U.S. Department of Transportation

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METRO
CENTRAL OMAHA BUS RAPID TRANSIT (BRT) TRANSIT SIGNAL PRIORITY DEPLOYMENT

Draft Concept of Operations

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1.0 SCOPE OF THE PROJECT

1.1 SYSTEM OVERVIEW

The purpose of this project is to support the development of the high-level functional requirements for the deployment of Transit Signal Priority (TSP) in the Metro's Central Omaha Bus Rapid Transit (BRT) system and form the foundation for design and deployment of the TSP system.

TSP is one of the elements of the BRT intended to enhance the effectiveness of the new service. The BRT system will travel primarily along existing Dodge Street covering approximately eight miles from the west terminus at the existing bus transit center at the Westroads Mall, to the east terminus that includes a downtown loop along Dodge, 10th, Farnam, and 13th Streets. The TSP will be deployed at twelve (12) intersections along the BRT corridor. The locations of the proposed BRT stations are shown in the **Figure 1** below.

FIGURE 1: BRT STATION LOCATIONS

This Concept of Operations (ConOps) includes evaluation of the traffic signal controller requirements, traffic signal system as well as other related items, which include:

- Traffic signal controllers and firmware
- TSP devices – on-board emitter, receiver at a TSP enabled intersection
- Communication infrastructure between transit vehicle priority request emitter and priority request receiver at intersection
- A CAD/AVL system
- City of Omaha's Advanced Traffic Management System Software

1.2 Document Overview

The Concept of Operations (ConOps) is a document that describes the expected operations of the TSP system from the user's viewpoint and provides documentation in compliance with the FTA Final Policy on Architecture and Standards Conformity and the Federal Highway Administration (FHWA) Rule 23 CFR 940.11 and applicable Systems Engineering Guidelines. The ConOps is the third document in the set of systems engineering deliverables including the Project Plan, the Systems Engineering Management Plan (SEMP), and the Requirements and Verifications Plan. The ConOps consists of:

- Scope of the Project
- Referenced Documents
- User-Oriented Operational Description
- Operational Needs
- System Overview
- Operational Environment
- Support Environment
- Operational Scenarios
- Summary of Impacts

The purpose of the ConOps document is to communicate overall qualitative system characteristics to Metro, the City of Omaha, FTA, FHWA and other involved stakeholders. This document will define the user needs that will drive the requirements for the TSP system.

1.3 Goals and Objectives

The goal of the project is to develop, plan and design a flexible TSP system that supports the Central Omaha BRT project and augments other service enhancement strategies such as transit lanes, queue jumps, wider stop spacing, off-board fare collection and level boarding to create a transit service that is faster and more reliable than existing transit service in the corridor. Some system components such as traffic signal controllers, central traffic management and local controller software and communication infrastructure necessary to support the proposed TSP system will be implemented as a part of the on-going City of Omaha traffic signal system upgrade project.

Some specific objectives, not listed in any particular order, include:

- Add to the attractiveness of the new BRT service
- Improve transit travel time along the Dodge street corridor
- Reduce excessive transit delay at congested intersections
- Reduce excessive transit delay along the Dodge Street corridor
- Improve reliability (schedule adherence and headway management)
- Collect performance measures to evaluate system operations
- Improve the overall safety and operations of the Dodge Street BRT at the designated intersections.

2.0 REFERENCED DOCUMENTS

The following documents have been used in the preparation of this ConOps. Some of these documents provide policy guidance for the TSP system, some are standards with which the TSP system must comply, while others report the conclusions of discussions, workshops and other research used to define the needs of the project and subsequently identify project requirements.

- *MAPA Regional ITS Architecture* - http://www.mapacog.org/intelligent-transportation-systems-its
- *MAPA Long Range Transportation Plan 2035* - http://www.mapacog.org/long-range-transportation-planning
- *City of Omaha Transportation Master Plan* - http://www.cityofomaha.org/tmplan/
- *MAPA Transportation Improvement Program* - http://www.mapacog.org/transportation-improvement-program
- *City of Omaha Capital Improvements Program 2012-2017* - http://www.cityofomaha.org/finance/images/stories/pdfs/CIP2012-2017.pdf
- *City of Omaha Traffic Signal System Master Plan*
- *Intelligent Transportation Systems and System Engineering Process Document,* Nebraska Department of Roads, Operations Division, ITS Section
- *Omaha BRT- User Needs Questions, June 25, 2015*
- *Systems Engineering Guidebook for ITS, California Department of Transportation, Division of Research & Innovation, Version 3.0* - http://www.fhwa.dot.gov/cadiv/segb/
- *Nebraska* 2012-*2016 Strategic Highway Safety Plan (SHSP)* - http://www.nebraskatransportation.org/traffeng/shsp/shsp-current.pdf
- *Omaha-Council Bluffs Traffic Incident Management Operations Guidelines* - http://www.tim.ne.gov/alternate-routes/metro-ocb/O-CB%20TIM%20Ops%20Guide%202011-03-22.pdf

The MAPA Regional ITS Architecture identifies elements of the traffic signal system improvement project in the City of Omaha. The City of Omaha has developed a Traffic Signal

System Master Plan and has hired a System Manager to assist the City with planning, design and deployment of system upgrades. The new signal system will provide TSP functionality.

3.0 EXISTING AND PLANNED SIGNAL SYSTEM INFRASTRUCTURE

A through assessment of the City of Omaha's existing traffic signal system including signals along the BRT corridor was conducted and documented in the *City of Omaha Traffic Signal System Master Plan (TSSMP)*. The Advanced planning, NEPA and Preliminary Engineering Task of the BRT is on-going and identified the signals where the TSP service will be installed. The TSSMP document provides a detailed description of the existing traffic signals on the BRT corridor and documented cabinet type, controller, firmware, mode of operation, detection and communications of each signal. Details of the new signals on the BRT corridor will be finalized once the design phases of the City of Omaha Traffic Signal System and the BRT Projects is completed. The inventories of the existing and the planned signals along the BRT corridor are presented in **Table 1** and **Table 2** respectively.

TABLE 1: EXISTING TRAFFIC SIGNAL DETAILS ON THE BRT CORRIDOR

		Cabinet/Controller				Communications		Detection		Other			
	Locations	Cabinet Type	Controller Type	Controller Firmware	Operational Mode	Comm In-use	Phase 0 Fiber	Loops	Cameras	UPS	CCTV Cameras	Opticom	RWIS
Downtown	10 ST & FARNAM ST	336	170E	Wapiti	SA	Yes		Yes					
	13 ST & FARNAM ST	336	170E	Wapiti	FT	Yes							
	10 ST & DOUGLAS ST	336	170E	Wapiti	FT	Yes							
	13 ST & DOUGLAS ST	336S	170E	Wapiti	FT	Yes							
	10 ST & DODGE ST	332	170E	Wapiti	FT	Yes			Yes			Yes	
	12 ST & DODGE ST	336	170E	Wapiti	FT	Yes							
	13 ST & DODGE ST	303	170E	Wapiti	FT	Yes							
	14 ST & DODGE ST	303	170E	Wapiti	FT	Yes							
	15 ST & DODGE ST	336	170E	Wapiti	FT	Yes							
	16 ST & DODGE ST	303	170E	Wapiti	FT	Yes							
	17 ST & DODGE ST	303	170E	Wapiti	FT	Yes							
	18 ST & DODGE ST	303	170E	Wapiti	FT	Yes							
	19 ST & DODGE ST	303	170E	Wapiti	FT	Yes							
	20 ST & DODGE ST	303	170E	Wapiti	FT	Yes							
	24 ST & DODGE ST	336	170E	Wapiti	FT	Yes							
	28 ST & DODGE ST	303	170E	Wapiti	SA	Yes		Yes					
	PARK AVE & DODGE ST	303	170E	Wapiti	FT	Yes							
	TURNER BLVD & DODGE ST	303	170E	Wapiti	FT	Yes							
	33 ST & DODGE ST	336S	170E	Wapiti	SA	Yes	YES		Yes				
	35 AVE & DODGE ST	303	170E	Wapiti	SA	Yes	YES	Yes					
	38 ST & DODGE ST	303	170E	Wapiti	SA	Yes	YES	Yes					
	40 ST & DODGE ST	336	170E	Wapiti	FT	Yes	YES					Yes	

