SYSTEM ENGINEERING MANAGEMENT PLAN (SEMP)

EO2852

Work Order No.3

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Draft

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Table of Contents

LIST OF TABLES

LIST OF FIGURES

LIST OF ACRONYMS

ConOps	Concept of Operations
FHWA	Federal Highway Administration
ITS	Intelligent Transportation Systems
PennDOT	Pennsylvania Department of Transportation
PSEMP	Project Systems Engineering Management Plan
RCTO	Regional Concept for Transportation Operations
RITSA	Regional ITS Architecture
RTM	Requirements Traceability Matrix
SEA	Systems Engineering Analysis
SATMS	Statewide Advanced Traffic Management Software
SHT	Squirrel Hill Tunnel
SITSA	State ITS Architecture
SPC	Southwestern Pennsylvania Commission
TMC	Transportation Management Center
TSM&O	Transportation Systems Management and Operations
GIS	Geographic Information Systems
DMS	Dynamic Message Sign
SOP	Standard Operating Procedure
VPN	Virtual Private Network

1 PURPOSE

The Systems Engineering Management Plan (SEMP) is prepared in support of the I-376/ Parkway East Corridor Transportation Network Active Transportation Management System (ATMS) project that includes development of a Concept of Operations (ConOPS), high level System Requirements, ITS Architecture Conformance and Conceptual ITS design to help advance the implementation of ATMS along the Parkway East corridor in the Pittsburgh Metropolitan area. This document describes the system engineering process used to develop the ATMS strategies. The SEMP identifies what items are to be developed, delivered, integrated, installed, verified, and supported for a future ATMS solution along the corridor. The SEMP establishes a structured and easier understanding of the systems engineering tasks and advise projects stakeholders of their involvement in the various systems engineering processes within the project.

Finally, the SEMP will provide a process to be used to develop each of the project's ATMS strategies.

1.1 Overview of the SEMP

The SEMP focuses on the technical planning of the project and the Systems Engineering Analysis (SEA) processes to be used to develop the Concept of Operations (ConOps) and System Requirements for the Parkway East Corridor project. The SEMP outlines engineering tasks and provides detailed information on the processes to be used.

Developing the Preliminary Engineering for I-376 Active Transportation management system (ATMS) tasks e.g. Concept of Operations (ConOPS), high level system requirements, ITS Architecture Conformance and Conceptual ITS Design will address conformance in the Regional Architecture "Step 1", and the Concept of Operations, high level System Requirements and Design "Steps three through 5" of the Systems Engineering development process, as shown in **Figure 1** below.

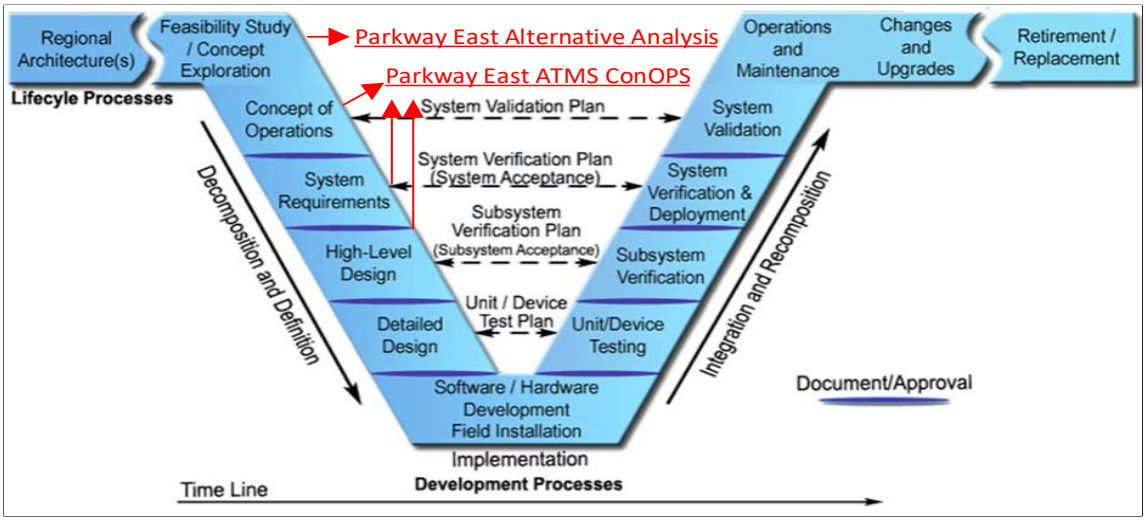


Figure 1 Systems Engineering "Vee" Diagram

***Systems Engineering definition: An inter-disciplinary approach and a means to enable the realization of successful systems. Systems engineering requires a broad knowledge, a mindset that keeps the big picture in mind, a facilitator, and a skilled conductor of a team.**

This SEMP will comment on the additional steps of the Systems Engineering process, including high level design, testing, validation and operations/maintenance that will be required when the ATMS conceptual strategies are further defined in later phases of the project.

