System Engineering Management Plan
MDOT-ITS 001-01-006

ITS Projects - Systems Engineering Process Compliance

FHWA Final Rule (23 CFR 940)

Version 2.0
March 20, 2009

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MDOT ITS Mission Statement:

"MDOT will use ITS technologies to improve the quality of life for State residents and visitors by providing more reliable, informative, safer, and flexible passenger and freight multi-modal transportation services."

Revision History

Date	Version	Description
01/24/07	0.1	Draft submittal sent to FHWA for review.
08/22/07	0.2	Revised draft submitted for internal review.
01/17/08	1.0	First final version submitted for MDOT use.
03/20/09	2.0	Second final version submitted for MDOT use.

Forward

The Mississippi Department of Transportation (MDOT) has initiated the development of an Intelligent Transportation System (ITS) Program. Consistent with U.S. Department of Transportation (U.S. DOT) guidelines and rules, MDOT has established a framework (Statewide ITS Architecture) to guide regional ITS planning, project development and implementation. This framework is intended to effectively support MDOT's mission to promote the planning and implementation of an integrated, intermodal transportation network.

Federal Highway Administration (FHWA) Rule 940 provides policies and procedures for implementing Section 5206(e) of the Transportation Equity Act of the 21st Century (TEA-21), Public Law 105-178, 112 Stat. 457, pertaining to the conformance with the National ITS Architecture and supporting standards.

General Purpose of MDOT's Systems Engineering Management Plan:

- *Identify the process for system(s) development*
- *Define how the plan will be carried out*
- *Describe how progress will be tracked against the plan*

The rule states that all ITS projects, funded in whole or in part with funding from the Highway Trust Fund, shall be based on a systems engineering analysis consisting of seven required elements. Conformity with the Rule 940 requirements, listed below, is required for both routine and non-routine projects. However, with routine projects, the effort and scope of systems engineering analysis should be minimal. For non-routine projects, the scale of the systems engineering analysis depends on the scope of the project.

Rule 940 Requirements

As stated in 23 CFR 940, the systems engineering analysis shall include, at a minimum:

1. Identification of portions of the regional ITS architecture being implemented (or, in MDOT's case, the Statewide ITS Architecture and supporting Regional ITS Architectures);
2. Identification of participating agencies' roles and responsibilities;
3. Requirements definitions;
4. Analysis of alternative system configurations and technology options to meet requirements;
5. Procurement options;
6. Identification of applicable ITS standards and testing procedures; and
7. Procedures and resources necessary for operations and maintenance.

Source: (http://ops.fhwa.dot.gov/its_arch_imp/docs/20010108.pdf)

A separate, but functionally equal regulation promulgated by the Federal Transit Administration (FTA) applies to federally funded transit projects.

This *Systems Engineering Management Plan (SEMP)* is a statement of standard operating procedure (SOP) for ensuring compliance with the Rule 940 requirements for qualifying ITS projects under the oversight of the MDOT and/or Local Public Agencies (LPAs). As such, the systems engineering process guidelines contained herein are an extension of the MDOT and LPA existing processes and procedures for ITS planning and project development.

This document is intended to serve as a working reference for public agency management, planning, construction and operations staff relating to the systems engineering and architecture requirements by standing FHWA and FTA policy and procedures for ITS project development.

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List of Acronyms

AASHTO	American Association of State Highway and Transportation Officials
ANSI	American National Standards Institute
APTA	American Public Transit Association
ATMS	Advanced Traffic Management System
CCTV	Closed Circuit Television
CDR	Critical Design Review
CFR	Code of Federal Regulations
CM	Configuration Management
ConOps	Concept of Operations
COTS	Commercial off-the-shelf
CVISN	Commercial Vehicle Information Systems Network
DMS	Dynamic Message Sign
DSRC	Dedicated Short Range Communications
FHWA	Federal Highway Administration
FTA	Federal Transit Administration
IEEE	Institute of Electrical and Electronics Engineers
ISO	International Standards Organization
IT	Information Technology
ITE	Institute of Transportation Engineers
ITS	Intelligent Transportation Systems
JPO	Joint Program Office
LPA	Local Public Agency
MDOT	Mississippi Department of Transportation
NEMA	National Electrical Manufacturer’s Association
NIST	National Institute of Standards and Technology
NTCIP	National Transportation Communications Protocol for ITS

O&M	Operations and Maintenance
PAR	Project Activation Request
PDM	Project Development Manual
PDR	Preliminary Design Review
PS&E	Plans, Specifications and Estimates
RFP	Request for Proposal
RITSA	Regional ITS Architecture
ROW	Right-of-Way
SAE	Society of Automotive Engineers
SE	Systems Engineering
SEA	Systems Engineering Analysis
SEMP	Systems Engineering Management Plan
SITSA	Statewide ITS Architecture
SOP	Standard Operating Procedures
SRS	Software Requirements Specification
STIP	Statewide Transportation Improvement Program
STP	Surface Transportation Program
TIP	Transportation Improvement Plan
TMC	Traffic Management Center
TMDD	Traffic Management Data Dictionary
USDOT	United States Department of Transportation
V&V	Verification and Validation
WBS	Work Breakdown Structure

Definitions[1, 2]

Acceptance — An action by an authorized representative of the acquirer by which the acquirer assumes ownership of products as a partial or complete performance of the contract.

Acceptance Test — Formal testing conducted to determine whether or not a system satisfies its acceptance criteria and to enable the acquirer to determine whether or not to accept the system.

Architecture — The organizational structure of a system, identifying its components, their interfaces, and a concept of execution among them.

Approval — Written notification by an authorized representative of the acquirer that the developer's plans, design, or other aspects of the project appear to be sound and can be used as the basis for further work. Such approval does not shift responsibility from the developer to meet contractual requirements.

Baseline — An approved product at a point in time. Any changes made to this product must go through a formal change process.

Concept — A high-level conceptual project description, including services provided and the operational structure.

Concept Exploration — The process of developing and comparing alternative conceptual approaches to meeting the needs that drive the project.

Concept of Operations — A document that defines the way the system is envisioned to work from multiple stakeholder viewpoints [Users including operators, maintenance, management].

Configuration Item — A product such as a document or a unit of software or hardware that performs a complete function and has been chosen to be placed under change control. That means that any changes that are to be made must go through a change management process. A baseline is a configuration item.

Configuration Management — A discipline applying technical and administrative direction and surveillance to identify and document the functional and physical characteristics of Configuration Items [CI's]; audit the CI's to verify conformance to specifications, manage interface control documents and other contract requirements control changes to CI's and their related documentation; and record and report information needed to manage CI's effectively, including the status of proposed changes and the implementation status of approved changes.

Configuration Management Plan — A plan defining the implementation [including policies and methods] of configuration management on a particular program/project.

Consultant — The firm, individual, or other entity that provides contractual professional services to the Department or the Local Public Agency.

Control (Decision) Gates — Formal decision points along the life cycle that are used by the system's owner and stakeholders to determine if the current phase of work has been completed and that the team is ready to move into the next phase of the life cycle.

Commercial Off-the-Shelf Software — Commercially available applications sold by vendors through public catalogue listings, not intended to be customized or enhanced. [Contract-negotiated software developed for a specific application is not COTS software.]

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[1] *Systems Engineering Guidebook for ITS*, Caltrans, Version 2.0, January 2007

[2] Mississippi S.O.P No.: ADM-24-01-00-000, *Professional Services Consultant Selection*

Cross-cutting Activities — Enabling activities used to support one or more of the life cycle process steps.

Database Management System — An integrated set of computer programs that provide the capabilities needed to establish, modify, make available, and maintain the integrity of a database.

Decomposition — The process of successively breaking down the system into components that can be built or procured. Functional and physical decomposition are the key activities that are used. Functional decomposition is breaking a function down into its smallest parts. For example, the function ramp metering decomposes into a number of sub-functions, e.g. detection, meter rate control, main line metering, ramp queuing, time of day, and communications. Physical decomposition defines the physical elements needed to carry out the function. For example, the ramp metering physical decomposition includes loops or video detection, WWV time [world wide standard clock for accurate time], fiber or twisted pair for communications, 2070 or 170 controllers, and host computer.

Detailed Design Document — The product baseline used to develop the hardware and software components of the system.

Development Model — A specific portion of the life cycle model that relates to the definition, decomposition, development, and implementation of a system or a part of a system.

Elicitation — The process to draw out, to discover and to make known so to gain knowledge and information, often used in defining needs.

Enabling Products — Products that enable the end product to be developed, supported, and maintained. For example, these products typically are the software compilers, prototypes, development workstations, plans, specifications, requirements, and training materials.

Feasibility Assessment — A pre-development activity to evaluate alternative system concepts, selects the best one, and verifies that it is feasible within all of the project and system constraints.

Gap Analysis — A technique to assess how far current [legacy] capabilities are from meeting the identified needs, to be used to prioritize development activities. This is based both on how far the current capabilities are from meeting the needs [because of insufficient functionality, capabilities, performance or capacity] and whether the need is met in some places and not others.

Intelligent Transportation Systems — A broad range of diverse technologies which, when applied to our current transportation system, can help improve safety, reduce congestion, enhance mobility, minimize environmental impacts, save energy, and promote economic productivity. ITS technologies are varied and include information processing, communications, control, and electronics.

Interface — The functional and physical characteristics required to exist at a common boundary - in development, a relationship among two or more entities [such as software-software, hardware-hardware, hardware-software, hardware-user, or software-user].

Interface Control — Interface control comprises the delineation of the procedures and documentation, both administrative and technical, contractually necessary for identification of functional and physical characteristics between two or more configuration items that are provided by different contractors/acquiring agencies, and the resolution of the problems thereto.

Legacy System — The existing system to which the upgrade or change will be applied.

Life Cycle — The end-to-end process from conception of a system to its retirement or disposal.

Life Cycle Model — A representation of the steps involved in the development and other phases of an ITS project.

Local Public Agency	Any unit of government in the State of Mississippi (other than MDOT) participating in the Federal-aid programs with MDOT. Examples include cities, counties, Metropolitan Planning Organizations, planning and development districts, public transit providers, Rails-to-Trails Districts, other state agencies, and tribal governments.
National ITS Architecture	A general framework for planning, defining, and integrating ITS. It was developed to support ITS implementations over a 20-year time period in urban, interurban, and rural environments across the country. The National ITS Architecture is available as a resource for any region and is maintained by the USDOT independently of any specific system design or region in the nation.
Needs Assessment	An activity accomplished early in system development to ensure that the system will meet the most important needs of the project's stakeholders, specifically that the needs are well understood, de-conflicted, and prioritized
Operational Baseline	The system that is currently in use, including all of the design, development, test, support and requirements documentation.
Operational Concept	The roles and responsibilities of the primary stakeholders and the systems they operate.
Process	An organized set of activities.
Professional Services Contract	A contract for any non-bid professional services such as engineering, architectural, accounting, transportation planning, management, construction engineering and inspection, or such other services as may be directed by the MDOT Executive Director or Local Public Agency's Chief Administrative Official.
Project	An undertaking requiring concerted effort, which is focused on developing and/or maintaining a specific product. The product may include hardware, software, and other components. Typically, a project has its own funding, cost accounting, and delivery schedule with the acquirer [customer].
Project Architecture	High Level Design.
Project Plan	A description [what is to be done, what funds are available, when it will be done and by whom] of the entire set of tasks that the project requires.
Regional ITS Architecture	A specific regional framework for ensuring institutional agreement and technical integration for the implementation of ITS projects in a particular region.
Requirements	The total consideration as to WHAT is to be done [functional], HOW well it is to perform [performance], and under WHAT CONDITIONS it is to operate. [Environmental and non-functional].
Reverse Engineering	The process of documenting an existing Intelligent Transportation Systems functional [what it does – requirements], physical [how it does it – design], and support [the way it was built and maintained – enabling products] characteristics.
Risk Management	An organized process to identify what can go wrong, to quantify and access associated risks, and to implement/control the appropriate approach for preventing or handling each risk.
Software Development	A set of activities that result in software products. Software development may include new development, modification, reuse, re-engineering, maintenance, or any other activities that result in software products.

Sole Source Contracts — A method of procuring consultant services in a non-competitive selection for one of the following reasons: (a) The service is available only from a single source; (b) There is an emergency which will not permit the time necessary to conduct competitive negotiations; or (c) After solicitation of a number of sources responding is determined to be inadequate.

Specification — A document that describes the essential technical requirements for items, materials or services including the procedures for determining whether or not the requirements have been met.

Stakeholders — The people for whom the system is being built, as well as anyone who will manage, develop, operate, maintain, use, benefit from, or otherwise be affected by the system.

Statement of Work — A document primarily for use in procurement, which specifies the work requirements for a project or program. It is used in conjunction with specifications and standards as a basis for a contract. The SOW will be used to determine whether the contractor meets stated performance requirements.