		Cabinet/Controller				Communications		Detection		Other			
	Locations	Cabinet Type	Controller Type	Controller Firmware	Operational Mode	Comm In-use	Phase 0 Fiber	Loops	Cameras	UPS	CCTV Cameras	Opticom	RWIS
	42 ST & DODGE ST	303	170E	Wapiti	SA	Yes	YES	Yes				Yes	
	44 ST & DODGE ST	303	170E	Wapiti	SA	Yes	YES	Yes				Yes	
	46 ST & DODGE ST	303	170E	Wapiti	SA	Yes	YES	Yes					
	49 ST & DODGE ST	303	170E	Wapiti	SA	Yes	YES	Yes					
	50 ST & DODGE ST	303	170E	Wapiti	FT	Yes	YES						
	52 ST & DODGE ST	303	170E	Wapiti	FT	Yes	YES						
	HAPPY HOLLOW BLVD & DODGE ST	336	170E	Wapiti	FT/SC	Yes	YES						
	60 ST & DODGE ST	303	170E	Wapiti	SA	Yes	YES	Yes					
	62 ST & DODGE ST	303	170E	Wapiti	SA	Yes	YES	Yes					
	66 ST & DODGE ST	303	170E	Wapiti	SA	Yes	YES	Yes					
	67 ST & DODGE ST	303	170E	Wapiti	SA	Yes	YES	Yes				Yes	
Dodge Adap. Corridor	69 ST & DODGE ST	336	170E	Wapiti	SA	Yes	YES	Yes				Yes	
	72 ST & DODGE ST	332	170E	Wapiti	SA	Yes	YES		Yes	Yes	Yes	Yes	
	74 ST & DODGE ST	332	170E	Wapiti	SA	Yes	YES	Yes	Yes			Yes	
	76 ST & DODGE ST	332	170E	Wapiti	SA	Yes	YES	Yes				Yes	
	78 ST & DODGE ST / BEVERLY DR	332	170E	Wapiti	SA	Yes	YES	Yes	Yes			Yes	
	84 ST & WEST DODGE RD	332	170E	Wapiti	SA	Yes	YES	Yes	Yes			Yes	
	CASS ST & DODGE ST	336	170E	Wapiti	SA	Yes	YES	Yes				Yes	
	90 ST & WEST DODGE RD	332	170E	Wapiti	SA	Yes	YES		Yes	Yes	Yes	Yes	Yes
	93 ST & DODGE ST	332	170E	Wapiti	FT	Yes	YES					Yes	
Westroads Mall Area	100 ST & CALIFORNIA ST	336	170E	Wapiti	SA	Yes	YES	Yes					
	REGENCY PKWY & WEST DODGE RD	303	170E	Wapiti	FA	n/a	YES	Yes					
	102 ST & CALIFORNIA ST / ENT #2	303	170E	Wapiti	SA	Yes	YES	Yes					
	98 ST & CALIFORNIA ST	332	170E	Wapiti	SA	Yes	YES	Yes					
	98 ST & ENT #8 / WESTROADS	336	170E	Wapiti	SA	Yes	YES	Yes					
	102 ST & NICHOLAS ST	332	170E	Wapiti	SA	Yes	YES	Yes					

TABLE 2: PLANNED TRAFFIC SIGNAL DETAILS ON THE BRT CORRIDOR

		Cabinet/Controller		
	Locations	New Cabinet	New Controller	New Firmwire
Downtown	10 ST & FARNAM ST	NO	YES	YES
	13 ST & FARNAM ST	NO	YES	YES
	10 ST & DOUGLAS ST	NO	YES	YES
	13 ST & DOUGLAS ST	NO	YES	YES
	10 ST & DODGE ST	NO	YES	YES
	12 ST & DODGE ST	NO	YES	YES
	13 ST & DODGE ST	YES	YES	YES

		Cabinet/Controller		
	Locations	New Cabinet	New Controller	New Firmwire
	14 ST & DODGE ST	YES	YES	YES
	15 ST & DODGE ST	NO	YES	YES
	16 ST & DODGE ST	YES	YES	YES
	17 ST & DODGE ST	YES	YES	YES
	18 ST & DODGE ST	YES	YES	YES
	19 ST & DODGE ST	YES	YES	YES
	20 ST & DODGE ST	YES	YES	YES
	24 ST & DODGE ST	NO	YES	YES
	28 ST & DODGE ST	YES	YES	YES
	PARK AVE & DODGE ST	YES	YES	YES
	TURNER BLVD & DODGE ST	YES	YES	YES
Reversible Lane Corridor	33 ST & DODGE ST	YES	YES	YES
	35 AVE & DODGE ST	YES	YES	YES
	38 ST & DODGE ST	YES	YES	YES
	40 ST & DODGE ST	YES	YES	YES
	42 ST & DODGE ST	YES	YES	YES
	44 ST & DODGE ST	YES	YES	YES
	46 ST & DODGE ST	YES	YES	YES
	49 ST & DODGE ST	YES	YES	YES
	50 ST & DODGE ST	YES	YES	YES
	52 ST & DODGE ST	YES	YES	YES
	HAPPY HOLLOW BLVD & DODGE ST	YES	YES	YES
	60 ST & DODGE ST	YES	YES	YES
	62 ST & DODGE ST	YES	YES	YES
	66 ST & DODGE ST	YES	YES	YES
	67 ST & DODGE ST	YES	YES	YES
Dodge Adap. Corridor	69 ST & DODGE ST	YES	YES	YES
	72 ST & DODGE ST	NO	YES	YES
	74 ST & DODGE ST	NO	YES	YES
	76 ST & DODGE ST	NO	YES	YES
	78 ST & DODGE ST / BEVERLY DR	NO	YES	YES
	84 ST & WEST DODGE RD	NO	YES	YES
	CASS ST & DODGE ST	YES	YES	YES
	90 ST & WEST DODGE RD	NO	YES	YES
	93 ST & DODGE ST	NO	YES	YES
Westroads Mall Area	100 ST & CALIFORNIA ST	YES	YES	YES
	REGENCY PKWY & WEST DODGE RD	YES	YES	YES
	102 ST & CALIFORNIA ST / ENT #2	YES	YES	YES
	98 ST & CALIFORNIA ST	NO	YES	YES
	98 ST & ENT #8 / WESTROADS	YES	YES	YES
	102 ST & NICHOLAS ST	NO	YES	YES

4.0 USER-ORIENTED OPERATIONAL DESCRIPTION

The primary users of the proposed TSP systems are Metro, City of Omaha Traffic Engineering and the travelling public utilizing Metro transit buses or driving his or her own car. While Metro and the travelers using Metro buses want an efficient BRT system with minimum travel time, the City Traffic Engineering and the driving public desire an efficient signal system which minimizes the possibility of signal disruption. The expectations of these two user groups are

different and they view the TSP system from two different perspectives as described in the following sections.

4.1 METRO AND METRO USERS PERSPECTIVE

At present, Metro operates fixed route, express/commuter bus downtown weekday rush hour and ADA Complementary Paratransit Services within the city limits of Omaha, Douglas County, NE. In addition Metro has turn-key contracts to provide transit services in the five contiguous neighboring jurisdictions. These jurisdictions include Ralston, LaVista, Bellevue, and Papillion in Nebraska and Council Bluffs in Iowa. There is no TSP service installed in any signal located in Metro's current operational routes. Metro's existing Route 2, Dodge Street, is in the proposed BRT corridor. The dispatchers of the Central Operations Center communicate with the Metro fleet via two-way radios.

