U.S. Department of Transportation

Federal Transit Administration

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

Draft Systems Engineering Management Plan

September 24, 2015

DOCUMENT VERSION CONTROL

Document Name	Submittal Date	Version No.
Version 1.0	Sept 24, 2015	1.0

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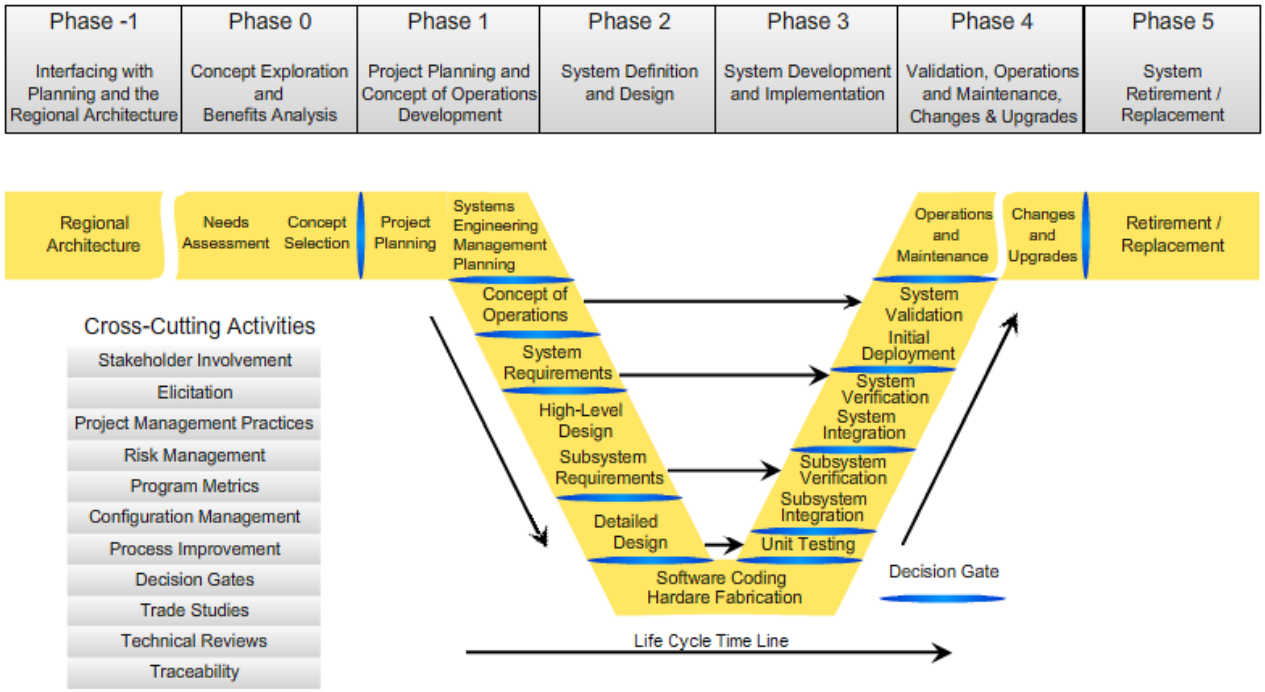
1.0 PURPOSE OF DOCUMENT

The Systems Engineering Management Plan (SEMP) supports the development of the high-level functional requirements for the Transit Signal Priority (TSP) deployment in Metro's Central Omaha Bus Rapid Transit (BRT) system. It provides a high-level plan for the management of Systems Engineering in compliance with the FTA Final Policy on Architecture and Standards Conformity and the Federal Highway Administration (FHWA) Rule 23 CFR 940.1 and applicable Systems Engineering Guidelines. The SEMP is the second document in the set of systems engineering deliverables identified in the Project Plan, and consists of:

- Project Overview
- Project and Systems Engineering Documentation
- Project Management and Control
    - Traceability and Technical Review
    - Procurement Management
    - Risk Management
    - Change Management
    - Quality Management
    - Systems Acceptance
    - Operations and Maintenance, Upgrade and Retirement

The purpose of the SEMP is to describe how the Systems Engineering Process, illustrated in **Figure 1,** will be integrated into the development of the high-level functional requirements for the TSP system and into the subsequent design and deployment phases. The SEMP will guide the project from conception to operations and maintenance in a systematic way. The SEMP is an evolving document that will be updated as the project progresses.