System Elements — A system element is a balanced solution to a functional requirement or a set of functional requirements and must satisfy the performance requirements of the associated item. A system element is part of the system [hardware, software, facilities, personnel, data, material, services, and techniques] that, individually or in combination, satisfies a function [task] the system must perform.

System — An integrated composite of people, products, and processes, which provide a capability to satisfy a stated need or objective.

Systems Engineering — An interdisciplinary approach and a means to enable the realization of successful systems. Systems engineering requires a broad knowledge, a mindset that keeps the big picture in mind, a facilitator, and a skilled conductor of a team.

System Specifications — A top level set of requirements for a system. A system specification may be a system/sub-system specification, Prime Item Development Specification, or a Critical Item Development Specification.

Technical Reviews — A series of system engineering activities by which the technical progress on a project is assessed relative to its technical or contractual requirements. The formal reviews are conducted at logical transition points in the development effort to identify and correct problems resulting from the work completed thus far before the problem can disrupt or delay the technical progress. The reviews provide a method for the contractor and procuring activity to determine that the identification and development of a CI have met contract requirements.

Trade-off Study — An objective evaluation of alternative requirements, architectures, design approaches, or solutions using identical ground rules and criteria.

Validation — The process of determining that the requirements are the correct requirements and that they form a complete set of requirements this is done at the early stages of the development process. Validation of the end product or system determines if the system meets the users' needs.

Verification — The process of determining whether or not the products of a given phase of the system/software life cycle fulfill the requirements established during the preceding phase.

Work Breakdown Structure (WBS) — A product-oriented listing, in family tree order, of the hardware, software, services, and other work tasks, which completely defines a product or program. The listing results from project engineering during the development and production of a materiel item. A WBS relates the elements of work to be accomplished to each other and to the end product.

1.0 Purpose

The guidelines presented in this *Systems Engineering Management Plan (SEMP)* for the Mississippi Department of Transportation (MDOT) follow the recent establishment of MDOT's Statewide Intelligent Transportation System (ITS) Architecture - the overarching framework for ITS in Mississippi – and the recent revisions to the *Project Development Manual for Local Public Agencies* defining the project initiation activities associated with systems engineering and architecture requirements for ITS projects. The *SEMP* is generally intended to describe the systems engineering management process and requirements for planning, designing, deploying, operating and maintaining projects containing ITS elements.

This SEMP applies to projects administered by the Mississippi DOT as well as Local Public Agencies . . .

The guidelines will aid in ensuring that ITS deployments in Mississippi result in a fully operational and integrated transportation system that utilizes public resources in the most cost effective and efficient manner. And, that those deployments are in compliance with the Federal Highway Administration (FHWA) Federal Regulation 23 CFR 940, ITS Architecture and Standards, Final Rule and the Federal Transit Administration (FTA) policy on ITS, as it applies to federally funded transit projects.

To this end, the MDOT *SEMP*:

. . . and, is generally intended to describe the systems engineering development process requirements for planning, designing, deploying, operating and maintaining projects containing ITS elements.

- Describes how systems engineering analyses (SEAs) will be applied to projects;
- Provides guidelines for SE activities required to plan, design, deploy, operate and maintain the components of a typical ITS project;
- Describes critical control points (decision gates) in the process and defines criteria for project milestones;
- Provides information on resource planning needs and procurement options available for project implementation;
- Describes how project specific plans for systems integration and verification should be developed;
- Describes how traceability requirements should be developed to ensure that requirements are verified throughout the life of the system; and
- Describes how the design, deployment, operation and maintenance of the project will be tracked against the Project Plan.

These guidelines apply to all projects within Mississippi's transportation network qualifying for funding under the Federal-Aid System, as well as projects under Jurisdictional Systems to which funds from the Highway Trust Fund may be applied. These qualifying systems are further described in the following documents:

- *Mississippi Design Manual*
- *Project Development Manual for Local Public Agencies*

The reader should note that the general identification of participating agencies' roles and responsibilities in the Mississippi ITS program have been functionally defined under the Statewide ITS Architecture and its supporting Regional ITS Architectures, some of which remain under development at this time. Accordingly, stakeholder involvement is not addressed in detail in this *SEMP* document. However, provisions for validating stakeholder involvement in a particular project against the architectures is provided for in the project planning and concept of operations development sections of this *SEMP,* as well as the systems engineering process checklists appended to the document.

2.0 SEMP Document Organization

This *SEMP* is organized to serve as a reference document on the steps required to validate compliance with the Rule 940 requirements and complete project-specific Systems Engineering Analyses (SEAs) (See Section 4.5). In some cases, it may be sufficient in its use as a stand-alone document to ensure compliance with the systems engineering (SE) process for ITS projects, by use of the SE Process Compliance Checklist appended to this document. The process activities described in this *SEMP* can be adapted to fit the individual project.

This *SEMP* is arranged around two important aspects of the SE process:

- Managing ITS Projects Using the SE process (Section 4) and
- Technical Planning and Control (Sections 6).

A table is presented in the beginning of Section 4 and 6 that summarizes the SE processes, work activities that are involved, necessary reviews and analysis, associated deliverables, and decision gates or project milestones. These tables should serve as a usable reference tool for each phase of the ITS project development life cycle. Additionally, Table 3 on Page 16 provides a list of the minimum SEA requirements, which will provide sufficient documentation for most ITS projects.

Sections of the SE Process Compliance Checklist, appended to this document, are intended to be completed by the MDOT/LPA project management staff and should be submitted to MDOT as part of the overall documentation required at each major review/approval milestone (Ref: Section 3.2, Figure 2) for review/approval as indicated. Blank and example copies of the SE Process Compliance Checklist for ITS projects are provided in Appendix A and B, respectively.

It should be noted that the intent of this *SEMP* is not to replicate the voluminous documentation currently available on applying the SE process to ITS projects but, rather, to serve as a user's guide in navigating through linkages to the national ITS program documentation and the supporting efforts and documentation of various research agencies and organizations.

Icons used throughout the text of this *SEMP* are listed below.

Indicates a link to documentation on the Internet.

Indicates additional or emphasized information about the report text or a recommended action by the reader.

Indicates project or activity initiation

Indicates a major project milestone and its associated section of the SE Process Compliance Checklist that requires approval from MDOT.

3.0 Systems Engineering (SE) Process Overview and SEMP Requirements

In all cases, the MDOT ITS Manager, in conjunction with the State Traffic Engineer, shall have responsibility for determining permissible exceptions from the systems engineering process in the interest of public safety, security, and compliance with the MDOT policy and applicable regulations

Benefits of Using the SE Process:

- *Better system documentation*
- *Higher level of stakeholder participation*
- *System functionality that meets stakeholders' expectations*
- *Potential for shorter project life cycles*
- *Systems can evolve with a minimum of redesign and cost*
- *Higher level of system reuse*
- *More predictable project outcomes*

It is important that the development of all ITS projects comply with both the Mississippi ITS Architectures and these *SEMP* requirements as they describe the SE activities needed to develop, deploy, operate and maintain the components of the Mississippi ITS Program.

Federal Regulation 23 CFR 940 defines ITS as "electronics, communications, or information processing used singly or in combination to improve the efficiency or safety of a surface transportation system." As the Mississippi ITS program develops and matures, it is anticipated that a wide range of transportation engineering projects that incorporate ITS capabilities will be developed and implemented.

Additionally, MDOT is working towards integrated statewide management capabilities. As a result, ITS projects in Mississippi will often include multiple capabilities and should be considered complex systems; therefore, the systems engineering processes for ITS must be consistent throughout the life cycles of the projects.

MDOT elects to apply the systems engineering process guidelines contained herein to all ITS projects, regardless of size, with the exception of the following:

- Emergency situations requiring immediate implementation, such as recovery from natural disasters, major weather or security events;
- Isolated traffic control improvements, such as individual intersection improvements or enhancements, spot signing, striping or delineation activities, etc.;
- Routine and preventive maintenance of ITS devices and subsystems, including related non-ITS traffic control devices; and
- System expansions that add no new interfaces and no new functionality to an existing system (e.g., adding additional closed-circuit television [CCTV] cameras to an existing system).

3.1 SE Process vs. Traditional Transportation Project Development

Although it may be appropriate for some ITS-oriented projects to follow MDOT's or a LPA's traditional transportation project development process, many ITS projects involve hardware and software development and integration that require systems engineering processes that are not part of the traditional project development process.

Introduced through the development of the Statewide ITS Architecture, all projects identified for application of the SE process must generally follow the "V" development model. The traditional transportation project development process is mapped to the "V" model in **Figure 1**. The traditional processes are shown in the orange boxes above the standard systems processes with which they correspond.

The mapping of the traditional processes to the "V" diagram in Figure 1 also visually relates the traditional project development process to the ITS Life Cycle Phases, as defined by the National ITS Architecture and Standards program.

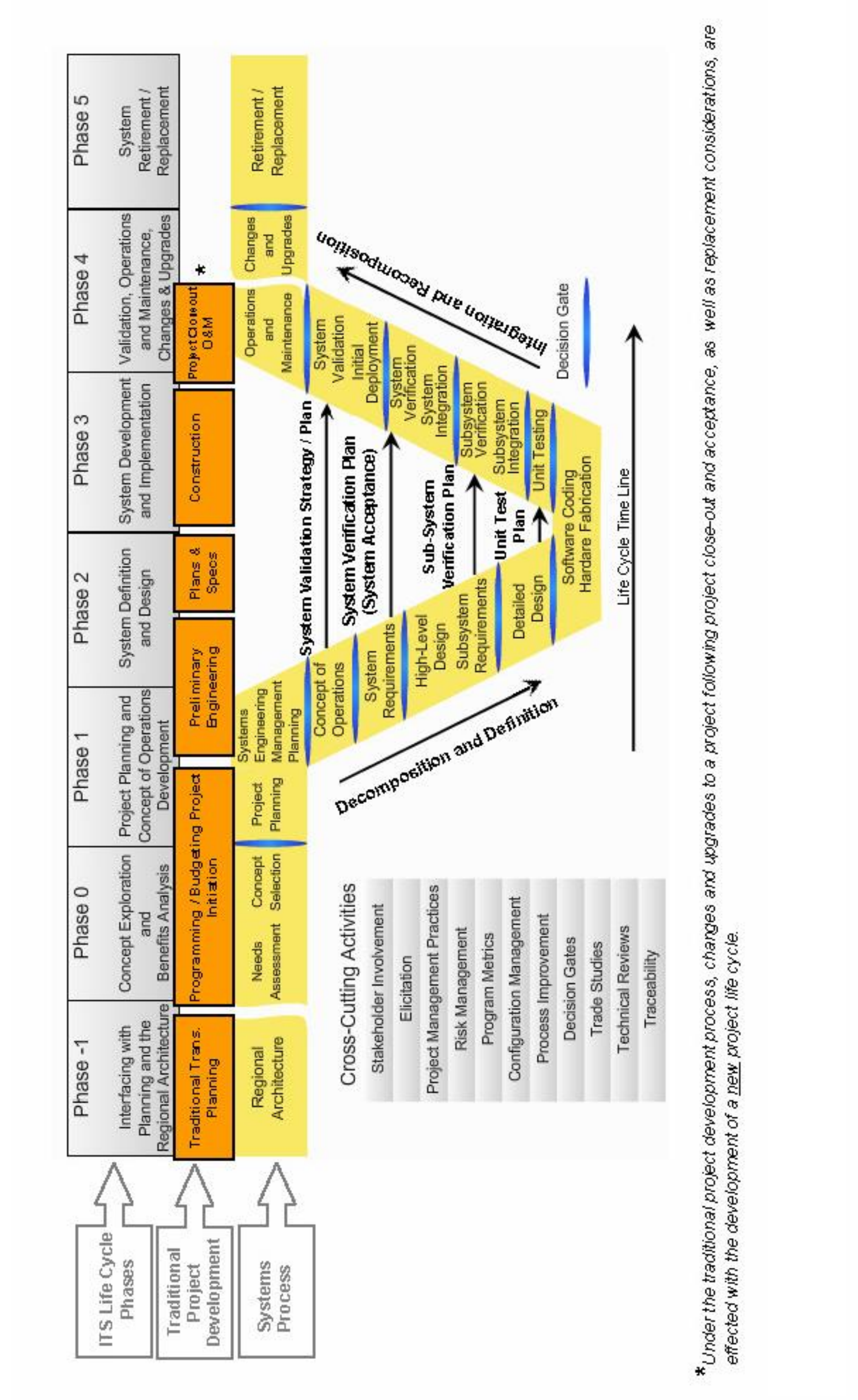


Figure 1: Traditional Transportation Project Development Process Steps Mapped to "V" Diagram and ITS Life Cycle Phases[2]

[2] http://www.fhwa.dot.gov/cadiv/segb/views/process/index.htm (with modifications for this report)

3.2 Mississippi ITS Project Life Cycle Framework

The relationship of the Federal ITS program ITS Life Cycle Phases is further linked to typical MDOT/LPA project development phases in **Figure 2**, Mississippi ITS Project Life Cycle Framework. Additionally, a comparison of the MDOT/LPA project development cycle to a typical capital project development cycle is provided.