Primary goals of the proposed BRT project are to provide a simple route structure with a high frequency of service, service reliability and reduction of travel time on the Dodge street corridor. TSP at some intersections on the BRT project will be implemented to enhance the effectiveness of the new BRT service. In particular, Metro desires to achieve the following enhancements of its operation in the corridor by implementing TSP in addition to other strategies:

- Reduction of round trip travel time from 75 min to 60 min
- Improve transit travel time along the Dodge Street corridor
- Reduce excessive transit delay at congested intersections
- Reduce excessive transit delay along the Dodge Street corridor
- Improve reliability (schedule adherence and headway management)

To achieve these goals, conditional TSP service will be implemented at twelve (12) intersections. It is anticipated that green extension and early green TSP strategies will be implemented at all intersections while the queue jump TSP strategies will be implemented at only the 72nd/Dodge and 42nd/Farnam intersections.

4.2 CITY OF OMAHA PUBLIC WORKS PERSPECTIVE

The City of Omaha Traffic Engineering - a division of the Public Works, operates and maintains the signals at the intersections on the proposed BRT corridor. Currently, TSP service is not implemented at any intersection in the city. Even without TSP service, maintaining satisfactory level of service at some intersections is difficult. Some examples of the intersections where implementing TSP will be difficult are:

- **72nd Street and 90th Street:** At these intersections, when pedestrians push the pedestrian pushbutton, the additional time provided to accommodate the north-south Walk and Flashing Don't Walk is longer than the program split time. As a

result, the signal controller must temporarily leave coordination which impacts progression. In addition, the controller must go through a period of transition to get back in coordination which typically results in left-turn movements that are near capacity to have seconds taken from the phase. This can cause queueing of the left-turn movements back into the through movements. Due to the saturated conditions at these locations, there will be limited opportunities to provide early green or green extension operation as part of TSP.

- Signals around Westroads are difficult to manage due to queue spillback on to West Dodge Road.

With these existing conditions, the Traffic Division would prefer to see that the all other transit performance strategies be implemented before TSP is utilized in the corridor. The improved transit performance strategies to be considered are: advanced fare collection, reduced dwell time, reduced boarding times, reduction of number of stops, etc. all of which will contribute to reduction in round trip travel time. There will be an increase in pedestrian crossing activity in the BRT corridor and since the TSP would not impact the pedestrian actuations on the signal, the increased pedestrian activity will disrupt the signal coordination more than the TSP in the corridor. In addition to this, the City traffic division also anticipates there will be an impact on pedestrian crossing time due to potential roadway widening to accommodate any queue jump lane. The proposed TSP should have flexibility to accommodate different TSP settings in different parts of the route. The TSP deployment strategy should be consistent for the route limits and operational goals of the corridor. This means that the system must be able to summarize system performance for the corridor but have the flexibility to have intersection adjustments.

5.0 OPERATIONAL NEEDS

Implementation of TSP service at the designated intersections on the BRT corridor will occur during the same approximate timeframe as an on-going traffic signal system upgrade project being led by the Public Works Department. As part of the signal system upgrade project, City staff has compiled existing traffic signal system inventory data and completed the operational needs assessment to identify stakeholder needs that must be satisfied in order for the City to meet its goals and objectives relative to an upgraded traffic signal system. Given the traffic signal system needs previously identified, a stakeholder meeting was conducted as part of the Metro BRT project to gather the high-level needs specific to the TSP system. The focus of this section is to document those high-level needs and to add details to create operational needs that can be used to build an action plan and more detailed requirements. Once the needs were described, a preliminary list of performance measures was identified to support the evaluation of the goals and objectives.

The needs identified in this section were gathered primarily through the stakeholder meeting held on June 25, 2015 where various operational scenarios were discussed that identified equipment (such as hardware, software, and communications), staffing, transit management

and traffic management needs with the proposed TSP service at the intersections on the BRT corridor.

Five categories were created to identify high-level needs and include:

1. BRT System Operation
    - Reduce travel time delay
    - Improve transit service reliability by improving schedule adherence
    - Decrease headway
    - Improve efficiency of the traffic signal system
    - Decrease BRT system operating cost
    - Reduce round trip travel time of BRT buses
    - Improve operations of transit vehicles at traffic signals
    - Implement conditional TSP which:
        - could be in operation on each day (weekday, weekend) of the week
        - can be used in achieving schedule adherence during off peak
        - would be based on multiple priority conditions (time of day; directional: EB, WB; priority type: schedule adherence, reduction of delay; etc.)
        - will minimize disruption to signal operation
        - would improve safety for transit vehicles
        - would improve operations for transit vehicle and transit users
        - would improve safety for all modes of transportation
    - Provide special signal phasing to support queue jumps
2. TSP System Operation
    - To be as flexible as possible with the bus ITS system (AVL, APC, etc.)
    - To be integrated with the Metro CAD/AVL system
    - Capable of generating conditional priority request without operator intervention
    - To be capable of operating under free and coordinated signal operation modes on the BRT corridor
    - To be flexible in adjusting priority condition parameters
    - Conditional parameters should be adjustable at each intersection
    - Configurable based on the day of the week
    - Configurable based on the time of day
    - Capable of generating priority requests based on different types of conditions (Schedule adherence, delay, etc.) based on the travel direction
    - Capable of handling future vehicle growth
    - Free of issuing false priority request
    - Capable of tracking the condition under which the TSP is granted
3. Communications Systems
    - The Metro AVL/CAD needs to be integrated with the TSP system
    - Bus emitter devices need to be in communication with receivers at TSP enabled intersections
    - Provide communications between the intersections

- Provide communications between intersection and the City Traffic Operation Center (TOC)

4. Traveler Information Systems
   - Improve travel time estimate
5. System Monitoring and Reporting
   - System should be capable of storing data necessary for monitoring the deployed TSP performance

Through stakeholder workshops continued small group discussions, more detailed needs were identified based on various operational scenarios that are further described in the next section. These needs and associated requirements are further documented in the requirements and verification plan. **Table 3** summarizes the Operational Needs developed:

TABLE 3: OPERATIONAL NEEDS

NO.	Needs Identified in Stakeholder Workshops (June 25, 2015)
1.0	**BRT SYSTEM OPERATION**
1.01	Need to reduce travel time by reducing running time delay
1.02	Need to improve schedule adherence
1.03	Need to decrease headway
1.04	Need to reduce round trip travel time from 75 minutes to 60 minutes
1.05	Need to reduce travel time in peak periods
1.06	Need to stay as flexible as possible in regards to integration and potential functionality with the bus ITS system (AVL, APC, etc.)
1.07	Need to reduce system operational cost
1.08	Need to implement advanced boarding to reduce boarding times for the corridor
1.09	Need to reduce the number of stops in the corridor
1.10	Need to implement conditional TSP capable of operating everyday (weekday, weekend) of the week
1.11	Need to achieve schedule adherence during off-peak
1.12	Need to implement conditional TSP based on the direction of travel (EB, WB)
1.13	Need to implement TSP with minimum disruption to signal operation
1.14	Need to provide special signal phasing to support queue jumps
2.0	**TSP SYSTEM OPERATION**
2.01	Need to provide real-time (live)data
2.02	Need to provide packets of data between devices
2.03	Need to provide the capability of synchronizing time (clock)
2.04	Need to capture the vehicle locations in real time
2.05	Need to estimate the time of arrival and departure at the designated locations along the corridor
2.06	Need to observe and store the operational and conditional priority characteristics and values in real time
2.07	Need to exchange the vehicle location and status information with the Transit Operation Center
2.08	Need to transfer the operational and conditional priority characteristics to the on–board Priority Request Generator (PRG)
2.09	Need the on-board Priority Request Generator (PRG) to receive priority parameters from Transit Operation Center