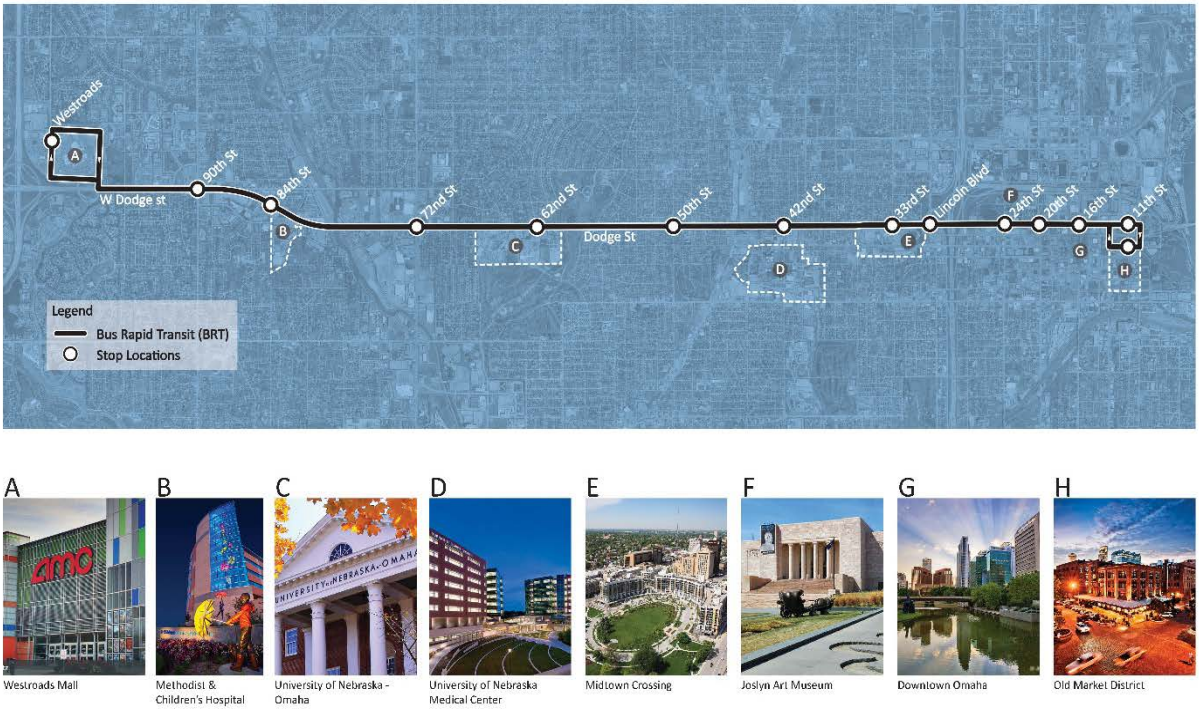
FIGURE 1: SYSTEMS ENGINEERING PROCESS "V" DIAGRAM



2.0 PROJECT OVERVIEW

The purpose of this project is to support the development of the high-level functional requirements for the deployment of the TSP services in the Central Omaha BRT system and form the foundation for design and deployment of the hardware, software and the communication infrastructure necessary for implementing the TSP service. The proposed TSP service will be implemented to enhance the effectiveness of the new BRT system on Dodge Street. The TSP will be deployed in the intersections located west of West of Turner Boulevard and Dodge Street intersection along the BRT corridor. Depending on the final design, the number of intersections where TSP will be deployed could be anywhere from eleven (11) to sixteen (16). The locations of the BRT stations are shown in the **Figure 2**.

