LOOP 101 Mobility Project

SYSTEMS ENGINEERING MANAGEMENT PLAN

Final Draft

Led by:

U.S Department of Transportation Federal Highway Administration

ADOT

Maricopa County

In Partnership with:

Arizona Department of Public Safety

ASU

Chandler Arizona

Glendale Arizona

mesa·az

Peoria Arizona

City of Phoenix

City of Scottsdale

Tempe

Maricopa Association of Governments

Gila River Indian Community

The University of Arizona

Valley Metro

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Table of Contents

1 INTRODUCTION 1

1.1 Systems Engineering Approach 1

1.2 Project Area 3

1.3 Project Partners and Stakeholders 4

2 TECHNICAL PLANNING AND CONTROL 8

2.1 Work Breakdown Structure and Decision Gates 8

3 SYSTEMS ENGINEERING PROCESS 22

3.1 Regional ITS Architecture 22

3.2 Systems Requirement Analysis 23

3.2.1 Requirements Development 24

3.2.2 Traceability of Requirements 25

3.3 System Analysis 25

3.4 Sub-system Analysis 26

3.5 Design Development Approach 26

3.6 Risk Management Plan 27

3.6.1 Risk Identification 27

3.6.2 Risk Documentation 28

3.6.3 Risk Analysis 28

3.6.4 Risk Strategies 28

3.6.5 Risk monitoring and Control 29

3.7 Configuration Management 29

3.7.1 Change Management Board 30

3.7.2 Configuration Identification 30

3.7.3 Configuration Change Control 30

3.7.4 Configuration Review 31

3.7.5 Configuration Management Tools 32

4 TRANSITIONING CRITICAL TECHNOLOGIES 32

5 INTEGRATION OF THE SYSTEM 33

5.1 Verification 34
5.2 Validation 34
5.3 Integraton, Operations, and Maintenance 35
6 INTEGRATION OF THE SYSTEMS ENGINEERING EFFORT 35

List of Tables

Table 1– Proposed Loop 101 Mobility Project Techncial Task Teams 5
Table 2– Loop 101 Mobility Project Stakeholder Roles and Responsibilities 6
Table 3 – Loop 101 Mobility Project Techncial Tasks and Decision Gates 9

Table of Figures

Figure 1 – Systems Engineering 'Vee' Diagram 2
Figure 2 – Loop 101 Mobility Project Area 4
Figure 3 – Configuration Control Process (proposed) 31

Version History

Version	Date	Author	Comments
1	12/31/2019	KH	Preliminary draft submitted for review
2	06/05/2020	KH	Revised draft for review by PMT, Technical Team lead
3	09/17/2020	KH	Revised Final Draft for review by PMT, Technical Team lead and PAT
4	10/08/2020	KH	Final Draft for full Technical Team and Stakeholder Review
5	11/16/2020	KH	Final Draft addressing stakeholder comments

List of Acronyms

ADOT – Arizona Department of Transportation

ARC-IT – Architecture Reference for Cooperative and Intelligent Transportation

ASU – Arizona State University

ATCMTD – Advanced Transportation Congestion Management and Technology Demonstration

ATIS – Advanced Traveler Information System

AVL – Automatic Vehicle Location

CCTV – Closed-circuit Television Cameras

CM – Configuration Management

ConOps – Concept of Operations

DMS – Dynamic Message Signs

DPS – Department of Public Safety

DSS – Decision Support System

EGT – Executive Governance Team

FHWA – Federal Highway Administration

FSP – Freeway Service Patrol

GEC – General Engineering Consultant

ICM – Integrated Corridor Management

IRU – Incident Response Units

IT – Information Technology

ITS – Intelligent Transportation Systems

MAG – Maricopa Association of Governments

MCDOT – Maricopa County Department of Transportation

OET – Outreach and Education Team

PAT – Program Administration Team

PIO – Public Information Officer

PMP – Project Management Plan

PMT – Project Management Team

PS&E – Plans, specifications, and estimates

RADS – Regional Archived

RCN – Regional Community Network

REACT – Regional Emergency Action Coordinating Team

RFI – Request for Information

RFP – Request for Proposal

RIA – Regional ITS Architecture

SE – Systems Engineering

SEMP – Systems Engineering Management Plan

SR – State Route

SRPMIC – Salt River Pima Maricopa Indian Community

TT – Technical Team

UA – University of Arizona

1 INTRODUCTION

The Arizona Department of Transportation (ADOT) and Maricopa County Department of Transportation (MCDOT) partnered to successfully secure funding through joint leadership through the Federal Highway Administration (FHWA) Advanced Transportation Congestion Management and Technology Demonstration (ATCMTD) program in 2017 to implement Integrated Corridor Management (ICM) systems on the Loop 101 corridor in the Phoenix metropolitan area. This Loop 101 Mobility Project leverages significant investments over the years by ADOT, MCDOT, Valley Metro, the Maricopa Association of Governments (MAG) and local agencies in freeway, arterial, and transit operations and management strategies. Building on the successful ADOT Freeway Management System (FMS) and several regional/local agencies traffic operations and management systems, ICM will facilitate improved real-time freeway-arterial coordination when incidents impact Loop 101 and divert traffic onto local streets. The ICM program will increase agency awareness of incidents, develop enhanced Decision-Support System (DSS) capabilities for advanced Transportation System Management and Operations (TSMO) strategy implementation, promote cross-agency information sharing, and provide advanced warning and alerts to travelers on the corridor to promote trip decision-making. The ATCMTD application also will pilot connected vehicle applications to support incident management and transit operations for ICM.

In 2019, ADOT selected Kimley-Horn as the General Engineering Consultant (GEC) to support planning, design, implementation, and stakeholder coordination for the four-year duration of the Loop 101 Mobility Project.

The purpose of the Loop 101 Mobility Project is to develop a concept and requirements for the proposed ICM systems as well as complete the necessary steps to implement the concept. As part of the initial grant efforts for the Loop 101 Mobility Project, agencies have identified several preliminary concepts for technology-based projects aimed at improving overall traffic and incident management within the corridor. Key systems that were identified in the successful grant include:

- Multi-agency DSS to support ICM;
- Adaptive Ramp Metering;
- Adaptive Traffic Signal Systems for special event traffic management near the sports arena in Glendale;
- Connected Vehicle Applications for transit and incident responder communications; and
- Integrated Traveler Mobility Application.

1.1 SYSTEMS ENGINEERING APPROACH

The Loop 101 Mobility Project consists of multiple projects that will be planned, designed and implemented across multiple phases. The project will be a complex project incorporating software acquisition and development, hardware acquisition, field device firmware and the integration of these into a system that supports both short-term and long-term decision-making. This Systems Engineering Management Plan (SEMP) will serve as a guiding document for how the systems engineering tasks and processes will be planned and implemented.

The SEMP will help to guide technical decision-making and coordination among technical tasks. It will identify roles, responsibilities and relationships of project activities, major decision points and key milestones. It will

detail stakeholder coordination and involvement in technical decision, how work products will be managed and updated, and identify the specific relationships in the process.

Figure 1 shows the overall SE "Vee" Diagram and the different phases and deliverables that will be used in the Loop 101 Mobility Project.

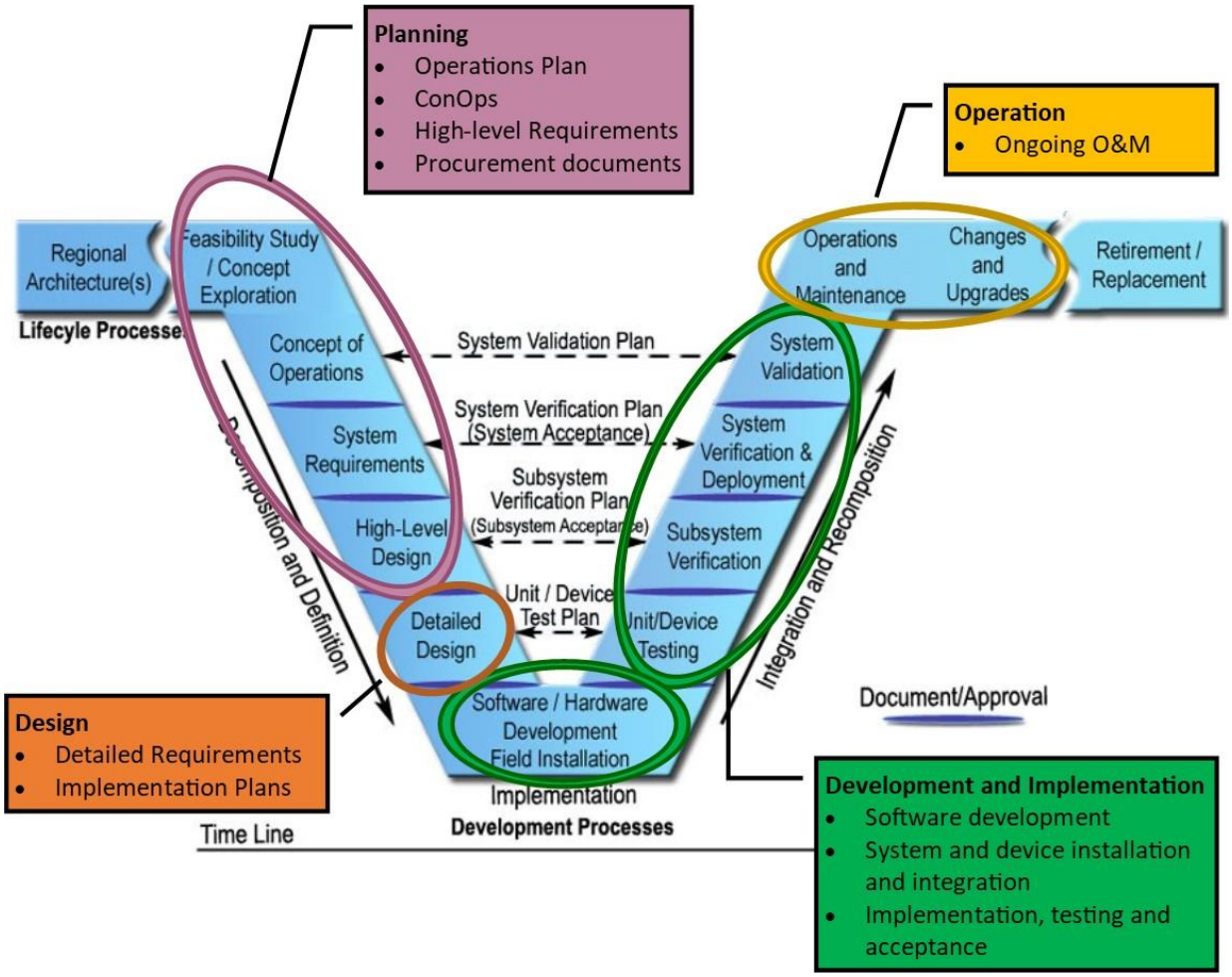

Figure 1 – Systems Engineering 'Vee' Diagram

With multiple projects comprising the Loop 101 Mobility project, it is recognized that individual projects will be planned, designed, implemented and tested on different timeframes. Individual projects are at different levels of readiness, and due to foundational work already completed or underway, some projects will be ready for design and implementation processes sooner than others and can move forward through key processes at a faster pace. The Glendale Adaptive Traffic Signal Project and the Adaptive Ramp Meter project are two examples of projects that can move forward on an accelerated schedule. The remaining projects will be completed on timeframes that are more suitable to the complexity levels, institutional collaboration needed, and other factors, such as national policy decisions on technologies and communications.