2.10	Need the on-board Priority Request Generator (PRG) to set priority request call based on conditional priority parameters
2.11	Need the Priority Request Generator (PRG) and the Priority Request Server (PRS) to exchange priority requests
2.12	Need the Priority Request Generator (PRG) and the Priority Request Server (PRS) to exchange priority status
2.13	Need the Priority Request Generator (PRG) to log all priority requests and their status received from PRS
2.14	The PRS needs to receive priority parameters from the Traffic Operation Center
2.15	The PRS needs to send the status of the priority requests received back to the PRG
2.16	Need the PRS and the traffic controller to exchange priority requests
2.17	Need the PRS and the traffic controller to exchange signal clearance status
2.18	Need the PRS and the traffic controller to exchange priority request status
2.19	The traffic signal controller needs to receive the priority parameters from the City Traffic Operation Center
2.20	The traffic signal controller needs to determine eligibility of priority request
2.21	The traffic signal controller needs to select the TSP signal strategy
2.22	The traffic signal controller needs to check out granted request
2.23	The traffic signal controller needs to send the status of the priority requests received back to the PRS
3.0	**COMMUNICATIONS SYSTEMS & INTEGRATION**
3.01	Need to integrate the TSP system with the Metro AVL/CAD system
3.02	Need to provide communication link between the on-board PRG to the receiver at the intersection
3.03	Need to provide adequate speed, bandwidth, and reliability of field to field communications
3.04	Need to provide adequate speed, bandwidth, and reliability of center to field communications
3.05	Need to provide staff in the field access to network
3.06	Need to develop interagency agreements between Metro and the City of Omaha Traffic Engineering Division
3.07	Need to provide communications to all signals
3.08	Need to provide remote access to networks for management, software upgrades, and troubleshooting
3.09	Need to develop and implement network security protocols
4.0	**TRAVELER INFORMATION SYSTEMS**
4.01	Need to provide accurate travel time estimate on the roadside display devices
4.02	Need to improve procedures to get accurate information disseminated in a timely manner
5.0	**SYSTEM MONITORING AND REPORTING**
5.01	Need the Metro Transit Operation Center to monitor the on-board AVL/CAD and TSP system diagnostics and status
5.02	Need the City of Omaha Traffic Operation Center to monitor the signal, communication network and the TSP devices to perform system diagnostics and to know device status
5.03	Need to provide capability of configuring the Metro AVL/CAD and the TSP system component remotely from the Metro Transit Operation Center
5.04	Need the PRG to log all priority requests
5.05	Need the PRS to log all priority requests
5.06	Need traffic signal controller to log all priority requests

6.0 SYSTEM DESCRIPTION

To support the goals of the BRT, TSP is proposed to be implemented at 12 signalized intersections west of 33rd street located on the BRT route. The concept for the TSP system has

been established through coordination with stakeholders to address the needs identified in Section 5.0. This section describes the conceptual architecture of the proposed TSP system.

The system architecture described in this section is based on the NTCIP (National Transportation Communications for ITS Protocol) and TCIP (Transit Communications Interface Profiles) for the TSP system planning and design to the extent possible.

The proposed TSP system is described from three different perspectives: system architecture, TSP strategies and communication interfaces which are elaborated in the following sections.

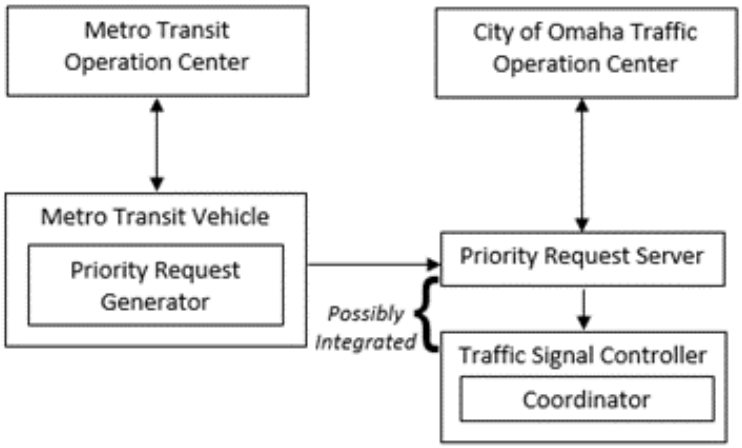
6.1 System Architecture

The system architecture defines the system logically without mentioning specific technology. It identifies the logical entities, their locations and the interfaces between them in the overall TSP system. The naming convention of the logical components is adopted from the NTCIP 1211 – Object Definitions for Signal Control and Prioritization and from the TCIP – Transit Communications Interface Profiles.

6.1.1 Logical Architecture

The TSP system will consist of two primary components: a Priority Request Generator (PRG) and a Priority Request Server (PRS) defined in the NTCIP 1211 – Object Definitions for Signal Control and Prioritization standards. The PRG is a logical entity that generates a priority request on behalf of a transit vehicle. PRS is a logical entity in the TSP enabled intersection that determines the disposition of a TSP priority request from the PRG. The logical view of the system is shown in the **Figure 2** below:

Figure 2: TSP System Logical Architecture



Metro's transit fleet vehicle carries a PRG. Priority requests are sent to the PRS in the field over the wireless communication medium as shown in **Figure 5** for processing.

Primary functions of the PRG are:

- To determine whether a vehicle is in need of transit signal priority at a signalized intersection based on the pre-defined priority request triggering criteria.
- To send the vehicle's request for priority, its time of arrival, and its time of service desired at the signalized intersection to the PRS.
- Keeping a log of all priority requests. These requests will be processed by the Metro Transit Management Center for reporting and tracking performance measures.

Primary functions of the PRS are:

- To receive multiple priority requests from different PRGs.
- To produce an estimate of the vehicles' calculated time for service desired at the signalized intersections.
- The PRS generates a priority service request to the traffic signal controller. The PRS prioritizes different priority requests coming from different PRGs based on vehicle's classification (Emergency Vehicle vs. Transit), vehicle level and time of service desired.
- To produce a log of all the received priority requests and granted service requests by the PRS for review by Metro and the City of Omaha traffic engineering division.

6.1.2 System Components

The TSP system will consist of five (5) primary components: Metro Transit Operation Center, Metro BRT buses, Communication Devices (emitter on a transit vehicle), Priority Request Receiver at TSP enabled intersections, and the City of Omaha Traffic Operation Center. The overall physical views of the TSP system from different perspectives are shown in **Figure 3**, **Figure 4** and **Figure 5**.