FIGURE 2: BRT STATION LOCATIONS



2.1 PROJECT 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.

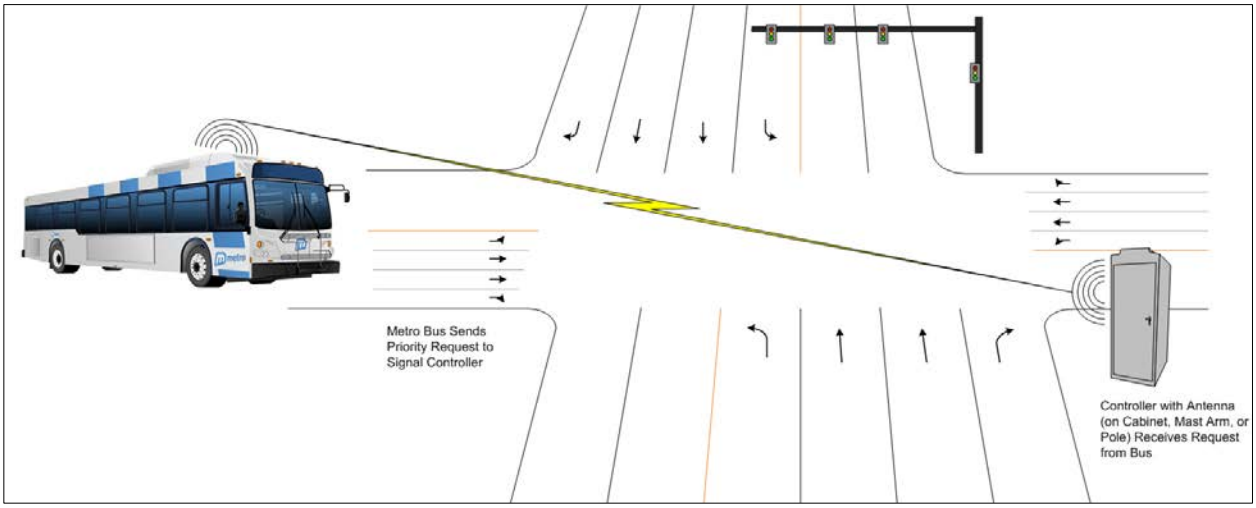
2.2 HIGH LEVEL SYSTEM DESCRIPTION

At a high level (context level) the TSP system consists of the interfaces between the Metro Operation Management System (AVL/CAD) and transit vehicles and between the on-board emitter and the receiver at a TSP enabled intersection.

- **Interface between Transit Vehicle and Operation Management System** -The proposed Operations Management System (AVL/CAD) will have an interface with the TSP system. The Operations Management System will be capable of providing data to the TSP system such as schedule adherence and agency-defined thresholds to determine when a vehicle is off schedule as a means of triggering TSP. Other data, such door opening and closing can also be transmitted for use by TSP.
- **Interface between On-board Emitter and Receiver at a TSP Enabled Intersection** - **An** emitter device will be installed on BRT vehicles to provide a wireless communication link between the bus and the receiver. The emitter will automatically send the necessary data to the receiver at designated intersections. This receiver will send information to a processing unit which will determine, based on some 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 are currently available. For example, infrared detection is a widely used and proven detection method for transit signal priority applications. An advantage is its relatively low cost, as well as the fact that the technology is well-tested and is widely used for emergency vehicle preemption (EVP) systems. An appropriate communication technology for this interface will be selected in the subsequent design phase of this project. An intersection TSP system schematic is shown in the **Figure 3.**

FIGURE 3: INTERSECTION TSP SYSTEM SCHEMATIC



2.3 PROJECT TSP STRATEGY

A stakeholder meeting was held on June 25, 2015 to determine the TSP system needs. The operational conditions under which a priority request will be generated and strategies to implement the TSP were discussed in this meeting. The agreed upon conditions and the strategies are described in the following sections.

