535),
        priorityRequestTimeOfEstimatedDeparture        INTEGER (1..65535),
        priorityRequestTSPPhaseRequired_chi            INTEGER (0..16),
        priorityRequestVehicleLatitude_chi             INTEGER (-900000000..900000001),
        priorityRequestVehicleLongitude_chi            INTEGER (-1800000000..1800000001),
        priorityRequestIntersectionID_chi              OCTET STRING (SIZE (7)),
        priorityRequestRouteID_chi                     OCTET STRING (SIZE (7)),
        priorityRequestRunNumber_chi                   OCTET STRING (SIZE (9)),
        priorityRequestScheduleLateness_chi            INTEGER (0..65535),
        priorityRequestVehicleOccupancy_chi            INTEGER (1..255),
        priorityRequestStatusInPRS                     INTEGER
        }

PriorityRequestTableEntryNumber OBJECT-TYPE
        SYNTAX INTEGER (1..10)
        ACCESS read-only
        STATUS optional
::= { PriorityRequestTableEntry_chi 1 }

priorityRequestID OBJECT-TYPE
        SYNTAX INTEGER (1..255)
        ACCESS read-only
        STATUS mandatory
        DESCRIPTION
                "This object is the 'PRG requested' priority request identifier. It is assigned by the priority
                request generator so that further information related to a priority request can be identified.
                It shall be unique for this intersection from a vehicle ID of vehicle type."
        DEFVAL { 1 }
::= { PriorityRequestTableEntry_chi 2 }

priorityRequestVehicleID_chi OBJECT-TYPE
        SYNTAX OCTET STRING (SIZE (6))
        ACCESS read-only
        STATUS mandatory
        DESCRIPTION
                "This object is the 'PRG requested' identifier of the entity requesting priority. For fleet
                vehicles, this is a 6-byte alphanumeric identifier assigned by the operating agency. For
                management centers, the value is not defined but shall still be unique to differentiate the
                source of the priority request."
        DEFVAL { "" }
::= { PriorityRequestTableEntry_chi 3 }

priorityRequestAgencyID_chi OBJECT-TYPE
        SYNTAX INTEGER {
                cta  (1),
                pace (2)
                }
        ACCESS read-only
        STATUS mandatory
        DESCRIPTION
                "This object is an enumerated value that identifies the agency requesting priority for
                logging and TSP monitoring purposes."
        DEFVAL { cta }
::= { PriorityRequestTableEntry_chi 4 }
```

```
priorityRequestVehicleClassType OBJECT-TYPE
        SYNTAX INTEGER (1..10)
        ACCESS read-only
        STATUS mandatory
        DESCRIPTION
                "This object is the PRG requested class type to establish the relative priority of a request.
                The order of precedence is by class type with:
                 1 highest
                 ...
                 10 lowest
                 A request with a higher class type will override a lower class type."
        DEFVAL { 10 }
::= { PriorityRequestTableEntry_chi 5 }

priorityRequestVehicleClassLevel OBJECT-TYPE
        SYNTAX INTEGER (1..10)
        ACCESS read-only
        STATUS optional
        DESCRIPTION
                "This object is the 'PRG requested' class level indicating the relative priority of a request
                within each class of request.  The order of precedence is by class type and then class level
                with:
                 1 highest
                 ...
                 10 lowest
                 A request with a higher class level will NOT override a lower class level."
        DEFVAL { 10 }
::= { PriorityRequestTableEntry_chi 6 }

priorityRequestTimeOfServiceDesired OBJECT-TYPE
        SYNTAX INTEGER (1..65535)
        ACCESS read-only
        STATUS mandatory
        DESCRIPTION
                "This object is the 'PRG requested' desired time in seconds to arrive at the intersection's
                stopping point relative to the receipt of the message. A near side stopping point is
                assumed to be sufficiently close to the intersection's stop bar that regular queues
                frequently back up across the stopping point. In this case, advance queue clearance prior
                to the arrival of fleet vehicle will be normally required. For all practical purposes, arrival
                at the stopping point is the same as arrival at the stop bar. This is a relative time.  It is the
                responsibility of the PRG to take into account any communications delays between the
                PRG and the PRS."
        DEFVAL { 1 }
::= { PriorityRequestTableEntry_chi 7 }

priorityRequestTimeOfEstimatedDeparture OBJECT-TYPE
        SYNTAX INTEGER (1..65535)
        ACCESS read-only
        STATUS mandatory
        DESCRIPTION
                "This object is the 'PRG requested' estimated time in seconds of departure from
                 the intersection's stopping point relative to the receipt of the message. This
                 is a relative time.  It is the responsibility of the PRG to take into account
                 any communications delays between the PRG and the PRS."
        DEFVAL { 1 }
```

```
::= { PriorityRequestTableEntry_chi 8 }

priorityRequestTSPPhaseRequired_chi OBJECT-TYPE
        SYNTAX INTEGER (0..16)
        ACCESS read-only
        STATUS mandatory
        DESCRIPTION
                "This object indicates the traffic signal controller NEMA-based phase that service the
                direction of TSP desired at the intersection. A value of 0 indicates that there is no
                direction indicated and the message is for log purposes only."
        DEFVAL { 0 }
::= { PriorityRequestTableEntry_chi 9 }

priorityRequestVehicleLatitude_chi OBJECT-TYPE
        SYNTAX INTEGER (-900000000..900000001)
        ACCESS read-only
        STATUS mandatory
        DESCRIPTION
                "Adapted from SAEJ2735.  This object is geographic latitude of the vehicle expressed in
                1/10th integer micro-degrees, providing a range of plus-minus 90 degrees.  The value
                900000001 shall be used when unavailable."
        DEFVAL { 900000001 }
::= { PriorityRequestTableEntry_chi 10 }

priorityRequestVehicleLongitude_chi OBJECT-TYPE
        SYNTAX INTEGER (-1800000000..1800000001)
        ACCESS read-only
        STATUS mandatory
        DESCRIPTION
                "Adapted from SAEJ2735.  This object is geographic longitude of the vehicle expressed
                in 1/10th integer micro-degrees, providing a range of plus-minus 180 degrees.  The value
                1800000001 shall be used when unavailable."
        DEFVAL { 1800000001 }
::= { PriorityRequestTableEntry_chi 11 }


priorityRequestIntersectionID_chi OBJECT-TYPE
        SYNTAX OCTET STRING (SIZE (7))
        ACCESS read-only
        STATUS mandatory
        DESCRIPTION
                "This object is the 'PRG requested' globally unique identifier of the intersection for which
                priority is being requested.  It is comprised of a one-byte agency code followed by a 6-
                byte alphanumeric intersection identifier."
        DEFVAL { "" }
::= { PriorityRequestTableEntry_chi 12 }

priorityRequestRouteID_chi OBJECT-TYPE
        SYNTAX OCTET STRING (SIZE (7))
        ACCESS read-only
        STATUS mandatory
        DESCRIPTION
                "This object is an alphanumeric string representing a unique route ID that will be used for
                logging and TSP monitoring purposes."
        DEFVAL { "" }
```