FIGURE 3: TSP SYSTEM COMPONENTS IN PLAN VIEW

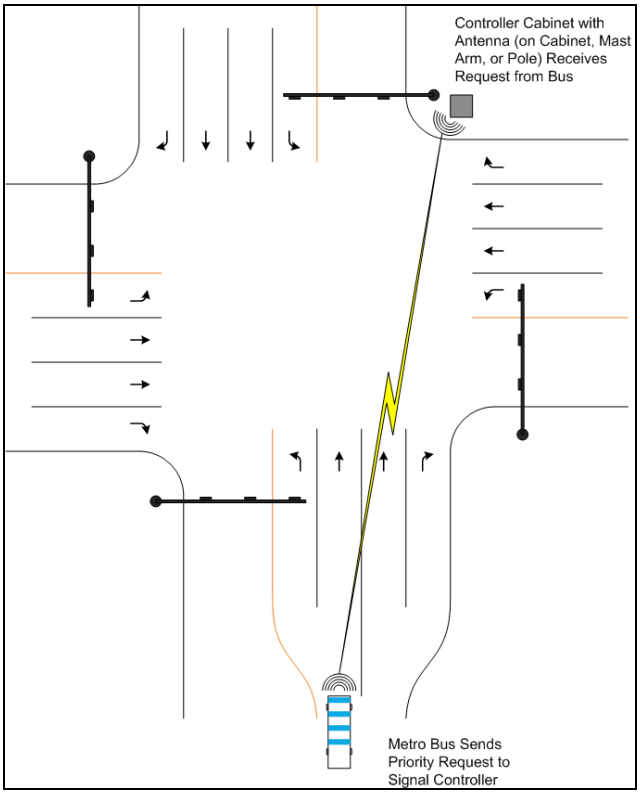


FIGURE 4: TSP SYSTEM COMPONENTS IN PROFILE VIEW

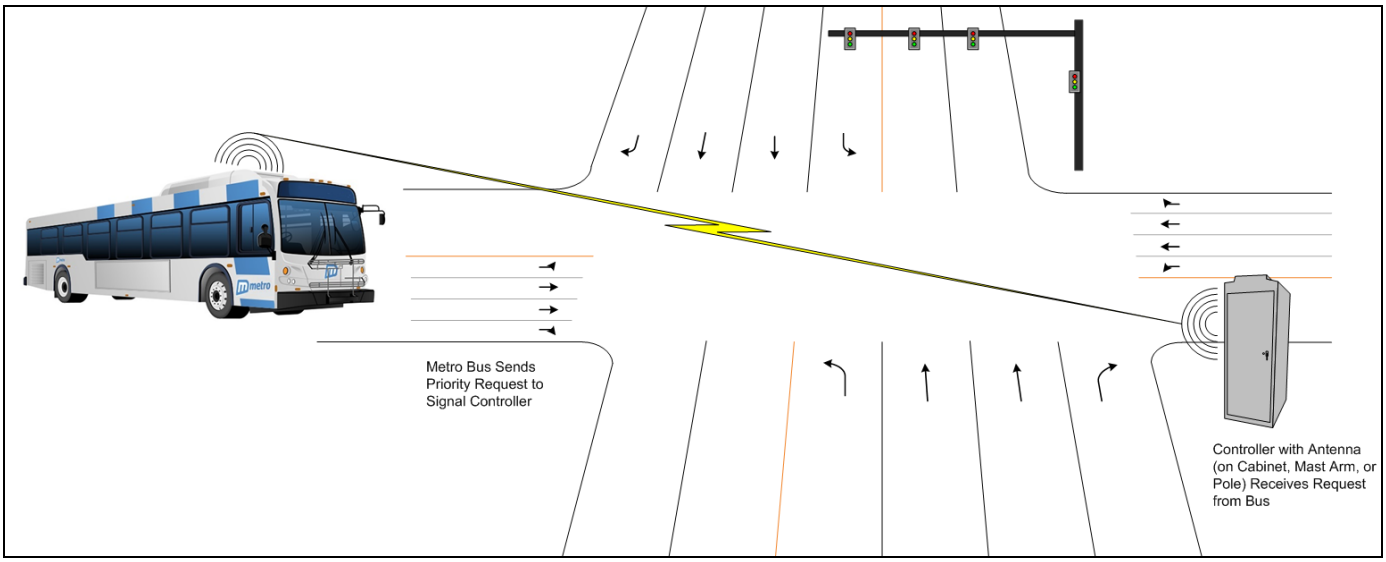
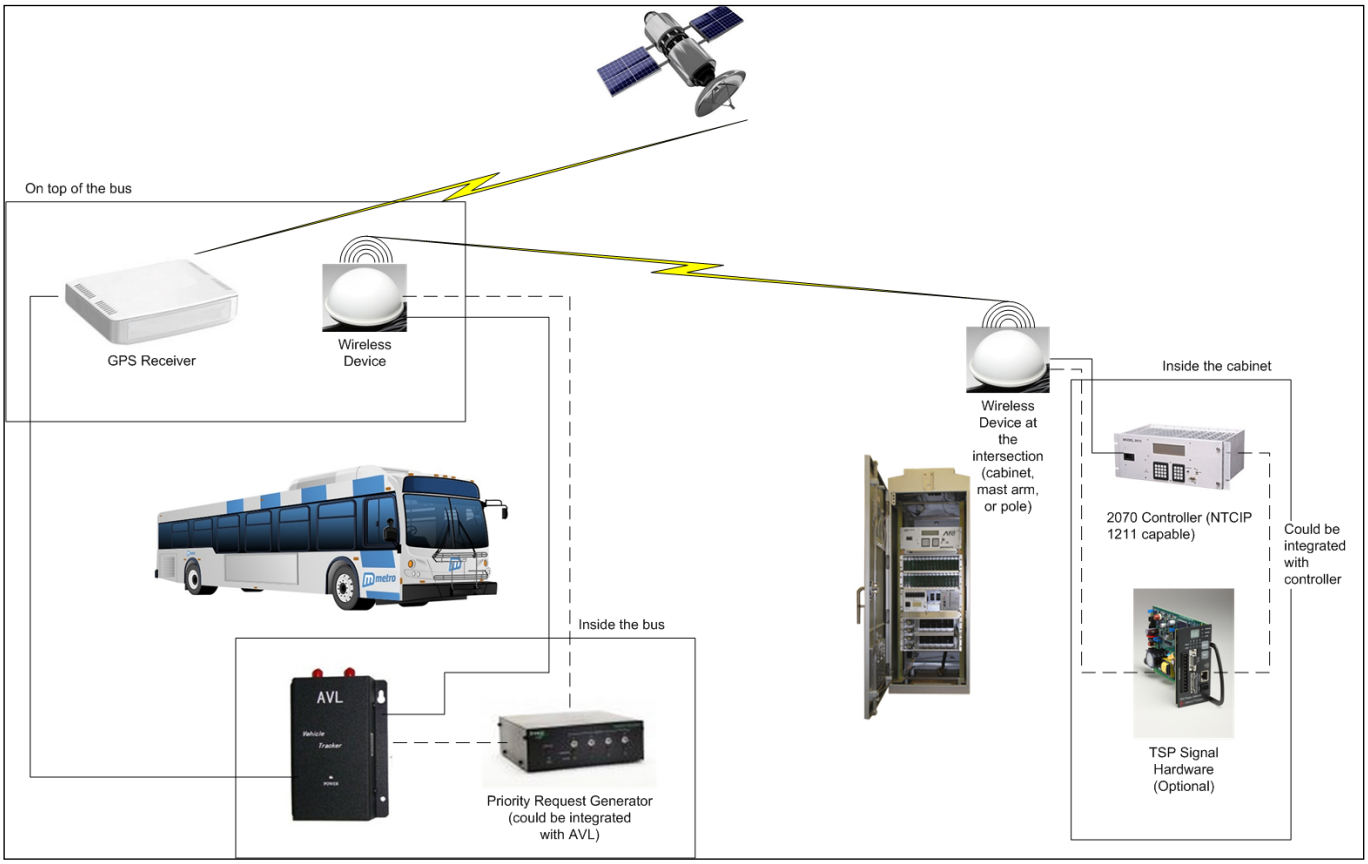