Conditional TSP is recommended for the BRT. Conditional priority requires that certain criteria be met before transit priority can be granted. The intent of conditional priority is to be selective with regard to which buses receive priority. TSP will be provided to the buses that are behind schedule, have high passenger occupancies, or fail to maintain minimum headways. Among these, the schedule adherence condition is the most critical one.

The BRT TSP strategies will include:

- **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. Phase lengths and other details to be determined.
- **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 lengths and other details to be determined.
- **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 to provide BRT with an advanced green shortly before adjacent traffic. Phase lengths and other details to be determined.

Most intersections will use only the green extension and early green strategies. The 72nd/Dodge and 90th /Dodge intersections will possibly 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.

2.4 TSP System Components

The TSP system will be comprised of the following components:

- 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

2.5 Project Scope and Schedule

The primary scope of the systems engineering documentation is to support the development of the high-level functional requirements for the deployment of TSP as part of the Central Omaha BRT project. A Technology Needs Assessment and Implementation Strategy will also be developed as part of the TSP planning task and inform the requirements development process.

The MAPA Regional ITS Architecture includes projects to improve the traffic signal system in the City of Omaha. The full documentation of this ITS architecture can be found at http://www.mapacog.org/intelligent-transportation-systems-its. The City of Omaha has also 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.

The high-level TSP requirements and implementation strategy will address major system components including:

- Interface between Metro's Operations Management System and the TSP system
- Traffic signal system hardware and software
- Communications infrastructure between emitter devices installed on BRT vehicles and receivers at the TSP enabled intersections
- Intersection to intersection communications
- Intersection to center communications

Table 1 summarizes the project scope and schedule including key tasks and deliverables, team members involved, and expected schedule milestones. Dates of draft deliverables are

approximate and subject to change based on review by Metro, City of Omaha, NDOR, FTA and FHWA staff.

TABLE 1: PRELIMINARY PROJECT TASKS AND SCHEDULE

Tasks and Deliverables	Key Team Members	Start Date	Completion Date
1. Systems Engineering Management Plan	– Iteris (Lead) – HDR – Metro – City of Omaha	February 2015	October 2015
2. Concept of Operations	– Iteris (Lead) – HDR – Metro – City of Omaha	February 2015	October 2015
3. Requirements and Verification Plan	– Iteris (Lead) – HDR – Metro – City of Omaha	February 2015	October 2015
4. Technology Needs Assessment	– HNTB (Lead) – Iteris – Metro – City of Omaha	February 2015	October 2015
5. Implementation Strategy	– HNTB (Lead) – Iteris – Metro – City of Omaha	June 2015	October 2015

Final design and construction will be conducted as part of future projects. The Systems Engineering process will also be integrated, depending on the technical complexity of the project, into all required project tasks.

2.6 STAKEHOLDERS

Project Stakeholders anticipated for this project include:

- Omaha Metro Area Transit
- City of Omaha Traffic Engineering Division
- City of Omaha Traffic Maintenance Shop
- Omaha Fire Department
- City of Omaha Planning Department
- Douglas-Omaha Technology Commission (DOT.Comm)
- Metropolitan Area Planning Agency (MAPA)

- Federal Transit Administration(FTA) Region VII
- Federal Highway Administration (FHWA) Nebraska Division
- NDOR District 2
- Other Agencies' Public Works, Police, and Fire Departments in Omaha Metropolitan area
- Metropolitan Entertainment and Convention Authority (MECA)
- Media
- Traveling Public

The Concept of Operations will formally identify these stakeholders. Some stakeholders may choose not to participate, or the lead agency may determine the agency should not be a stakeholder.