This document should be updated throughout the lifecycle of the project process to reflect developments in the design concepts as they occur. There are several sections in this current document that follow the required SEMP format, but are described in high-level terms. PennDOT and Stakeholders are in the process of identifying a system to be developed under the Concept of Operations development effort. As project conceptual planning decisions are made and documented, the critical stakeholders will provide input to the SEMP updates. PennDOT's funding to develop additional feasibility phases is not yet identified. Later sections of this document refer to design, verification, implementation and other tasks that are not part of this current projects effort, but indicate the systems engineering process.

2 PROJECT OVERVIEW

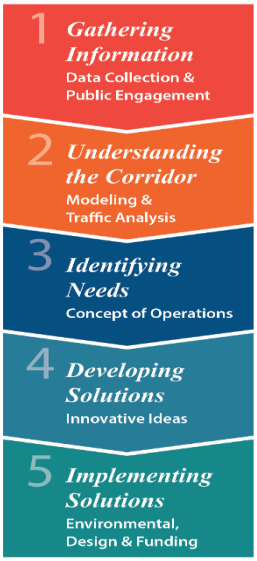
2.1 Project Purpose

The Parkway East Corridor Transportation Network Preliminary Engineering for I-376 Active Transportation management system (ATMS) project is the result of an ongoing effort by PennDOT local and regional representatives and stakeholder agencies along the study area to support steps towards implementation of ATMS strategies. These ATMS conceptual and recommended strategies will review the transportation corridor and apply traffic control modes with respect to normal operations, incidents, maintenance, weather related circumstances and other special events that may impact the Parkway East Corridor Transportation Network. During the project stakeholders' interviews, discussion topics may identify additional regional needs for secondary corridor responses and coordination processes during incidents to help reduce impacts on emergency services, traveling public demands and transit/freight operations. This project is also developing a high-level cost estimate for implementing ATMS along the Parkway East corridor and within the City of Pittsburgh.

Initial ATMS conceptual planning activities will focus more improving operations and critical strategies for major congestion, on motorist advisory during incidents and on closures on the Parkway East corridor including:

- Implementing ATMS technologies and system strategies that will support enhanced real-time monitoring, automated traffic control plans and internal and external agency communication.
- Supporting proactive Parkway-secondary arterial roadway coordination and operations strategies.
- Informing motorist of current Parkway conditions through a variety of means of technology to support pre-route decision making and current traveler route decisions.

The Parkway East Corridor Transportation Network Preliminary Engineering for I-376 Active Transportation management system (ATMS) project will involve multiple deliverables. The project tasks involve Public Involvement meetings, Environmental Documentation, Data Collection and Analysis, Development of the Parkway East Concept of Operations, High level System Requirements, Systems Engineering Management Plan (SEMP), and ITS Architecture Conformance and Conceptual Design.



Study Process

2.2 Assumptions and Constraints

The Parkway East Corridor Transportation Network Preliminary Engineering for I-376 Active Transportation management system (ATMS) project is being developed under the following Assumptions:

- The existing infrastructure is compatible with ATMS along the parkway, tunnel and arterials to support ATMS components; and infrastructure.

The following items are existing constraints to the development of the Parkway East Corridor Transportation Network Preliminary Engineering for I-376 Active Transportation management system (ATMS) project:

- There are multiple existing systems used for traffic operations and management within the Parkway East project corridor; e.g. regional TMC and Tunnel systems.
- Along portions of the project area, there is insufficient roadway infrastructure to accommodate increased traffic volumes as a result of ATMS strategies (such as diverting traffic to arterials); and there is limited interagency coordination capability after-hours, with local city traffic operations centers and tunnel operation center.
- Multi-agencies arrangements may need to be discussed on how the corridor will interact for after-hours coordination and traffic management between PennDOT, City of Pittsburgh and local City operation centers along the corridor.

3 PROJECT PLANNING

3.1 Project Summary and Estimated Schedule

This current project was built upon a previous study “Phase 2 Alternatives Analysis” that outlined multiple concepts per below for consideration along the corridor that occurred July 2018.

Comprehensive Approach:

- Build Consensus
- Stakeholder and Public Input
- Define Purpose and Need
- Brainstorming Concepts
- Data and Technical Analysis

Selecting the projects:

- 200 initial concepts
- 75+ evaluated
- Benefit-cost ratio
- High construction costs
- Benefits constrained by tunnel impacts
- 25 were determined to be feasible
- Similar projects grouped together for consideration
- Stakeholder input

Needs Analysis:

- The Parkway East is congested
- Alternate Routes are congested
- Crash rates are above average
- The Parkway East does not meet current design standards
- Parkway East travel times are unreliable
- Multimodal transportation options are limited

The Parkway East Corridor Transportation Network Preliminary Engineering for I-376 Active Transportation management system (ATMS) project tasks deliverables and schedule are outlined below:

Public Involvement

- Current Project Website Updates
- Public/Stakeholders meeting

Environmental Documentation

- Effects Report

Data Collection and Analysis

- Update VISSIM model
- Model Dynamic Junction Control

Develop Systems Engineering Management Plan

- Outline systems management plan
- Prepare document

Develop ITS Architecture Conformance memo

- Review existing ITS architecture for conformance
- Prepare document

Develop Systems Requirement document

- Stakeholders coordination
- Define Stakeholders system requirements
- Develop traceability matrix
- Identify ATMS conceptual design elements
- Prepare document