1.2 PROJECT AREA

Loop 101 is a 61-mile urban beltway around the Phoenix metropolitan area that connects major cities, freeways and destinations in the region. Loop 101 traverses several cities and communities, including Phoenix, Scottsdale, Tempe, Mesa, Chandler, Glendale, and Peoria, as well as portions of the Salt River Pima Maricopa Indian Community (SRPMIC) and Maricopa County. Loop 101 also connects to all major freeways in the Phoenix area, including the Interstates 10 and 17, US 60, State Route (SR) 202L (Loop 202), and SR 51.

The Loop 101 corridor, shown in **Figure 2**, provides access to several dynamic downtown business districts, educational institutions (including Arizona State University and multiple community colleges), and several state-of-the-art medical facilities and hospitals, including the Mayo Clinic. There are a variety of residential communities along the corridor, including those with a large aging population towards the western portion of the corridor, each which require different amenities related to shopping, recreation and community gathering. The corridor also provides access to major event venues that are critical to the state's and region's economic development and tourism.

Figure 2 – Loop 101 Mobility Project Area

1.3 PROJECT PARTNERS AND STAKEHOLDERS

Project partners and stakeholders will be integrated throughout the project development process to create collaborative opportunities as well as ground the analysis in a needs-based foundation.

The project will be co-managed by ADOT and MCDOT, with oversight by the FHWA. The FHWA is a full participant in the Loop 101 Mobility Project. FHWA will be a member of all project management committees developed for the project and will be invited to participate in operations and technical discussions to develop the key deliverables across all phases.

Project partners are those who have formal intergovernmental agreements (IGAs) in place to provide financial resources to support the Loop 101 Mobility Project. These include Valley Metro and the cities of Phoenix, Glendale, Scottsdale, Peoria, Tempe, Mesa, and Chandler. The Loop 101 Mobility Project will also involve several additional project stakeholders as part of operations discussions, concept planning, requirements development and future implementation and operations. Additional project stakeholders include the Arizona Department of Public Safety, the Maricopa Association of Governments, and the Salt River Pima Maricopa Indian Community. Arizona State University and the University of Arizona will participate in technical tasks. All project partners are considered stakeholders. The term stakeholder is used throughout this document unless there is a need to specifically differentiate partner agencies.

The PMP describes the project Governance Structure in more detail, which consists of the following groups:

- Executive Governance Team (EGT)
- Project Management Team (PMT)
- Program Administration Team (PAT)
- Technical Team (TT)
- Outreach and Education Team (OET)

The Technical Team will organize the establishment the specific technical task teams for each application area. Initial Technical task teams will be established in advance of the Partnering Meeting and will be further revisited/revised during the ConOps development process. **Table 1** provides initial assumptions for technical task teams that will be formed and the participants that may be involved in each team.

Table 1– Proposed Loop 101 Mobility Project Techncial Task Teams

Proposed Technical Task Teams	Proposed Agency Participants
DSS team	All agency stakeholders
Adaptive traffic signal system team	City of Glendale staff, ADOT, and MCDOT, with coordination with staff from City of Peoria and City of Phoenix for implementation
Adaptive ramp metering team	ADOT
Connected Vehicle team	ADOT (TSMO and the Incident Response Unit (IRU)), MCDOT (TSMO and REACT), Valley Metro, Scottsdale (TOC and Transit), University of Arizona
Traveler information and mobility application team	ADOT, MCDOT, Valley Metro, and OET

Table 2 identifies the stakeholders that will be involved in the project development as well as their roles and responsibilities. The PMP identifies communication strategies between Loop 101 Agency Partners, the GEC, and the FHWA.

Table 2– Loop 101 Mobility Project Stakeholder Roles and Responsibilities

Stakeholder	Technical Responsibilities	Organization Responsibilities				
		PMT	EGT	PAT	TT	OET
FHWA	• Program and project oversight and management • Review of project documentation and reporting	X	X			

ADOT	• Overall Project Co-Lead
	• PMT Leadership
	• Co-Lead Program Administration Team
	• Co-Chair Executive Governance Team
	• Co-lead Outreach and Education Team
	• Procurement of design consultants for:
	  ○ Adaptive Ramp Meter
	  ○ Integrated Traveler Mobility Application
	• Procurement of vendors for system development and equipment for all applications
	• FMS operations and management, including ramp meters
	• ICM freeway operations lead
	• Freeway service patrol (FSP) and IRU
	• Traveler information – 511 and Public Information Officer
	• Highway condition/restriction reporting system
	• Freeway incident response and management
		X	X	X	X	X

MCDOT	• Overall Project Co-Lead
	• Project Technical Team leadership
	• Co-Lead Program Administration Team
	• Co-Chair Executive Governance Team
	• Co-Lead Outreach and Education Team
	• Procurement of design consultants for:
	  ○ Multi-agency DSS
	  ○ Connected Vehicle Applications
	• Arterial system implementation coordination lead
	• ICM arterial operations lead
	• Advanced traffic management system (ATMS) operations and management
	• Arterial traffic incident management – Regional Emergency Action Coordinating Team (REACT)
	• Advanced Traveler Information System (ATIS) and PIO
	• Regional Archived Data System (RADS) operation and management and integration with DSS
	• University of Arizona Task Management - Connected vehicle strategies, studies, deployment support, testing
	• Arizona State University Task Management – data analysis and modeling
		X	X	X	X	X

Stakeholder	Technical Responsibilities	Organization Responsibilities				
		PMT	EGT	PAT	TT	OET
MAG	• Regional Community Network (RCN) management • Participate in EGT, technical team meetings; Provide input to operations plan, concept development and other systems engineering tasks. • Support for data analysis and modeling • Regional planning and programming • Inter-governmental coordination and outreach • Regional Intelligent Transportation Systems (ITS) Architecture management and tracking of updates		X		X	
Valley Metro, Scottsdale Transit, Phoenix Transit	• Local and regional transit operations and management (bus, trolley, light rail, demand-responsive vehicles) • Transit traveler information – mobile applications; website; PIO • Transit management systems – scheduling, bus and rail automatic vehicle location (ALV) system • Providing data to regional databases and archives and DSS • Participate in applicable technical task team meetings, operations plan and concept development • Implement ICM operational agreement • Support on-board connected vehicle application installation and maintenance	X	X		X	
AZ DPS	• Freeway incident response and ICM response strategies • Computer-aided dispatch system for freeway incident data • Public information dissemination/PIO • Participate in applicable technical task team meetings, operations plan and concept development • Incident management collaboration with ADOT IRU, MCDOT REACT				X	
Local Municipalities, Tribal Governments	• ATMS operations and management • ICM applications operations • Participate in applicable technical task team meetings, Operations Plan, concept development and other systems engineering tasks • Executive level participation in Executive Governance team • Sending data to RADS and DSS • Implement ICM inter-agency operations in accordance with Operations Plan • Local incident response and management (Police and Fire), including computer-aided dispatch system • Local event management (Stadium (Glendale), spring training stadiums, ASU (Tempe), Westworld and TPC (Scottsdale) • Public information and outreach				X	X

Stakeholder	Technical Responsibilities	Organization Responsibilities				
		PMT	EGT	PAT	TT	OET
ASU	• Data analysis and modeling / evaluation support • Participate in applicable technical task team meetings, Operations Plan, concept development and other systems engineering tasks during planning and design stages				X	
UA	• Connected vehicle applications / evaluation support • Participate in applicable technical task team meetings, Operations Plan, concept development and other systems engineering tasks, including design, testing and operations				X	
GEC Team	• Coordinate project activities per project scope and schedule • Develop initial SE documents • Review additional SE documents provided by vendors and developers • Coordinate stakeholder outreach and activities • Develop key project deliverables and required reporting (per project scope) • Support procurement strategy and coordinate with ADOT and MCDOT on procurement activities • Support identification, review, and management of vendors • Support testing and implementation of vendor products	X	X	X	X	X

2 TECHNICAL PLANNING AND CONTROL

This section describes the technical plans, documents, and decision gates that will be used throughout the project lifecycle. These documents represent anticipated technical deliverables from the Loop 101 Mobility Project and provide the "control" for the SE process by identifying what constitutes the completion of each critical project activity or deliverable. Many of these plans will be refined over time and will be used through multiple steps of the SE process.

2.1 WORK BREAKDOWN STRUCTURE AND DECISION GATES

Table 3 identifies the technical tasks that will be performed as part of the Loop 101 Mobility Project and identifies the inputs, resources, deliverables, and required controls or decision gates for each of these tasks. Decision gates take the form of reviews and approvals that will occur before classifying a task as complete.