2.7 Relevant Project Documentation

Metro is the lead agency in the TSP high-level functional requirements development and subsequent design and deployment phases for the TSP system implementation. The other core agencies involved in the development of this project are the Federal Transit Administration (FTA) and the City of Omaha since their daily traffic operations will be affected by the TSP system. The following regional-level planning documents describe the need for the implementation of the TSP System in the BRT system:

- MAPA Regional ITS Architecture
- Central Omaha Transit Alternative Analysis

3.0 PROJECT AND SYSTEMS ENGINEERING DOCUMENTATION

Table 2 identifies and describes the system engineering processes and deliverables that will be completed. Items 1-4 will be completed in conjunction with the TSP high-level functional requirements development, while the remaining system engineering documents (Items 5-8) will be completed as TSP service is designed, deployed, tested, and accepted at each intersection.

Table 2: Transit Signal priority System Deployment Documentation

Systems Engineering Processes	Status	Description	Deliverables
1. Project Plan	In Progress	The Project Plan will provide a guide for all stakeholders that clearly defines the scope, goals and objectives, schedule, and budget of the TSP.	Draft and Final Project Plan

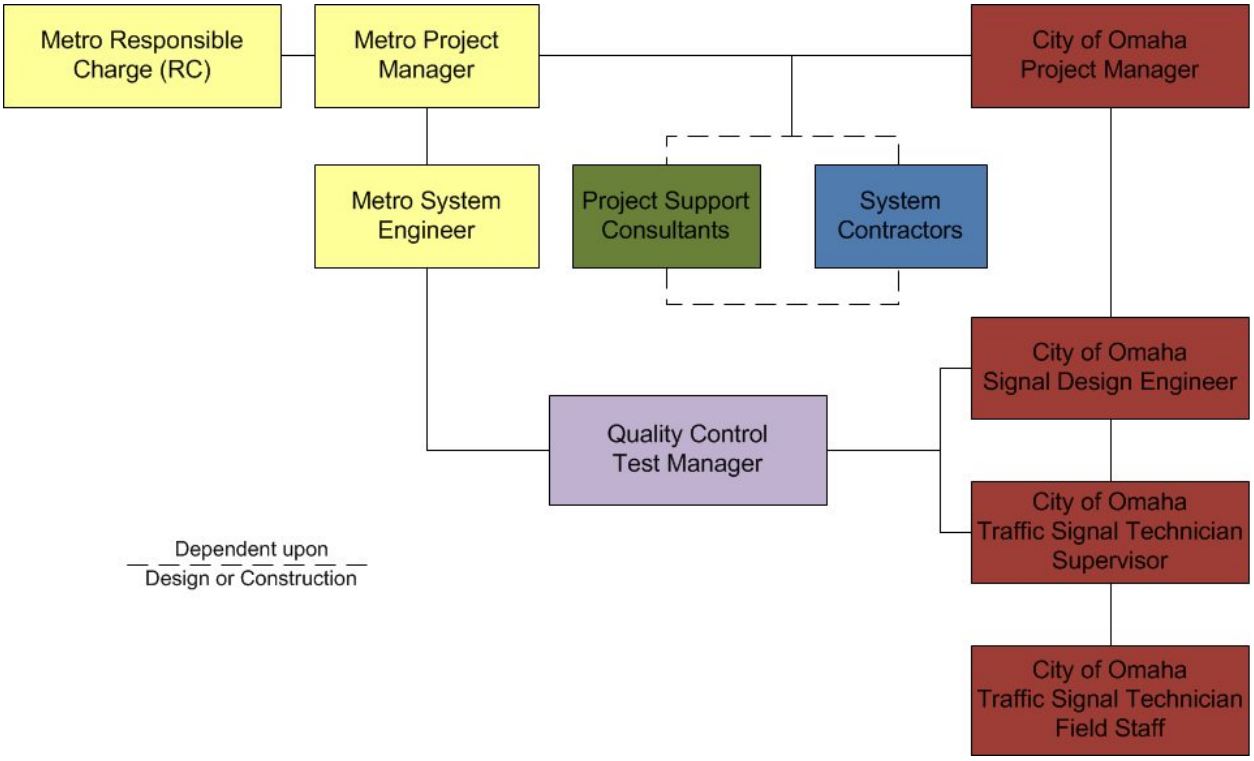
SYSTEMS ENGINEERING PROCESSES	STATUS	DESCRIPTION	DELIVERABLES
2. System Engineering Management Plan	In Progress	The Systems Engineering Management Plan (SEMP) will provide project managers and stakeholders an overview of how the TSP high-level functional requirement development and subsequent design and deployment phases will follow and be integrated with the systems engineering processes.	Draft and Final Systems Engineering Management Plan
3. Concept of Operations	In Progress	The Concept of Operations will identify the needs as well as roles and responsibilities of all stakeholders identified in the SEMP as it relates to the TSP deployment. The Concept of Operations will define what the TSP system will look like and how it will operate based on discussion of operational scenarios and alternative concepts.	Draft and Final Concept of Operations
4. High-Level Requirements and Verification Plan	In Progress	The High-Level Requirements and Verification Plan will develop high-level requirements for the TSP system. The requirements will be traced back to the stakeholder needs that were identified in the Concept of Operations. The System Requirements determine what the system must do and drive the system design. A Requirements and Verification Plan will be prepared as part of this project that addresses the expected process to determine that the requirements are satisfied during the subsequent deployment of system components.	Draft and Final High-Level Requirements and Verification Plan
5. High-Level Design	Not Started	High-level Design Plans will develop a plan package for individual transit signal priority system components that will adequately meet the requirements identified in the System Requirements and Verification Plan.	Draft and Final High-Level Design Plan Package(s)