Figure 2 also depicts the major milestones defined for the SE Process for Mississippi ITS Projects, which are summarized in **Table 1** below. The SE Process includes reviews at "decision gates" or milestones, which are intended to generate visibility into the project development process, promote involvement from the stakeholders as well as allow for the identification of problems and their corrections during the development process.

Table 1: Minimum Project Review/Approval Milestone Requirements - ITS Project Life Cycle

Milestone Type	Milestone Description
GO	Project Initiation
A	Project Development Start-up
B	Project Activation
C	Project Plan and SEA Approval
D	Concept of Operations Approval
E	Design Approval
F	Development Approval
G	O&M Plan Approval
H	Replacement/Retirement Plan Approval

The symbols used to represent the major project approval milestones in Table 1 and Figure 2 can also be found in the sidebar throughout the rest of this *SEMP* to indicate where approval is required. The letters inside the "stop sign" symbols represent the applicable sections of the SE Process Compliance Checklist that must be completed and submitted to MDOT for approval.

These and other control points in the typical ITS project life cycle are described in more detail in other sections of this *SEMP.*

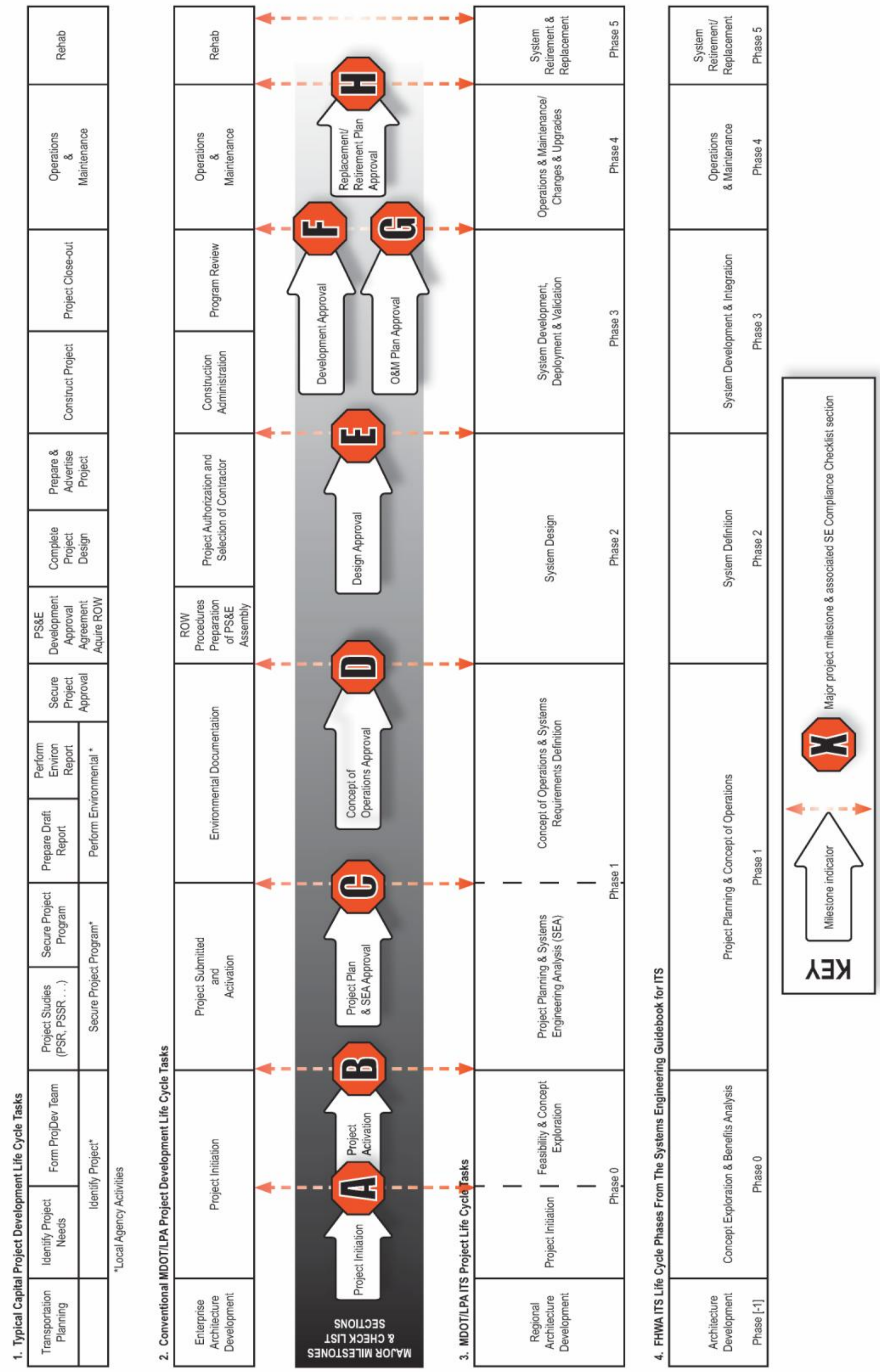


Figure 2: Mississippi ITS Project Life Cycle Framework

4.0 Managing ITS Projects Using the SE Process

Systems engineering management planning involves performing a systems engineering analysis (SEA). Components of the SEA involve creation of a work breakdown structure (WBS), selection of the appropriate procurement method, identification of the task inputs and deliverables, necessary reviews / meetings, project milestones, and task resources for each activity in the WBS.

The SE process is initially a planning exercise, promoting up-front planning and system definition prior to technology identification and implementation. Once the project development activities are initiated by the MDOT Planning Division the systems engineering process outlined in this *SEMP* should begin.

The SE process initially involves documenting the general project data and identifying the general project needs. Compliance with the Statewide ITS Architecture (SITSA) and/or applicable Regional ITS Architecture (RITSA) should be demonstrated and used as a planning tool in developing the project's high-level operational concept and functional requirements. Needs should be elicited from stakeholders and documented, which will become the basis for defining what the project will accomplish. One key functional driver of the SE process is to ensure that the installed system meets the original stakeholder needs.

Table 2, on the following page, summarizes the SE processes, activities that are involved, necessary reviews and analysis, associated deliverables, decision gates and applicable sections of the SE process checklist. It should serve as a usable reference tool for each phase of the SE management portion of the ITS project life cycle.

4.1 Documentation of General Project Data /Project Need

GO

Project Development Initiation

Complete Section A of the SE Process Compliance Checklist.

One of the first steps that need to occur in the SE process is the documentation of general project related information, which can be accomplished by filling out Part 1 of the SE Compliance Checklist. General project data should include the following:

- A brief description of the project
- Contact person
- Location of the project
- Funding source
- Nature of the work
- Relationship to other projects and phases
- Types of equipment to be purchased with project funds
- Project status
- Status of work plan for the project

In addition to the project data, an identified project need should be documented. The documented need should state the problems that exist with the current situation and how the ITS project will alleviate some or all of the stated problems. Detailed information should be provided on how the needs were identified, determined to be valid, and prioritized in the "Needs Assessment" (Ref: Part 4 of the SE Process Compliance Checklist) portion of the SEA.

Table 2: SEMP Requirements Summary – Managing ITS Projects Using the SE Process

Systems Process Task	Activities / Work Products	Reviews and Analysis	Deliverables	Decision Gate	Applicable Part(s) of SE Process Checklist
PHASE -1 –> INTERFACING WITH PLANNING and the REGIONAL ARCHITECTURES					
Review the Regional and Statewide Architecture	▪ Identify the applicable sections of the SITSA / RITSA ▪ Identify need that will be satisfied by the current project ▪ Check that project is consistent with SITSA/RITSA	▪ Identify information from the RITSA necessary for successful integration with associated ITS projects ▪ Identify information needed for interoperability	▪ Documented need to modify the SITSA/RITSA, if necessary ▪ High-level project architecture (if not already part of the SITSA/RITSA)	▪ Project Development Start-up	Parts 1,2,3 A B
PHASE 0 –> FEASIBILITY and CONCEPT EXPLORATION					
Needs Assessment	▪ Identify stakeholders ▪ Elicit needs ▪ Document needs ▪ Validate needs ▪ Prioritize needs ▪ Perform gap analysis ▪ Compare costs	▪ Technical reviews are effective to get stakeholder feedback on the collected needs	▪ Needs Assessment Documentation / Report	▪ Project Initiation	Part 4 B
Concept Selection	▪ Define/refine goals and objectives ▪ Define vision ▪ Identify constraints ▪ Define evaluation criteria ▪ Identify candidate solutions ▪ Identify alternative concepts ▪ Evaluate alternative concepts ▪ Document results	▪ Each step of the concept selection process should be reviewed by the stakeholders ▪ Using the Architecture High Level requirements, refine the scope of what is needed and whether technologies are available ▪ Refine the project concept to provide scope and budget constraints ▪ Review schedule alternatives and possible schedule challenges	▪ *Concept Description White Paper*, including: ○ Selection rationale ○ Recommended concept ○ Feasibility assessment	▪ Project Activation Approval	Part 5 B
PHASE 1 –> PROJECT PLANNING and SYSTEMS ENGINEERING ANALYSIS (SEA)					
Project Planning	▪ Define and budget project tasks ▪ Identify needed resources ▪ Make procurement decisions ▪ Develop project schedule ▪ Prepare project plan ▪ Prepare supporting management plans, if necessary	▪ Assess viable procurement options with Tier 1 stakeholders ▪ Conduct Project Procurement Planning Review ▪ Document record of decision	▪ Project Plan ▪ Supporting management plans (if needed) ▪ Request for Proposal(s)	▪ Project Plan and SEA Approval	Part 6 C

Systems Process Task	Activities / Work Products	Reviews and Analysis	Deliverables	Decision Gate	Applicable Part(s) of SE Process Checklist
Systems Engineering Management Planning	▪ Assess project management activities and technical tasks ▪ Identify technical tasks necessary to mitigate project risk ▪ Define needed systems engineering processes and resources ▪ Make procurement decisions and specify integration activities ▪ Prepare Systems Engineering Analysis and supporting plans (as needed)	▪ Review Project Plans and SEAs from prior project, if available ▪ Update the sections of the existing SEA that are affected by this project, if applicable ▪ Integrate the SEA with he Project Plan ▪ Conduct Project SEA Review with Tier 1 stakeholders	▪ *Systems Engineering Analysis Report* ▪ Supporting technical plans (as needed) ▪ Request for Proposal(s)	▪ Project Plan and SEA Approval	Part 7

Source: *Systems Engineering Guidebook for ITS, Version 2.0* (modified for this report)

4.2 Compliance with the Regional ITS Architecture

The applicable ITS Architecture(s) should be used as a preliminary means for identifying stakeholders, developing a high-level operational concept, developing functional requirements and identifying interconnections between ITS projects planned for surrounding regions within Mississippi.

The current ITS planning documents Department (i.e., Mississippi Statewide ITS Architecture (SITSA) and the applicable Regional ITS Architecture (RITSA)) should be reviewed by the MDOT / LPA. If it is identified that the project is not part of the SITSA or RITSA, an update must be performed to all affected documents to incorporate the project. This update should be accomplished by MDOT with input from the LPA, if required.

The SITSA and RITSAs are very broad in nature and include most market packages; consequently, it is unlikely that projects being implemented will necessitate Architecture updates. If the LPA has any doubts about an ITS system or subsystem being included in the Architectures they should contact the MDOT ITS Manager.

The Statewide and Regional Architectures can be found on the “Go MDOT” Web site.

For more information on this step of the planning process, refer to the *Systems Engineering Guidebook for ITS* Web site.

4.3 Needs Assessment

The “Needs Assessment” process is a preliminary task used to ensure that the needs of the stakeholders are well understood prior to starting project development. Initially, it is likely that there will be more needs identified than are feasible to include in project deployment, thus making needs prioritization an important step in defining the project.

One of the first steps in the Needs Assessment process is to identify the stakeholders and their needs. These needs should be documented and validated to ensure that they are accurately represented. Once the needs have been validated, they should be prioritized and the most critical needs should be selected.

For more information on this step of the planning process, refer to the *Systems Engineering Guidebook for ITS* Web site.

4.3.1 Stakeholder Identification

The first step in the Needs Assessment process is to identify the stakeholders who will own, operate, maintain, use, benefit from or in some way be affected by the ITS

The results from the stakeholder process should be submitted to MDOT for project. The RITSA / SITSA should be used as a preliminary means of identifying stakeholders. The MDOT / LPA should identify any additional local stakeholders not included in the architecture documents.