Develop Conceptual ITS Design

- Inventory existing ITS infrastructure
- Develop base mapping
- Develop table of required devices
- Develop conceptual renderings
- Develop cost estimate

Develop Concept of Operations

- Identify technical ITS Stakeholders
- Stakeholders coordination
- Develop needs/requirements questionnaire
- Stakeholders meetings
- Define conceptual ATMS strategies for corridor
- Define conceptual Operational needs for corridor
- Define conceptual ATMS overview (operational impacts, modes, infrastructure)
- Prepare ConOPS document

Estimated Project Schedule

- October 2019: Notice to Proceed
- November 2019: Project Kick off
- November-April 2020: Data Collection, Website update, SEMP and ConOPS development
- April 2020: Stakeholders Email Blast, Website updates Live
- April-May 2020: Stakeholders and Public meetings
- May-August 2020: Draft final SEMP, Draft final ConOPS and Conceptual ATMS design
- August- October 2020: Finalize SEMP, ConOPS and Conceptual ATMS design

3.2 Stakeholders

Stakeholders are critical to the project development process to identify system requirements and user needs collaboration opportunities. Public and technical/operational stakeholder meetings are scheduled throughout the project to solicit stakeholders input for the ATMS strategy concepts that will support interagency or interconnect across disparate sub-systems. This stakeholder's collaboration will define means to integrate the conceptual ATMS strategies into the existing regional systems and/or processes and define possible unknown system requirements.

Table 1 below identifies the stakeholders and managers that will be involved in the project's stakeholder meeting, as well as their agency name and job title. An important goal of this project is to ensure interagency collaboration and project awareness between agencies along the corridor.

Agency Name	First Name	Middle	Last Name	Suffix	Job Title
Pittsburgh Bureau of Emergency Medical Services	Chief Ronald		Romano		Director of Emergency Medical Services
FHWA Federal Highway Administration	Tony		Mento		Director of Project Management and Engineering
FHWA Federal Highway Administration	Phillip		Bobitz		State Division Safety Specialist
Churchill Volunteer Fire Department	Ralph	G.	Zatlin		Fire Chief
Edgewood Volunteer Fire Department	Jared		Amos		Fire Chief
Forest Hills VFD	James		Theilacker		Fire Chief
Monroeville Fire Department Station 4	Scott		Feyes		Fire Chief
Monroeville Fire Department Station 5	Benjamin		Rudd		Fire Chief
Penn Hills No.7 VFC	Bill		Jeffcoat		Fire Chief
Pittsburgh Bureau of Fire	Darryl		Jones		Fire Chief
Swissvalle Fire Dept.	Clyde		Wilhelm		Fire Chief
Wilkins Township VFD	Chad		Hoover		Fire Chief
Allegheny County	Jason	J.	Molinero,	P.E.	Deputy Director Engineering
Churchill Borough	Donna	J.	Perry		Borough Manager
City of Pittsburgh	Jeff		Skalican		Deputy Director Mobility and Infrastructure
City of Pittsburgh	Mike		Gable		Assistant Director, Department of Public Works Administration
City of Pittsburgh	Wendell		Hissrich		Pittsburgh Public Safety Director
Edgewood Borough	Rob		Zahorchak		Borough Manager
Forest Hils Borough	Steve		Morus		Borough Manager
Monroeville	Timothy		Little		Municipal Manager
Penn Hills Borough	Scott		Andrejchak		Borough Manager
Pennsylvania Emergency Management Agency (PEMA)	William	T.	Spencer		Western Area Assistant Director
Pennsylvania Office of Homeland Security	Marcus	L.	Brown		Director
Southwestern Pennsylvania Commission (SPC)	Domenic		D'Andrea		Manager, Transportation Operations and Safety
Swissvale Borough	Clyde		Wilhelm		Borough Manager
Wilkins Township Borough	Rebecca		Vargo		Township Manager
Wilkinsburg Borough	Pamela		Macklin		President (2nd Ward)
PennDOT - District 11-0 Tunnels	Ben		DeVore	P.E.	Tunnel Maintenance Manager
PennDOT Central Offices	Daniel		Farley		Highway Administration Program Manager
PennDOT Central Offices	Justin		Smith		Engineer PennDOT Central Office
PennDOT Central Offices	Steve		Gault		Engineer PennDOT Central Office
PennDOT Central Offices	Daniel		Whetzel		Emergency and Incident Management
PennDOT Central Offices	Vince		Mazzocchi		AVL Program Manager
PennDOT District 11-0	Todd	M.	Kravits	P.E.	District Traffic Engineer
PennDOT District 11-0 Maintenance Office	Lori		Musto		PennDOT Allegheny County Maintenance Engineer
Churchill Borough Police Department	Chief Ronald	M.	Akerley		Police Chief
Edgewood Police	Chief Robert		Payne		Police Chief
Forest Hills Police	Chief Charles		Williams		Police Chief
Monroeville Police	Doug		Cole		Police Chief
Penn Hills Police	Howard		Burton		Police Chief
Pennsylvania State Police (PSP) Pittsburgh Sta.	Corporal Craig		Johnson		Officer
Pennsylvania State Police (PSP) Troop B - Washington	Lieutenant Steven	P.	Driscol		Patrol Section Commander
Pittsburgh Bureau of Police	Scott		Schubert		Police Chief
Pittsburgh Police	Eric		Engelhardt		Officer
Pittsburgh Police Zone 2	Reyne		Kacsuta		Commander
Pittsburgh Police Zone 4	Daniel		Herrmann		Commander
Swissvale Police	Chief Ellis		Watson		Police Chief
Wilkins Township Police	Harry		Fruecht		Police Chief
Wilkinsburg Police	Ophelia		Coleman		Police Chief
Port Authority of Allegheny County	David		Huffaker		Executive Director Engineering and Technical Support
Port Authority of Allegheny County	Keith	A.	Wargo	P.E.	Assistant General Manager Engineering and Technical Support
Westmoreland County Transit Authority	Rick		Boman		Westmoreland County Transit Authority
Westmoreland County Transit Authority	Samantha		Grimm		Westmoreland County Transit Authority
Pennsylvania Turnpike Commission (PTC)	Thomas	R.	Macchione	P.E.	Manager of Traffic Engineering
Pennsylvania Turnpike Commission (PTC)	Todd		Leiss		Traffic Incident Management Coordinator