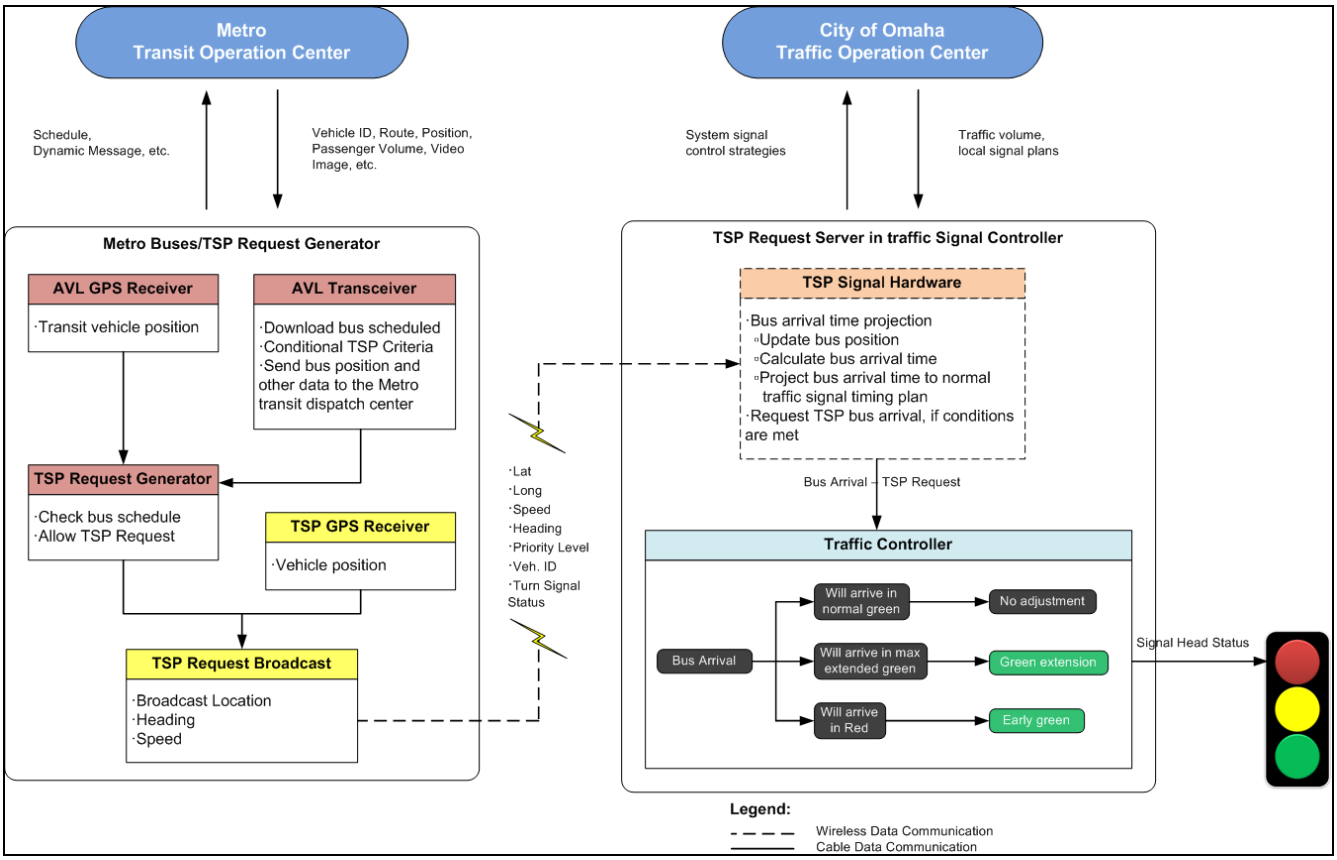
FIGURE 5: TSP SYSTEM SCHEMATIC



6.1.3 PHYSICAL ARCHITECTURE

The physical architecture of the TSP system is illustrated in **Figure 6**.The TSP service request will begin with the Metro Automatic Vehicle Location (AVL) system collecting and monitoring bus position and referencing bus schedule time points. Based on bus schedule and bus position data, the current schedule adherence condition will be calculated and checked against the predefined TSP criteria (e.g., number of minutes behind schedule). If the bus meets the criteria, the AVL system will send a message to the on-board PRG allowing TSP requests to be generated. The PRG will generate a TSP request and information such as latitude, longitude, speed, heading, vehicle ID, and priority level (e.g., low for TSP) will be included in the request. This information will be transmitted from the bus wirelessly to the receiver installed at the individual intersection as a priority request.

FIGURE 6: TSP PHYSICAL ARCHITECTURE



After the receiver receives the TSP request and related information from the approaching bus, it will send the request to the PRS which could be either a separate component or integrated with the controller. The PRS would resolve the request against any other priority requests (e.g., emergency vehicle, other TSP calls). When the estimated bus arrival time (ETA) to the stop bar is calculated (from continuously updated bus position data sent from the on-board GPS vehicle equipment), the PRS will output a pulsating signal corresponding to the phase to be served to the traffic signal controller. The traffic signal controller will interpret the pulsating input as a TSP call on the appropriate priority input.

As soon as the TSP call is forwarded to the controller, the controller compares the time when the call is received to the programmed time of service desired (TSD) and the time of estimated departure (TED) values which should be already programmed into the controller. The ETA in the PRS is calculated time which estimates when the bus arrives at the intersection. The TSD is the predicted bus arrival time and will be projected into the normal traffic signal timing plan by the controller to determine the bus arrival time relative to the timing plan.

Depending on the bus arrival time in the traffic signal timing plan, one of the following TSP strategies will be executed:

- If the bus arrival time is projected to fall in the normal green time of the bus phase, the normal signal timing plan will not be adjusted.
- If the bus arrival time is projected to fall in the maximum extended green time and TSP is granted, the green signal will be extended until the bus checks out or maximum extended green time is reached.
- If the bus arrival time is projected to fall in the red time of the bus phase and TSP is granted, the green signal will return early to the bus phase. The green times for non-bus phases will be shortened to provide an early return to the green signal for the bus phase with the minimum green time for those non-bus phases being maintained.

During the servicing of either green extensions or early green/red truncations, the traffic signal will maintain all vehicle and pedestrian minimum times, yellow and all-red change intervals, and should remain in coordination.

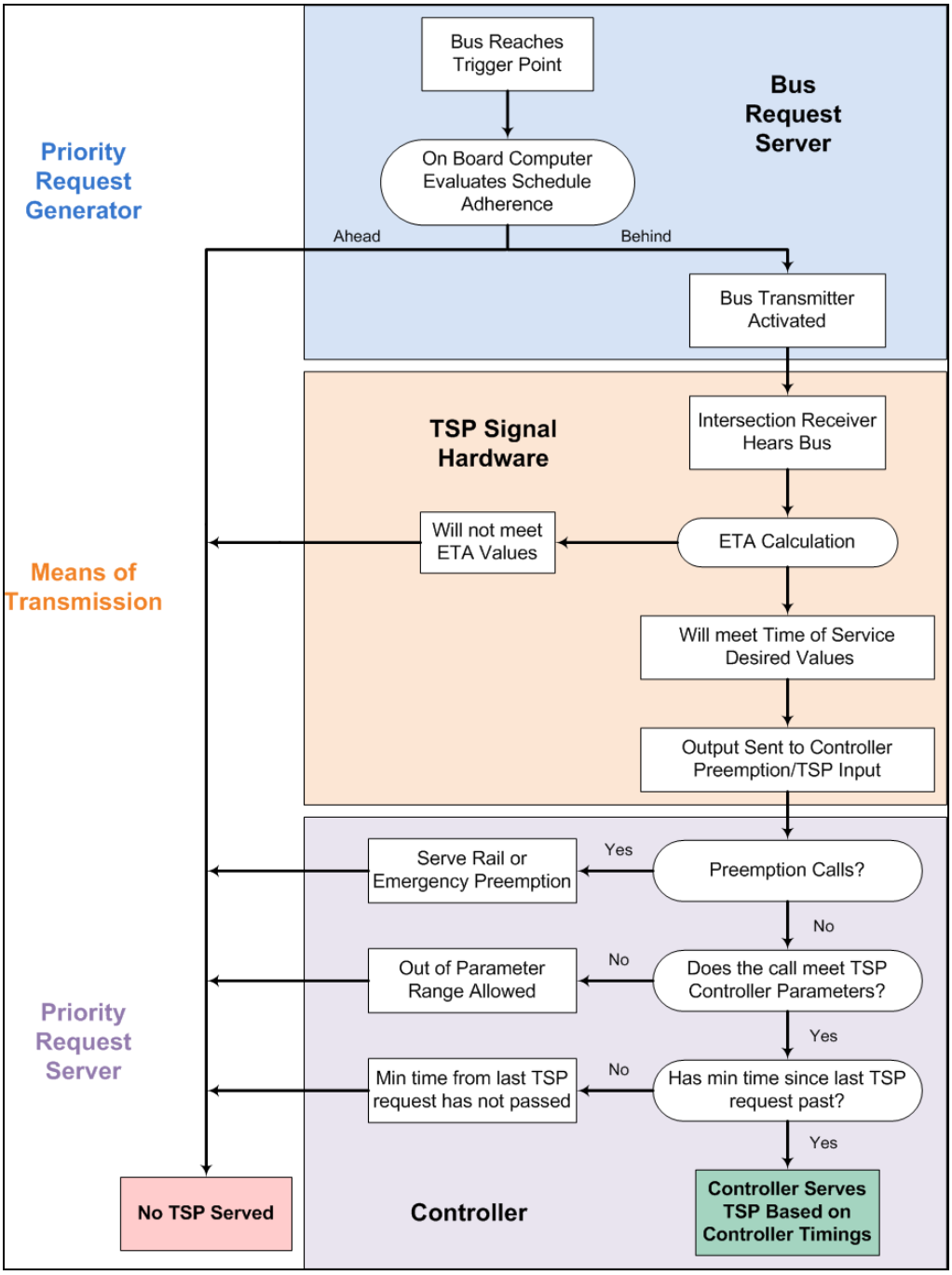
In the case of more than one TSP request at the same intersection, the PRS will address this event on a first come-first served basis. The PRS will also address the servicing of high priority preemption calls for Fire & Rescue vehicles by immediately overriding all low priority calls (e.g., TSP).