Table 3 – Loop 101 Mobility Project Techncial Tasks and Decision Gates

Milestone Title	Milestone Description	Required Inputs/ Resources	Control/Decision Gate	Responsible Parties	Milestone Date (Proposed)
General Project Management Deliverables					
Project Management Plan	Defines overall plan and approach for project administration, scope, and deliverable management, including a project schedule and plan for managing activities Identifies communications plan with FHWA and project stakeholders and roles and responsibilities; Identifies project risks, a risk management plan, and Quality Management Plan First updated draft occurs after procurement for all components is completed; Second updated draft occurs prior to testing of all components; Final version is updated after successful acceptance of all components.	▪ FHWA SE guidance ▪ ATCMTD grant proposal ▪ FHWA/ADOT Agreement for project ▪ Stakeholder input from kickoff meetings and Partnering Workshop ▪ PMT input	▪ Review and approval of processes and frameworks for project tasks and risk mitigation by the PMT, PAT, and FHWA ▪ Document will be updated as individual project tasks progress and warrant an update	Kimley-Horn, PMT (lead), PAT, and stakeholder agencies	Initial First Draft: October 2019 Revised First Draft: September 2020 Overall Final: September 2022
Systems Engineering Management Plan	Defines key SE management processes and tasks, relationships of project activities, decision points, key milestones, and how work products will be managed and updated Details stakeholder roles and responsibilities, coordination processes, and involvement in technical decisions First updated draft occurs after procurement for all components is completed; Second updated draft occurs prior to testing of all components; Final version is updated after successful acceptance of all components.	▪ FHWA SE guidance ▪ ATCMTD grant proposal ▪ FHWA/ADOT Agreement for project ▪ Stakeholder input from Partnering Workshop ▪ GEC scope of services	▪ Review and approval of processes and frameworks for project tasks and risk mitigation by the PMT, TT, PAT, and FHWA ▪ Document will be updated as individual project tasks progress and warrant an update	Kimley-Horn, Technical Team (lead), PMT, PAT, and stakeholder agencies	Initial First Draft: October 2019 Revised First Draft: September 2020 Overall Final: September 2022

Milestone Title	Milestone Description	Required Inputs/ Resources	Control/Decision Gate	Responsible Parties	Milestone Date (Proposed)
Corridor Inventory	Inventory of Loop 101 agency assets to support ICM and the Loop 101 Mobility Project, including development of a GIS-based dataset of existing, permanent technology infrastructure within the corridor, including assets for arterials up to two miles on either side of the Loop 101 freeway.	▪ Stakeholder input during agency one-on-one meetings ▪ Stakeholder documentation – plans, GIS files, maps	▪ Review and approval by PMT and stakeholder agencies	Kimley-Horn, PMT (lead), and stakeholder agencies	Draft: July 2020 Final: December 2021
Partnering Workshop and Plan	First Partnering Workshop will review project and partnership goals, review project objectives, define lines of communication, formalize the project governance structure, identify strategies for engaging agencies and leadership, and discuss how project decisions will be made, how issues will be resolved, and identify roles and responsibilities for partners and stakeholders	▪ PMP, SEMP ▪ Stakeholder input during workshop	▪ Review and approval of workshop notes and resulting plan by PMT, PAT, EGC, and stakeholder agencies ▪ Review and approval of any changes to PMP and SEMP as a result of the workshop by PMT, PAT, and stakeholder agencies	RHA/Kimley-Horn, PMT (lead), Outreach and Education Team, and stakeholder agencies	Draft: June 2020 Final: September 2020
Communications and Outreach Plan	Identify strategies to be implemented, tools to be developed, and a schedule for key updates to stakeholder agencies and the public. Includes roles and responsibilities for implementing the Communications and Outreach Plan and milestones for agency and public communications will be documented.	▪ PMP, SEMP ▪ Stakeholder input during OET meetings to develop plan	▪ Review and approval of plan by OET, PMT, EGC, and stakeholder agencies	Central Creative/ Kimley-Horn, Outreach and Education Team (lead), stakeholder agency PIOs	Draft: December 2020 Final: February 2021
Long-Term Operations and Management Plan	Identify a plan for ongoing operations and management of the Loop 101 systems beyond the grant funded period, such as identifying agency roles and responsibilities; future operational needs; performance monitoring activities and responsibilities; ongoing maintenance needs; and estimated cost and resource requirements for sustaining operations.	▪ Operations Plan ▪ ConOps ▪ High-Level and Detailed Requirements ▪ Stakeholder input during workshop	▪ Review and approval of plan by PMT, TT, and stakeholder agencies	Kimley-Horn*, PMT and Technical Team (joint lead) and stakeholder agencies	Draft: January 2024 Final: March 2024

Milestone Title	Milestone Description	Required Inputs/ Resources	Control/Decision Gate	Responsible Parties	Milestone Date (Proposed)
Project Final Report	Summarize each of the three phases of the project and document the Loop 101 Mobility Project process, development activities, stakeholder engagement, and implementation outcomes. Documents lessons learned that could be transferred to other corridors in the Phoenix area or to other corridors in the country.	▪ All project deliverables ▪ All project meeting notes ▪ All required ATCMTD grant reporting deliverables ▪ Stakeholder input	▪ Review and approval of report by PMT, TT, PAT, EGC and stakeholder agencies ▪ Review and approval by FHWA	Kimley-Horn, PMT (lead), Technical Team and stakeholder agencies	Draft: August 2022 Final: September 2022
ATCMTD Grant Reporting	Quarterly Project Outcomes and Monitoring Reports Includes annual reporting on local match contributions from partner agencies Annual Reports to the US DOT Secretary	▪ Notes from project activities, workshops, and meetings ▪ All project deliverables ▪ PMT input ▪ Local match tracking	▪ Review and approval of report by PMT and ADOT grants administrator ▪ Review and approval by FHWA	Kimley-Horn, ADOT, PMT (lead)	Quarterly Reports: January, April, July, and October of each year Annual Reports: August 31 of each year
DSS Deliverables					
Operations Plan	Describes how the Loop 101 corridor will operate in an ICM environment from an agency perspective. Includes existing and proposed operational strategies, communications/notifications plans, operations scenarios and plans, and roles and responsibilities. Identifies performance measures and targets to guide modeling activities for DSS	▪ Stakeholder input during working sessions and meetings ▪ Corridor inventory ▪ Information and lessons learned from previous ICM efforts locally and nationally ▪ Modeling report results	▪ Formal acceptance of the Operations Plan by all agency stakeholders will be required	Kimley-Horn, Technical Team (lead), PMT, and stakeholder agencies	Draft: November 2020 Final: January 2021
DSS Modeling Report	Outputs and recommendations from modeling task (completed by ASU) based on operational concepts and proposed performance measures. Provide input to final Operations Plan and draft ConOps.	▪ Operational Plan ▪ Data from MAG, RADS, ADOT and other sources (local agencies, third party) to support building and running a model	▪ Modeling results will be reviewed by TT, PMT, PAT, and technical task teams to identify any adjustments or changes that should occur prior to finalizing	Kimley-Horn, Technical Team (lead), PMT, ASU	May 2021

Milestone Title	Milestone Description	Required Inputs/ Resources	Control/Decision Gate	Responsible Parties	Milestone Date (Proposed)
Concept of Operations	Describes the DSS, how it functions, and how it interacts with other systems. Reflects stakeholder input on needs and identifies potential functions and system alternatives to address corridor operational needs. Establish initial performance objectives for system-related functions. The ConOps is the foundation for writing high-level requirements.	▪ ATCMTD grant proposal ▪ Previous ConOps developed for similar applications ▪ Operations Plan ▪ Stakeholder input from Concept Planning Workshops ▪ Results of strategy modeling to finalize ConOps	▪ Review and approval of overall systems concepts, stakeholder roles and responsibilities and operational scenarios by TT, PMT, PAT, technical task teams and FHWA	Kimley-Horn, Technical Team (lead), PMT, and stakeholder agencies	Draft: April 2021 Final: May 2021
High Level System Requirements	Describes what the DSS will do (functional requirements), how well it will function (performance requirements) and under what conditions it will perform. Requirements will form the basis for procurement documents and procurement contracts with designers and vendors (developers).	▪ ConOps ▪ Stakeholder input from Operations Plan and Concept Planning workshops and requirement walkthrough meetings	▪ Requirements should be directly traceable back to identified needs, deficiencies, and constraints in ConOps ▪ Review and approval of identified functionality for components and supporting systems by TT, PMT, PAT, and technical task teams	Kimley-Horn; Technical Team (lead), PMT, and stakeholder agencies	Draft: June 2021 Final: July 2021
Design Procurement Document	Procurement documents to hire a design consultant for the DSS to develop detailed requirements	▪ Operations Plan ▪ ConOps ▪ DSS High Level Requirements	▪ Review and approval of RFP language by lead procurement representatives, TT, PMT, and DSS technical task team ▪ Review and approval of final procurement document by FHWA	Kimley-Horn, Technical Team (lead), PMT, and stakeholder agencies	July 2021
**DSS Design Sequence Plan (Part of DSS Design task on overall project schedule)	Outlines DSS design activities, including decision points, schedule, and key milestones. Identify roles and responsibilities of key stakeholders	▪ ConOps ▪ High Level Requirements ▪ Stakeholder input ▪ Design consultant contracts	▪ Review and approval of activities and schedule by TT, PMT, and PAT	Design consultant, Kimley-Horn, Technical Team (lead), PMT, and stakeholder agencies	Draft: October 2021 Final: November 2021