```
::= { PriorityRequestTableEntry_chi 13 }

priorityRequestRunNumber_chi OBJECT-TYPE
        SYNTAX OCTET STRING (SIZE (9))
        ACCESS read-only
        STATUS mandatory
        DESCRIPTION
                "This object is a 9-Byte alphanumeric value that identifies the run number of the bus
                making a TSP request for logging and TSP monitoring purposes."
        DEFVAL { "" }
::= { PriorityRequestTableEntry_chi 14 }

priorityRequestScheduleLateness_chi OBJECT-TYPE
        SYNTAX INTEGER (0..65535)
        ACCESS read-only
        STATUS mandatory
        DESCRIPTION
                "This object is the schedule lateness at the time of the priority request in seconds used for
                logging and TSP monitoring purposes."
        DEFVAL { 0 }
::= { PriorityRequestTableEntry_chi 15 }


priorityRequestVehicleOccupancy_chi OBJECT-TYPE
        SYNTAX INTEGER (1..255)
        ACCESS read-only
        STATUS optional
        DESCRIPTION
                "This object is the vehicle occupancy at the time of the priority request used for logging
                and TSP monitoring purposes. A value of 255 indicates that occupancy equipment is not
                available."
        DEFVAL { 255 }
::= { PriorityRequestTableEntry_chi 16 }

priorityRequestStatusInPRS OBJECT-TYPE
        SYNTAX INTEGER {
                idleNotValid                (1),
                readyQueued                 (2),
                readyOverridden             (3),
                activeProcessing            (4),
                activeCancel                (5),
                activeOverride              (6),
                activeNotOverridden         (7),
                closedCanceled              (8),
                reserviceError              (9),
                closedTimeToLiveError       (10),
                closedTimerError            (11),
                reserved                    (12),
                closedCompleted             (13),
                activeAdjustNotNeeded       (14),
                closedFlash                 (15)
                }
        ACCESS read-only
        STATUS mandatory
        DESCRIPTION
```

```
                "This object provides status information about requests in the PRS.
                 idleNotValid: PRS determined that row does not contain valid data
                 readyQueued: PRS has validated the request but is waiting for the CO to activate
                 readyOverridden: CO has overridden the request
                 activeProcessing: CO is processing the requested strategy
                 activeCancel: PRS has asked that request be canceled
                 activeOverride: PRS has asked that request be overridden
                 activeNotOverridden: CO did not process the requested override
                 closedCanceled: CO has canceled the request
                 reserviceError: PRS determined that the request came too soon after a previous
                 request
                 closedTimeToLiveError: CO determined that TSD exceeds the time to live
                 closedTimerError: CO indicated that the requested times could not be met
                 reserved: reserved for future use
                 closedCompleted: CO has completed the requested strategy previous request
                 activeAdjustNotNeeded: CO indicated that the request can be met by the current
                 timing and no adjustment is necessary
                 closedFlash: CO indicated that the controller is in flash"
        DEFVAL { idleNotValid }
::= { PriorityRequestTableEntry_chi 17 }

priorityRequestMessages OBJECT IDENTIFIER ::= {scp 2}

prgPriorityRequest_chi OBJECT-TYPE
        SYNTAX OCTET STRING (SIZE (49))
        ACCESS write-only
        STATUS mandatory
        DESCRIPTION
                "This object defines the elements that make up the priority request message. The object
                values in this octet string are as follows:

                 priorityRequestID                              (1 byte)
                 priorityRequestVehicleID_chi                   (6 bytes)
                 priorityRequestAgencyID_chi                    (1 byte)
                 priorityRequestVehicleClassType                (1 byte)
                 priorityRequestVehicleClassLevel               (1 byte)
                 priorityRequestTimeOfServiceDesired            (2 bytes)
                 priorityRequestTimeOfEstimatedDeparture        (2 bytes)
                 priorityRequestTSPPhaseRequired_chi            (1 byte)
                 priorityRequestVehicleLatitude_chi             (4 bytes)
                 priorityRequestVehicleLongitude_chi            (4 bytes)
                 priorityRequestIntersectionID_chi              (7 bytes)
                 priorityRequestRouteID_chi                     (7 bytes)
                 priorityRequestRunNumber_chi                   (9 bytes)
                 priorityRequestScheduleLateness_chi            (2 bytes)
                 priorityRequestVehicleOccupancy_chi            (1 byte)

                 The byte order for packing shall follow the rules of ASN with the MSB first. If an
                optional data object is not to be transmitted, then its bits shall be set to zero so that the
                resulting data object shall always be exactly 49 bytes in length."
::= { priorityRequestMessages 1 }

prgPriorityUpdate_chi OBJECT-TYPE
        SYNTAX OCTET STRING (SIZE (25))
        ACCESS write-only
```

```
        STATUS mandatory
        DESCRIPTION
                "This object defines the elements to update an existing priority request.
                 The object values in this octet string are as follows:

                 priorityRequestID                          (1 byte)
                 priorityRequestVehicleID_chi               (6 bytes)
                 priorityRequestAgencyID_chi                (1 byte)
                 priorityRequestVehicleClassType            (1 byte)
                 priorityRequestVehicleClassLevel           (1 byte)
                 priorityRequestTimeOfServiceDesired        (2 bytes)
                 priorityRequestTimeOfEstimatedDeparture    (2 bytes)
                 priorityRequestTSPPhaseRequired_chi        (1 byte)
                 priorityRequestVehicleLatitude_chi         (4 bytes)
                 priorityRequestVehicleLongitude_chi        (4 bytes)
                 priorityRequestScheduleLateness_chi        (2 bytes)

                The byte order for packing shall follow the rules of ASN with the MSB first. If an
                optional data object is not to be transmitted, then its bits shall be set to zero so that the
                resulting data object shall always be exactly 25 bytes in length."
::= { priorityRequestMessages 2 }

prgPriorityStatusControl_chi OBJECT-TYPE
        SYNTAX OCTET STRING (SIZE (10))
        ACCESS write-only
        STATUS mandatory
        DESCRIPTION
                "This object defines the elements to request the status of an existing priority reqeust. The
                object values in this octet string are as follows:

                 priorityRequestID                  (1 byte)
                 priorityRequestVehicleID_chi       (6 bytes)
                 priorityRequestAgencyID_chi        (1 byte)
                 priorityRequestVehicleClassType    (1 byte)
                 priorityRequestVehicleClassLevel   (1 byte)

                 The byte order for packing shall follow the rules of ASN with the MSB first. This
                message will cause the PRS to initialize the contents of the priority status buffer"
::= { priorityRequestMessages 3 }

prgPriorityStatusBuffer_chi OBJECT-TYPE
        SYNTAX OCTET STRING (SIZE (11))
        ACCESS read-only
        STATUS mandatory
        DESCRIPTION
                "This object defines the elements to define the status of a priority
                 request. The object values in this octet string are as follows:

                 priorityRequestID                  (1 byte)
                 priorityRequestVehicleID_chi       (6 bytes)
                 priorityRequestAgencyID_chi        (1 byte)
                 priorityRequestVehicleClassType    (1 byte)
                 priorityRequestVehicleClassLevel   (1 byte)
                 priorityRequestStatusInPRS         (1 byte)
```

```
                     The byte order for packing shall follow the rules of ASN with the MSB first. The
                     contents of the priority status buffer is initialized by the PRS in response to a Priority
                     Status Control message."
::= { priorityRequestMessages 4 }

prgPriorityCancel_chi OBJECT-TYPE
          SYNTAX OCTET STRING (SIZE (10))
          ACCESS write-only
          STATUS mandatory
          DESCRIPTION
                    "This object defines the elements to cancel an existing priority request.
                     The object values in this octet string are as follows:

                     priorityRequestID                        (1 byte)
                     priorityRequestVehicleID_chi             (6 bytes)
                     priorityRequestAgencyID_chi              (1 byte)
                     priorityRequestVehicleClassType          (1 byte)
                     priorityRequestVehicleClassLevel         (1 byte)

                     The byte order for packing shall follow the rules of ASN with the MSB first."
::= { priorityRequestMessages 5 }

prgPriorityClear_chi OBJECT-TYPE
          SYNTAX OCTET STRING (SIZE (10))
          ACCESS write-only
          STATUS mandatory
          DESCRIPTION
                    "This object defines the elements to clear an existing priority request. The object values
                    in this octet string are as follows:

                     priorityRequestID                        (1 byte)
                     priorityRequestVehicleID_chi             (6 bytes)
                     priorityRequestAgencyID_chi              (1 byte)
                     priorityRequestVehicleClassType          (1 byte)
                     priorityRequestVehicleClassLevel         (1 byte)