The servicing of repeated TSP service requests will be controlled through a pre-defined value (e.g., re-arm or reservice value). This value will define the minimum number of cycle lengths required between successive TSP service requests. After servicing of the TSP request, the local traffic signal controller will return to normal operations.

The TSP service request process described above is illustrated graphically in **Figure 7**. This process will be automatic for Metro buses in service and will not require driver activation or active management by signal operators other than the retrieval of system component logs for monitoring purposes.

The controllers of the intersections in the BRT corridor will be upgraded as part of the City of Omaha Traffic Signal System upgrade project and will have the TSP functionality.

FIGURE 7: TSP SERVICE REQUEST DECISION DIAGRAM



6.2 TSP STRATEGIES

While the system architecture gives a system overview including descriptions of the TSP system components and the interfaces between them, the TSP strategies describe the system from operational perspective. This view of the system describes what TSP strategies including green

extension, early green/red truncation and insertion of new phase will be implemented and the conditions required to grant a TSP request.

The conditional priority requires that certain criteria be met before a transit priority request can be generated. The intent of conditional priority is to be selective with regard to which buses are allowed to make a priority request. Buses that are behind schedule, have high passenger occupancies, or fail to maintain minimum headways will be granted the ability to make a TSP request along the BRT corridor.

The following TSP strategies will be implemented:

- **Green extension** - extends the green time for the TSP movement when a bus is approaching. The green is extended up to a maximum permitted time or until the bus is no longer detected. This strategy only applies when the signal is green for the approaching bus.
- **Early green** - shortens the green time of preceding phases to the minimum permitted time to expedite the return to green (i.e., red truncation) for the movement where a bus has been detected. This strategy only applies when the signal is red.
- **Phase insertion** - a special priority phase is inserted within the normal signal sequence. The phase can only be inserted when a transit vehicle is detected and requests priority for this phase. An example would be the insertion of a bus queue jump phase at the intersections to provide BRT with an advanced green shortly before adjacent traffic.

Most intersections will use only the green extension and early green strategies. The 72nd/Dodge and 42nd/Farnam intersections will have queue jumps and may require phase insertion to allow an early green phase for buses exiting the queue jump. This determination will be made during the preliminary design of the queue jumps. Special transit-only signal heads may be required for this application.

6.3 COMMUNICATION INTERFACES

This view of the TSP system identifies and provides general descriptions of the interfaces among the various entities comprising the TSP system.

Metro's proposed Operations Management System (AVL/CAD) will include an interface with the TSP system. The AVL/CAD will be capable of providing data to the TSP system such as schedule adherence data, and agency-defined thresholds to determine when a vehicle is off schedule as a means of triggering a TSP request. Other data, such door opening and closing can also be transmitted for use by TSP.

An emitter device will be installed on BRT vehicles to provide the communications link between the two systems that will automatically send the necessary data to receivers at designated intersections. This receiver will send information to the PRS which will determine, based on predefined conditions, if the priority request will be sent to the traffic controller or not.

Several communications technologies such as light-based, sound-based, radio frequency (RF)-based, satellite and radio-based are currently available. The communication technology will be finalized as part of the preliminary and final design.

The intersection to intersection communication necessary to relay data between the City Traffic Operation Center and each signalized intersection location in the corridor will be implemented as part of the City of Omaha Signal System Upgrade project.

7.0 OPERATIONAL ENVIRONMENT

Realizing the intended performance enhancement of the proposed BRT system by deploying the TSP service will require the operational agreement and sharing of responsibilities between Metro and the City Traffic Engineering Division. From the stakeholder meeting on June 25, 2015, the following agreements were identified.

Metro will design, deploy and maintain all of the elements of the BRT along the corridor. They will also operate and maintain the Transit Operation Center. Also Metro is responsible for operating and maintaining all of the equipment on the bus. Defining routes, schedules and monitoring the schedule adherence is also under Metro's day-to-day transit operational responsibility.

City Traffic Engineering Division will deploy and maintain the communication network and will provide the wireless access point to the communication at each of the intersection in the BRT corridor at no cost to Metro. They will also maintain the TSP equipment installed at the intersection.

In addition to those distinct responsibilities of Metro and City Traffic Engineering, they have some shared responsibilities including assessment of the deployed TSP service, Metro generating performance measurement reports and the City reporting the number of times TSP was requested and granted.

8.0 SUPPORT ENVIRONMENT

The TSP system will utilize the planned traffic signal communication infrastructure to communicate with the TSP request receiver. Traffic Engineering will provide the password protected wireless LAN access point at the intersection through which the Metro bus will communicate with the TSP request receiver. Both Metro and the Traffic Engineering will be

supported by the IT Network Management Service provided by Douglas-Omaha Technology Commission (DOTComm). DOTComm is the information technology department for the City of Omaha and Douglas County and owns a 96-pair fiber ring in the downtown which will be utilized by both Metro and the City. Also as part the City of Omaha Signal System Upgrade project, new fiber will be installed which will also be used for TSP if required. Metro and the City will maintain the TSP equipment installed on buses and at intersections, respectively.

9.0 OPERATIONAL SCENARIOS

This section presents a number of operational scenarios that are intended to capture activities associated with operation of the system. The objective of developing operational scenarios is to capture user needs from the perspective of the users.

The operational scenarios capture the activities to be performed which are both routine and non-routine, in order to identify user requirements. It is important that the operational scenarios are realistic and reasonable.

Before going into the detail description of the scenarios, the overall description of the normal initiation (start of the TSP service) and termination (end of the TSP service) of a TSP service is necessary to understand the sequence of events that generally occur in any TSP request.

At login each morning, each Metro transit vehicle will download and store in the on board AVL/CAD system and PRG: 1) Updated schedule information for the routes and trips assigned to the vehicle for the day and 2) Conditional priority factors by trip that accounts for type of service, direction, time of day, and historic passenger loading. Higher order factors will be granted TSP first when simultaneous priority requests are received at an intersection. As the transit vehicle is leaving the yard, the mobile AVL/GPS and the vehicle detection/location and communications will be tested, along with requests for priority. At the end of each day (or run), the transit vehicle will upload to the Metro Transit Operation Center using operation center to vehicle communications the service performance log data including the automatic passenger information, the schedule adherence of each trip, and the requests for transit signal priority.

The Metro Transit Operations Management System will archive the logged data. The Metro Transit Operation Center will also request the City Traffic Operation Center the logged wayside PRS data, and signal control data. These will be archived, and a fused performance database for the day will be analyzed to track the performance measures of the TSP system.

The operational scenarios include the following:

- Scenario 1: Transit Bus Running Behind Schedule
- Scenario 2: Transit Bus Running Without Maintaining Headway
- Scenario 3: Transit Bus With High Passenger Load

- Scenario 4: Transit Signal Priority During Special Event

The scenarios listed above are detailed below for the proposed system.