Milestone Title	Milestone Description	Required Inputs/ Resources	Control/Decision Gate	Responsible Parties	Milestone Date (Proposed)
Design Acceptance Process	Identifies evaluation criteria and a process for obtaining consensus on preliminary acceptance of design deliverables. Criteria to demonstrate traceability back to needs and requirements, and demonstrate compliance with specific design decisions and directions provided by Loop 101 Stakeholders	▪ ConOps ▪ High Level Requirements ▪ Design consultant contracts ▪ Stakeholder input on design decisions and direction	▪ Review and approval of acceptance process by TT, PAT, and EGT ▪ Need consensus of approval for all design deliverables provided by design consultants	Kimley-Horn, Technical Team (lead), PMT, and stakeholder agencies	December 2021
*DSS Detailed Requirements	DSS design consultant will develop detailed system requirements (i.e. design) for DSS which will later guide the system developer in developing the system	▪ Operations Plan ▪ ConOps ▪ High level Requirements ▪ Stakeholder input on design decisions and direction	▪ Review and approval by TT, PMT, and GEC ▪ Approval of detailed design required before vendors can be procured for system development and implementation	Design consultant, Technical Team (lead), Kimley-Horn, PMT, and stakeholder agencies	Draft: January 2022 Final: February 2022
DSS System Procurement Document	Procurement document to hire a vendor to develop software for the DSS based on the detailed requirements	▪ Operations Plan ▪ ConOps ▪ Detailed Requirements	▪ Review and approval of procurement document language by appropriate agency procurement representatives, PAT, PMT and TT ▪ Review and approval of final procurement documents by FHWA	Kimley-Horn, PMT (lead), Technical Team, and stakeholder agencies	March 2022
**Systems Engineering Documentation for DSS Development (Part of vendor Development task on overall project schedule)	PMP, SEMP, and other documents outlining approach to management, decision-making, and project development that each consultant and vendor will use and follow Defines steps and documentation to achieve project objectives and traceability for compliance with requirements Considered living documents and are finalized at end of development process	▪ Overall Loop 101 Mobility Project PMP and SEMP ▪ ConOps and High Level Requirements ▪ Design consultant proposals and contracts	▪ Review and approval of plans and approach by TT, PMT, PAT, FHWA, and GEC	DSS software developer, Kimley-Horn*, Technical Team (lead), and PMT	Draft: August 2022 Final: July 2023

Milestone Title	Milestone Description	Required Inputs/ Resources	Control/Decision Gate	Responsible Parties	Milestone Date (Proposed)
**Software Development and Test Plan (Part of vendor Development task on overall project schedule)	Describes how DSS developer will manage the software development process, including developer's software development approach, tools, modules, and integration approach Describes processes for requirements traceability, defect tracking, and code/document configuration management Describes a strategy and procedures for vendor and GEC to manage the iterative testing process, including schedules and timeframes. Includes unit testing, subsystem integration testing, and system verification testing showing alignment of systems and sub-systems against requirements	▪ ConOps ▪ High-level and Detailed System Requirements ▪ Software developer contract ▪ System developer tools and processes	▪ Review and approval of development approach, development tools to be used, and integration sequence and testing processes and approach by TT, PMT, and PAT ▪ Approval of Software Development and Testing Plan required prior to initiation of software development activities	DSS vendor, Kimley-Horn*, Technical Team (lead), PMT, and stakeholder agencies	Draft: September 2022 Final: October 2022
**Data Management Plan (Part of vendor Development task on overall project schedule)	Identifies data necessary for system development, testing, and integration. Describes how and which data will be controlled, methods of documentation, and responsibilities for data storage and archiving, data accessibility, data security, and data quality control.	▪ ConOps ▪ Detailed Requirements and design documentation ▪ Stakeholder input on design decisions and direction related to data	▪ Review and approval of roles and responsibilities and data security approach by PMT, Technical Team leads, and agency staff, such as IT staff	DSS vendor, Kimley-Horn*, Technical Team (Lead), PMT, and stakeholder agencies	Draft: October 2022 Final: November 2022
DSS Implementation Plan and Testing Process	Identifies staff involved in testing, responsibilities of vendors during testing, and testing schedules and timeframes. Outline a process and conditions for how system will be accepted and how issues will be communicated to vendors for resolution. This will include demonstrating traceability back to needs and requirements, as well as requiring developers to demonstrate compliance with specific design decisions and directions provided by Loop 101 agency stakeholders.	▪ Stakeholder input implementation needs and processes ▪ Vendor contracts ▪ Vendor-developed design plans/ documentation ▪ Software Development and Testing Plan	▪ Review and approval of roles and responsibilities, schedule, and acceptance conditions by PMT, TT, and impacted agencies	Kimley-Horn*, Technical Team (Lead), PMT, and stakeholder agencies	Draft: June 2023 Final: July 2023

Milestone Title	Milestone Description	Required Inputs/ Resources	Control/Decision Gate	Responsible Parties	Milestone Date (Proposed)
**System Implementation	Initial implementation and integration of system following completion of development and in preparation for system testing.	▪ Completed DSS ▪ Software Development and Test Plan ▪ Implementation Plan	▪ Review and approval of initial implementation conditions by the TT, PMT, and impacted agencies.	DSS vendor, Technical team (lead), PMT, Kimley-Horn*, and stakeholders	September 2023
Testing and System Acceptance Report	Required system testing based on the Implementation Plan. System Acceptance Report will document testing outcomes, requirements for addressing and resolving issues, and compliance with an acceptance state. The Final System Acceptance Report will document changes that were made to facilitate acceptance	▪ System Requirements ▪ Implementation and Testing Plan ▪ Vendor-developed Software Development and Testing Plans ▪ Stakeholder input on acceptance conditions	▪ Review and approval of test results by all impacted agencies, the TT, PMT, and impacted agency staff. ▪ Test results should indicate correctly operating and stable development, test, and production hardware and software environments at identified agencies facilities and other project system nodes.	Kimley-Horn*, DSS vendor, Technical team (lead), PMT, and stakeholders	January 2024
Adaptive Ramp Meters Deliverables					
Task Kick-off Meeting	Initial meeting of ADOT and GEC team to map out task priorities	▪ ATCMTD grant proposal ▪ GEC contract	▪ Participation by relevant ADOT staff	WSP/Kimley-Horn, ADOT, TT (lead), PMT	May 2020
Ramp Metering Existing Conditions Summary	Summarizes current design projects that are implementing adaptive ramp meters and current operating approaches	▪ Documentation of current and completed ADOT ramp metering projects for the L101 ▪ Input from relevant ADOT staff	▪ Review and approval of summary document by ADOT and the PMT	WSP/Kimley-Horn, ADOT, TT (lead), PMT	Draft: July 2020 Final: September 2020
Recommended Coordination Plan for Adaptive Ramp Meters	Recommended operational practices and operational considerations for adaptive ramp meter operations	▪ Existing Conditions Summary ▪ Lessons learned and guidance from other adaptive ramp metering applications ▪ Operations Plan ▪ ConOps	▪ Review and approval of recommendations by ADOT and TT ▪ Implementation of recommendations in the field by the end of the project	WSP/Kimley-Horn, ADOT, Technical Team (lead), PMT	Draft: TBD Final: TBD *Adaptive Ramp Meter Pilot deployment date is not known based on current traffic conditions.*

Milestone Title	Milestone Description	Required Inputs/ Resources	Control/Decision Gate	Responsible Parties	Milestone Date (Proposed)
Adaptive Traffic Signal System Deliverables					
Task Kickoff Meeting	Meeting with PMT and Technical Team Task leads to review key project tasks	▪ ATCMTD grant proposal ▪ PMT and TT input ▪ Information and lessons learned from previous Adaptive traffic signal efforts locally	▪ Approval by TT and PMT to commence meetings with City staff ▪ Approval of KO meeting notes by the TT and PMT	Kimley-Horn, Technical Team (lead), PMT	April 2020
City Kickoff Meeting	Kickoff meeting with City of Glendale staff to discuss adaptive traffic signal control concept, including key locations and desired functionalities	▪ ATCMTD grant proposal ▪ PMT and TT input ▪ Information and lessons learned from previous Adaptive traffic signal efforts locally	▪ Agreement from City of Glendale on task approach and expected outcomes ▪ Approval of City KO meeting notes	Kimley-Horn, Technical Team (lead), PMT, City of Glendale	April 2020
ConOps	Identifying user needs statements for the system, using the Concept of Operations Needs Statements from the Final FHWA Model Documents as the foundation and specifying for the Glendale Adaptive System needs.	▪ ATCMTD grant proposal ▪ FHWA model documents for Adaptive Traffic Signal Systems ▪ Example ConOps from recently completed adaptive systems involving Glendale (Bell Road and Olive Ave) ▪ Input from City of Glendale on key needs, locations, and concept	▪ Approval from City of Glendale and TT on ConOps Need Statements and format	Kimley-Horn, Technical Team (lead), City of Glendale, PMT	Draft: June 2020 Final: September 2020
High-Level Requirements	Tailored requirements document to inform procurement documents	▪ FHWA model documents for Adaptive Traffic Signal Systems ▪ Example ConOps from recently completed adaptive systems involving Glendale (Bell Road and Olive Ave) ▪ Input from City of Glendale on key needs, locations, and concept	▪ Approval from City of Glendale and TT on Requirements document and format	Kimley-Horn, Technical Team (lead), City of Glendale, PMT	Draft: June 2020 Final: September 2020

Milestone Title	Milestone Description	Required Inputs/ Resources	Control/Decision Gate	Responsible Parties	Milestone Date (Proposed)
Adaptive System Procurement Document	Develop procurement package for adaptive system based on the requirements and advertise the project. Select and contract with a vendor.	▪ ConOps and Requirements document ▪ Input from City of Glendale on procurement needs ▪ Environmental Clearances ▪ Input from ADOT on applicable procurement processes	▪ Approval from City of Glendale, PMT, TT, and FHWA on procurement model being used ▪ Review and approval from City of Glendale, TT, and FHWA on procurement document language ▪ Review and approval from ADOT procurement on procurement package materials	Kimley-Horn, ADOT, MCDOT, Technical Team (lead), City of Glendale, PMT	November 2020
Adaptive Signals Implementation Plan and Testing Process	Identify roles of vendor and staff in testing; identify testing schedules and timeframes and outline a process and conditions for how system will be accepted and how issues will be communicated to vendors for resolution. This will include demonstrating traceability back to needs and requirements, as well as requiring developers to demonstrate compliance with specific design decisions and directions provided by the City of Glendale or other impacted agencies.	▪ City of Glendale and TT input on field site and building access needs and restrictions ▪ Vendor contract ▪ Vendor products and documentation for development and testing	▪ Review and approval of roles and responsibilities, access requirements, and schedule by City of Glendale and TT	Kimley-Horn, MCDOT, City of Glendale, Technical Team (Lead)	May 2021
**Adaptive System Implementation	City of Glendale staff and members of the technical task team will coordinate with the vendor to deploy and install hardware and software in preparation for testing and acceptance.	▪ Adaptive signal system software, hardware, and field devices ▪ Implementation Plan ▪ Environmental clearances	▪ Review and approval of initial implementation conditions by the City of Glendale and TT	System vendor, City of Glendale (lead), MCDOT, Technical Task Team, Kimley-Horn	December 2021