Table 1 List of Stakeholders

3.3 Project Tasks

This section describes the tasks that will need PennDOT's approval on the project's systems engineering activities that involve producing deliverables, conducting meetings and reviews. The list of deliverable tasks for the Parkway East Corridor Transportation Network ATMS project involves the following technical tasks:

Public Involvement/Project Website Updates

- Update existing website with ATMS Video and detailed ATMS strategies for project descriptions and information about the project progress during this work order.
- Anticipate three updates: one at the beginning of the work order to present information on Active Transportation Management System and its advancement on the Parkway East corridor as a result of findings during the previous project phases; the second at the time of the Stakeholder Meeting discussed below with information similar to that presented to the Stakeholders; and the third at the conclusion of this work order providing information on the recommendations for advancement of the PE ATMS and of the next steps in the process. Maintain the website (without updates) for at least one year following the posting of this third update to maintain continuity through the next steps in the project.

Public/Stakeholder Involvement

- This task includes the attendance and preparation of informational materials to be viewed and/or distributed to the general public at public meetings
- Obtain approval from public meeting coordinator to proceed with public involvement activities. Prepare announcement for public meeting. Prepare visual materials and/or flyers for general public meetings. Attend all public meetings and address comments made at the meetings. Prepare minutes for the meetings and submit to the Project Manager for review. Revise if necessary.
- Continue the public involvement process that was initiated during the previous study
- Update the existing stakeholder list to reflect changes in elected officials and agency staffing. Coordinate with the District on an email notice to the updated list and a press release to be issued by the District informing the public of the advancement of the project in this work order.

Environmental Documentation

- Effects Report: this includes any other necessary PennDOT environmental clearance/designation activities for the project which are not otherwise covered under the standard environmental clearance/designation tasks.

Data Collection and Analysis

- Use the VISSIM Model developed and calibrated under Work Order #1(Parkway East Corridor-Phase 2 Alternatives Analysis) to evaluate Dynamic Junction Control for feasibility, if identified during development of the Concept of Operations. Operation of the Bates Street interchange under this existing lane configuration condition was modeled in the Phase 2 Analysis.

Develop Systems Engineering Management Plan

- Provide a high-level plan to guide the Department in managing the systems engineering effort, in compliance with PennDOT and FHWA ITS guidance. The SEMP purpose is to detail out those engineering tasks, specially to provide detailed information on the processes to be used. The SEMP will enable the ITS Project Manager to manage a project using systems engineering principles and methods.

Develop ITS Architecture Conformance memo

- Provide an overview of the compliance of an architecture to mandated enterprise standards.
- Identify where the standards themselves may require modification.
- Identify services that are currently application-specific but might be provided as part of the enterprise infrastructure.
- Document strategies for collaboration, resource sharing, and other synergies across multiple architecture teams.
- Communicate the status of technical readiness of the project to management and what regional architecture data points/inter-agency interconnection may be required in future design phase.

Develop Systems Requirement document

- Gather information elicited from the ITS stakeholders in the stakeholders meeting to define system requirements. This will include information on which stakeholders will have need to control, input data, or receive data from the system and definitions of the required data and format.
- Develop system requirements incorporating stakeholder requirements and functional requirements identified previously, as well as existing Department and stakeholder ITS systems and architecture. This will include functional, performance, interface, data, nonfunctional, enabling requirements and constraints.