The MDOT / LPA should develop a list of stakeholders and submit it to MDOT for review. The MDOT ITS Manager will determine if stakeholder meetings are necessary on a project by project basis. In many cases the stakeholder meetings held during the Architecture development will have covered the necessary items. In some cases a stakeholder meeting would be beneficial, while in other cases a letter sent to the affected stakeholders notifying them of the proposed project should suffice.

In any event, input from the stakeholders is encouraged. All stakeholder input should be closely reviewed.

4.3.2 Elicit /Document Needs

There are various means of eliciting needs. Some of the techniques recommended in the *Systems Engineering Guidebook for ITS* are literature searches, day-in-the-life studies, surveys, one-on-one interviews and stakeholder workshops. It should be noted that stakeholder needs are usually vague and different elicitation techniques can be used to help clarify those needs.

The results from the elicitation process should be consolidated and documented. In order to validate the needs, this document will be reviewed by the stakeholders.

NOTE: It is just as important to capture the constraints as it is the needs. A constraint for a single stakeholder, such as the maximum height of maintenance's bucket trucks, will impact the system for all. Mississippi State policy also needs to be considered here.[3]

4.3.3 Validate Needs

The documented results from the elicitation process should be presented to the stakeholders. This will be most successfully accomplished in a workshop where the stakeholders are encouraged to give feedback until they agree that all of the needs have been accurately documented.

[3] http://www.fhwa.dot.gov/cadiv/segb/views/document/Sections/Section3/3_3_1.htm

4.3.4 Prioritize needs

Rarely does a project satisfy every need of every stakeholder. The project should address the most important needs that can be implemented in a cost effective manner.

The needs should be analyzed and prioritized. The *Systems Engineering Guidebook for ITS* recommends that the following techniques be used to aid in needs prioritization:

- Draw needs out of previous project documents and prioritize them with concurrence of the stakeholders
- Conduct a workshop where the stakeholders review and rank candidate needs
- Use surveys
- Define a decision process (e.g., voting, majority, and negotiation)

4.3.5 Perform Gap Analysis

A gap analysis should be performed to identify the "gap" between the capability of the system in fulfilling the identified needs of the stakeholders and the desired capabilities. Funding is not always available to deploy an entire system. More often systems are deployed in phases across a number of years and projects. It is helpful to identify the gap(s) between the stakeholders' ultimate requirements and system as it will stand after the completion of the current project. As subsequent projects go through the systems engineering process, the gap between the installed and planned equipment should be measured. At some point the stakeholders' requirement will be met and the gap will be zero.

Many different qualitative methods of gap analysis could be used. One is not inherently better than the other, however, the important thing is to select a methodology which fits the situation, document the methodology and apply it consistently.

One method of qualitative analysis is described below.

> Each of the needs should be ranked in terms of both the breadth (e.g., 70% of the freeways currently collect speed data) and depth (criticality) of the gap (e.g., 30% gap) between current and desired capabilities. The depth of the gap should be assigned a qualitative ranking on a scale of 0 to 10, 0 representing that the need is completely met with the current system and 10 representing that there is no current capability to satisfy the need. This rating of the depth of the gap (i.e., the 1-10 assignment) should be multiplied by the criticality of the depth (i.e., 30% gap), which results in a unit-less number that can be used to gauge how significant the gap is for each need.

Many times funding sources will determine the systems or subsystems which can be targeted. While the overall gap analysis of a system may indicate a greater need in other areas, specific funding may have to be used to fill lower priority gaps. For example the greatest need may be closed circuit television (CCTV) coverage of an area but only Federal Transit Administration funds are available in the project budget.

In order to rank the needs, an inventory of the current system capabilities should be performed. The legacy system inventory should include all ITS devices currently in the field, an evaluation of the functionality of the existing Traffic Management Centers and the ITS communications network infrastructure.

4.3.6 Compare Costs

A cost estimate should be developed to meet each of the needs. Qualitative estimates will be sufficient (e.g., high/medium/low or easy/moderate/difficult to implement). It will be virtually impossible to come up with accurate cost estimates this early in the process, but the qualitative estimates may help in eliminating some of needs early in the process due to excessive cost or difficulty of implementation. It is helpful during this process to identify the typical funding sources for the project types. Some projects require larger matching funds than others. The amount of local funding required to complete a project is often the critical factor in deciding which projects can go forward.

4.3.7 Validate Key Needs

The most critical needs should be identified by taking into account the gap analysis and qualitative cost estimates performed in the steps above. These critical needs should be documented and presented to the stakeholders, and a forum should be provided for the stakeholders to comment on the selected needs.

4.4 Concept Selection

The concept selection process documents the effectiveness and feasibility of the project with justification based on a benefit cost analysis. It should include enough detail that it can be used to develop the Concept of Operations (ConOps).

For more information on this step of the planning process, refer to the *Systems Engineering Guidebook for ITS* Web site.

The activities that need to occur during the selection process are as follows:

Define goals and objectives – A description of the goals and objectives of the project should be written from the point of view of the traveling public and should identify what the project is intended to accomplish.

B

Complete Section B of the SE Process Compliance Checklist & submit completed Sections A&B of checklist to MDOT for approval.

Define vision – The vision should be a brief description of what the system will achieve when implemented. This description should be written using non-technical terms and should be easy for the stakeholders to understand.

Identify constraints – Constraints can be drawn from the SITSA and RITSAs but also obtained from the stakeholders during the Needs Assessment process. It should be noted that MDOT Policy and Procedures should also be examined when identifying constraints.

Define evaluation criteria – Since multiple projects may be considered for implementation at the same time, it is important to develop a set of evaluation criteria so that each project will be evaluated in a consistent manner.

Identify candidate solutions – Candidate solutions to meet the stakeholders' needs should already be identified in the SITSA / RITSA. These documents should be referenced during this process.

Identify alternative concepts – Alternative project concepts should be developed at a high-level and should be built from the identified candidate solutions in conjunction with the SITSA / RITSA.

Document results – The results from the concept exploration process as well as the rationale for the selected concept should be well documented.

Each step in the process listed above needs to include input / review from the stakeholders.

4.5 Systems Engineering Management Planning

A Systems Engineering Analysis (SEA) shall be performed and documented for all ITS projects in Mississippi. The result of this process should be the development of a project plan that identifies the project's needs and constraints, work activities, resources, budget and implementation timeline.

The SEA shall conform to the guidelines contained in this *SEMP*. It should be noted that the level of detail required by the SEA depends on the project scope. If the procuring agency is deploying a market package which has previously been deployed by another LPA, or statewide by MDOT, a SEA may already exist and should be used and modified as necessary. The level of detail necessary will be determined by the MDOT ITS Manager and/or FHWA, however, at a minimum, the SEA should address the following requirements outlined in **Table 3** on the following page.

A brief project outline & draft WBS should be submitted to the MDOT ITS Manager as early in the process as possible.

Table 3: Minimum SEA Requirements

Section of SEA	Description
Purpose	Stated purpose for performing the SEA
Description of the project	Overall description of the project (i.e., its geographic location, ITS elements to be installed, etc…)
Identification of sections of the SITSA/RITSA being implemented	Ensure that the project is consistent with the SITSA/RITSA
Identification of participating agencies' roles and responsibilities	Identification of MDOT/LPA and stakeholder roles and responsibilities
Requirements definitions	User services included in the National ITS Architecture should be used to develop a set of requirements for the project
Analysis of alternative system configurations	Alternative system configurations should be analyzed to determine the best option to meet the requirements
Procurement options	The procurement type should be determined based on project scope
Identification of applicable ITS standards	The most recent ITS and testing standards should be identified
Operations and maintenance plan	Procedures and resources necessary for operations and maintenance should be identified

The procuring agency should submit a brief outline of the proposed SEA with a draft Work Breakdown Structure (WBS) as early in the process as possible to the MDOT ITS Manager. The MDOT ITS Manager, or approved designee, will coordinate document review and initial activities required to perform the SEA. Guidance will be provided to the procuring agency to complete this requirement. The general requirements of the SEA are described in the sections that follow.

For more information on the systems engineering management planning process, refer to the *Systems Engineering Guidebook for ITS* Web site.

4.5.1 Project Procurement Planning

Procurement of ITS projects with Federal Highway funds presents unique challenges to the MDOT and the LPAs. The challenges are especially paramount when procuring ITS projects that involve advanced technologies which require specialized skills and knowledge. Even deployment of simple ITS system expansions have become complex undertakings to ensure consistency with National ITS Architecture and evolving standards. Typically, the requirements of ITS projects cannot easily be specified at the outset of the project—resulting in the difficulty of establishing realistic low bids and ensuring end-product quality.

The selection of appropriate contracting options for designing and constructing an ITS project depends on many variables. These variables include:

- Type and complexity of the required products, systems, and services;
- Interdependence of project components and subsystems;
- Inclusion of ITS systems components with roadway construction projects;
- Use of varied and rapidly changing advanced technologies;
- Need to pre-qualify consultants and/or contractors;
- Constrained deployment schedule;
- Magnitude of construction impacts on road users; and
- Risk management factors associated with capital investments in transportation systems.

Portions of this section of the *SEMP* have been excerpted from the *NCHRP 560 Report, Guide to Contracting ITS Projects*.

Project Planning Phase

In general, the project planning phase of the overall planning process for ITS projects will conform to current MDOT and/or LPA standard procedures. There are, however, two process steps requiring additional consideration with ITS project development. These are highlighted in **Figure 3**, which depicts a simple, generic planning process.

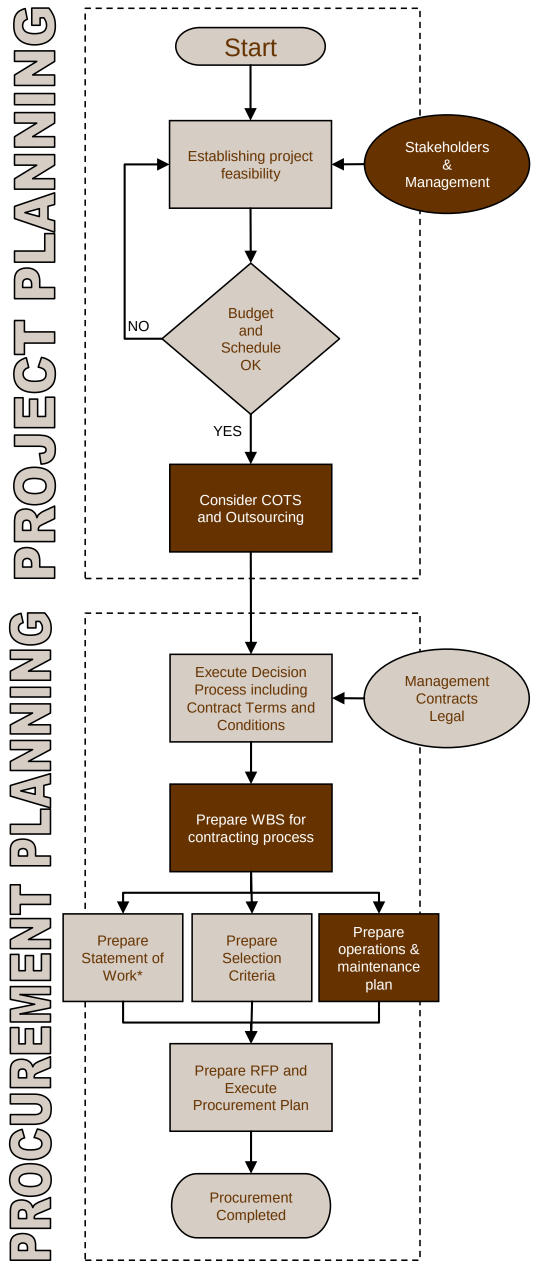
The reader should refer to MDOT and/or LPA project development documentation (*Project Development Manual for Local Public Agencies*) for applicable detail on Mississippi requirements.

Project planning for ITS projects involves preparing of a project management plan and developing a procurement strategy consistent with an applicable system development process.

In the **Project Planning Phase** it is necessary to consider alternative fundamental approaches to the system development, such as:

- Stakeholder and management input in establishing project feasibility is represented by demonstration of conformance with the SITSA / RITSA(s). In the event of a project procurement requiring multiple sponsoring agencies, that the procuring agency and its project partners (stakeholders) "have their act together" and that their plans are compatible with the financial and personnel resources of the agency(s).

- The traditional project planning phase needs to also consider whether or not commercial-off-the-shelf (COTS) or outsourcing requirements are applicable to the project. These requirements will impact procurement type, as well as budget planning for the project.



**May also include plans and specifications as required by the selected contracting alternative*

Figure 3: Project/Procurement Planning

- Decisions regarding COTS should be based on a critical comparison of needs with the features of available systems. If a good match can be achieved, COTS-type procurement should be considered.
- A project is a candidate for outsourcing if an agency concludes that it does not have either the personnel or experience to manage the system acquisition.