                     The byte order for packing shall follow the rules of ASN with MSB first."
::= { priorityRequestMessages 6 }

END
```

Appendix B – Standard Dialogs for Development and Testing

This Appendix B defines the standard message dialogs for implementation by the Priority Request Generator (PRG) and the Priority Request Server (PRS) devices that are a part of the Regional Transit Signal Priority Implementation Program (RTSPIP). The Regional TSP Message Set (Appendix A) defines the data objects and messages to be communicated between the PRG and the PRS to be deployed for the program.

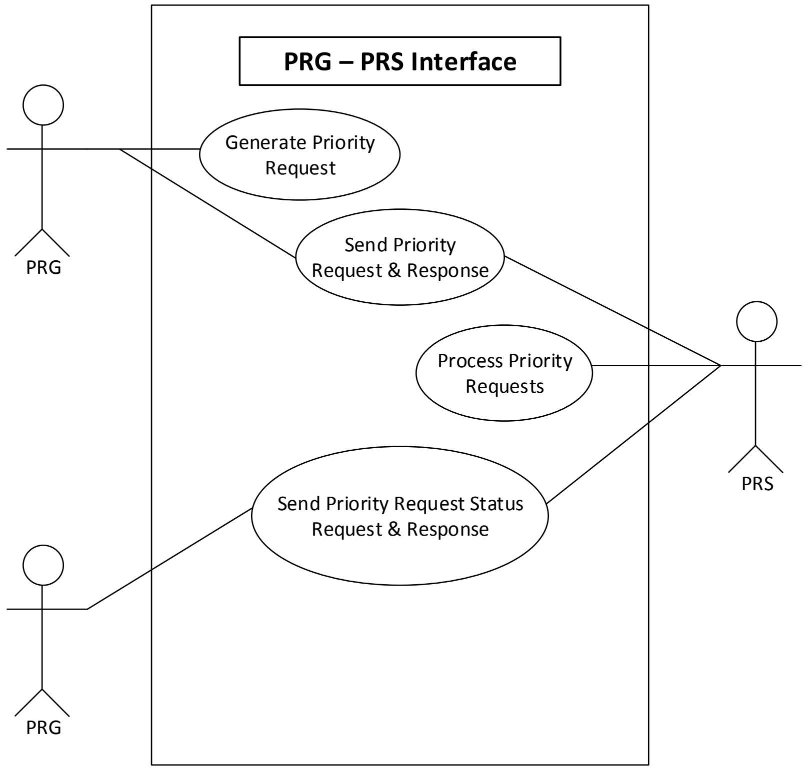
The standard message dialogs described within this Appendix B define the exchange of messages between the PRG and PRS, and some of the actions to be taken by the PRS in response to messages from the PRG. This will reduce the potential for misinterpretation by equipment vendors regarding the intended usage of the TSP Message Set in PRG and PRS interaction.

Section 1.0 below provides an overview of the PRG-PRS Interface. Section 2.0 defines the standard message dialogs to occur between the PRG and PRS devices to be deployed for the program.

PRG and PRS testing tools will be provided to Contractors responsible for designing and developing the PRG and PRS devices of the RTSPIP. The testing tools will verify the correct usage of data objects within the TSP Message Set in Appendix A, as described by standard dialogs defined below in Section 2.0. The testing tools will also be used during bench testing activities to confirm that the PRG and PRS devices being developed are interoperable with one another, prior to proceeding with field testing activities and implementation of the PRG and PRS devices.

1.0 Signal Control Priority (SCP) PRG-PRS Interface

This interface allows a PRG to send a request for preferential treatment to the PRS. The PRS may also simultaneously receive requests for preferential treatment from other PRGs and has to prioritize these competing requests. The PRS also sends the status of the priority request back to the PRG through the interface upon request. The PRS may be internal to the traffic signal controller or may be separate from the traffic signal controller at a signalized intersection. The requirements for data exchanges between a PRG and a PRS are provided in the following subsections.



1.1 Receive Priority Requests

The requirements for exchanging priority requests between a PRG and a PRS are provided in the following subsections.

1.1.1 Initiate a Priority Request

A PRG shall send a priority request message to a PRS to initiate a new priority request. The priority request information consists of:

- Unique (from the vehicle's perspective) priority request identification number;
- Identification number of the vehicle;
- Agency to which the vehicle belongs;
- Class type of the vehicle;
- Class level of the vehicle;
- Duration of the TSP call (in seconds);
- Estimated time of arrival of the vehicle (in seconds);
- Estimated time of departure of the vehicle (in seconds);
- Vehicle location Latitude;
- Vehicle location longitude;
- Intersection identification number;
- Route identification number;
- Run number;

- Lateness of the vehicle making the request; and
- Passenger loading.

1.1.2 Send a Priority Request Update

A PRG shall send a priority request update message to a PRS to update the time of service desired (in seconds), the estimated time of arrival and departure (in seconds), the priority level, the latitude of the vehicle making the request, the longitude of the vehicle making the request, and the lateness of the vehicle making the request. The priority request update message will also include the following items: the unique priority request identification number, the identification number of the vehicle, the agency to which the vehicle belongs, the class type of the vehicle, and the class level of the vehicle, with values identical to those included in the original priority request message.

1.1.3 Send a Cancel Priority Request

A PRG shall send a cancel priority request message to a PRS to cancel a previously sent priority request. The cancel priority request message consists of the unique priority request identification number, the identification number of the vehicle, the agency ID of the vehicle, the class type of the vehicle, and the class level of the vehicle.

1.1.4 Send a Clear Priority Request

A PRG shall send a clear priority request message to a PRS to clear all information in a previously sent priority request. The clear priority request message consists of the unique priority request identification number, the identification number of the vehicle, the agency ID of the vehicle the class type of the vehicle, and the class level of the vehicle.

1.1.5 Receive Priority Request Status

A PRG shall receive the status of a priority request from the PRS. The status of a priority request consists of the unique priority request identification number, the identification number of the vehicle, the agency ID of the vehicle, the class type of the vehicle, and the class level of the vehicle.

2.0 Signal Control Priority (SCP) Standard Dialogs for the PRG-PRS Interface

The NTCIP device standards effort is based on SNMP. An SNMP Dialog is defined as a sequence of data exchanges (i.e. SNMP GET and/or SET requests). SNMP offers a high degree of flexibility as to how a manager (i.e. PRG) structures its requests. For example, with SNMP, a manager can do any of the following:

a) Send only those requests that are critical at the current time, whereas a standardized dialog typically sends requests relating to all associated data, regardless of whether it is critical for current purposes.
b) Combine a number of requests in a single packet, whereas a standardized dialog dictates the exact contents of each packet.
c) Separate a group of requests into multiple packets, whereas a standardized dialog dictates the exact contents of each packet.
d) Interweave requests from multiple dialogs, whereas a standardized dialog dictates the exact ordering of messages, which are not interrupted with other messages.