SYSTEMS ENGINEERING PROCESSES	STATUS	DESCRIPTION	DELIVERABLES
6. Detailed Design Plans and Requirements Traceability Spreadsheet	Not Started	Detailed Design Plans will be prepared that are consistent with the Concept of Operations, System Requirements, and High-Level Design. The Requirements Traceability Spreadsheet will be developed to trace requirements through the final design phases, procurement, installation, integration, testing, and acceptance.	Detailed Design Plans and Specifications; Requirements Traceability Spreadsheet(s)
7. Procurement, Installation and Integration	Not Started	Using the final plans and specifications, TSP components will be procured, installed and integrated into the traffic signal system, transit vehicle and transit management center by Metro and City of Omaha staff and/or contractors/vendors (depending on the procurement process).	System Component Procurement, Installation and Integration Documentation
8. Testing and Acceptance Plans	Not Started	This Plan will summarize the expected testing and schedule associated with the installation of system components and will build on the High-Level Requirements and Verification Plan. Depending on the component being installed, the documentation of the test could include inspection, demonstration and/or execution of basic scripts. The QC/Test Manager will be responsible for performing and documenting all testing with Metro, City of Omaha or its agents present to observe and verify the results. All modifications will be reviewed and either approved or rejected by Metro and/or the City of Omaha Project Managers.	Testing and Acceptance Plans and Results Documentation

4.0 PROJECT MANAGEMENT AND CONTROL

Figure 4 illustrates the organizational structure for the BRT TSP high-level functional requirements development process and subsequent design and deployment phases. Brief descriptions of anticipated project roles are included following the organizational chart.

FIGURE 4: BRT TSP DESIGN AND DEPLOYMENT ORGANIZATIONAL CHART



Metro Project Manager – The Metro Project Manager will be responsible for the management of the high-level functional requirements development process as well as subsequent design and deployment of the TSP system. The Project Manager will be responsible for managing consultant and contractor staff that support Metro throughout the planning, design and deployment phases of the project. Being the lead stakeholder, the Metro Project Manager is also responsible for communicating with the City of Omaha Project Manager to update and review the project scope, to build and maintain the consensus between City and Metro and to resolve any project related issues in all phases of the project.

City of Omaha Project Manager – The City of Omaha Project Manager will coordinate with the Metro Project Manager to ensure that the TSP system is designed in accordance with the agreed upon system specifications as the deployed TSP system will affect traffic operation along the BRT corridor. In addition to the Metro Project Manager, the City of Omaha Project Manager will also manage consultants and contractors that plan, design and deploy the TSP system, monitor the

project progress and ensure, with the support from the City of Omaha Signal Design Engineer, that the TSP system meets established goals and objectives.