Milestone Title	Milestone Description	Required Inputs/ Resources	Control/Decision Gate	Responsible Parties	Milestone Date (Proposed)
**Testing and System Acceptance Report	Required system testing performed by vendor in coordination with GEC based on the Implementation Plan. System Acceptance Report will document testing outcomes, requirements for addressing and resolving issues, and compliance with an acceptance state. The Final System Acceptance Report will document changes that were made to facilitate acceptance	▪ System Requirements ▪ Implementation Plan ▪ Vendor-developed system documentation ▪ City of Glendale input on acceptance conditions	▪ Review and approval of test results by the City of Glendale TT, PMT, impacted agency staff, and GEC. ▪ Test results should indicate correctly operating and stable development, test, and production hardware and software environments at Glendale facilities or other system nodes.	System vendor, Kimley-Horn, City of Glendale (lead), MCDOT, Technical Task Team	December 2021
Connected Vehicle Applications Deliverables					
Task Kick-off Meeting	Meeting with Technical Team Task leads, including City of Scottsdale, to review key project tasks, identify key stakeholders to be involved in this task and develop overall work plan for task elements.	▪ ATCMTD grant proposal ▪ PMT and TT input ▪ Information and lessons learned from previous applications	▪ Approval by TT, City of Scottsdale, PMT, and MCDOT REACT to commence with task ▪ Approval of KO meeting notes and work plan by TT, City of Scottsdale, PMT, and MCDOT REACT	Kimley-Horn, Technical Team (lead), City of Scottsdale, PMT, MCDOT, ADOT	September 2020
CV Readiness Assessment and Scoping	Assessment of existing infrastructure, such as traffic signal controllers, to confirm hardware and software are compatible with CV hardware and software needs.	▪ Information and lessons learned from previous applications ▪ Information on field assets (traffic signal controllers) at the City of Scottsdale ▪ Input from TT, University of Arizona, City of Scottsdale,	▪ Approval of assessment (including any necessary hardware of software updates to be pursued) and proposed scope/next steps by TT, City of Scottsdale, and PMT	Kimley-Horn, Technical Team (lead), University of Arizona, City of Scottsdale, MCDOT, ADOT	Draft: December 2020 Final: January 2020

Milestone Title	Milestone Description	Required Inputs/ Resources	Control/Decision Gate	Responsible Parties	Milestone Date (Proposed)
CV Concept and Requirements	Updating existing documentation for CV user needs and requirements based on results of Smart Drive Test Bed in Anthem and current federal policy. Preparing preliminary design concepts and configuration for on-board and roadside infrastructure and software (mapping map messages). Development of equipment specifications	▪ Documentation (user needs, Concept, software requirements) and lessons learned from previous applications ▪ Federal guidance on CV (including 5.9 GHz spectrum) ▪ Input from TT, University of Arizona, City of Scottsdale, City of Phoenix Transit, Valley Metro, and MCDOT REACT	▪ Approval of concept, locations, systems, and roles and responsibilities, by TT, City of Scottsdale, PMT, MCDOT REACT, other implicated agencies, and FHWA to commence with procurement and installation	Kimley-Horn, University of Arizona, MCDOT, Technical Team (lead), City of Scottsdale, City of Phoenix Transit, Valley Metro, MCDOT REACT, ADOT IRU, PMT	Draft: June 2021 Final: July 2021
CV Equipment Procurement Document(s)	Develop procurement package for CV infrastructure needs (devices, hardware, others) based on the requirements and advertise the project. Select and contract with a vendor.	▪ Readiness Assessment ▪ Concept and Requirements ▪ Input from ADOT on applicable procurement processes ▪ Input on equipment specifications from University of Arizona, City of Scottsdale, MCDOT REACT, and other impacted agencies ▪ Environmental Clearances	▪ Approval from PMT, TT, and FHWA on procurement model being used ▪ Review and approval from University of Arizona, City of Scottsdale, MCDOT REACT, other impacted agencies, and FHWA on procurement document language ▪ Review and approval from ADOT procurement on procurement package materials	Kimley-Horn, ADOT, Technical Team (lead), University of Arizona, City of Scottsdale, City of Phoenix Transit, Valley Metro, MCDOT REACT, ADOT IRU, PMT	September 2021

Milestone Title	Milestone Description	Required Inputs/ Resources	Control/Decision Gate	Responsible Parties	Milestone Date (Proposed)
**CV Software Development	Development or re-configuration of CV software and algorithm to accommodate the operational and field environment along the identified corridors in Scottsdale.	▪ CV Readiness Assessment ▪ CV Concept and Requirements ▪ Information and lessons learned from previous applications ▪ Federal guidance on CV (including 5.9 GHz spectrum)	▪ Review and approval from TT and GEC that system adheres to concept and requirements and is ready for testing	University of Arizona, Technical Team (lead)	December 2021
CV Implementation Plan Testing Process	Identify testing roles, schedules, and timeframes and outline a process and conditions for how system will be accepted and how issues will be resolved. This will include demonstrating traceability back to needs and requirements, as well demonstrating compliance with specific design decisions and directions provided by the City of Scottsdale, MCDOT REACT or other impacted agencies.	▪ ConOps and Requirements ▪ Input from TT, University of Arizona, City of Scottsdale, MCDOT REACT, other implicated agencies on procurement needs	▪ Review and approval of roles and responsibilities, implementation and access requirements, and schedule by University of Arizona, City of Scottsdale, MCDOT REACT, other implicated agencies, and the TT	Kimley-Horn, University of Arizona, Technical Team (lead), City of Scottsdale, City of Phoenix Transit, Valley Metro, MCDOT REACT, ADOT IRU, PMT	December 2021
**CV Implementation and Configuration	Installation and configuration of software and hardware as well as deployment of field and on-board devices in preparation for testing and acceptance of the application.	▪ CV software and hardware ▪ Field devices and on-board equipment ▪ Implementation Plan ▪ Environmental clearances	▪ Review and approval of initial implementation conditions by TT, City of Scottsdale, MCDOT REACT, other implicated agencies, and GEC	University of Arizona, Technical Team (lead), City of Scottsdale, City of Phoenix Transit, Valley Metro, MCDOT REACT, ADOT IRU, PMT, Kimley-Horn	April 2022

Milestone Title	Milestone Description	Required Inputs/ Resources	Control/Decision Gate	Responsible Parties	Milestone Date (Proposed)
**Testing and System Acceptance Report	Required system testing based on the Implementation Plan. System Acceptance Report will document testing outcomes, requirements for addressing and resolving issues, and compliance with an acceptance state. The Final System Acceptance Report will document changes that were made to facilitate acceptance	▪ System Requirements ▪ Implementation Plan ▪ Information and lessons learned from previous applications	▪ Review and approval of test results by all impacted agencies, the TT, PMT, FHWA, and the GEC ▪ Test results should indicate correctly operating and stable development, test, and production hardware and software environments at identified agencies facilities and other project system nodes.	University of Arizona, Technical Team (lead), Kimley-Horn City of Scottsdale, City of Phoenix Transit, Valley Metro, MCDOT REACT, ADOT IRU, PMT	April 2022
Integrated Traveler Mobility Application Concept Deliverables					
Exploration of local and industry applications for traveler information	Explore ADOT Alerts Mobile App functionality as it compares to functionalities identified in Operations Plan and DSS ConOps. Develop RFI to solicit industry input on current/emerging technologies that can address traveler information needs identified in the Operations Plan and DSS ConOps	▪ Input from ADOT staff responsible for ADOT Alerts App ▪ ATCMTD grant application ▪ Operations Plan ▪ DSS ConOps ▪ Input from stakeholders	▪ Review of RFI by TT, PMT, Outreach and Education Team, agency stakeholders, and FHWA prior to its release ▪ Review of results of exploration activities (including RFI response) and agreement on next steps by TT, Outreach and Education Team, and agency stakeholders	Kimley-Horn, Technical Team (lead), PMT, Outreach and Education Team, and stakeholders	November 2021
**Pilot of Mobility Application	Based on findings from local and industry exploration, the project team will partner with either ADOT or a third party vendor or company to implement enhanced traveler information pilot application and evaluate results and impacts of pilot.	▪ Results of traveler mobility app exploration ▪ Operations Plan ▪ DSS ConOps ▪ Input from stakeholders	▪ Review/evaluation of results of pilot by TT, PMT, Outreach and Education Team, and agency stakeholders	ADOT or third party vendor, Technical Team (lead), PMT, Outreach and Education Team, agency stakeholders, and Kimley-Horn*	August 2022 – July 2023

* Indicates deliverable dates that are beyond the current GEC contract term.

** Indicates deliverables that will be developed by contractors and vendors external to the project governance teams and GEC for the Loop 101 Mobility Project.

3 SYSTEMS ENGINEERING PROCESS

Emphasis in this SEMP is placed on stakeholder involvement in the entire system's life cycle and depends on feedback from the stakeholders at key points to improve the system. Significant focus is on gathering user needs at the beginning of the project and using the Operations Plan and ConOps process to refine those needs into a consensus agreement among the stakeholders for the system's top-level functional requirements. As those requirements are translated into system functional and performance requirements, frequent reviews with the stakeholders will help refine the interpretation and understanding of the requirements in the context of the system as a whole. During the technical development phase, early demonstrations at stakeholder workshops of system functionality will be used to confirm that the requirements were clearly understood and properly interpreted. The SEMP provides a process to identify and correct deficiencies and incorporate improvements while supporting the system's operation throughout its life cycle.

3.1 REGIONAL ITS ARCHITECTURE

In order to receive and use federal funding for the Loop 101 Mobility Project, the functionality defined by this project must be included in the Regional ITS Architecture. The Regional ITS Architecture is a long-range framework developed by the region's ITS community that sets standards to enable integration between transportation systems. The Regional ITS Architecture in the Phoenix Metro area where the Loop 101 Mobility Project is being pursued is the MAG Regional ITS Architecture (RIA). In 2019, the MAG RIA is in the process of being updated from the 2013 version that references an old version of the National ITS Architecture, to a 2019 version that is in line with the new common National ITS Architecture standard called the Architecture Reference for Cooperative and Intelligent Transportation (ARC-IT).