This flexibility can be a powerful tool allowing a manager to optimize the use of communication facilities, which is the primary reason that SNMP was chosen as the core NTCIP protocol for devices. However, this flexibility also means that there are numerous allowable variations in the management process that a manager may choose to employ, which presents a challenge to ensuring interoperability. To overcome this challenge, this section defines the lowest common denominator approach to PRG-PRS communications; it defines the standardized dialog for each PRG Data Exchange Requirement.

Managers may support other dialogs to fulfill these same requirements, but a ‘conformant manager’ is required to offer a mode in which it only uses the standardized dialogs as defined in this section. With this limited definition, there is relatively little variability in what constitutes a conformant manager. Thus, fully testing a manager for conformance is a relatively straight forward process that can be done within the practical constraints faced by most procuring agencies, and a conformant manager provides an agency with a much greater probability of achieving interoperability.

The following are the rules for the aforementioned standardized dialogs:

a) The dialogs are defined by a sequence of SNMP GET and/or SET requests.
b) The contents of each request are identified by an object name. Each object name consists of an object type and an instance identifier. Formal definitions of each object type are provided in the Regional TSP Message Set. The meaning of the instance identifier is provided by these same definitions coupled with standard SNMP rules (see RFC 1212).
c) Each message shall contain all of the objects as shown, unless otherwise indicated.
d) A message shall not contain any other objects.
e) The contents of each message sent by the manager must appear in the order as shown in this section.

This section defines the standardized dialogs for the more complicated data exchange requirements. Each of these dialogs is defined by a number of steps. Many of the steps reference data elements that are defined in the Regional TSP Message Set.

The dialogs are accompanied by an informative figure that provides a graphical depiction of the normative text. The figures conform to the Unified Modeling Language and depict the manager as an outside actor sending a series of messages to the agent and the agent returning responses. If there is any conflict between the figure and the text, the text takes precedence.

This section provides the dialogs that shall occur between the PRG and the PRS. This section includes only those dialogs that have special semantics or impose special restrictions on the operations allowed. For this communications interface, the PRG is always the manager and the PRS is always the agent.

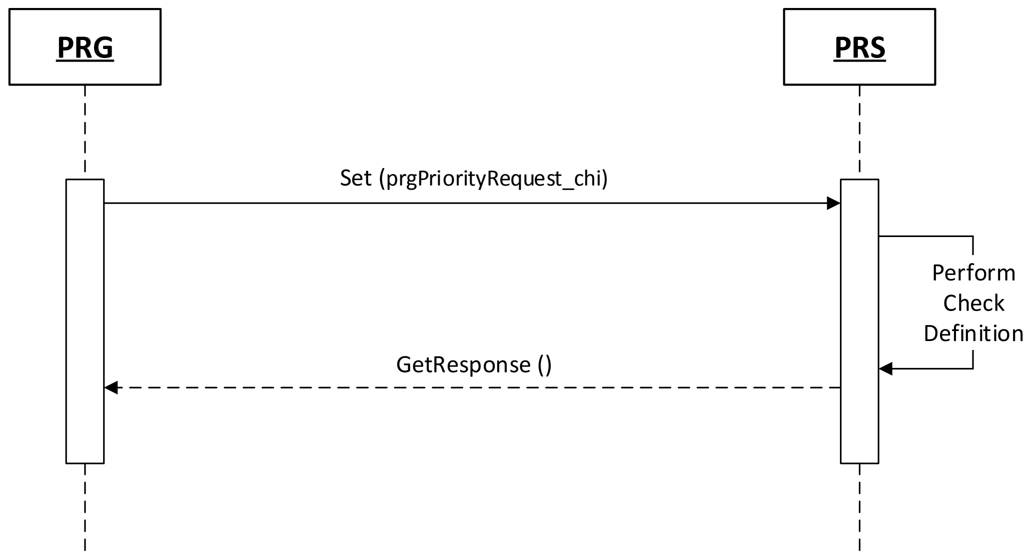
2.1 Exchange Priority Request

2.1.1 Standardized Dialog

The standardized dialog for a PRS to receive a priority request from a PRG shall be as follows:

a) The PRG shall SET **prgPriorityRequest_chi** with the desired values. This shall cause the PRS to perform a priority request check definition (See Section 2.1.2).

b) If the PRS sends a GetResponse with '**noError**', the priority request has been accepted and the PRS is waiting for the completion of its service processing. The PRG may then exit the process.



2.1.2 Check Definition

Upon receiving a SET **prgPriorityRequest_chi** message from a PRG, the PRS shall perform several checks and processes before responding with an acknowledgement.

a) If the SET length is NOT 49, or if the contents of any message OID field cannot be parsed to fit the SYNTAX defined for the referenced object, then the PRS shall return an Error Status of '**badValue (3)**' to the PRG and no further processing takes place.

b) If the **priorityRequestTable** does not have at least one row with a **priorityRequestStatusInPRS** of '**idleNotValid**', the PRS shall return an Error Status of '**noSuchName (2)**' to the PRG and no further processing takes place (This error-status can be considered as a buffer full error – no table rows available for new requests).

c) If the above checks are completed without error, the PRS shall store the contents of the **prgPriorityRequest_chi** message in the appropriate **priorityRequestTableEntry_chi**.

d) The PRS shall set **priorityRequestID, priorityRequestVehicleID_chi**, **priorityRequestAgencyID_chi, priorityRequestVehicleClassType,**

priorityRequestVehicleClassLevel, priorityRequestTimeOfServiceDesired, priorityRequestTimeOfEstimatedDeparture, priorityRequestTSPPhaseRequired_chi, priorityRequestVehicleLatitude_chi, priorityRequestVehicleLongitude_chi, priorityRequestIntersectionID_chi, priorityRequestRouteID_chi, priorityRequestRunNumber_chi, priorityRequestScheduleLateness_chi, and priorityRequestVehicleOccupancy_chi in the appropriate **priorityRequestTableEntry_chi**.

e) The PRS shall determine if the request was received too soon after a previous request, and if it has, it shall set **priorityRequestStatusInPRS** to '**reserviceError (9)**' for the appropriate **priorityRequestTableEntry_chi**. Otherwise, the PRS shall set **priorityRequestStatusInPRS** for the appropriate **priorityRequestTableEntry_chi** to '**readyQueued (2)**'.

f) If for the request, there exists a corresponding request with a lower Class Type and/or Level, with a **priorityRequestStatusInPRS** state of '**activeProcessing (4)**' or '**activeAdjustNotNeeded (14)**', the PRS shall set **priorityRequestStatusInPRS** of the lower Class Type and/or Level **priorityRequestTableEntry_chi** to '**activeOverride (6)**'.

g) The PRS shall return an Error Status of '**noError**' to the PRG.

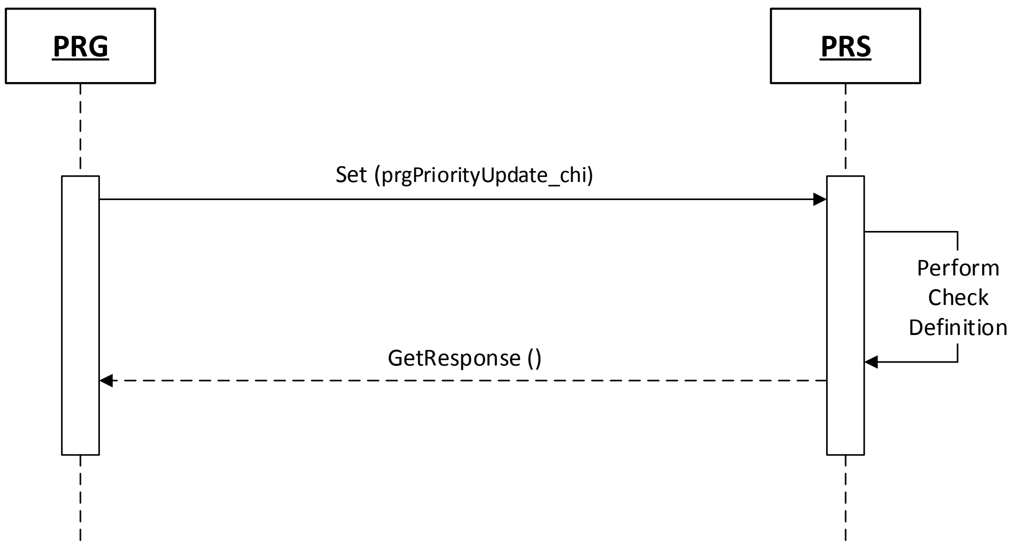
2.2 Exchange Priority Update

2.2.1 Standardized Dialog

The standardized dialog for a PRS to receive a priority request update from a PRG shall be as follows:

a) The PRG shall SET **prgPriorityUpdate_chi** with the desired values. This shall cause the PRS to perform a priority request update check definition (See Section 2.2.2).

b) If the PRS sends a GetResponse with '**noError**', the priority request update has been accepted and the PRS is waiting for the CO to complete its service processing. The PRG may then exit the process.



2.2.2 Check Definition

Upon receiving a SET **prgPriorityUpdate_chi** message from a PRG, the PRS shall perform several checks before responding with an acknowledgement.

a) If the SET length is NOT 25, or if the contents of any message OID field cannot be parsed to fit the SYNTAX defined for the referenced object, then the PRS shall return an Error Status of '**badValue (3)**' to the PRG and no further processing takes place.

b) The PRS shall check for a matching entry in the **priorityRequestTable**. A matching entry requires a **priorityRequestStatusInPRS** of other than '**idleNotQueued (1)**' and all of the following to have the same values as in the SET **prgPriorityUpdate_chi** message:
   i) **priorityRequestID**,
   ii) **priorityRequestVehicleID_chi**,
   iii) **priorityRequestAgencyID_chi**
   iv) **priorityRequestVehicleClassType**,
   v) **priorityRequestVehicleClassLevel**

c) If the PRS is unable to find a matching entry in the **priorityRequestTable**, the PRS shall return an Error Status of ‘**noSuchName (2)**’ to the PRG and no further processing takes place.

d) If the above checks are completed without error, the PRS shall set **priorityRequestTimeOfServiceDesired**, **priorityRequestTimeOfEstimatedDeparture**, **priorityRequestTSPPhaseRequired_chi**, **priorityRequestVehicleLatitude_chi**, **priorityRequestVehicleLongitude_chi,** and **priorityRequestScheduleLateness_chi**, in the appropriate **priorityRequestTableEntry_chi** to the values received.

e) The PRS shall return an Error Status of ‘**noError**’ to the PRG.

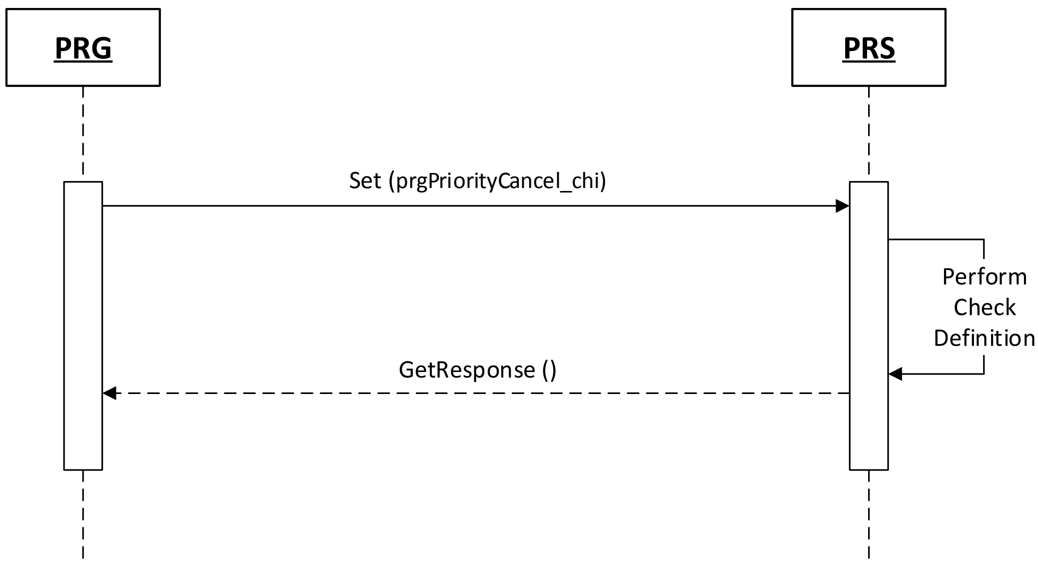
2.3 Exchange Priority Cancel

2.3.1 Standardized Dialog

The standardized dialog for a PRS to receive a priority request cancel from a PRG shall be as follows:

a) The PRG shall SET **prgPriorityCancel_chi** with the desired values. This shall cause the PRS to perform a priority request cancel check definition (See Section 2.3.2).

b) If the PRS sends a GetResponse with '**noError**', the priority request cancel has been accepted and the PRS shall attempt to cancel the priority request. The PRG may then exit the process.



2.3.2 Check Definition

Upon receiving a SET **prgPriorityCancel_chi** message from a PRG, the PRS shall perform several checks before responding with an acknowledgement.

a) If the SET length is NOT 9, or if the contents of any message OID field cannot be parsed to fit the SYNTAX defined for the referenced object, then the PRS shall return an Error Status of '**badValue (3)**' to the PRG and no further processing takes place.

b) The PRS shall check for a matching entry in the **priorityRequestTable**. A matching entry requires a **priorityRequestStatusInPRS** of other than '**idleNotQueued (1)**' and all of the following to have the same values as in the SET **prgPriorityCancel_chi** message:
   i) **priorityRequestID**,
   ii) **priorityRequestVehicleID_chi**,
   iii) **priorityRequestAgencyID_chi**,
   iv) **priorityRequestVehicleClassType**, and
   v) **priorityRequestVehicleClassLevel**

c) If the PRS is unable to find a matching entry in the **priorityRequestTable**, the PRS shall return an Error Status of ‘**noSuchName (2)**’ to the PRG and no further processing takes place.

d) If the above checks are completed without error, the PRS shall return an Error Status of ‘**noError**’ to the PRG.

e) If **priorityRequestStatusInPRS** in the appropriate **PriorityRequestTableEntry_chi** is ‘**readyQueued (2)**’ or ‘**readyOverridden (3)**’, then the PRS shall set **priorityRequestStatusInPRS** to ‘**closedCanceled (8)**’.

f) If **priorityRequestStatusInPRS** in the appropriate **PriorityRequestTableEntry_chi** is ‘**activeProcessing (4)**’ or ‘**activeAdjustNotNeeded (14)**’, the PRS shall set **priorityRequestStatusInPRS** to ‘**activeCancel (5)**’.

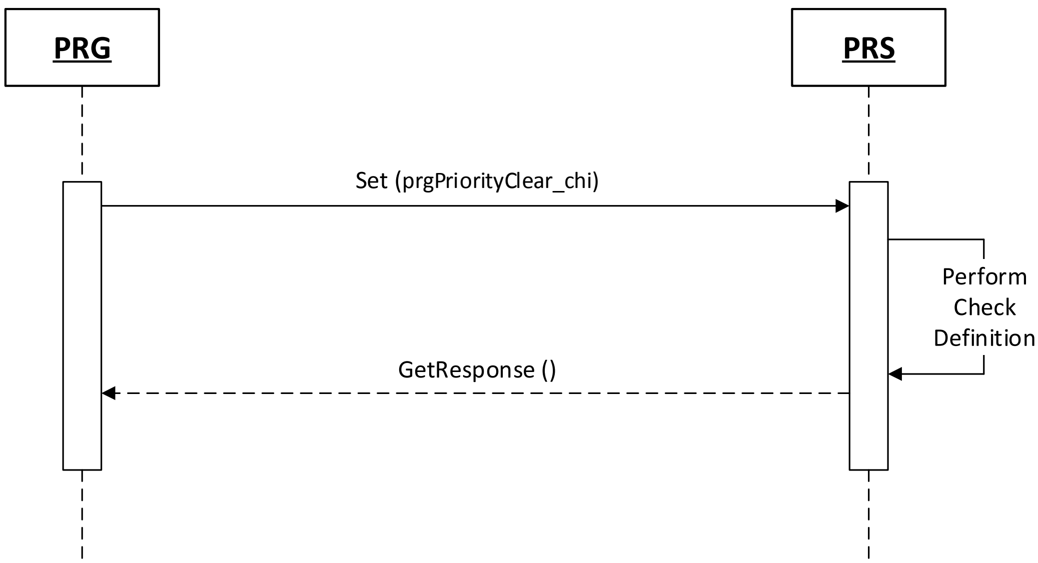
2.4 Exchange Priority Clear

2.4.1 Standardized Dialog

The standardized dialog for a PRS to receive a priority request clear from a PRG shall be as follows:

a) The PRG shall SET **prgPriorityClear_chi** with the desired values. This shall cause the PRS to perform a priority request clear check (See Section 2.4.2).

b) If the PRS sends a GetResponse with '**noError**', the priority request clear has been accepted and the PRS is waiting for the CO to complete its service processing. The PRG may then exit the process.



2.4.2 Check Definition

Upon receiving a SET **prgPriorityClear_chi** message from a PRG, the PRS shall perform several checks before responding with an acknowledgement.

a) If the SET length is NOT 9, or if the contents of any message OID field cannot be parsed to fit the SYNTAX defined for the referenced object, then the PRS shall return an Error Status of '**badValue (3)**' to the PRG and no further processing takes place.

b) The PRS shall check for a matching entry in the **priorityRequestTable**. A matching entry requires a **priorityRequestStatusInPRS** of other than '**idleNotQueued (1)**' and all of the following to have the same values as in the SET **prgPriorityClear_chi** message:

    i) priorityRequestID,
    ii) priorityRequestVehicleID_chi,
    iii) **priorityRequestAgencyID_chi**,
    iv) priorityRequestVehicleClassType, and
    v) priorityRequestVehicleClassLevel

c) If the PRS is unable to find a matching entry in the **priorityRequestTable**, the PRS shall return an Error Status of '**noSuchName (2)**' to the PRG and no further processing takes place.

d) If **priorityRequestStatusInPRS** in the appropriate **priorityRequestTableEntry_chi** is not '**closedCanceled (8)**', '**reserviceError (9)**', '**closedTimeToLiveError (10)**', '**closedTimerError (11)**', '**closedCompleted (13)**' or '**closedFlash (15)**', the PRS shall return an Error Status of '**genError**' to the PRG and no further processing takes place.