Develop Conceptual ITS Design

- Develop base mapping of the project area using available aerial mapping, GIS asset management data, and as-built drawings of existing ITS equipment.
- Develop a table of required ITS devices based upon the System Requirements document and the inventory of existing equipment.
- Develop a conceptual plan showing conceptual locations of proposed gantries, DMS signs, gates, and other ITS equipment. This will be developed on the base mapping that will be approximately 25 sheets.
- Develop renderings illustrating up to three ATMS implementations superimposed on photographs of existing site conditions.
- Develop a cost estimate for the system implementation based upon the table of required ITS devices and the ATMS conceptual plan.

Develop Concept of Operations

- ConOps document will describe the scope of the project, list of referenced documents related to the ConOps (including reports and technical memos from Work Order 1, District and Statewide ITS architecture and documentation, and ATMS-related

documentation from other agencies identified in this task), Scope, User-Oriented Operational Description, user of the ATMS, operational functions, policies, procedures, constraints and organizational structure.

- ConOps will identify PennDOT's and stakeholders' operational needs, priorities, assumptions and constraints that will drive the requirements for the Parkway East ATMS. An operational concept for the ATMS will be developed based on the needs from PennDOT/Stakeholders that will describe systems functions needed to meet user's needs.
- ConOps will describe the ATMS operational and support environments including hardware, software and personnel needs, will be outlined.
- Operational/mode scenarios will also be included, which will be used to describe how the users interact with the Concept of Operations
- ConOps document will describe the scope of the project, list of referenced documents related to the ConOps (including reports and technical memos from Work Order 1, District and Statewide ITS architecture and documentation, and ATMS-related documentation from other agencies identified in this task), Scope, User-Oriented Operational Description, user of the ATMS, operational functions, policies, procedures, constraints and organizational structure.
- ConOps will identify PennDOT's and stakeholders' operational needs, priorities, assumptions and constraints that will drive the requirements for the Parkway East ATMS. An operational concept for the ATMS will be developed that is based on the needs from PennDOT/Stakeholders that will describe systems functions meet user's needs.
- ConOps will describe the ATMS operational and support environments including hardware, software and personnel needs.
- Operational/mode scenarios will also be included, which will be used to describe how the users interact with the major functions of the ATMS.

3.4 Future Systems Integration Plans

3.4.1 Validation

Project validation, or acceptance testing per the system engineering process, consists of testing the system against the functional and technical requirements and making sure that the system is functioning as it was conceptually intended. If a software system is developed as a result of the planning phase of the ATMS project, a Software Test Plan will be developed in a subsequent design and integration project. This future test plan will describe the environment in which the conceptual proposed system will be tested and eventually accepted per the system engineering process. The Software Test Plan will include detailed written procedures outlining the steps for testing the system to determine if it works in a manner that meets all of the functional and performance requirements. Software validation should include positive and negative test cases to identify bugs or issues.

System acceptance will be documented based on traceability back to the requirements, which is discussed later in this document. The acceptance testing will be carried out by PennDOT and other client representatives (including representatives from the Planning Partners), to observe the testing results. The Software Test Plan will test each of the requirements to determine the final system performs in accordance with the written requirements. The Software Test Plan would be a part of a future ATMS build/integration project.

3.4.2 Verification

The systems acceptance/verification phase per the system engineering process is critical because this is where the agency allocates operational validation of the proposed system, which will be identified in the ConOps.

Acceptance testing for each of the system requirements will be developed to detail the system testing procedure to verify that the overall system requirements are satisfied. The result of the testing will be documented as PASS or FAIL during the final acceptance test.

3.4.3 Integration

A new Parkway East Corridor ATMS may be recommended and will require the development of an Integration plan for Future System Integration Opportunities and Future System Needs. With the unique operating and maintenance environments of each of the partnering agencies, a direct focus on future integration technical and functional requirements is imperative. The long-term success of an ATMS will need to factor in potential near-term changes to agency systems or technologies, as well as new data sources or new operational priorities. The final ConOps will be a document summarizing possible future integration opportunities and considerations while factoring in planned agency system enhancements, integration requirements, and a future level of integration of the system within each of the agency's domains.

3.4.4 Operations and Maintenance

Along with a future systems Integration Plan, an Operations and Maintenance Plan will be required for the resulting technologies, devices or systems that will be recommended in the ConOps. This document would be developed in a separate task/work order and would take the ConOps and create a plan that includes procedures and requirements for operating the ATMS solution concept from the perspective of each of the agencies. The plan will also identify maintenance requirements, including corridor and interagency system upgrades that will be required.

3.5 Configuration Management

Configuration management in the Systems Engineering process insures consistency of the systems and sub-systems are maintained throughout the project lifecycle. The goal of configuration management is to ensure that the resulting system does not deviate from the expected functionalities, characteristics, or requirements described in the system documentation. The configuration management plan described in this section details the system engineering control process and procedures to ensure that the configuration of the hardware and software infrastructure components of the system are maintained closely throughout the project.