9.1 Scenario 1: Transit Bus Running Behind the Schedule

A Metro transit vehicle is travelling eastbound on Dodge Street approaching the 90th Street signal at 6:00 am on Monday. It is running 5 minutes behind schedule. Since the vehicle is running more than 3 minutes behind the established transit schedule in the AM peak period, the vehicle meets the priority request generating criteria.

The PRG transmits a message to the PRS at the intersection to request priority on the eastbound approach. The message contains the vehicle ID, position, speed, priority level (accounting for type of service, direction, time of day, and historic ridership), passenger count, schedule adherence and headway.

The PRS at the intersection receives the request from the approaching vehicle and compares the current position of the vehicle to its list of detection zones, determines that it has just entered the eastbound detection zone for the intersection and estimates when it will reach the intersection. It then logs the vehicle ID, date and time, priority level, passenger count, the schedule and gap, and intersection approach. The PRS activates the input in the detector rack that corresponds to the eastbound through phase and checks the vehicle in. The arrival time for the vehicle is calculated to be 30 seconds from check in. The traffic signal controller senses that this input is active. At that time, the through phases for Dodge Street are green, with 24 seconds remaining until their force-off point. An extended green TSP is provided for 6 seconds to allow the eastbound transit vehicle to pass through the intersection. The transit vehicle proceeds, leaving the detection zone and clearing the intersection, and is checked out. The extended green is terminated and the signal reverts to its normal cycle.

9.2 Scenario 2: Transit Bus Running Without Maintaining Headway

A Metro transit vehicle is travelling westbound on Dodge Street approaching the 50th Street signal at 3:30 pm on Wednesday. It is approaching the intersection 3 minutes behind schedule. It has been receiving the location and speed data of all the transit vehicles in service along the corridor at 1 minute intervals and has calculated that it has been 11 minutes since the prior transit vehicle passed the intersection. The priority request triggering criteria under the headway control is satisfied with this headway and the transmitter on the vehicle is turned on to transmit a message to the PRS at the intersection to request priority on the westbound approach. The message contains the vehicle ID, position, speed, priority level, passenger count, schedule adherence and headway.

The PRS at the intersection receives the request from the approaching vehicle and compares the current position of the vehicle to its list of detection zones, determines that it has just

entered the westbound detection zone for the intersection and estimates when it will reach the intersection. It then logs the vehicle ID, date and time, the priority level, passenger count, schedule and gap, and intersection approach. The PRS activates the input in the detector rack that corresponds to the westbound through phase and checks the vehicle in. The arrival time for the vehicle is calculated to be 20 seconds from check in. The traffic signal controller senses that this input is active. At that time, the through phase for 50th street is green, with 30 seconds remaining for the phase. Also the controller finds that if the existing green phase is served another 20 seconds it will meet the minimum green time requirement for the phase. Meeting the minimum green time allows the controller to provide an early green TSP to allow the westbound transit vehicle to pass through the intersection. The transit vehicle passes through the intersection and is checked out. The early green is terminated and the signal reverts to its normal cycle.

9.3 Scenario 3: Transit Bus With High Passenger Load

On the Black Friday sale in the Westroads Shopping Mall, a westbound Metro transit vehicle carrying an unusually high number of passengers is approaching the 72nd and Dodge intersection at 11: 30 am. With the increased passenger loading time at different stations on its way, the vehicle is running behind 5 minutes behind schedule which triggers the on-board PRG and the wireless emitter on the vehicle sends the priority request to the PRS in the intersection. The message contains the passenger count and the other data fields of the standard request message.

Upon receiving the request, the PRS will estimate the time when the vehicle will reach the intersection from the request message data. It then logs the vehicle ID, date and time, priority level, passenger count, schedule and gap, and intersection approach. The arrival time for the vehicle is calculated to be 15 seconds from check in. At that time, the through phase for Dodge Street is green, with 13 seconds remaining for the phase. With the capability of providing the queue jump service at this intersection, the controller activates the transit only through phase on Dodge Street instead of starting the green for the 72nd street through phase. The transit vehicle passes through the intersection and is checked out. The queue jump phase is terminated and the signal reverts to its normal cycle.

9.4 Scenario 4: Transit Signal Priority During Special Event

A number of “special events” are likely to occur annually along the Dodge street corridor. Examples include NCAA Men’s College World Series, Summer Art Festival, Sand in the City, MAHA Music Festival, etc. The TSP treatment will depend on the event and service plan agreed between the City Traffic Engineering Division and Metro. The key elements of their agreement should include the service plans and operating plans during special events. For this example, let’s assume that NCAA Men’s College World Series is taking place one Saturday afternoon on or near the corridor. The steps to plan and respond to this event are:

- The City Traffic Engineering and Metro receive notification 3 months in advance of the event schedule including anticipated attendance and other details.
- Metro proposes staging transit vehicles for people leaving the event at the end of the night. Metro vehicles would be inserted into the regularly scheduled service for 5 minute headways to the Westroads Mall and the Dodge/10th street intersection.
- Operating mode will be set to "Special Event Service" and parameters sent to PRG and PRS devices impacted.
- Within 1/2 mile of the event locations, signals will be under manual police direction. In this area all TSP will be suspended for safety reasons.
- Outside of this radius, all conditional priority will be turned off, and the vehicles will operate under unconditional active priority (always issuing a priority request) in the outbound direction from the event location.
- The lockout period (the period when no TSP will be served) will also be set to zero.
- These parameters will remain in effect for 1 hour after the event ends.
- The operating mode will be set to "Recovery" until normal service patterns, schedules, and headways can resume.

10.0 SUMMARY OF IMPACTS

10.1 OPERATIONAL IMPACTS

The implementation of the elements identified in the TSP system concept will allow for significant operational improvements. The TSP system will reduce transit delay, reduce roundtrip travel time, increase transit reliability (schedule adherence), increase efficiency of the BRT system and provide accurate information to the public that can be used to make travel decisions. The following summarizes the expected operational impacts on the traffic in the BRT corridor due to the implementation of the TSP system.

1. Reduced average and the maximum round trip run times due to reduced delay at traffic signals.
2. Improved on-time performance and consistent headways by reducing travel time variability due to reduced traffic signal delay.
3. Reduced number of vehicles and operators required to provide the specified service in each time period. This will reduce the total system operation cost.
4. Reduced parallel traffic delay and LOS due to increased green time from TSP.
5. Potential increased crossing traffic delay and LOS due to decreased green time from TSP.

10.2 ORGANIZATIONAL IMPACTS

TSP also has organizational impacts. In order to implement and operate TSP, the operating agreements and memorandum of understanding between the City Public Works and Metro is necessary to formally establish the initial TSP service, locations, roles and responsibilities, and a

process for managing change. Equally important is the need to define maintenance and access rights to equipment and systems along the corridor. Because of the need to merge and integrate data from multiple sources (the City of Omaha Traffic Operations Center with their signal controllers, PRS and the Metro Transit Operation Center with their AVL/CAD system, PRG, etc.), there will be a need to have IT and database administrators to process, store and analyze the TSP performance data.

11.0 NEXT STEPS

The project team will develop high-level system requirements and a preliminary verification plan consistent with this Concept of Operations to support the development of the high-level functional requirements for the TSP deployment. This final section of the Concept of Operations summarizes the need to manage and document the system engineering design and installation process to meet stakeholder needs.

Metro and the City of Omaha or their representatives will track and amend the verification plan, project plans, specifications and requirements based on the Change Management process described in the System Engineering Management Plan (SEMP). The responsibility to manage the project changes will be the responsibility of Metro Project Manager. These changes will be documented in the acceptance testing and tracked through the mapped requirements back to the Concept of Operations. Metro and the City will review the mapped changes and determine the time-frame to amend the Concept of Operations.