e) If the above checks pass, the PRS shall set all information in the appropriate **priorityRequestTableEntry_chi** to its default value state, thereby clearing the priority request.

f) The PRS shall then set **priorityRequestStatusInPRS** in the appropriate **PriorityRequestTableEntry_chi** to '**idleNotValid (1)**'.

g) The PRS shall return an Error Status of '**noError**' to the PRG.

2.5 Exchange Priority Request Status

2.5.1 Standardized Dialog

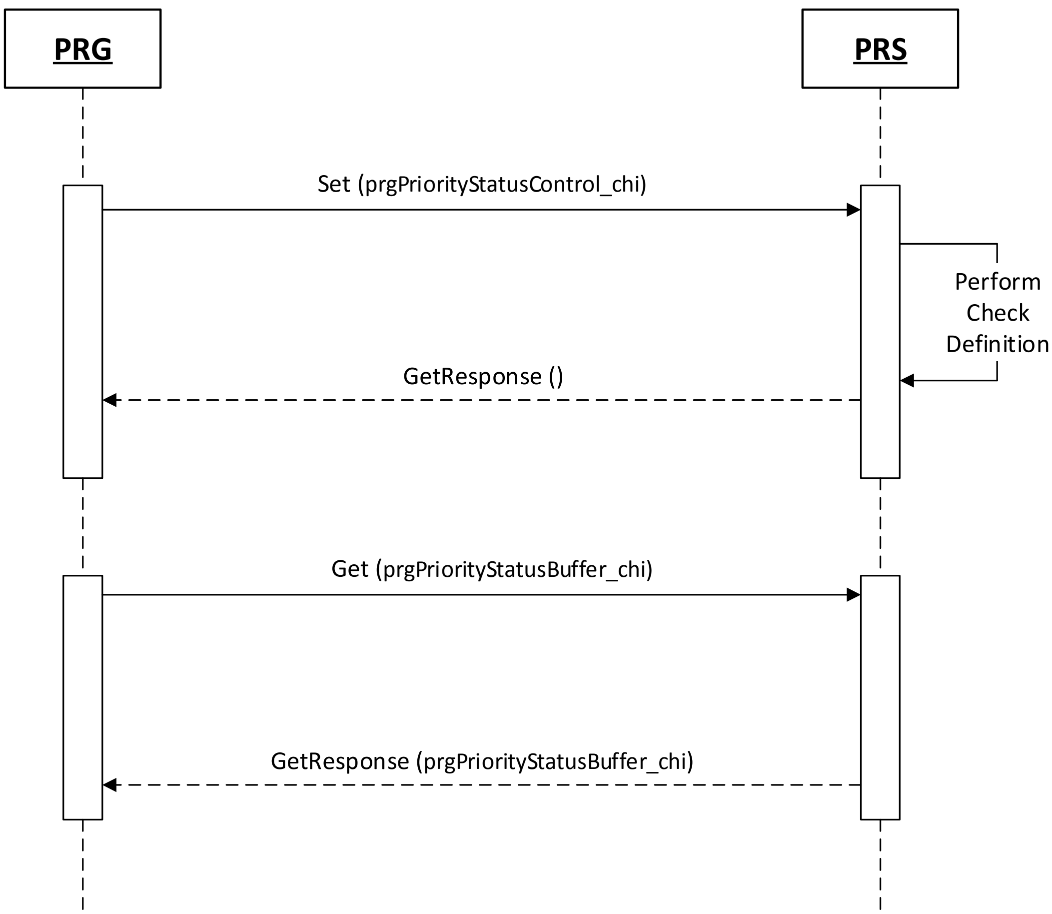
The standardized dialog for a PRS to receive a priority request status from a PRG shall be as follows:

a) The PRG shall SET **prgPriorityStatusControl_chi** on the PRS with the desired values. This shall cause the PRS to perform a priority request status check (See Section 2.5.2).

b) If the PRS sends a GetResponse with '**NoError**', the PRG shall GET **prgPriorityStatusBuffer_chi** from the PRS.

c) If the **prgPriorityStatusControl_chi** has invalid data (i.e. the PRS has not yet completed the priority request status check), the PRS shall send a **GetResponse** with an Error Status of '**badValue (3)**' to the PRG. The PRG may need to send 1 to 3 subsequent GET **prgPriorityStatusControl_chi** requests in order to receive a GetResponse with '**NoError**'.

d) If **prgPriorityStatusControl_chi** has valid data, the PRS shall utilize values currently in prgPriorityStatusControl to define the data to be returned in the response to a GET **prgPriorityStatusBuffer_chi** request.



2.5.2 Check Definition

Upon receiving a SET **prgPriorityStatusControl_chi** message, the PRS shall perform several checks before responding with an acknowledgement.

a) If the SET length is NOT 9, or if the contents of any message OID field cannot be parsed to fit the SYNTAX defined for the referenced object, then the PRS shall return an Error Status of '**badValue (3)**' to the PRG and no further processing takes place.

b) The PRS shall check for a matching entry in the **priorityRequestTable**. A matching entry requires a **priorityRequestStatusInPRS** of other than '**idleNotQueued (1)**' and all of the following to have the same values as in the SET **prgPriorityStatusControl_chi** message:
   i) **priorityRequestID**,
   ii) **priorityRequestVehicleID_chi**,
   iii) **priorityRequestAgencyID_chi**,
   iv) **priorityRequestVehicleClassType**, and
   v) **priorityRequestVehicleClassLevel**

c) If the PRS is unable to find a matching entry in the **priorityRequestTable**, the PRS shall return an Error Status of '**noSuchName (2)**' to the PRG and no further processing takes place.

d) If the above checks pass, the PRS shall set all relevant information from the appropriate **priorityRequestTableEntry_chi** to the **prgPriorityStatusBuffer_chi**.

e) The PRS shall return an Error Status of '**noError**' to the PRG.

Appendix C -- Verification Plan and Relation to Technical System Requirements

ID	Type	Requirement	Importance	Verification Method
PRG-1	S	The PRG shall generate priority requests based on schedule adherence conditions measured by the AVL System	M	D
PRG -2	S	The PRG shall generate priority requests based on vehicle location (need to reference a level of accuracy within space and time)	M	D
PRG -3	S	The vehicle location shall be provided by the AVL system	V	D
	S	The PRG shall generate priority requests based on conditions in addition to schedule adherence measured by the AVL System, including:	O	D
PRG -4	S	a) Passenger occupancy	O	
PRG -5	S	b) Time-of-day	V	
PRG -6	S	c) Type of route (BRT, express, local, etc…)	V	
PRG -7	S	d) Presence of exclusive transit phase	V	
PRG -8	F	The PRG shall generate a TSP corridor check-in message at the first TSP intersection encountered on the corridor, regardless of schedule adherence or other conditions measured by the AVL system, for the purposes of travel time analysis and TSP performance reporting	V	D
PRG -9	F	The PRG shall generate a TSP corridor check-out message at the last TSP intersection encountered on the corridor, regardless of schedule adherence or other conditions measured by the AVL system, for the purposes of travel time analysis and TSP performance reporting	V	D
PRG -10	E	The PRG shall interface with the battery of the bus for power supply, and be capable of full operation from 12 to 28 VDC	M	I
PRG -11	F	The PRG shall require no action from the bus driver to initiate operations of the TSP System, and thus cause no interference to the bus driver	M	I
PRG -12	F	The PRG shall log priority requests made through messages sent to the PRS	M	D
		a) Each bus should log each time it traverses a TSP intersection regardless of whether it is requesting TSP		D
		b) Each log should include whether or not the bus met the schedule adherence (lateness) threshold (needs further discussion)		D
PRG -13	P	The PRG shall successfully operate to request signal priority at a minimum performance rate of 99%	M	A
	E	The PRG that is not part of the AVL system shall successfully operate and not suffer any	M	I

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ID	Type	Requirement	Importance	Verification Method
		performance degradation, corrosion, deterioration, or abnormal wear under the following conditions:		
PRG -14	E	a) Temperature: operate over a temperature range specified by NEMA T2 standards	M	I
PRG -15	E	b) Humidity: operate over a relative humidity range of 20 percent to 95 percent	M	I
PRG -16	E	c) Inclination: operate from 0 to 18 degrees off vertical	M	I
PRG -17	E	d) Water/Moisture: water/moisture from wind-blown rain, passengers, and/or interior and exterior bus/car wash equipment	M	I
PRG -18	E	e) Vibration: FCC Part 15 Class A Devices	M	I
PRG -19	F	PRG equipment that is not part of the AVL System shall be remotely accessible for purposes of retrieving logs and configuring PRG equipment	M	I
		a) In garage (mandatory)		I
		b) For bus on route (value)		I
PRG -20	F	PRG equipment that is not part of the AVL System shall be compatible with installed communication systems of existing Priority Request Servers in the region	V	D