3.6 Risk Management

There are risks involved in the development of any project as well as risks involved in the ultimate integration of systems into each of the partnering agency's unique operating systems and the systems environments. Certain known and presumed risks have been defined as part of this SEMP. Risks are evaluated throughout a project's life cycle, as risks may change during the course of the project. As a future design and build project moves forward, this SEMP will need to be updated to track risks and changes to inter-agencies operating systems and the systems environments.

In addition to process risks, there are also technical risks for a future Parkway East Corridor Transportation Network ATMS project. Strategies for mitigating and controlling these system

infrastructure risks will be outlined in the ConOps and during project meetings. At the end of the Preliminary Engineering for I-376 Active Transportation management system (ATMS), it will also be important for the regional planning POC's to understand and convey any remaining risks and mitigation strategies while communicating with their senior executives within their agency.

Possible Technical risks include:

- System interoperability between the stakeholder agencies
- Compatibility of new systems/technologies with life cycle stage and limits of the existing systems
- Speed of technology innovation and life cycle
- Need for periodic system maintenance and upgrades
- Longevity of regional commitment to system due to the dynamic ATMS environment in the region
- Ability to obtain support and commitment from agencies for the establishment and maintenance of systems/technology
- Ability to provide periodic staff training
- Ability to provide technical staff continuity

3.8 Procurement Management

Based on the outcomes of the I-376 Parkway East ATMS project and the identification of the conceptual ATMS strategies, a future Procurement Management Plan should be developed that provides a list of items and resources that need to be procured, as well as documents and development solutions that need to be specified for procurement.

3.9 Systems Security

A future ATMS project will follow PennDOT Cyber Security Regulations and Standard Operating Procedure (SOP) if there is a system network breach or critical failure on the ATMS network. Additional system SOP's will be needed and developed that provide interoperability through PennDOT's statewide software application and the ability to remotely log-in to the system via a secured Virtual Private Network (VPN) connection. The resiliency of a regional system is critical to cyber-security priority, and a well-developed and comprehensive security plan will need to be developed by collaborating with technical partners and the participating agencies to set up proper security designs, standard operating procedures (SOP's) and protocols as well as contingency plans.

4 SYSTEMS ENGINEERING PROCESS

Critical overall system infrastructure discussions and user requirement needs are based on stakeholders' involvement in the entire project life cycle of the ConOps and future design and build project development. Much emphasis is placed on gathering user needs at the beginning of the project (stake holders meeting) as the foundation for the ConOps process, where those needs will be refined into a consensus among the stakeholders for the ATMS strategies solution's requirements. As those requirements are translated into system functional and performance requirements, reviews with the agencies planners will help refine the interpretation and understanding of the requirements in the context of the system. During the ConOps development, early ATMS strategy examples at stakeholder meetings of system functionality will be discussed to confirm that the requirements were clearly defined and properly interpreted.

System development cannot be defined until after the development of the ConOps, and the actual development of a future design and build ATMS project would not occur until agreements on approaches for project process was approved from Statewide and Regional agency executives.

Setting system engineering project objectives, project risk management, and project planning are key to an overall future design project development. The user can test some of the functionality before the entire system is completed.

4.1 Systems Engineering Planning

This section describes the intended guidelines of the systems engineering processes used to develop the project. The FHWA's Final Rule (23 CFR Part 940 part 11) places requirements on the minimum description of the systems engineering analysis for projects with federal funding.

Previous efforts in the development and updating of the Regional D11-0/ Parkway East ITS Architecture addressed the first task of the Systems Engineering "Vee" Diagram, Regional Architectures. The ITS Architecture Conformance task of the Parkway East ATMS addresses steps two through four of the Systems Engineering process. Additionally, this SEMP identifies where later steps in the Systems Engineering process will be addressed after the Parkway East ATMS strategies concepts are defined in the ConOps and during later phases where there is funding identified for the development and deployment of the Parkway East ATMS concepts.

4.2 Regional ITS Architecture

To receive federal funding for a proposed ITS project, its functionality must include a Regional ITS Architecture. For this project, the Parkway East Regional ITS Architecture will be verified for conformance and will outline items that may not be conforming to the existing Regional ITS architecture. For any future ATMS projects which PennDOT and Southwestern Pennsylvania Commission (SPC) manages, the Regional ITS Architecture should be reviewed for future ATMS project changes.

The SPC regional architecture services packages are included in the **Figure 2** below. Strategies such as variable speed limits, dynamic lane management, and dynamic roadway warning are not currently identified for future implementation in the SPC Regional ITS Architecture.