One focus of the 2019 update is to make sure the MAG RIA reflects the anticipated Loop 101 Mobility Project concepts that may not have been reflected in the previous version. The planned decision-support capabilities will be reflected, as well as anticipated new data exchanges among state, county, transit, local agencies, and potentially public safety agencies, many of which might not be currently captured in the previous ATMS07, ATMS08, or ATMS09 service packages. There will likely be changes to the traveler information capabilities (to be captured in the new TI02) as a result of the personal mobility application planned as part of the Loop 101 Mobility Project. Other changes to the architecture include the need to document transit connected vehicle functionalities, likely through the new TM04 Connected Vehicle Traffic Signal System service package.

The following is a summary of key RAD-IT service packages that capture the anticipated functionality from the Loop 101 Mobility Project and that will be reflected in the 2019 MAG RIA:

- DM01 – ITS Data Warehouse – regional repositories of transportation data to support transportation planning, condition and performance monitoring, safety analysis, and research
- TM01 – Infrastructure-Based Traffic Surveillance – agency operation and data collection from infrastructure such as closed-circuit television (CCTV) cameras and detection
- TM03 – Traffic Signal Control – agency operation and data collection from traffic signal infrastructure
- TM04 – Traffic Metering – ADOT operation and data collection from freeway ramp meters
- TM06 – Traffic Information Dissemination – agency dissemination of information via permanent hard asset methods such as dynamic message signs (DMS) or wayfinding signage

- TM07 – Regional Traffic Management – agency collaboration in managing mobility and response
- TM08 – Traffic Incident Management System – agency coordination during incidents, and could apply to special events, construction, or other threshold that warrants activation of this type of coordination
- TM09 – Integrated Decision Support and Demand Management – performance-driven decision-making related to transportation choices
- PT08 – Transit Traveler Information – broadcast information to transit users to inform decisions
- TI01 – Broadcast Traveler Information – agency dissemination of information via soft asset methods such as software, website, or media
- TI02 – Personalized Traveler Information – real-time interactive request/response systems and information systems that "push" a tailored stream of information to the traveler based on a specific request
- TI03 – Dynamic Route Guidance – advanced route planning and guidance that is responsive to current conditions

3.2 SYSTEMS REQUIREMENT ANALYSIS

The beginning processes for conducting SE activities involves establishing needs of the stakeholders, relationships to other projects/programs, and identifying how the system will operate, before moving into steps toward designing the product. The overarching mission and goal of the Loop 101 Mobility Project is to implement advanced ICM transportation technology systems, including freeway, arterial, transit, data sharing and ICM operations processes. The emerging transportation technologies, data, and their applications will be effectively deployed and integrated with existing systems to improve access to essential services, destinations, and key corridors.

The Loop 101 Mobility Partner Agencies have agreed to support the following concept and goals for the Loop 101 Mobility Project:

- Improve safety and the use of existing arterial capacity in the Loop 101 corridor by deploying technology and systems to support ICM through a DSS;
- Enhance public transportation service and incident response by using lessons learned from the local connected vehicle testbed to deploy intelligent signal priority within the corridor;
- Elevate transportation operations partnerships with public sector agencies and innovative private sector partners;
- Use regional experience combined with advanced technologies to improve traffic management operations for large-scale planned special events; and
- Improve data availability and consistency of traveler information to assist with traveler decision making and influence traveler behavior toward shared mobility.

All of the efforts to establish needs and operational requirements for the system will be captured in a ConOps; this list of needs will be based on, but not be constrained by, the needs and goals identified in the ATCMTD grant application. The Requirements Analysis is the process whereby the functional requirements are analyzed and managed from ConOps to detailed system design. The ConOps document that will be developed will describe the functionality and integration of the Loop 101 ICM system and its components. The established system engineering process for the ConOps ensures that requirements are only developed for those functions for which a need has been established. This approach provides a focused development and strong traceability for testing and acceptance. The ConOps document will be refined during the course of this project to support the design and development of the Loop 101 ICM system.

3.2.1 REQUIREMENTS DEVELOPMENT

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

- Acknowledging the fundamental operational context in region and considering where nuanced or different processes are required to align with the operational environment of a DSS;
- Defining the system from a need- and user-based standpoint;
- Identifying requirements that promote compatibility with all existing systems and all known, future changes and upgrades; and
- Identifying risks and mitigation strategies associated with manual or future automated features of the system.

Formal system requirements will be developed for the DSS, Adaptive Traffic Signal System and Connected Vehicle applications. Requirements will be used to support procurement of design consultants and developers. The level of requirements to be developed for the Traveler Mobility Application will be determined following an industry RFI to get feedback on potential technologies.

DSS requirements will be defined after the development of the ConOps. Development of High Level Requirements represent the first step in the design and development of the Loop 101 Mobility Project concept. There are multiple inputs that are necessary to understand and identify system requirements that will be needed. Inputs into the High Level System Requirements include:

- Needs and goals identified by partner agencies for each segment of the corridor;
- The existing inventory of devices and infrastructure used for operations on the Loop 101 corridor, information collection and dissemination, and incident management within the ICM study area;
- Existing systems, requirements, policies, and procedures used for operations and management of roadways within the study area by partner agencies;
- Characteristics of the existing roadway network including, roadway capacity, and future planned developments; and
- Past and current ICM and traffic management-related projects and initiatives in and around the study area.

Needs that are identified will be mapped to requirements to provide traceability. Each requirement will be uniquely identified in the High Level Requirements. These requirements will be analyzed and allocated to system and subsystem elements. These elements include hardware configuration items, software configuration items, or human interface items. Interfaces between items will also be identified. System requirements will be allocated to the items, such that each item satisfies one or more requirements, and each requirement is allocated to at least one item.

The following steps and strategies will be used to define requirements specifications:

- Using graphics to communicate functionality;
- Using matrices to number and track requirements against identified needs;
- Identifying integration and interoperability needs for new functions with existing systems and equipment; and
- Ensuring configuration management among the project team, including decisions on documentation procedures, product format, and procedure for submitting and finalizing deliverables.

During requirements development, a series of meetings will be conducted to discuss operational and technical requirements to implement the Loop 101 Mobility Project systems concepts. A draft High Level Requirements document will be distributed to stakeholders for review and a meeting will be scheduled to directly present some of the high-priority requirements to stakeholders. The draft requirements will be updated and circulated for a final review by stakeholders.

Detailed requirements, or system design, will be developed by a design consultant that is procured during Phase 2. The design consultant will be expected to adhere to the same principles and strategies related to engagement with the Loop 101 Mobility teams and stakeholders and documenting and tracking of requirements. Detailed requirements will be developed based on the Operational Plan, ConOps, and High-Level Requirements developed in Phase 1.

3.2.2 TRACEABILITY OF REQUIREMENTS

A requirements database will be used to track requirements. The matrix below shows a method to trace a specified need that is identified in the ConOps and identify necessary subsystems requirements derived from those needs.

Reference Number	Level of Importance	Requirement	Needs Statement

All system and software requirements will be written in the form of 'shall' statements. Determination of the requirements will be critical for system interface design. This traceability approach is consistent with the SE approach, where only user needs drive the requirements.

The detailed requirements will be a critical input into the procurement of a qualified system developer who will translate the requirements into specific software. During the development of procurement documents for procuring a system developer, specific attention will be paid to crafting language that will highlight a proposer's ability to effectively translate the requirements into software while maintaining the level of engagement and traceability that was used during the planning and design phases.

3.3 SYSTEM ANALYSIS

System analyses, including discussions related to trade-offs and risk mitigation, will occur during the process of component prototype design and development.

The requirements will define a set of technical objectives for the Loop 101 Mobility Project. Once the requirements are defined, trade-off analyses can help determine if all the requirements can be met with the available funding and resource allocation. There may be cases where multiple viable and reasonable alternatives for meeting the requirements are presented and there is not clear consensus among project stakeholders about the way forward. In these cases, the technical task teams, in coordination with the PMT, TT and PAT may define measurable evaluation criteria to support decision-making, which will be driven by performance measures, cost, schedule, technical criteria, and additional metrics developed during the ConOps and System Requirements tasks. Additionally, identification of risks involved with each alternative and the process to mitigate risks will be documented during the alternative analyses. Design alternatives may be necessary to ensure that any future

system is compatible with the operating systems and IT policies for ADOT, MCDOT, Valley Metro and other stakeholder agencies that are implicated.

3.4 SUB-SYSTEM ANALYSIS

Sub-systems will be identified and defined based on the outputs of the ConOps and the System Requirements tasks. At a minimum, the following sub-systems will be important considerations for any future system:

- User interface - how users will interact with the system how and when alerts and notifications are issued, and how they are presented to users;
- Data exchanges and interfaces - how the system will extract and integrate data from a variety of sources;
- Operating platform - how the system will be accessed, including unique requirements of workstation and mobile environments;
- Operation decision support – how response strategies are formulated and suggested to users based on current conditions and established thresholds;
- Functional elements - including how communications and coordination among users is facilitated, how operational decisions are supported, and how historical information is captured;
- System management - how data archiving is handled, how system updates are handled, and how overall system management and maintenance is accomplished; and
- System end of life-cycle management - how the system will be upgraded or replaced at the end of its life-cycle. Where will the data be stored, and for how long should any data with this system be stored.

The process of defining and allocating specific requirements to the appropriate sub-system will occur during the design and development of the system prototype in Phase 2 of the project. The System Test Plan framework will be developed to detail all testing that will occur on the project including subsystem integration testing to verify the system against subsystem and system requirements. A Final Acceptance Test will be conducted during Phase 3 and will be considered the final control gate for system design and implementation.

3.5 DESIGN DEVELOPMENT APPROACH

This section describes the process or methods that will be used to translate the system requirements into system design. High-level requirements will be written as ‘shall’ statements, will be numbered, and will have clear traceability back to specific needs in the ConOps document. A draft High Level Requirements document will be distributed to Loop 101 Mobility Project partners for review and comment. A requirements walk-through meeting with stakeholders will be held to discuss comments and feedback on the requirements. These high-level requirements will form the basis for procurement documents and procurement contracts with potential developers, designers, and vendors.