PRG -21	F	PRG equipment not part of the AVL System shall interface (via the AVL) with bus door open / close sensors to allow the ability to disable requests for TSP when bus doors are opened. This should be configurable by intersection, route, etc. This has to be addressed at the PRS, communication system, logs (i.e. incorporated into the message set).	O	D
PRG -22	F	PRG equipment not part of the AVL System shall interface (via the AVL) with next stop pull cords to allow the ability to disable requests for TSP when pull cords are activated to request a stop at a near-side bus stop. This should be configurable by intersection, route, etc. This has to be addressed at the PRS, communication system, logs. (i.e. incorporated into the message set).	O	D
PRG -23	E	PRG equipment not part of the AVL System shall be surge protected and not suffer damage or corruption of data as a result of short duration spikes in peak voltage. Refer to 47 CFR Ch. I, subchapter A, part 15, subparts A and C.	M	I
PRG -24	F	PRG equipment not part of the AVL System shall utilize Simple Network Management Protocol (SNMP) version 2 for alerting staff about: a) devices not receiving communications from AVL Systems, b) devices not communicating to signal controllers, c) devices not reporting to central software.	V	D

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ID	Type	Requirement	Importance	Verification Method
PRS-1	F	The PRS shall process priority requests from eligible buses according to the VehicleClassType and VehicleClassLevel	V	D
PRS -2	F	The PRS shall differentiate between a preemption and a priority request such that preemption requests are granted higher priority over priority requests from buses	V	D
	F	The PRS shall log the following information regarding TSP events:	M	D
PRS -3	F	a) Date and time that TSP request begins	M	D
PRS -4	F	b) Date and time that TSP request ends	V	D
PRS -5	F	c) Duration of the TSP request	V	D
PRS -6	F	d) Indication of whether or not TSP was granted or denied by the signal controller	V	D
PRS -7	F	e) Directional heading of the vehicle	V	D
PRS -8	F	f) Vehicle ID number	M	D
PRS -9	F	g) Intersection ID number	M	D
		The PRS shall send the following information to the PRG regarding TSP events:		D
PRS -10	F	a) Indication of whether or not TSP was granted or denied by the signal controller	V	D
PRS -11	F	b) Reason for TSP denial by signal controller	V	D
		The PRS shall log all information transmitted from the vehicle to the intersection as reflected in the following requirements		D
PRS -12	F	a) PRO-2 through PRO-21	M	D
PRS -13	F	The PRS shall process priority requests from eligible buses based on the schedule lateness of the vehicle requesting TSP	O	D
	F	The PRS shall inhibit TSP requests made to the signal controller by the following:	V	D
PRS -14	F	a) Time-of-day	V	D
PRS -15	F	b) Day-of-week	V	D
PRS -16	F	c) Direction of TSP request (i.e. north or south, east or west)	V	D
PRS -17	F	PRS equipment that is not part of the signal controller shall be remotely accessible for purposes of retrieving logs and configuring PRS equipment	M	I
PRS -18	F	PRS equipment that is not part of the existing traffic signal controller shall be compatible with existing PRG components in the region	V	D

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ID	Type	Requirement	Importance	Verification Method
PRS -19	S	PRS equipment that is not part of the existing traffic signal controller shall receive power located within the signal cabinet through available circuit breakers located within the signal cabinet	M	I
PRS -20	F	PRS equipment that is not part of the existing traffic signal controller shall be furnished with appropriate power supply unit and power cables in the event that existing power at the traffic signal cabinet or the source of power cannot be utilized	M	I
PRS -21	P	PRS equipment that is not part of the existing traffic signal controller shall successfully operate to receive and process signal priority requests from transit vehicles at a minimum performance rate of 99%	M	A
PRS -22	E	PRS equipment that is not part of the existing traffic signal controller shall comply with NEMA TS2 standards for temperature ranges	M	I
PRS -23	S	PRS equipment that is not part of the existing traffic signal controller shall require minimal maintenance, which is no more frequently than on an annual basis	M	I
PRS -24	F	PRS equipment that is not part of the existing traffic signal controller shall utilize Simple Network Management Protocol (SNMP) version 2 for alerting staff about: a) devices not receiving communications from buses, b) devices not communicating with signal controllers, c) devices not reporting to central software.	M	D
PRS -25	F	PRS equipment that is not part of the existing traffic signal controller shall utilize Simple Network Management Protocol (SNMP) version 3 for alerting staff about: a) devices not receiving communications from buses, b) devices not communicating with signal controllers, c) devices not reporting to central software	V	D
PRO-1	F	The TSP request shall be a secure priority request that utilizes NTCIP 1211 protocols for signal priority	V	D
	F	The message shall include, at a minimum, the following critical items in the stated formats:	M	D
PRO -2	F	a) Vehicle ID (alphanumeric value)	M	
PRO -3	F	b) Intersection ID (numeric value)	M	
PRO -4	F	c) Direction of TSP Required (numeric value)	M	
PRO -5	F	d) Unique ID for PRS (numeric value)	M	
	F	The message shall include the following additional items in the stated formats:	M	D

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ID	Type	Requirement	Importance	Verification Method
PRO -6	F	e) Route ID (alphanumeric value)	M	
PRO -7	F	f) Run number (numeric value)	M	
PRO -8	F	g) Request ID (numeric value)	M	
PRO -9	F	h) Agency ID (numeric value)	M	
PRO -10	F	i) TSP Request: initiate TSP request (numeric value)	M	
PRO -11	F	j) TSP Clear: clear TSP request (numeric value)	M	
PRO -12	F	k) TSP Cancel: cancel TSP request (numeric value)	M	
PRO -13	F	l) Route type (numeric value)	M	
PRO -14	F	m) Vehicle Approach (alphabetic value)	M	
PRO -15	F	n) GPS Timestamp of TSP call (numeric value)	M	