FIGURE 2

NATIONAL ITS SERVICE PACKAGES APPLICABLE TO ACTIVE TRAFFIC MANAGEMENT STRATEGIES			
Service Package	Name	Description	SPC Status
APTS09	Transit Signal Priority	Determines the need for transit priority on routes and at certain intersections and requests transit vehicle priority at these locations.	Future
ATMS03	Traffic Signal Control	Provides the central control and monitoring equipment, communication links, and the signal control equipment that support traffic control at signalized intersections. A range of traffic signal control systems are represented by this service package.	Existing
ATMS04	Traffic Metering	Provides central monitoring and control, communications, and field equipment that support metering of traffic and supports the complete range of metering strategies including ramp, interchange, and mainline metering.	Not identified in regional architecture or recommended for this project.
ATMS06	Traffic Information Dissemination	Provides driver information using roadway equipment, such as dynamic message signs.	Existing
ATMS07	Regional Traffic Management	Provides for sharing traffic information and control among traffic management centers to support regional traffic management strategies.	Planned
ATMS09	Transportation Decision Support and Demand Management	Recommends courses of action to traffic operations personnel based on an assessment of current and forecast road network performance	Planned
ATMS18	Reversible Lane Management	Provides for the management of reversible lane facilities; also includes the equipment used to electronically reconfigure intersections and manage right-of-way to address dynamic demand changes and special events.	Existing
ATMS19	Speed Warning and Enforcement	Monitors vehicle speeds and supports warning drivers when their speed is excessive; also, the service includes notifications to an enforcement agency to enforce the speed limit of the roadway.	Existing
ATMS22	Variable Speed Limits	Sets variable speed limits along a roadway to create more uniform speeds, to promote safer driving during adverse conditions (such as fog), and/or to reduce air pollution; also known as speed harmonization.	Not identified in current regional architecture – would be required for ATMS project
ATMS23	Dynamic Lane Management and Shoulder Use	Provides for active management of travel lanes along a roadway, including the associated hardware and control electronics that are used to manage and control specific lanes and/or the shoulders.	Not identified in current regional architecture – would be required for ATMS project

ATMS24	Dynamic Roadway Warning	Includes systems that dynamically warn drivers approaching hazards on a roadway (e.g., roadway weather conditions, road surface conditions, traffic conditions including queues, obstacles or animals in the roadway and any other transient event that can be sensed).	Not identified in current regional architecture – would be required for ATMS project
MC08	Work Zone Management	Manages work zones, controlling traffic in areas of the roadway where maintenance, construction, and utility work activities are underway.	Existing

Interfaces and data exchange with ITS devices such as variable speed limit control, lane management operation and automatic queue detection throughout the corridor have not been identified in the current system architecture diagrams.

As part of the regional architecture, the following functional needs are known and are anticipated to be included in the functionality of the ATMS strategy concepts of this project, but the regional ITS Architecture will need to be updated for ATMS infrastructure.

- Disseminate incident information efficiently
- Improve information exchange between stakeholders
- Improve interagency coordination
- Improve incident response times and management SOP's
- Improve traveler information during incidents
- Improve work zone and safety; and up-to-date information to review closures, congestion, incidents, etc.

The ATMS strategy concepts are expected to have a combination of parkway functions and secondary arterial functions with the primary focus on congestion relief, but a secondary and day-to-day focus on incident management.

The following ITS Architecture nonconformance statements have been identified by the project team:

ATMS22, Variable Speed limits – sets variable speed limits along a roadway to create more uniform speeds, to promote safer driving during adverse conditions (such as fog), and/or to reduce air pollution; also known as speed harmonization.

ATMS23, Dynamic lane management and shoulder use – provides for active management of travel lanes along a roadway, including the associated hardware and control electronics that are used to manage and control specific lanes and/or the shoulders.

ATMS24, Dynamic roadway warning – includes systems that dynamically warn drivers of approaching hazards on a roadway (e.g., roadway weather conditions, road surface conditions, traffic conditions including queues, obstacles or animals in the roadway and any other transient event that can be sensed).

After the development of the ConOps, where the ATMS strategies are identified, changes or updates will be required for future revisions for the I-376 Active Transportation Management System (ATMS), Regional ITS Architecture.

Regional ITS Architecture updates that may be required would include addition of a statewide centralized software system that manages the entire Parkway East ATMS, corridor infrastructure.

4.3 Systems Engineering Documents

The following describes the Systems Engineering documentation that will be developed for this project in addition to the Project Management Plan and SEMP:

ConOps – The document provides an easy to understand view of how the ATMS strategies will work from the perspective of the operating agencies and external stakeholders.

The ConOps lists the stakeholders and their roles and responsibilities and describes brief operational scenarios of the basic functions of the system.

System Requirements – The document will be developed using the ConOps and the SEMP to provide traceability throughout the system development. It will have a list of functional (what the system is supposed to do) and performance requirements (how well the system does in its functions). The requirements will cover the scope of work for the project.

4.4 Concept of Operations

The beginning processes for conducting Systems Engineering involves first:

- establishing needs of the stakeholders,
- identifying relationships to other projects/programs,
- and identifying how the system will operate,

then moving into steps toward designing the product which are captured in a Concept of Operations. The ConOps document will describe the functionality of the ATMS strategies solution from a customer and stakeholder perspective.

A draft ConOps will be distributed to PennDOT for review and a workshop will be scheduled to discuss concepts with internal PennDOT stakeholders and elicit input. Stakeholders in this task will include operations and maintenance representatives as well as agency IT staff, as IT policies may drive several of the ultimate design decisions. The draft ConOps will be updated and a final review by stakeholders will occur before final conceptual designs are proposed.