Based on the outcomes of the advertisement and procurement process, the system development process for this project will follow and agile development approach to support design traceability and synthesis. The agile method to development allows the project development process to best adapt to changing requirements and may involve the following approaches:

- Holding a series of stakeholder workshops 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 will be integral to designing a system that meets the intended purpose that the ConOps has defined; and

- Incrementally updating the functional design and functional specifications based on stakeholder input to fine tune the functional design into a final version that can then be taken to develop the software to match the design.

Iterative development will require that the requirements be continuously managed throughout all defined design iterations. Any changes to requirements will require a traceability analysis, and modifications to the requirements will be tracked using a requirements change management tool to document the change that is made, who it was made by, the reason for the change (i.e. the flaw or issue that necessitated the change management process), and the traceability back to the defined user need.

3.6 RISK MANAGEMENT PLAN

There are risks involved in the development of this project as well as risks involved in the ultimate integration of the Loop 101 Mobility Project applications into an operational environment. These risks have been and will be referred to by the project team and GEC throughout the development of the project. Project-level risks will be managed and monitored through a Risk Management Plan within the PMP.

Key points of reference for the review of these and other risks will be in advance of the submittal of any draft deliverable. The identification of these risks will act as the overarching requirements to be met prior to any submittal or review of a deliverable.

3.6.1 RISK IDENTIFICATION

Risk identification is done throughout the life-cycle of the project through use of tools and processes, which may include the following:

- Documentation and tracking of risks through a Risk Register
- Analysis of critical SE deliverables, including, but not limited to, the project schedule, ConOps, High Level Requirements, Detailed Requirements, and System Development and Testing Plans
- Documentation and analysis of scope change requests
- Stakeholder and vendor input
- Formal risk identification during stakeholder meetings (including PMT, TT, PAT, and EGC)
- Previous lessons learned from other projects in the region as well as other ICM projects throughout the country

Potential technical risks for the Loop 101 Mobility Project concept development include:

- Defining functionality without identifying specific technologies;
- Defining operational environments that would require specific technology types without identifying specific vendor products;
- Creating functionality and operational characteristics that are too vague which may make them difficult to attain through application development;
- Uncertainty about the pace of evolution of core technologies that would be required to support the Loop 101 desired functionality;
- Gaining trust with automation for decision-making;
- Ensuring interoperability and compatibility of agency operating environments and systems;
- Business models and industry environments required to support the Loop 101 Mobility Project may be untested; and

- Institutional challenges with openly sharing data as well as privacy and security concerns.

3.6.2 RISK DOCUMENTATION

All identified risks are documented in the **Risk Register**, which maintained in an excel-based spreadsheet by the GEC and PMT. Information captured for each risk includes:

- Risk ID
- Description of risk
- Risk trigger – the event that would trigger the potential outcome that, if present, is considered an issue to be resolved (i.e. a dependency)
- Potential outcome/issue of risk
- Source of risk
- Proposed mitigation
- Date identified

3.6.3 RISK ANALYSIS

Risk analysis considers the probability that the risk will occur and the potential impacts that would be realized if the risk occurs, and thus results in an adverse outcome.

- Risk Probability will be ranked very low, low, probable, high, or very high
- Risk Impact will be ranked very low, low, moderate, high, or very high

Risk analysis will also consider where the different risks may occur within the study tasks and phases, so that the project stakeholders can track risk probability and impact in relation to the number of concurrent risks at different parts of the project.

3.6.4 RISK STRATEGIES

Strategies and plans will be developed in response to identified risks to minimize potential effects of the risk. Different types of strategies to respond to risks include:

- **Risk Avoidance** – changing aspects of the project to eliminate the risk. This can be done by actions such as relaxing or shifting objectives, clarifying requirements, gathering information or expertise, or improving communication.
- **Risk Transfer** – shifting the negative impact of a risk to a different party so that the risk is not eliminated, but managed by someone else
- **Risk Mitigation** – reducing the probability and/or impact of the risk. This is often accomplished through proactive actions, such as identifying contingency plans
- **Risk Acceptance** – either taking no action or adjusting a part of the project (cost, schedule) to accommodate the risk.

The strategy taken to address each risk for the Loop 101 Mobility Project, including a responsible party, will be identified and tracked in the Risk Table.

3.6.5 RISK MONITORING AND CONTROL

Risks should be continuously monitored for new and changing risks. During PMT, PAT, EGC, and/or technical team meetings, discussions on the status of risk management will be discussed, including:

- Identification of new risks, including analysis and response planning strategy identification
- Tracking of identified risks, re-analyzing them, and monitoring for trigger conditions
- Review of any changes to project scope or status that may indicate a risk or that is part of a risk strategy
- Review of current risk mitigation strategies that are in place and their effectiveness

Any changes to existing risk status or new risks identified will be documented in the Risk Table.

3.7 CONFIGURATION MANAGEMENT

Configuration Management (CM) is a cross-cutting activity in the SE process that ensures that the integrity of the system is maintained throughout the project lifecycle. The goal of CM is to make sure that the resulting system does not deviate from the expected functionalities, characteristics, or requirements prescribed in the system documentation. As changes to the system are proposed, a CM process provides a consistent approach to identifying, evaluating, and implementing them in a way that considers impacts to the entire system and minimizes potential adverse effects of uncoordinated change.

Components of the CM process include:

- **Change Management Board** – identifies responsibilities related to the decision-making function of reviewing and approving or rejecting all requested changes for hardware, software, and documentation that are under CM control.
- **Configuration Identification** – identification of individual hardware, software, and documents (such as plans sets and drawings, software maintenance agreements, product warranties, and other guiding documents or contracts) that are under CM control and the process for identifying the configuration status of each. Proper configuration identification answers the following questions: What is the configuration of the system? What are the components of the system? What are the versions of the system components?
- **Configuration Change Control** – establishes mechanisms that will help ensure the integrity of the system in light of changes that are made to the configuration status of components. Configuration change control identifies and maintains configuration baselines for CM components and the overall system and documents a change control process to be followed.
- **Configuration Status Reporting** – a status record of all items in the infrastructure baseline, thus providing traceability of all changes to the infrastructure. While Change Control considers the process for identifying and making changes, Status Reporting documents configuration status and how and why the system has arrived in its current state.

The CM activities described in this section details the control process and procedures used to confirm that the configuration of the software components of the Loop 101 Mobility Project is maintained closely throughout the project. CM requirements and processes will also be incorporated into vendor contracts during Phase 2 and Phase 3 of the project.

3.7.1 CHANGE MANAGEMENT BOARD

A Change Management Board is designated for any system development process to provide oversight and an approval method for changes, updates, or additions to the system. During the Loop 101 Mobility Project system development, the functions of the Change Management Board will be undertaken by the PMT and the PAT and will be supported by the GEC during the ATCMTD grant-funded activities.

When the system moves into an operation and maintenance phase and beyond the timeline of the grant-funded activities, a formal Change Management Board should be established. The Board should include at least five representatives from the system owner(s), which will be former members of the various Loop 101 Mobility Project team and stakeholders, and the identified chairman/head of the Board that should rotate on an annual basis.

Any new or updated scenario for the Loop 101 Mobility Project system should be approved by the Change Management Board and will need to be run in Test Mode and verified through reports/data prior to implementation. No changes are allowed to any of the configuration items without the approval of the Change Management Board.

3.7.2 CONFIGURATION IDENTIFICATION

The major activities of configuration identification including selecting infrastructure components to be placed under CM control and creating an identification scheme for the components to uniquely identify each individual component.

At a minimum, the following documents that will be developed as part of this project will be managed under the configuration management process:

- SE documents – PMP, SEMP, ConOps, and High Level Requirements;
- Software Development Plan;
- Data Management Plan; and
- System Test Plans.

Additionally, the PMT and TT will determine the infrastructure components to be placed under CM. The following preliminary list of agency infrastructure (hardware and software) should be controlled as part of the Loop 101 Mobility Project.

- Data systems – RADS, agency closure or restriction systems
- Agency traffic and transit management systems and centers and associated software
- Field devices and hardware – DMS, CCTV, ramp meters, detection
- System – switches, routers, firewalls
- Additional software
- Traveler information systems and applications – 511, mobile apps

3.7.3 CONFIGURATION CHANGE CONTROL

The configuration change control process consists of a sequence of steps to prevent unilateral decisions that could have negative or unforeseen consequences. A control process makes sure the entire project team is

aware of a change being implemented and that an evaluation is performed to understand the potential risks, costs, and impacts of that action. **Figure 3** illustrates the steps in the process.

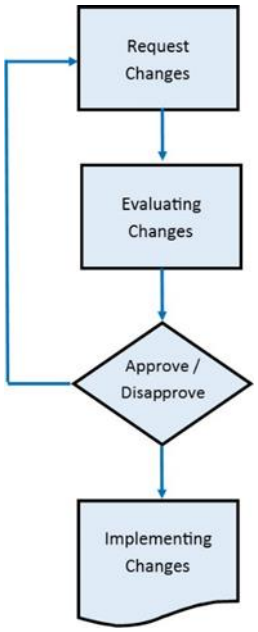

Figure 3 – Configuration Control Process (proposed)

Requests will be required to be submitted in written form, via email or a comment-tracking spreadsheet. At regular team meetings, the status of requested changes will be reviewed, and solutions will be discussed. The action resulting from a change request varies depending on the magnitude of the change requested. A low level priority often requires only a verbal request/approval. Higher magnitude changes that could have had a critical impact on configuration items should be reviewed by the project development team and could be taken to the stakeholder core team (i.e. the Change Management Board).

3.7.4 CONFIGURATION REVIEW

The goal of a configuration review is to verify that all infrastructure components have been identified correctly and that all infrastructure changes have been properly managed. These reviews will be periodically performed by project vendors with support from project stakeholders for devices and systems during development and implementation phases of the Loop 101 Mobility Project.