PRO -16	F	o) Time to hold call prior to TSP Clear (numeric value)	M	
PRO -17	F	p) Schedule lateness at time of request (numeric value)	M	
PRO -18	F	q) Bus occupancy at time of request (numeric value)	O	
PRO -19	F	r) Vehicle Location in Longitude, Latitude (numeric values)	M	
PRO -20	F	s) Time of Service Desired (numeric value)	M	
PRO -21	F	t) Estimated Departure Time (numeric value)	M	
COM -1	F	COM equipment shall not cause any radio interference to existing emergency vehicle communications at the intersection or transit radio communications on the buses.	M	D
COM -2	F	COM equipment on the buses shall utilize 5 GHz radios for vehicle-to-intersection communications with corresponding 5 GHz radios at the roadside for the purpose of sending TSP messages to traffic signals	M	I
COM -3	F	COM equipment shall use 802.11n protocols at a minimum for vehicle-to-intersection communications.	M	D
COM -4	F	COM equipment shall use multiple input multiple output MIMO Wi-Fi radios and antenna to mitigate multipath interference.	M	D
COM -5	F	COM equipment shall provide the bandwidth and latency adequate to reliably operate TSP.	M	D
COM -6	F	COM equipment shall use an existing antenna or combine antenna into one external housing.	V	I

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COM -7	F	COM equipment shall be designed to operate in a mobile environment, and able to handle the environmental conditions encountered in normal operation.	M	D
COM -8	F	COM equipment shall interface with the existing bus router for the respective agency.	M	D
COM -9	F	COM equipment on the bus shall utilize a minimum level of data encryption in sending data from the bus to the intersection	M	I
COM -10	F	COM equipment on the vehicle shall utilize Simple Network Management Protocol (SNMP) version 2 for device management and health monitoring purposes	M	D
COM -11	F	COM equipment on the vehicle shall utilize Simple Network Management Protocol (SNMP) version 3 for device management and health monitoring purposes	V	D
COM -12	F	COM equipment on the buses shall transmit log data from the PRG on the buses to a SQL database for processing by TSP Central Software, which shall include the following data elements previously defined in this document:	M	D
COM -13	F	a) PRO-2 through PRO-21	M	D
COM -14	F	b) PRS-10 and PRS-11	M	D
COM -15	S	COM equipment shall receive power from the signal cabinet	V	I
COM -16	F	COM equipment at the intersection shall utilize Simple Network Management Protocol (SNMP) version 2 for device health monitoring and configuration purposes	M	D
COM -17	F	COM equipment at the intersection shall utilize Simple Network Management Protocol (SNMP) version 3 for device health monitoring and configuration purposes	V	D
COM -18	F	Backhaul of COM equipment data shall utilize wired connections between intersections and central offices where possible.	V	I
SOFT-1	F	SOFT shall perform remote monitoring and configuration of TSP system components	M	D
SOFT -2	F	SOFT shall perform real-time remote monitoring and configuration of TSP system components	V	D
SOFT -3	F	SOFT shall retrieve TSP message sets and data logs transmitted from the PRG and the PRS	M	D
SOFT -4	F	SOFT shall utilize a web-based interface for retrieving TSP message sets and log data transmitted from the PRG	M	D
SOFT -5	F	SOFT shall utilize SNMP version 2 for COM device health monitoring and configuration purposes	M	D
SOFT -6	F	SOFT shall utilize SNMP version 3 for COM device health monitoring and configuration purposes	V	D

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SOFT -7	F	SOFT shall permit different levels of access for multiple user roles, agencies, or jurisdictions	M	D
		SOFT shall allow users to retrieve TSP data logs and view TSP data by selecting a combination of any of the following characteristics:		D
SOFT -8	F	a) Within a specified date range field	M	
SOFT -9	F	b) Time of day	M	
SOFT -10	F	c) Day of week	M	
SOFT -11	F	d) Agency ID field	M	
SOFT -12	F	e) One or multiple Route IDs	M	
SOFT -13	F	f) One or multiple Intersection IDs	M	
SOFT -14	F	g) One or multiple Vehicle IDs	M	
SOFT -15	F	h) Direction of travel	M	
SOFT -16	F	i) One or multiple Request ID fields	M	
SOFT -17	F	j) Number TSP requests granted and denied by signal controller	V	
SOFT -18	F	k) Reasons for TSP denial by signal controller	V	
SOFT -19	F	SOFT shall present TSP data logs in a table format with each data field in a separate column identified with a header row	M	D
SOFT -20	F	SOFT shall provide reporting functions of the data that is readily exportable to Microsoft Access or Microsoft Excel or equivalent	M	D
SOFT -21	F	SOFT shall query TSP System daily activity files	M	D
SOFT -22	F	SOFT shall archive TSP System daily activity files	V	D
SOFT -23	F	SOFT shall aggregate Intersection ID fields to present TSP system log data by TSP Corridor	M	D
SOFT -24	F	SOFT shall present vehicle travel times on TSP Corridors by Route ID for performance measurement purposes	V	D
SOFT -25	F	SOFT shall present number of communication failures as reported by COM devices on buses.	V	D
SOFT -26	F	SOFT shall provide a graphical user interface to all functions, settings, and technical parameters of PRG, PRS, and COM components	V	D

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SOFT -27	F	SOFT shall permit individual System Users and groups of System Users to log on with authorized user names and passwords, log off, print reports, view system status information, and configure TSP System operations	V	D
SOFT -28	F	SOFT shall allow a System Administrator to assign multiple levels of system configuration access privileges to individual System Users and groups of System User	V	D
SOFT -29	F	SOFT shall display PRG, PRS, and COM components against a graphical representation of their respective geographic locations	V	D
SOFT -30	F	SOFT shall display PRG, PRS, and COM components with icons that are automatically updated based on the current state of those components	V	D
SOFT -31	F	SOFT shall include tools for System Users / Administrators to modify and add functioning icons for new PRG, PRS, and COM components	V	D