Similarly, in the **Procurement Planning Phase**:

- Finalization of the contract terms and conditions is dependent upon the procurement method or type identified for the project. As described in the following parts of this section, the final work breakdown structure (WBS) will also vary depending on the contract type.
- Another important consideration is whether or not a project should be implemented using more than one contract. Not all contracts associated with a project require the same contracting approach. The magnitude of a project may involve a mix of complexity and incompatible services (e.g. construction, custom software development, systems integration, operations and maintenance) that diminishes the possibility for implementation success under a single contractor.
- The complexity of a project can have a significant impact on the selection of a procurement strategy. ITS projects can range in complexity from those that are relatively straightforward as in adding field devices (e.g., CCTV, DMS, etc.) to an existing traffic management system, to those that are extremely complex

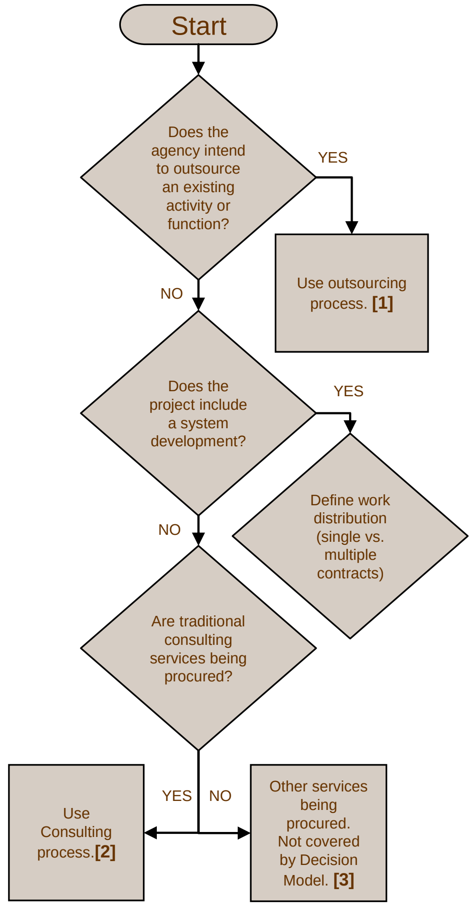
such as the implementation of a completely new transportation management system. The procurement strategy for these two undertakings would be significantly different.

- And, Operations and Maintenance (O&M) planning needs to be considered in many ITS projects prior to executing the final procurement plan. This follows the defined ITS Project Life Cycle Framework (Figure 2).

Contracting Options

Making initial decisions about the fundamental project characteristics that differentiate a system development, a consultant contract and an outsourcing contract is the key to a successful ITS procurement. The definitions of "construction," "engineering and design services" and "non-engineering/non-architectural" form the framework for determining how to procure an ITS project. Component interrelationships and system integration requirements must be considered in effectively grouping project elements into one or more component projects that individually meet these definitions. These component projects are procured using the most appropriate contracting options that will optimize project quality, deployment schedule and cost.

Logical and creative grouping of project elements into one or more component projects and selecting appropriate contracting options are critical for achieving success in procuring ITS projects. **Figure 4**, on the following page, represents the recommended logic to be used in initial project planning for ITS procurements.



[1] This outcome indicates you are planning to outsource an existing agency activity or agency function. Use outsourcing options. (See Table 3)

[2] This outcome indicates the use of traditional consulting procurement processes. Per MDOT/LPA procedures (SOP: ADM-24-01-00-000)

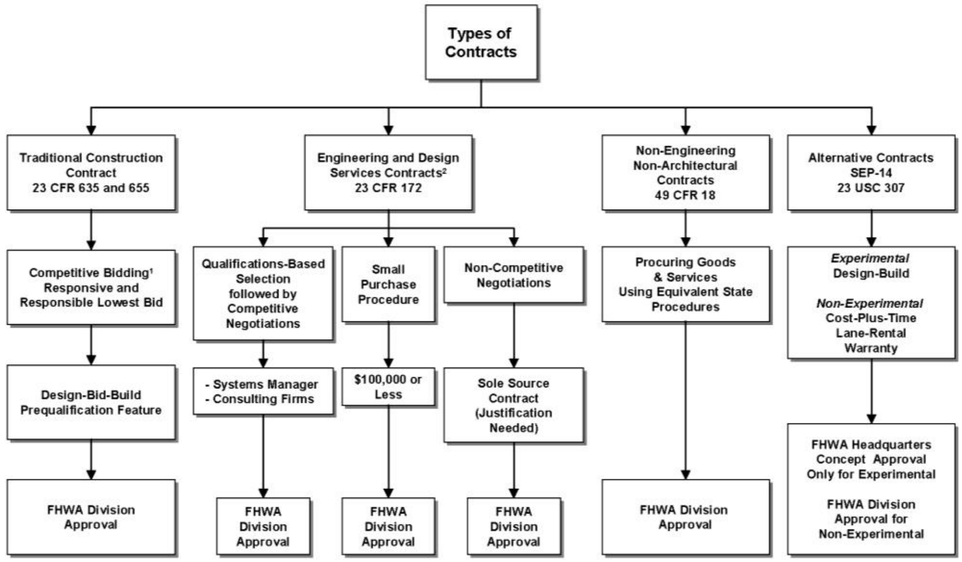
[3] This outcome indicates that you are procuring services not addressed by any of the procurement packages covered within this guide. For example, Public-Private Partnerships. (See Table 3)

Figure 4: Procurement Decision Model

There are various contracting techniques, features, and provisions allowed within the Federal-aid regulations that can effectively serve the procurement needs of transportation agencies. These contracting options, their applicability to ITS projects, and resulting FHWA approval requirements are presented in the following sections of the *SEMP*.

Currently, MDOT is using traditional construction contracting methods for ITS deployments. When using the traditional construction contracting methods the agency should become familiar with subsection 31-7-13 of the [*Mississippi Code of 1972*].

Figure 5 summarizes various types of contracting techniques, features and optional contracting provisions that are possible under the FHWA Federal-aid procurement regulations.



1. Except for force account
2. Or other selection procedures codified in Mississippi statutes

Figure 5: FHWA Federal-Aid Procurement Regulations and Contracting Options[4]

The FHWA Federal-Aid ITS Procurement Regulations and Contracting Options should be referenced for further guidance on the review and approval processes applicable by type of contract proposed for and ITS project. The level of FHWA review and oversight for any given project depends on the contract type and stewardship agreement that exists between the FHWA Division Office and MDOT.

This definition of "construction" is necessary to evaluate the various components of ITS projects. Projects meeting this definition must be awarded to the lowest responsive and responsible bidder. This allows agencies to optimally group project elements into one or more projects for subsequent design and construction using the most appropriate contracting techniques. This requires a thorough understanding of the proposed components, skills, and experience required to design and construct the project; the agency's capabilities; and the project's implementation schedule.

For example, contractor installation of field devices and hardware typically meets the definition of construction, whereas services such as software development, system integration, and system engineering and design **do not** meet the definition of construction. It is recommended that State and local agencies consult with the FHWA Division and Region offices when attempting to choose appropriate contracting techniques for their planned ITS projects.

[4] http://www.itsdocs.fhwa.dot.gov/jpodocs/repts_te/3029/chap3.htm

Specifications for ITS projects must be clearly written and include life cycle costs, documented experience, and warranty provisions. It has been shown that lowest bid is not always the best path to take for ITS projects. FHWA does not require a lowest bid approach. In fact they encourage a Life Cycle Cost approach. The MDOT/LPA should keep in mind that the selection other than the low bidder must be justified based upon the specifications.

Based on Figure 4 and eliminating Outsourcing Agency Activity or Function and Traditional Consultant services procurements, there are several primary procurement options available for ITS projects requiring any level of system development:

- Commodity Supplier
- Low-Bid Contractor with Consultant Design
- Systems Manager (Integrator)
- Design-Build Contractor with Design Consultant

Table 4, on the following page, summarizes the procurement approaches most commonly utilized for various elements of ITS implementation and operations and maintenance. It should be noted that design-build procurements require conformance with subsection 65-1-85 of the *Mississippi Code of 1972*.

Criteria to help reduce the number of procurement options considered include:

- Systems manager is preferred to design-build when a significant amount of new software development required.
- Design-build is preferred over systems manager only for major projects when significant amounts of field construction are involved and there is a desire to reduce implementation delays associated with having to administer multiple procurement contracts.
- If a project includes both new software and field construction, consider splitting it into multiple contracts.
- Low-bid contracting should only be used if required by agency policy, and/or projects are limited to field construction and supply of off-the-shelf equipment.
- Commodity procurement is only applicable if an existing package is available that does not require any modification to meet agency's requirements.

Table 4: ITS Procurement Types

Procurement Type	Method of Award	Contract Form	Contract Type	Comments
Commodity Supplier	Low-bid selection of pre-qualified packages	Single phase or purchase order	Fixed Price	Used for COTS procurements
Low-Bid Contractor with Consultant Design	Low-bid for contractor	Phased or Task Order	Fixed Price for contractor incentives optional	Consultant performs 100% of design. May provide additional services during implementation Use should be restricted to well-defined systems
Systems Manager	Quality-based selection (negotiated procurement)	Phased or Task Order	Fixed price, cost plus or time & materials incentives optional	Additional contracting burden placed on agency Field equipment procured by agency using low-bid process
Design-Build Contractor with Design Consultant	Best-value selection (based on consideration of price and quality)	Phased	Usually fixed price, cost plus or time & materials incentives optional	Consultant provides 30% design Most applicable to systems with time constraints and requirement for continuity between the design and implementation
Consultant	Negotiated	Phased or Task Order	Fixed price, cost plus or time & materials incentives optional	Used for system design and many other consultant services
Outsourcing Agency Activity	Low-bid may be based on rates	Usually single phase	Fixed price or time & materials incentives optional	Typical activities include maintenance, operations, signal timing, etc.)
Outsourcing Agency Function	Best value or low-bid	Single phase	Fixed price, cost plus or time & material contracts Incentives optional	Typical functions include traveler information and toll collection. May be public-private partnership Difficult to define measures and outcomes

NOTE: The Systems Integrator procurement type is typically used interchangeably with the Systems Manager type. Traditionally, the role of the Systems Integrator is similar to that of a systems manager, except that the integrator is not involved in the planning and design stages of the project unless the specific contract terms and conditions warrant it.

MDOT has chosen to develop the initial core Mississippi statewide ITS with the application of the Systems Manager procurement type. Under this contract, the Systems Manager is also providing specific project-level Consultant Design with construction engineering awarded to Low-Bid Contractors for field device implementations. Some elements are also being procured using the Commodity Supplier approach.

This hybrid mix of procurement types under a broad base ITS contract is indicative of the work distribution issues that require a significant amount of attention in the project and procurement planning phases of an ITS procurement. It also exemplifies the degree of desired flexibility required in the MDOT and/or LPA procurement processes in determining the contracting process and associated procurement types that best addresses the nature of the work to be performed.

4.5.2 Work Breakdown Structure

One of the first steps to be performed as part of the SEA process for an ITS project is the development of a Work Breakdown Structure (WBS). The purpose of a WBS is to show the way that work tasks are organized for a project. A WBS should be created in a graphical format for each ITS project to provide a hierarchical listing of the systems engineering activities necessary to develop, deploy, operate and maintain the project (i.e., the more detailed tasks should be shown underneath the high level tasks). It should be noted that ITS projects will vary in complexity, which will inherently affect the complexity of the WBS. In general, the underlying structure of the WBS should be defined by the Contract Scope of Work; however, additional key systems engineering tasks may be identified through other work efforts. The LPA should work closely with MDOT to determine the level of detail required for a specific project. MDOT will review the scope and functional requirements to determine the items required in the WBS. The LPA should not start work on the WBS until MDOT has provided guidance.

Refer to the *Systems Engineering Guidebook for ITS* Web site for detailed information on the development of the WBS and to the *Project Development Manual for Local Public Agencies* located on the "Go MDOT" Web site. These two documents, along with the detailed checklist in Appendix B of this document, provide valuable information and guidance to the users.

The WBS outlined in **Figure 6** shows the top-level SE flow process that needs to be followed when implementing ITS projects in Mississippi. This sample WBS may be modified as necessary and re-used for new ITS projects.