- Device review compares document configuration of devices (based on agency asset management documentation) with the actual field device configuration of the deployed infrastructure components at the time.
- Software systems review will compare documented software configuration (from agency asset management and configuration plans) with the actual software configuration of the deployed software systems and analyze and note any discrepancies between software versions or revisions.

The results of the configuration review will be documented and used to identify and correct discrepancies in configuration status information. It can also be used to analyze inefficiencies and problems identified in the CM process and to identify actions to resolve them.

3.7.5 CONFIGURATION MANAGEMENT TOOLS

For configuration management of project-related deliverables, a file naming scheme will be established, and a version history tracking table will be included at the beginning of each document.

The file naming scheme shall take on the following format to support configuration management and version control:

- Loop 101 Mobility Project_*doucment name_draft/final_date*

When comments are provided on a document, the following naming convention shall be used:

- Loop 101 Mobility Project_*document name*_draft _*date_commenter initials*

The version history table will include the categories of information exemplified below:

Version	Date	Author	Comments
1	09/13/2019	KH	Initial draft submitted to ADOT and MCDOT

Configuration management of vendor- or consultant-produced design plans, prototypes, and systems will be the responsibility of the identified vendor or consultant, with oversight being provided by the TT, PMT and the GEC. The software vendor will develop a Software Development and Testing Plan that will detail a description and design team usage of tools and processes for code/documentation configuration management, among other items as identified by the project team. This document will be reviewed and approved by the TT, PMT, PAT, and technical task team leads.

Additionally, per the Cooperative Agreement between ADOT and FHWA, the following intermediate working papers will be sent to the ATCMTD mailbox (ATCMTD@dot.gov) and the FHWA Arizona Division contact:

- Draft Final PMP and SEMP
- Final PMP and SEMP
- Final Communications and Outreach Plan
- Final Operations Plan
- Final DSS ConOps
- Final DSS High Level System Requirements
- Final DSS System Procurement Document
- Final Recommended Coordination Plan for Adaptive Ramp Meters
- Final Adaptive Systems Procurement Document
- Final CV Readiness Assessment
- Final Testing and System Acceptance Reports for all applications

4 TRANSITIONING CRITICAL TECHNOLOGIES

It will be critical for there to be methods and processes to be used to identify, evaluate, select, and incorporate critical technologies into the Loop 101 system design. While Phase 1 of the project will look to be largely technology-neutral and focus on the needs and desired functionalities of the systems through the development of the ConOps and High Level Requirements, in the project will include advertisement and procurement of design consultants, vendors and contractors that will provide, design, and/or develop systems and devices that

address the identified needs and functions. Procurement processes and requirements will be driven by ADOT and MCDOT procurement rules and procedures. In coordination with ADOT and MCDOT, and in partnership with the PMT, PAT, and TT, the GEC will identify technical evaluation criteria to evaluate the proposals that are received. Evaluation processes will largely be driven by individual agency procurement rules and processes. Some anticipated considerations during the evaluation of proposals include:

- Cost of the technology, system, or service;
- 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;
- Trade-offs that may be necessary to include the technology;
- The level of management and maintenance that is needed for the technology; and
- The perceived sustainability of the technology (how long is the technology perceived to stay relevant).

The documentation of the evaluation process is critical to managing risk and to provide consistency with staff turnover. Once a technology has been evaluated, the technical task teams, led by the TT, will work to build consensus for the technology selection and answer any questions or concerns that had not been previously considered. The technical task teams will continue to work together after a technology is selected to work with the vendor or software developer to identify customizations that need to be made, assist in determining the impact to schedule and budget, and understand the operations or support from the vendor.

The identification of candidate technologies will hinge on a broad knowledge of the technologies, systems, and services and their status and maturity. Members of the Loop 101 Mobility Project stakeholder group participate in national and international organizations that allow them to be well-informed and at the forefront of current and upcoming policies, technologies, processes, and initiatives related to ITS, operations, safety, and connectivity for transportation systems. In addition to the wealth of knowledge and connections that project partners bring, a project activity for Loop 101 Mobility Project will include performing research on best practices and engaging corridor stakeholders and others who have done similar work throughout the country to make sure that the development team had the necessary knowledge to make technology and system recommendations.

Additionally, the GEC will partner with design consultants to research and document cost items based on anticipated quantities, system requirements, materials required, construction and integration costs, and estimate labor for design, development and implementation. Costs for key systems (DSS, adaptive traffic signals and adaptive ramp meters) will be derived based on research findings including recent local deployments and using information from recent examples in other metropolitan areas.

5 INTEGRATION OF THE SYSTEM

This section describes the intended processes to integrate the developed components into a functional system that meets the system requirements and is operationally supportable. The right side of the SE Vee diagram, shown in Figure 1, is the integration and testing of the system. The integration for each subsystem is verified against the left side of the Vee using Implementation and Testing Plans, vendor-created Software Development and Testing Plans, and System Acceptance Reports. This process tests to make sure the resulting system meets the needs and requirements of the stakeholders.

Coordination with selected Loop 101 Mobility Project consultants, contractors and vendors for design and development will be completed prior to initiating Integration, Verification, and Validation steps of the SE process. The integration and acceptance process includes testing /approval points to be able to verify that the device/system is meeting the needs originally defined and the requirements established for its intended use. An overall review of the integration of the system will need to be reevaluated and may need to be updated over time.

5.1 VERIFICATION

Testing processes will occur in in stages. Testing requirements will vary among different types of equipment (e.g., ramp meters, DSS, connected vehicle devices, etc.). Prototype testing for equipment may be required to confirm quality, ease of maintenance, and compliance with the specifications.

The GEC will develop an Implementation and Testing Plan and the selected vendors and developers will develop a System Development and Testing Plan for the DSS, adaptive ramp metering systems, adaptive traffic signal systems, and connected vehicle applications. The Implementation and Testing Plans will identify staff that will be involved in testing, responsibilities of vendors during testing, schedules, and timeframes. They outline a process for how systems will be accepted and how issues will be communicated to vendors for resolution. For some items, the High Level Requirements may identify some of the tests that must be performed. In addition, there will be a general requirement that all tests and diagnostic activities recommended by the equipment manufacturer must be performed.

The Testing Plans will identify specific milestones and control gates during the testing process and will identify how approvals will be obtained; these milestones may then be linked to specific payment authorizations from the Loop 101 Mobility Project.

The software and hardware components will be verified through NTCIP testing and then integrated to produce higher-level assemblies or subsystems. These assemblies will also be individually verified before being integrated with others to produce yet larger assemblies, until the complete system has been integrated and verified.

Once all devices and components are individually tested and accepted by the PMT, TT, and impacted agencies, the contractor is responsible for testing of specific subsystems (adaptive ramp metering, adaptive traffic signal control, connected vehicles, etc.) to verify that they meet all pertinent operational and performance requirements as documented in the High Level and Detailed Requirements. Assigned members of the TT, PMT or technical task team leads will witness the testing and will either (a) develop a punch list of items or issues to be resolved, or (b), if there are no remaining items or issues to be resolved, authorize the start of the system acceptance test.

5.2 VALIDATION

A formal acceptance process will be implemented for systems that successfully pass testing. A System Acceptance Report will outline testing procedure and what constitutes a correctly operating and stable condition to be considered ‘accepted’. System acceptance will be documented based on traceability back to the requirements. The Acceptance Report will outline testing procedures that involve testing each of the

requirements to determine the final system performs in accordance with the written requirements. Acceptance tracking will detail the following:

Requirement ID	Need/Requirement	Testing Procedure	Result (Pass, Fail, Could Not Complete)	Comments	Date

The GEC will coordinate with vendors to identify requirements for addressing and resolving issues that failed or were not able to be tested. Vendors will develop documentation demonstrating changes that were made to facilitate acceptance, and the items will be re-tested to confirm that they pass. The validation may reveal opportunities to improve the procedures used to develop and implement similar projects in the future. More immediately, it may indicate a need to revise operational parameters or thresholds based on the performance of the devices/systems. It also may point out the need for additional improvements in the project area, such as additional infrastructure or new or updated systems.

Any issues relative to testing and the final testing outcomes will be summarized in the System Acceptance Report.

5.3 INTEGRATON, OPERATIONS, AND MAINTENANCE

A Long-Term Operations Plan will be developed to put forth a plan for ongoing operations and management of the Loop 101 Mobility Project systems and components. This Plan will identify agency roles and responsibilities, future operations needs, potential expansion opportunities, performance monitoring activities and responsibilities, future integration needs, and ongoing maintenance needs.

6 INTEGRATION OF THE SYSTEMS ENGINEERING EFFORT

The SE process is the guiding process for the development of the Loop 101 Mobility Project and provides the overarching structure for the organization of the project team. Further definition of the organizational structure is provided in the PMP.

The PMT and TT includes staff and agencies who are responsible for overall project management as well as technical project oversight. The PMT lead responsibilities include management of scope, schedule, and the involvement of the larger stakeholder team. The TT lead, supplemented by members of GEC and design consultant teams, is responsible for coordinating system design, development, testing, and implementation and oversight of technical documentation and products. The purpose of the division of labor is to define points of contact for each subsystem and to separate functional decisions (such as staffing and procurement) from technical decisions.

The PMT and TT is supplemented by members of the GEC who are supporting all phases of the Loop 101 Mobility Project. This GEC is involved in coordinating and facilitating activities, development of deliverables, coordination with project stakeholders, coordination with design consultants, vendors, system testing and implementation, and scope and schedule adherence.

In addition to the PMT, there is also a PAT that provides strategic oversight to the entire project. This team will also provide input and review to the SE process and deliverables and identify policy and strategic discussion necessary by the EGT. The PAT is anticipated to meet monthly during the project.

The EGT, which will be responsible for establishing policy and making strategic decisions related to the Loop 101 Mobility Project, will be comprised of key executive and management-level staff from Loop 101 partner agencies. This group will meet quarterly and will be advised of the status of project activities, challenges, or needed direction from the PAT.

To support coordination and collaboration for project SE activities and efforts, a secure project website will be used as a collaborative space where all agency partners will be able to access and download project files, including meeting schedules and deliverables for review. Draft documents will be clearly marked as such and will be removed from the website when a final document is available. This website is available at www.L101mobilityaz.com.