Metro Systems Engineer – The Metro Systems Engineer will oversee and ensure that the system is being deployed in accordance with the system requirements, design plans and specifications. While the Metro Systems Engineer will coordinate with the City of Omaha Traffic Signal Design Engineer for installing the TSP components that go into the signal system, it is the primary responsibility of the Metro Systems Engineer to deploy the other TSP components (emitter, communication between the emitter and the receiver etc.) necessary to implement TSP service.

Project Support Consultants – Project Support Consultants will provide technical support to both Metro and City of Omaha Project Managers. Initially, Project Support Consultants will develop Systems Engineering documentation. In subsequent deployment phases, Project Support Consultants will also develop final system requirements and plans, specifications and estimates (PS&E) packages required for project bidding.

System Contractor – The System Contractor will construct or install the TSP system components. The System Contractor will report directly to the Metro Project Manager and work closely with other Metro staff. The System Contractor will be expected to work with the Quality Control Test Manager to confirm requirements are satisfied through appropriate testing and acceptance procedures.

Metro Responsible Charge (RC) – NDOR requires the local public agency (LPA) designate a full time employee to be in "responsible charge" of federal-aid projects and assure compliance with the LPA Guidelines Manual for Federal-aid Projects and federal and state rules and regulations. Primary duties of this position include: administering activities dealing with cost, time, adherence to contract requirements; directing project staff (agency or consultant) to carry out administration and contract oversight, including proper documentation; and being aware of the qualifications, assignments, and on-the-job performance of the agency and consultant staff at all stages of the project.

City of Omaha Signal Design Engineer – The City of Omaha Signal Design Engineer will be responsible for working with the City of Omaha Project Manager and the City of Omaha Traffic Signal Technician Supervisor to implement the TSP at the designated intersections on the BRT corridor. The Signal Design Engineer will provide input into the development of the TSP high-level functional requirements. The Signal Design Engineer may also work with the Traffic Signal Technician Supervisor and may help the Metro Quality Control Test Manager in carrying out the Testing and Acceptance processes and documentation.

City of Omaha Traffic Signal Technician Supervisor – The City of Omaha Traffic Signal Technician Supervisor will be responsible for working with the City of Omaha Signal Design Engineer to provide input for the development of the TSP high-level functional requirements.

City of Omaha Traffic Signal Technician Field Staff – The City of Omaha Traffic Signal Technician Field Staff will work under direction of the Traffic Signal Technician Supervisor, and will also work with the System Contractors during deployment phases to properly install, integrate, and test the signal system components necessary for TSP service according to the project plans and specifications.

Quality Control Test Manager – The Quality Control Test Manager will be an independent third party and is expected to oversee all system testing. The Quality Control Test Manager will work with the System Contractor to prepare the final acceptance test plans. The Quality Control Test Manager will also be responsible for documenting and reporting the results of all testing to the Project Manager.

4.1 Traceability and Technical Review

The Metro Project Manager is responsible for technical review of all project and systems engineering documents related to development of the high–level functional requirements of the TSP deployment as well as all phases of future project deployments. The Project Manager will review documents to ensure that the needs and requirements identified in initial systems engineering documents (such as the Concept of Operations) are being carried forward through the System Requirements, Design Plans, and Testing and Acceptance Plans. This traceability makes certain that TSP functionality is being implemented in accordance with the original goals of the TSP system.