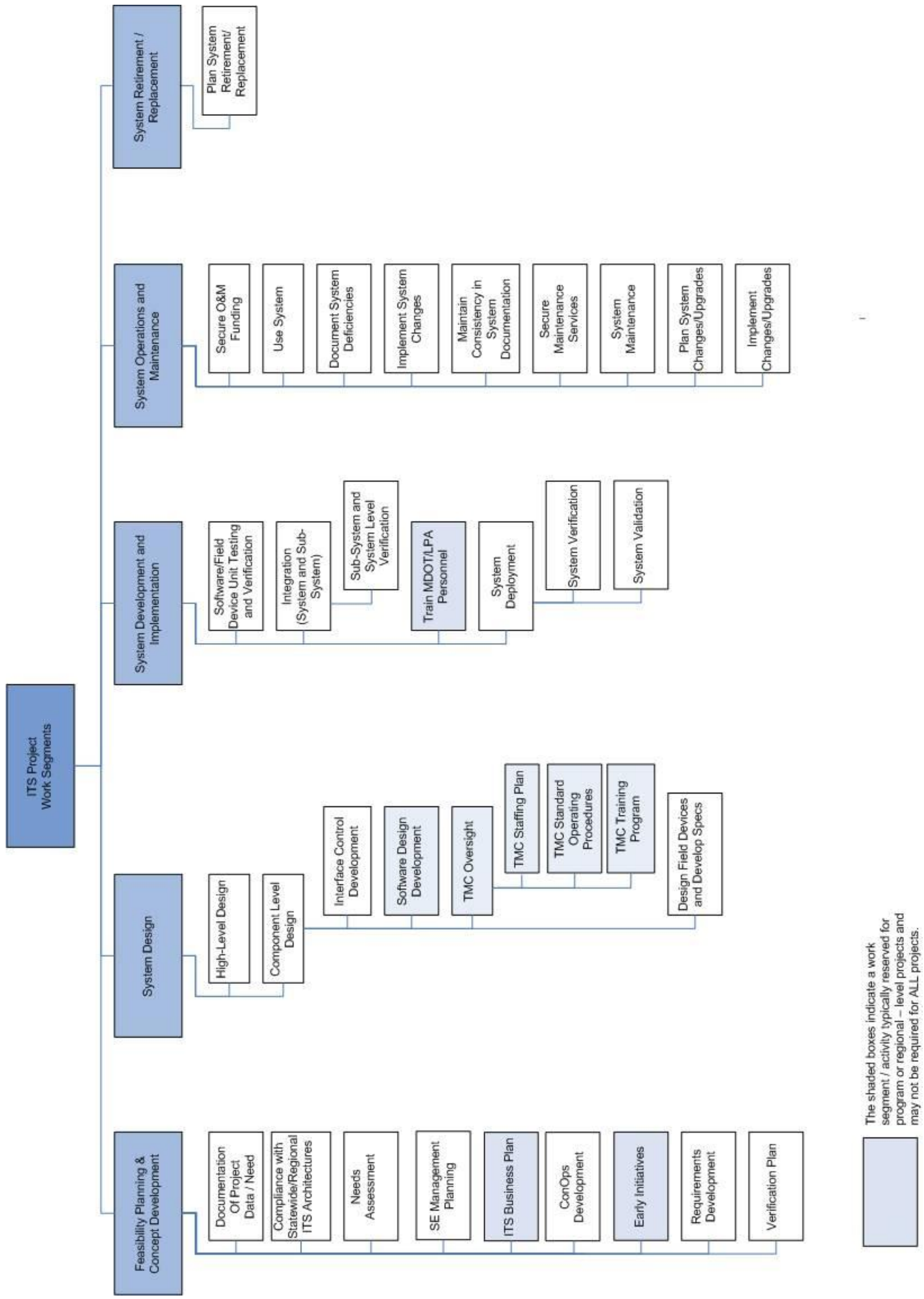


Figure 6: Work Breakdown Structure Diagram for the MDOT ITS System

4.5.3 Task Inputs and Deliverables

An outline type numbering scheme should be used to number the project tasks in the WBS (e.g., the first top-level box in Figure 5, above, should be assigned a 1.0 and the lower-level boxes should be assigned 1.1, 1.2, 1.3, etc.).

The graphical WBS should be followed by text describing the work involved in each task in order to provide a clear understanding of the different activities involved. This section of the SEA is called “Task Inputs and Deliverables” and should provide information on the inputs and deliverables required for each task. Examples of inputs and deliverables to be included are listed below.

Inputs – source requirements documents, interface descriptions and ITS Standards

Deliverables – documents, hardware and software

The Deliverables View of the *Systems Engineering Guidebook for ITS* Web site provides guidance on some of the most commonly used systems engineering documents. Suggested document outlines, checklists for tracking critical information, and real-world examples of many of the documents are available.

4.5.4 Project Schedule

The activities from the WBS should be translated to the schedule and a critical path should be identified for the project. It should be noted that, if software development is involved in the project, it will typically have the largest impact on the critical path of the project schedule.

Basically, the schedule should show the necessary sequence of activities using an SE-based project development process. A description of typical requirements for the project should also be developed at this time.

In the early phases of the project, there is a temptation to start the next task prior to completion and approval of the current task, this is sometimes called “concurrent engineering” and introduces significant risk into the project.

4.5.5 Decision Gates

Decision gates are critical project milestones that are used to move from one task of the project to the next (e.g., the completion of the systems requirements analysis must be completed and approved prior to developing the software requirements specification). The critical milestones / decision gates that are required as part of the ITS life cycle were established in Section 3.2 of this *SEMP* (Ref: Table 1 and Figure 2).

Each of the phases in the ITS project life cycle has an associated decision gate, thus discouraging the temptation to move to a future phase prior to completion of the current phase. MDOT is the approval authority for the procuring agency to move to the next task.

System retirement and replacement is a judgment only the procuring agency and stakeholders can determine. The MDOT and/or LPA should plan and budget for replacement of equipment and software at the estimated life cycle of the system. Although it may seem that moving to the next task without formal approval of the decision gate will shorten the project schedule, it may potentially introduce considerable risks into the project which could cause significant cost and schedule overruns in future phases.

It is important that the following activities are performed prior to a decision gate:

- Plan how the decision gate is to be performed
- Identify the participants including their roles and responsibilities
- Define the entrance criteria (what needs to happen before the decision gate review takes place – i.e., deliverable submittals, etc…)
- Define the exit criteria (what needs to happen before next phase or task begins)

4.5.6 Reviews and Meetings

Each step in the SE Process will require a full review prior to moving forward. The MDOT ITS Manager's approval is needed for a project to move from one step to the next. When a project is formally presented to MDOT, a meeting and review schedule should be established. The procuring agency must keep MDOT informed on the progress of the project at all times.

The first step in the SEA process is the development of a framework for the SEA and a preliminary WBS, which should be submitted to MDOT. MDOT will perform a management review and may meet with the submitted agency to discuss and refine the document.

The technical reviews are critical in recognizing design defects, identifying alternative approaches, communicating status, monitoring risk and coordinating tasks among project teams. The Institute of Electrical and Electronics Engineers [IEEE] 1028-1998 has identified the following types of reviews that are appropriate for ITS projects:

- Management Reviews
- Technical Reviews
- Inspections
- Walk-throughs
- Audits

A standard process/plan should be established for conducting reviews. Included in this plan should be a schedule of the technical reviews needed for the project, who will need to attend the meetings, the level of formality of each review, items needed prior to the review (deliverables), process for the review (informal or formal), and the exit criteria (100% consensus agreement, MDOT ITS Manager approval, etc.).

Refer to the *Systems Engineering Guidebook for ITS* Web site for detailed information on the Technical Review process.

Process Improvement Reviews

Performing process improvement reviews of the SE process will provide MDOT with the ability to identify and prioritize needs for successful ITS implementation. The SE process reviews should include the following steps:

- Plan method of assessment (e.g., reviews, questionnaires, surveys and workshops)
- Perform assessment
- Consolidate and validate data
- Analyze assessment data (i.e., Identify strengths and weaknesses of the process under assessment)
- Document lessons learned and update SE process

4.5.7 Resource Allocation

The MDOT/ LPA must identify the necessary, dedicated resources for the project. For each of the activities in the WBS, the MDOT / LPA should identify the lead agency. This may be a consultant or a department within the agency. The MDOT ITS Manager should be provided the name and contact information for a primary point of contact for the project. The funding source(s) for the items in the WBS must also be identified and submitted with the draft WBS.

NOTE: The procuring agency should be aware that project funding may not be available for the preparation of the ConOps and WBS which must be accomplished prior to the submittal of the Project Activation Request (PAR). If consultant services are used to produce these documents the MDOT / LPA should be prepared to fund this expense outside of the project funding; however, any money spent on these preliminary project planning tasks may be applied as matching funds once the PAR has been submitted and the project has been activated.

4.5.8 Risk Management Planning

Risk management involves identifying risks and developing a strategy for controlling or mitigating the risks during all phases of a project.

Risk Identification

It is imperative that the risk identification process be initiated at the beginning of the project. In order to identify all potential risks that may adversely affect the project, the key project team members and stakeholders should meet to develop a list of the areas where risk may exist that could cause the project to fail. Potential risks should be identified in all phases of the project, beginning with the initial stages all the way to the ultimate retirement/replacement of the system. The purpose of this exercise is not to identify generic risks that could affect any ITS project but to identify specific project risks. Initially, there may not be any apparent project specific risks, but it is critical to develop a process for identifying risks as they materialize throughout the life of the project. It should be noted that highly improbable risks do not need to be recognized but that events that are probable and are likely to impact the project negatively from a cost, schedule or technical perspective should be identified.

Potential sources for risks that may affect MDOT / LPA ITS projects include:

- Technical
- Institutional
- Funding
- Environmental
- Personnel
- Commercial

The following areas should be specifically considered for risk identification:

- Known problems in the existing system
- Operational danger
- Current technology
- Critical path tasks in the project schedule

Risk Assessment and Prioritization

After identifying all of the potential project risks, an assessment of each risk should be performed based on the severity of the negative affect that the subject risk will have on the project (e.g., impact on cost, schedule, quality, etc.), as well as, the likelihood that the risk will occur. The assessment of the severity of risk can be measured either qualitatively or quantitatively depending on the nature of the project.

Once each risk is analyzed, the risks can then be prioritized based on the severity of the impact and the likelihood that it will occur. It is recommended that the risk severity and risk likelihood be measured using one of three tiers: high (3), medium (2) and low (1). It may be helpful to relate each one of the qualitative tiers (i.e., high, medium, low) to some quantifiable criteria (e.g., a high severity risk may cause a cost overrun of more than $500K). Both risk severity and risk likelihood will receive a rating, thus allowing them to be prioritized in a traditional risk prioritization matrix. In general, a risk prioritization matrix shows how the risks are assigned (see Table 5).

As illustrated in the matrix, risks with a high severity of impact and a high likelihood of occurrence should be ranked as a high priority risk and will necessitate a risk mitigation strategy. Conversely, a risk with a low severity of impact and a low likelihood of occurrence will be ranked as low priority risk and may not require a risk mitigation strategy.

Table 5: Risk Prioritization Matrix

		Likelihood of Occurrence		
		High	**Medium**	**Low**
Severity of Impact	**High**	High	High	Medium
	Medium	High	Medium	Medium
	Low	Medium	Low	Low

Each risk that is assessed should be documented in a database or table, which will serve as a baseline for the risk management review process. If new risks are identified during the course of the project they should be assessed and added to the database.

Risk Mitigation/Monitoring

A risk mitigation strategy should be developed for each identified risk in order to lessen the probability and/or severity of the impact of each risk event. An owner should be assigned to each risk and a schedule and budget should be developed for each mitigation strategy. For the highest priority risks, triggers should be identified that will determine that a mitigation action is necessary. The owner of the subject risk must proactively implement the mitigation strategy developed for that risk. Project personnel should then collect and analyze whether the mitigation strategy has been effective in lessening the negative impact on the project. The mitigation strategy should produce an acceptable result for all parties, resulting in minor schedule and budget changes. The risk mitigation strategy may be documented in a stand alone risk management plan or be included in the project level SEMP documentation.

4.5.9 Project Specific Technical Plans

The specific technical plans should be completed concurrent with the advancement of the overall systems planning and engineering design activities. As these elements and technical processes are addressed, the appropriate documentation should be written.

The sets of plans listed on the following page are designed to address specific areas of the systems engineering activities. The MDOT ITS Manager will provide guidance to the LPA's as to which technical plans will be needed for their project. Some of the plans below are only rarely required. The unique characteristics of a project will dictate their need.

The LPA may elect to formalize more plans than MDOT requires, however, any additional plans should also be submitted to MDOT.

The following list of technical plans may be needed to address specific program and/or project level systems engineering activities.

- A **Software Development Plan** describes the organizational structure, facilities, tools and processes to be used to produce the project's software. It also describes the plan to produce custom software and procure commercial software products.

- A **Hardware Development Plan** describes the organizational structure, facilities, tools, and processes to be used to produce the project's hardware. It describes the plan to produce custom hardware [if any] and to procure commercial hardware products.

- A **Technology Plan,** if needed, will describe the technical and management process to apply new or untried technology to an ITS use and will address performance criteria, assessment of multiple technology solutions, and fall-back options to existing technology.

- An **Interface Control Plan** identifies the physical, functional, and content characteristics of external interfaces to a system and identifies the responsibilities of the organizations on both sides of the interface.