4.5 Systems Requirements

Formal system requirements will be defined after the development of the ConOps and will represent the first step in the design and development of the ATMS strategies. There are multiple inputs that are necessary to understand and identify system requirements that will be needed. Inputs into the ConOps include:

- The existing devices and infrastructure used for operations, information collection
- Dissemination and incident management within the proposed ATMS area

- Existing systems, requirements policies and procedures used for operations and management of roadways within the study area by partner agencies
- Existing roadway network, roadway capacity, future planned developments, and traveler information
- Funding mechanisms, agency preferences
- Needs and goals identified by partner agencies for each segment of the corridor
- Past and current traffic management-SOP's and elated projects and initiatives in and around the project area

During system requirements development, a workshop will be conducted to discuss operational and technical requirements for the ATMS strategies. A Draft system requirements document will be submitted to PennDOT for review and a discussion will be scheduled to directly present the requirements to elicit input. Stakeholders in this task will include operations and maintenance representatives as well as agency IT staff, as IT policies may drive several of the ultimate design decisions.

Technical objectives for this project which will be managed and carefully considered throughout the course of development include:

- Defining the system from a need- and user-based standpoint
- Defining high level system compatibility will ensure compatibility with all existing systems and all known, future changes and upgrade
- Discuss software compatibilities to ensure that new functionality (device types, expansion, etc.) can be accommodated at a later date without requiring complete replacement of the system
- Identifying risks and mitigation strategies associated with manual or automated features of the system

To ensure that each of the specified needs put forth in the ConOps and stakeholder input obtained through public meetings is incorporated into the final system requirements, a set of requirements will be developed that will guide the system development process.

A traceability matrix in **Table 2** will be used to help identify each specified user need that is identified in the ConOps and identify necessary subcomponent requirements that are derived from those user needs.

Table 2 – Requirements Traceability Matrix

User Need ID	User Need Description	Requirement ID	Requirement Description
USER NEED CATEGORY 1			
USER NEED CATEGORY 2			
USER NEED CATEGORY 3			

This traceability matrix enables the association of operational user needs (as identified in the ConOps) to system requirements. All requirements are to be written in the form of 'shall' statements. This traceability approach is consistent with the FHWA system engineering approach, where only user needs drive the requirements. The draft of the System Requirements will be distributed to PennDOT for review.

4.6 Future System Design and Development

The SEMP assumes that a future ATMS system will be developed from this project. The User Interface of the system will be defined through the ConOps and System Requirements task of the project as the first step in the design and development of the future system.

A series of stakeholder workshops will be held to incrementally offer opportunities to comment on the functional design as it is being developed, rather than after it has already been developed. This process is integral to designing a system that meets the intended purpose that the ConOps has defined.

4.7 Future Emerging Critical Technologies

This section describes the processes that will be used in future design phases of the Parkway East ATMS project to support the Systems Engineering process for system development and deployment.

4.7.1 Future Technology Assessments and Selection

In order to create the future PennDOT Parkway East ATMS design vision that is described in the ConOps, specific technology functionalities will be needed. The appropriate technology to provide these functionalities will need to be identified. During the process of developing and designing the system, a requirements methodology will be established to identify, evaluate, select, and integrate technologies into the system design approach. The identification of current and emerging technologies hinges on a broad knowledge of the technologies and experience of each technology's status and maturity. The

design project team will perform substantial research on best-practices and will engage all necessary stakeholders from within the study corridor as well as other software and hardware development firms who have done similar work throughout the country.

Future ATMS technologies that are identified as feasible will be evaluated for considerations with the following criteria:

- Cost of the technology
- The technology's ability to address or comply with system requirements
- The effort and time that would be necessary to develop and/or incorporate the technology
- The level of management and maintenance that is needed for the technology
- The perceived sustainability of the technology (how long is the technology perceived to stay relevant)

A technology evaluation process to analyze the risks and benefits of each technology should be put in place as part of the selection process for any ATMS technologies that are identified.

The processes for identifying, assessing and ultimately including desirable technologies will be defined in future phase.

4.7.2 Future Device Modernization/Life-Cycle Management Plan

A Device Modernization/Life-cycle Management Plan should be developed in future technology evaluation projects for the technologies and software-related components of the future ATMS project solution. With the current technology trends changing rapidly with respect to emerging technology devices and systems, it will be important to have a proactive plan to periodically revisit the ATMS functions and its hardware and software components and identify updates or replacements that might be necessary due to either age, new emerging technologies, obsolete and non-use of devices or compatibility with current PennDOT systems and technologies. The future plan will also be used to help identify upgrades or enhancements for the system that might be needed to maintain compatibility functionality within a constantly changing operating environment. The plan will also help plan for funding requests to support the upgrades that are identified and allow for adequate time to identify and secure necessary funding.

4.8 Identification of Other Important Future Plans

Additional planning documents have been identified in this SEMP with the understanding that they may need to be developed during the design phase of the future ATMS project. However, additional plans that should be completed or processes that should be followed may be identified during ConOps and System Requirements tasks of the project. Any additional plans or procedures that are identified during the ConOps or System Requirements phases of the project will need to be updated.