4.2 Risk Management

The risk associated with this project needs to be discussed with Metro and the City of Omaha staff and stakeholders. Project needs will be discussed to reduce the amount of risk in the project. Potential areas of risk may include:

- Condition of communications network
- Contractor installation and integration
- Changes in technology
- Reliability of latest technology
- Political and public support
- Metro transit staffing levels
- Staff expertise/training

Risk will be managed through coordination with project stakeholders and preparation of thorough plans and specifications that meet project requirements. The risk management group will be led by members from Metro and the City of Omaha. Metro and the City of Omaha Project Managers will coordinate with this team to ensure the installation, integration and maintenance elements are managed to reduce overall project risk. The risk management team is expected to include the following agencies:

- Metro Transit (Lead Agency)
- City of Omaha
- Federal Transit Administration
- Douglas-Omaha Technology Commission (DOT.Comm)
- Nebraska Department of Roads (NDOR)
- Metropolitan Area Planning Agency (MAPA)

4.3 Change Management

Change management is needed throughout the planning and deployment process to provide accurate documentation and approval of any changes related to stakeholder needs, system requirements, design plans, or product specifications. A change or system upgrade may be needed to keep pace with changing stakeholder roles and responsibilities, advancing and changing technology, or addition of system components over time.

The Metro Project Manager will be responsible for change management throughout the project (i.e., transit planning activities, design, deployment, and acceptance testing). In this capacity, the Change Management Team will review all proposed project changes and coordinate with the appropriate management for approval or rejection. Proposed changes will be discussed during project status meetings. If a change is accepted, Metro and City Project Managers, the Systems Engineer and the Project Support Consultant or Contractor will agree on the impact the change has on schedule and project budget.

The change management team is expected to include the following agencies:

- Metro Transit (Lead Agency)
- City of Omaha
- Federal Transit Administration
- Douglas-Omaha Technology Commission (DOT.Comm)
- Nebraska Department of Roads (NDOR)
- Metropolitan Area Planning Agency (MAPA)

4.4 Quality Management

Metro's Quality Management practices will be applied to all stages of the TSP deployment plan and the design and deployment of the TSP components. Metro should require all Project Support Consultants, System Contractors, and Quality Control Test Managers to develop and adhere to internal quality assurance/quality control practices and to develop and follow quality control procedures for all project activities.

4.5 Systems Acceptance

The Testing and Acceptance Plan will document how the TSP system will function and must be consistent with the agreed-upon functional requirements. The Quality Control Test Manager will be responsible for review and verification of the System Acceptance Plan. Verification by the Quality Control Test Manager means the test plan has adequate tests to address each system requirement. Depending on the project, testing and acceptance can be done at one or more levels (device, subsystem, and system).

The Quality Control Test Manager and System Contractor, in conjunction with the Metro Systems Engineer, the City of Omaha Signal Design Engineer, Traffic Signal Technician Supervisor, and Traffic Signal Technician Field Staff will be responsible for executing the Testing and Acceptance Plan for each TSP deployment.

The following are examples of acceptance tests that may be performed for system deployments:

- Factory acceptance testing
- Shop Drawing Review
- On-Site Visual Confirmation or Demonstration
- Scripted Demonstrations
    - One-day acceptance testing (System turn-on)
    - Reliability testing

Once the system is accepted by the Quality Control Test Manager, Metro and the City of Omaha accept and become responsible for the operation and maintenance of the system component. The Quality Control Test Manager will be responsible for reporting the results of all tests. Metro and the City of Omaha Project Managers will use this information to make final decisions on system acceptance.

4.6 Operations and Maintenance, Upgrade and Retirement

Operations and Maintenance, Upgrade and Retirement are dependent upon the technology deployed and the warranty of the products or services procured. The Concept of Operations should document at the high-level, the expected plan for:

- Operations – This will include a high-level summary of the staffing needs to operate the system and the roles and responsibilities for the TSP system operation, management, information sharing and reporting.
- Maintenance – This will include the staffing needed to maintain system software, hardware and communications. Current maintenance needs will be documented, and the purchase of extended warranties will be evaluated.

- Upgrade – This will include opportunities for hardware, software and communications upgrades. Metro will use potential upgrade options to develop a strategy for budgeting and performing system upgrades.
- Retirement – This will include estimates for software, hardware and communications replacement. This will be based on industry trends and Metro and the City of Omaha's vision for continued, proactive transit.