- A **Technical Review Plan** identifies the purpose, timing, place, presenters and attendees, subject, entrance criteria, (a draft specification completed) and the exit criteria (resolution of all action items) for each technical review to be held for the project.

- A **System Integration Plan** defines the sequence of activities that will integrate software components into sub-systems and sub-system into entire systems. This plan is especially important if there are many sub-systems produced by a different development team.

- A **Verification Plan,** which is almost always required, is written along with the requirements specifications. However, the parts on test conduct can be written earlier in accordance with IEEE standards. The software verification and validation (V&V) processes will address guidelines for ensuring the development of products of a given activity conform to the requirements of that activity and whether the software satisfies its intended use and user needs. Software V&V processes considered will include analysis, evaluation, review, inspection, assessment and testing of software products.

- **Verification Procedures** are developed by the Development Team and defines the step by step procedure to conduct verification and must be traceable to the verification plan.

- An **Installation Plan or Deployment Plan** describes the sequence in which the parts of the system are installed / deployed. This plan is especially important if there are multiple different installations at multiple sites. A critical part of the deployment strategy is to create and maintain a viable operational capability at each site as the deployment progresses.

- An **Operations & Maintenance Plan** defines the actions to be taken to ensure that the system remains operational for its expected lifetime. It defines the maintenance organization and the role of each participant. This plan must cover both hardware and software maintenance.

- A **Training Plan** describes the training to be provided for both maintenance and operation.

- A **Configuration Management Plan** describes the development team's approach and methods to manage the configuration of the system's products and processes. It will also describe the change control procedures and management of the system's baselines as they evolve.

- A **Data Management Plan** describes how and which data will be controlled, the methods of documentation, and where the responsibilities for these processes reside.

- A **Risk Management Plan** addresses the processes for identifying, assessing, mitigating, and monitoring the risks expected or encountered during a project's life cycle. It identifies the risk management roles & responsibilities of all participating organizations.

- **Other plans** that might be included are a Safety Plan, a Security Plan, a Resource Management Plan and/or a Validation Plan.

C

Project Plan and SEA should be submitted to MDOT for approval along with Section C of the SE Process Compliance Checklist.

5.0 ITS Business Plan

The ITS Business Plan should provide a high-level overview of the ITS program being deployed by the LPA and should be based on a reasonable timeline. Funding sources should be identified. Grants and assistance should be applied for, if desired. No project should move forward until all funding sources are identified and obtained. It is at this point that the funding for systems operations and support is identified. The plan must include the funding for operations and maintenance for the life cycle of the equipment being procured. The ITS Business Plan will enable MDOT managers to properly allocate and/or shift constrained resources as priorities are refined and facilitate a means to track the overall progress of the ITS Program.

The ITS Business Plan was originally prepared at the Statewide program level and should be revisited and updated, as necessary, based on each project. If a project is identified to be absent from the plan, an evaluation should be performed to determine what impact the implementation of the current project will have on any future planned projects.

6.0 Technical Planning and Control

This section is intended to provide guidance on the work efforts and preparation of deliverables that are associated with the technical planning aspects of the SE process, which include the development of a project-level Concept of Operations, Requirements Development, High Level Design, Component Level Detailed Design, Hardware and Software Development, Integration activities, Verification and Validation, Operations and Maintenance, Changes and Upgrades, and finally, the development of a plan for System Retirement / Replacement.

A table summarizing the SE processes, activities that are involved, necessary reviews and analysis, associated deliverables, decision gates and applicable sections of the SE process checklist is located on the following page (**Table 6**) and should serve as a usable reference tool for each phase of the technical planning portion of the ITS project life cycle.

6.1 Concept of Operations

Submit ConOps for MDOT review.

Complete Part 8 of Section D of the SE Process Compliance Checklist.

The first step that the LPA should take in creating a project level ConOps should be to review the MDOT program level ConOps. The ConOps will explain the operations of all aspects of the ITS system, including functional requirements, user interfaces, system needs, and operational processes and scenarios. If the scope of the LPA's project is covered in the MDOT ConOps it is likely that the deployment of the project is already covered in an approved market package within the Architecture. MDOT Traffic Engineering will help the LPA with this review if required.

A project level ConOps should be developed and submitted to MDOT for approval. In many cases the project level ConOps will come directly from the MDOT ConOps. In general, the ConOps should define the following:

- The known elements and high-level capabilities of the system
- The geographical / physical extents of the system
- The timeline in which activities will be performed
- The necessary resources to design, build, or retrofit the system
- Which stakeholders are involved with the system
- The identified need that will be satisfied by the system

For general information on the development of a ConOps, please refer to *The Systems Engineering Guidebook for ITS* Web site.

Additionally, the USDOT ITS Joint Program Office has compiled a list of "Lessons Learned" on the ConOps, which can be found on their Web site.

Table 6: SEMP Requirements Summary – Technical Planning and Control of ITS Projects Using the SE Process

Systems Process Task	Activities / Work Products	Reviews and Analysis	Deliverables	Decision Gate	Applicable Part(s) of SE Process Checklist
PHASE 1 –> CONCEPT OF OPERATIONS and SYSTEMS REQUIREMENTS DEFINITION					
Concept of Operations	▪ Define/refine project vision, goals and objectives ▪ Explore project concepts ▪ Develop operational scenarios ▪ Plan validation strategy ▪ Plan operations and maintenance ▪ Develop and document project concept of operations	▪ Technical reviews support continuing communications with the stakeholders ▪ If an update to an existing project, identify the sections of the document that must be updated. At a minimum, scope, project phases, and schedule must be updated. ▪ Review meeting with Tier 1 stakeholders and approval of ConOps is required before proceeding	▪ *Concept of Operations,* including: ○ Validation strategy documentation ○ Preliminary O&M requirements documentation		Part 8
Requirements Development	▪ Develop requirements ▪ Write and document requirements ▪ Check completeness ▪ Analyze, refine & decompose requirements ▪ Validate requirements ▪ Develop verification plan ▪ Manage requirements ▪ Perform risk management	▪ Technical reviews should be used to identify defects, conflicts, missing, or unnecessary requirements. ▪ Only requirements derived from information in the concept of operations document are viable. ▪ If it is determined during requirements definition that additional requirements are needed that are not based on the ConOps, the ConOps document will need to be updated. ▪ Review meeting and approval of Requirements Document, Risk Management strategy and any changes to the ConOps is required before proceeding.	▪ System requirements baseline ▪ Requirements specifications documentation, including: ○ Verification Plan (system level) ○ Traceability Matrix (at a minimum, showing the requirement number, the requirement name and the section number in the concept of operations that supports the definition of the requirement.	▪ Concept of Operations Approval	Part 9

Systems Process Task	Activities / Work Products	Reviews and Analysis	Deliverables	Decision Gate	Applicable Part(s) of SE Process Checklist
PHASE 2 –> SYSTEM DESIGN					
High Level Design (Project Level Architecture)	▪ Develop, decompose and evaluate project architecture alternatives ▪ Identify and evaluate internal and external interfaces ▪ Evaluate industry standards ▪ Select and document the high level design ▪ Perform preliminary design review (PDR) ▪ Update SEMP ▪ Perform risk management	▪ Technical reviews support continuing communications with the stakeholders ▪ Preliminary design review – review of High Level Design Document by the System's owner and stakeholders	▪ High-level design documentation ▪ Sub-system requirements baseline ▪ Sub-system level verification plans ▪ Updated Traceability Matrix ▪ Integration Plan	▪ Design Approval	Part 10
Component Level Detailed Design	▪ Evaluate COTS products and application ▪ Perform detailed design ▪ Perform technical reviews ▪ Perform critical design review ▪ Update SEMP ▪ Perform risk management	▪ Technical reviews should be used to identify defects, conflicts, and missing detailed design requirements to ensure that the component design is addressing all of the sub-system requirements ▪ Critical Design Review (CDR) needs to be performed in accordance with the SEA requirements – this will be the final approval of the design before implementation ▪ Review meeting and approval of the Design Document and completion of any changes to the ConOps and the Requirements Document is required before proceeding with other project activities	▪ Component Detailed Design, including: ○ List of selected COTS products ○ Unit Level Verification Plans ○ Updated Traceability Matrix ○ Updated Integration Plan ▪ Component detailed design (build-to) specifications		Part 11

Systems Process Task	Activities / Work Products	Reviews and Analysis	Deliverables	Decision Gate	Applicable Part(s) of SE Process Checklist
PHASE 3 –> SYSTEM DEVELOPMENT, DEPLOYMENT and VALIDATION					
Hardware/ Software Development and Unit Test	▪ Support, monitor and review development ▪ Develop system products ▪ Coordinate concurrent development activities ▪ Procure COTS products and applications ▪ Perform risk and configuration management	▪ Technical reviews are used for the project management and technical progress of the development. ▪ If multiple concurrent developments are being performed, coordination meetings may be needed to keep projects synchronized. ▪ Unit Test Review Meeting -- provides an opportunity to identify design issues, review problem reports, and discuss the overall progress of implementation. Unit test can result in changes that impact design, requirements, or the ConOps. ▪ Changes to the Design Document, the ConOps, the Requirements documents, and test documents resulting from unit test activities must be completed and retest of problems that were identified is required before proceeding with integration activities.	▪ Hardware components ▪ Software components ▪ COTS products (these should only be procured at this time if they are needed immediately) ▪ Unit verification procedures ▪ Configuration Management Reports	▪ Development Approval	Part 12
Integration (Sub-System and System Level Integration)	▪ Plan integration activities ▪ Define integration activities ▪ Perform integration activities ▪ Perform risk and configuration management	▪ Subsystem Test Review Meeting - subsystem test plan, test scenarios, and testing schedule for the areas to be tested. ▪ All updates to documents must be completed a before the agency provides notice to proceed with subsystem test activities.	▪ Updated Integration Plans ▪ Integrated sub-systems and system ▪ Updated O&M Plans		Part 13

Systems Process Task	Activities / Work Products	Reviews and Analysis	Deliverables	Decision Gate	Applicable Part(s) of SE Process Checklist
Verification (Sub-System and System Level Integration)	▪ Plan verification activities ▪ Develop verification plan ▪ Trace between verification and requirements ▪ Perform verification ▪ Document results ▪ Perform risk and configuration management	▪ Technical reviews include a test readiness review to determine all resources needed for a verification step are available. ▪ Each test case should be traced to a specific requirement to ensure all requirements are verified.	▪ Verification Plan ▪ Verification Reports ▪ Verified sub-systems and system	▪ Development Approval	Part 13 F
Initial System Deployment	▪ Development deployment strategy ▪ Write deployment plan (optional) ▪ Perform deployment activities ▪ Perform system burn-in ▪ Perform risk and configuration management	▪ For each deployment step, progress should be monitored / reviewed with the deployment team on a regular basis. ▪ Acceptance Test Review Meeting - functional acceptance test results and confirmation that any problems have been addressed and successfully retested or re-inspected. Final review of all system documents and certification that training is complete (if applicable).	▪ Operational baseline ▪ Deployment Plan (optional) ▪ Deployed system		Part 14 F
PHASE 4 –> OPERATIONS & MAINTENANCE, CHANGES and UPGRADES					
System Validation	▪ Develop validation strategy ▪ Plan validation ▪ Validate system (assessment of the system)		▪ Updated validation plan (becomes part of final SEA) ▪ Validation Report	▪ O&M Plan Approval	Part 15 F
Operations and Maintenance	▪ Update operations and maintenance plans ▪ Secure funding for on-going operations and maintenance ▪ Collect O&M information ▪ Perform operations	▪ Review meeting with Tier 1 stakeholders on planned operations and maintenance procedures.	▪ Operations and Maintenance Plan		Part 16 G

Systems Process Task	Activities / Work Products	Reviews and Analysis	Deliverables	Decision Gate	Applicable Part(s) of SE Process Checklist
Changes and Upgrades	▪ Analyze needed changes and upgrades ▪ Reverse engineering ▪ Forward engineering (following the V development model) ▪ Update SEA and ConOps ▪ Perform configuration management	▪ Operations and maintenance activities require the support of the comprehensive systems documentation developed during the phases of the systems engineering process. ▪ Sound systems engineering documentation must be kept up to date in order to support on-going operations as well as replacement planning.	▪ Legacy system documented ▪ Updated system documentation any new capabilities	▪ O&M Plan Approval	Part 16 G
PHASE 5 –> SYSTEM RETIREMENT and REPLACEMENT					
System Retirement or Replacement	▪ Plan retirement / replacement ▪ Perform gap analysis (legacy system capabilities vs. needed capabilities) ▪ Evaluate cost of upgrade vs. replacement ▪ Develop replacement / retirement strategy		▪ Retirement / Replacement Plan ▪ Retirement / Replacement Decision	▪ Retirement / Replacement Plan	Part 17 H

Source: *Systems Engineering Guidebook for ITS, Version 2.0* (modified for this report)

6.2 System Requirements Development

The project level ConOps should be used to define functional requirements. Functional requirements are functional characteristics that shall include general and detailed requirements performance requirements (i.e., what is expected of the system, item, or material). Both upper and lower performance limits should be given. The functional requirements should match the needs of the stakeholders and be reviewed by them.

The System Requirements determine WHAT the system must do.

An evaluation of legacy systems should be performed and functional requirements should be developed. The evaluation of the legacy system should include an inventory of ITS devices currently in the field, an evaluation of the functionality of the existing Traffic Management Centers and the ITS network infrastructure. This requirements definition task should include development of high level system requirements, detailed system requirements as well as software functional requirements. System requirements should be compiled in a requirements database, which will facilitate a method for requirements traceability (see Section 6.3 for more information on traceability).

Requirements should be checked to ensure that they are:

- Necessary (trace to a user need)
- Concise
- Feasible
- Testable
- Technology Independent
- Unambiguous
- Complete (function fully defined)

NOTE: Once the requirements are approved they are recognized as the 'baseline'. Any change to this baseline will lead to cost and/or schedule changes (i.e., scope creep). It is imperative that approved requirements are complete and well-written.

6.3 Managing System Requirements (Traceability)

Section D of the SE Process Compliance Checklist should be completed and submitted to MDOT for review.

The SEA should define the extent of requirements traceability needed for the project. The purpose of traceability is to ensure that the stakeholder's needs and goals are addressed by the system requirements and that the requirements are fulfilled by the high level and component level design.

Traceability has been determined to be extremely valuable in the design and implementation of ITS systems. "When we start to invest significant resources in hardware and software development so further changes in requirements...start to get very costly in terms of budget and implementation time."[5]

If system requirements are not managed properly, you run the risk of serious cost over-runs due to various situations, such as:

- Figuring out which system components to change when requirements change
- Re-doing an implementation because you implemented to meet requirements that had changed and you didn't communicate to all parties
- Losing productivity when a component is replaced with a flawed version and you can't quickly revert back to a working state
- Replacing the wrong component because it couldn't be determined exactly which component needed to be replaced[4]

There are three important aspects of traceability, which are described below:

Pre-Requirements Specification (Pre-RS) Traceability

Pre-RS traceability should trace the user needs/requirements and concepts to the system requirements. By prioritizing the user needs/requirements, traceability enables the system requirements to inherit the priority of the user needs, which supports system requirements prioritization schemes.

Post-Requirements Specification (Post-RS) Traceability

Post-RS traceability activities should begin once a requirements baseline has been established and should include tracing system requirements through sub-system requirements, design, implementation and verification.

Traceability should enable the LPA/MDOT to determine if all requirements are being implemented and verified. When and if changes occur during system development, traceability should support the assessment of the impact to the technical, budget and schedule aspects of the project.

Post-Delivery Traceability

During operations and maintenance of the system post-delivery traceability is used to support the technical, budget and schedule impact assessments when changes and upgrades are needed, and extends into replacement and retirement of the system.

More detailed information on requirements traceability can be found in the following documents:

- *Systems Engineering Guidebook for ITS*
- *A Guide to Configuration Management for Intelligent Transportation Systems*

5 *A Guide to Configuration Management for Intelligent Transportation Systems,* Mitretek Systems, Inc., April 2002, p. 8, 9.

NOTE: In general, if there are less than one hundred requirements for a project, they can be tracked in a spreadsheet. But, for larger projects with more than one hundred requirements, a database-driven requirements management tool should be used. Appendix 8.2.5 of the *Systems Engineering Guidebook for ITS* contains a listing of requirements management tools that are currently on the market.

Requirements should be assigned hierarchical identification numbers (ID) so that they can be easily managed and sorted using a database. For example, all system-level requirements should be assigned an ID beginning with the letter "S" followed by a three digit number (e.g., S001, S002, S003).

The subsystem and component level requirements should be assigned an alpha-numeric identifier as well. For example, a dynamic message sign (DMS) subsystem requirement may be assigned DM01 and the component level requirement simply adds a letter to the end of the subsystem requirement ID (i.e., DM01C, where the "C" stands for the sign controller)).

Table 7: Sample Requirements Traceability Matrix

System ID	Subsystem ID	Component ID	Requirement Description	Design Spec Section	Test Reference
S001	DM01	DM01C	The controller for the DMS shall . . .	5.1.2	

6.4 High Level Design

The high level design may also be referred to as the 'Project Level Architecture'. The high level design should include logical architecture diagrams that show the required data flows between the existing and future system, define the sub-systems that need to be built, and identify the internal and external interfaces that need to be developed and their associated standards. The LPA will find many of these architecture diagrams in the statewide or regional architecture. In the unlikely event that a suitable diagram is not available for modification the national architecture is available. MDOT will assist the LPA or consultant with this task as necessary.

Basically, the high level design should identify the institutional agreement(s) and technical integration necessary to interface the project with other ITS projects and systems in Mississippi.

For more information on developing the high level design for an ITS project, refer to the *Systems Engineering Guidebook for ITS* Web site.

The high-level and component-level design should be submitted to MDOT for review along with Section E of the SE Process Compliance Checklist.

6.5 Component Level Detailed Design

Based on the detailed system requirements and high level design, the component level design should be prepared. The component level detailed design for the hardware, software, communications and databases should demonstrate how the components will meet the required functionality of the system. The LPA and their Consultant, if used, should review all MDOT specifications and use any that fit the system requirements.

Good configuration management makes use of widespread shared specifications and installation practices. It may be necessary for an LPA to change, modify or rewrite a specification for a particular application. This should be accomplished in close coordination with the Traffic Engineering Department and it should be the exception rather than the rule. If a new specification is developed under a project managed by MDOT, the Department reserves the right to adopt the specification as an MDOT specification.

6.5.1 Interface Control Development

Interface control is a key configuration management practice since the interfaces give the system leverage and access to stakeholders. The LPA should be aware of NTCIP communications protocols which are published. Every effort should be made to specify equipment which is NTCIP compatible. Communications message sets should be documented in sub-system specific Interface Control Documents.

6.6 Hardware and Software Development

This task involves the design of new ITS field devices and software, the review of current technical specifications as well as the development of new technical specifications for any new types of ITS devices. The specifications should include guidelines for acceptance testing and final inspections of individual devices as well as the complete field device system.

Software Design Development

The software system design should be developed and documented in a Software Design Document. Prior to using newly designed software, the LPA should research software packages already in use within the system or other ITS systems. Using mature software has proven to be a better option in most cases.

6.7 Integration and Verification

Integration is an iterative process that takes the hardware and software components and combines them into sub-systems sets which are then combined to form the overall system.

Plan Integration Activities

Integration planning includes developing the sequence in which the components of the system should be integrated, identifying the resources necessary to perform the activities, as well as the timeframe in which the activities are supposed to occur.

Define Integration Activities

The integration activities should be defined in the high level design / project level architecture.

Perform Integration Activities

Software / Field Device Unit Testing and Verification – This section checks the performance of the installed devices against the detailed component level design. Tests should include functional tests of each component / sub-system, acceptance tests of each sub-system, and system tests of the entire ITS system. Consideration should be given to include a bench test of each item prior to installation.

Integration (System and Sub-system) – The installation and integration of all ITS field devices must be reviewed and all ITS field components must be inspected to ensure that the devices are installed according to the project plans and specifications.

Verification (System and Sub-system) – The verification of the system or sub-system checks the performance of the equipment against the requirements and architecture. The equipment must do what was envisioned during the definitions phases. The questions to be answered are: "Have the stakeholders received the capabilities they asked for, and was the equipment installed correctly?"

6.8 System Deployment

The complexity of the system deployment will depend on the complexity of the system itself as well as the number of stakeholders that are involved.

A written deployment strategy may be necessary for complex systems with a large number of deployment steps and should include the following items:

- Deployment schedule
- Needed support facilities for the deployment, such as the electrical, communications infrastructure, personnel training, etc…
- Stakeholder activities that need to be coordinated
- Stakeholder consensus for the deployment plan

The MDOT / LPA should monitor the progress during each step in the deployment process.

Complete and submit Section F of the SE Process Compliance Checklist to MDOT for review.

6.9 System Validation

The validation of the system or sub-system checks the performance of the equipment against the requirements and architecture. The equipment must do what was envisioned during the definitions phases.

The questions to be answered are: "Have the stakeholders received the capabilities they asked for, and was the correct equipment selected?"

It can only be determined if the system meets the stakeholder's needs through the validation process

A written validation plan may be necessary for complex systems and should identify what needs to be validated, where the validation needs to take place, and when it should happen. This validation plan may be required as part of the SEA process.

In order to begin the validation process, the procuring agency should have an accepted and deployed system. The functionality and performance of the system should be validated against the needs and goals as they were stated in the ConOps.

6.10 Operations and Maintenance / Changes and Upgrades

This task begins once the ITS system has been deployed and is fully operational but has been planned for since the development of the System Requirements. No ITS project shall be permitted to be deployed without the system O&M requirements being fully addressed, planned and funded.

6.10.1 Plan Operations and Maintenance

The O&M aspects of the system should be defined during the ConOps development.

The complete O&M Plan should:

- Identify funding and policies supporting on-going O&M;
- Identify the aspects of the system needing O&M;
- Identify the manuals [users, administrators, and maintenance], configuration records, and procedures that are to be used in O&M;
- Identify the personnel who will be responsible for O&M;
- Identify initial and on-going personnel training procedures, special skills, tools, and other resources;
- Identify O&M related data to be collected and how it is to be processed and reported; and
- Identify methods to be used to monitor the effectiveness of O&M.

6.10.2 Secure Operations and Maintenance Funding

The involved agency or agencies should secure funding for operations and maintenance for the parts of the system for which they are responsible. The maintenance and operations philosophy must be fully thought out early in the process. The capability of the MDOT / LPA to operate and maintain the system is critical to the successful deployment of an ITS system. If the MDOT / LPA cannot obtain the necessary skill sets in funded positions the use of contracted maintenance and operations should be considered.

Many agencies have successfully deployed systems with a mix of contract and agency personnel. Each situation is different and different solutions are acceptable. The procuring agency shall submit a detailed O&M Plan to MDOT prior to the submittal of the PAR.

No PAR shall be approved for ITS projects without a long term viable plan for maintenance and operations.

> **G**
>
> Submit O&M Plan to MDOT for approval along with Section G of the SE Process Compliance Checklist.

6.10.3 Collect Operations and Maintenance Information

The types of O&M information that should be collected throughout the operational life of the system should include a record of any disruption of service of the system, measure taken to repair the system, down time of the system as well as the time to make the repair.

6.10.4 Changes and Upgrades

Inevitably, technology and stakeholder needs will evolve over time. Some upgrades may be planned from the initial system deployment but changes will take place that were not planned. In order to maintain the integrity of the system, the system documentation must be accurate in terms of the system's functional, performance and enabling products.

> **H**
>
> Submit a Retirement Replacement Analysis to MDOT for review along with Section H of the SE Process Compliance Checklist.

6.11 System Retirement and Replacement

The involved agencies should plan for the retirement of the system and determine how to transition to the system replacement.

It should be determined, using cost benefit analysis, whether upgrading the legacy system or procuring a new system would be more cost effective. One important component to consider is the cost of O&M for both the upgraded legacy system as well as the new system. It should also be noted that if a new system is procured, the SE process should be followed.

7.0 References

The following is a list of reference documents used in creating this report:

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2. Caltrans and FHWA. January 2, 2007, Version 2.0. *Systems Engineering Guidebook for ITS*.

3. FHWA. October 2006. *Mississippi ITS Systems Engineering Process Improvement Review: Final Report and Recommendations*.

4. FHWA. October 2006. *Mississippi ITS Systems Engineering Process Improvement Review: Supporting Information*.

5. FHWA and FTA. January 2007. *Systems Engineering for Intelligent Transportation Systems: An Introduction for Transportation Professionals*.

6. Marshall, Kenneth R., and Philip J. Tarnoff. 2006. *NCHRP Report 560: Guide to Contracting ITS Projects*.

7. Mitretek Systems, Inc. April 2002. *A Guide to Configuration Management for Intelligent Transportation Systems*.

8. PBS&J. March 7, 2005. Florida's Statewide Systems Engineering Management Plan.

9. PBS&J. September 29, 2006, Version 4. Technical Memorandum, Supplement for Florida's Statewide Systems Engineering Management Plan – Writing a Project Systems Engineering Management Plan.

10. Siemens ITS. February 14, 2006, Version 1.0. STARNET Systems Engineering Management Plan.

11. URS Corporation, and Gresham, Smith and Partners. December 5, 2006, Draft. *Mississippi Statewide Intelligent Transportation Systems Architecture*.

APPENDIX A

SE Process Compliance Checklist