CHAPTER 8

INTELLIGENT TRANSPORTATION SYSTEMS

8.0 INTRODUCTION

This Chapter of the Tennessee Department of Transportation Traffic Design Manual will be used to address policies, guidelines, standard procedures, etc. related to Intelligent Transportation Systems (ITS) and the Systems Engineering Analysis (SEA) documentation.

TDOT's Intelligent Transportation System is referred to as the TDOT SmartWay. It is designed to reduce traffic congestion by decreasing incident clearance time, increase safety by decreasing the number of secondary accidents, and, working alongside our incident management program (HELP), improving emergency response to traffic situations. TDOT SmartWay uses cameras to monitor the highways from Traffic Management Centers, sensors to gauge traffic flow, large electronic message signs to send urgent traffic notices to drivers along the highways and the Highway Advisory Radio system to alert motorists of important information. Nashville, Knoxville, Memphis, and Chattanooga have fully integrated TDOT SmartWay systems.

TDOT SmartWay advanced information technologies take many forms such as:

Roadway Traffic Sensors to report traffic counts, speed and travel time;

Camera Video Surveillance to monitor freeway traffic flows and provide improved incident management capabilities;

Dynamic Message Signs to provide real-time traffic, construction, and weather information to motorists, as well as provide information on Amber Alerts;

Highway Advisory Radio to provide urgent real-time traffic, construction, and weather information to motorists via AM radio, as well as provide information on Amber Alerts;

HELP Freeway Service Patrols to reduce congestion by removing minor incidents in a timely fashion;

Transportation Management Centers (TMC) serve as a central location for traffic management operations and communications in their respective Regions;

Incident Management to detect, verify, and respond to incidents in an efficient manner and manage traffic conditions around the incident site;

Construction Information is provided to advise motorists traveling through construction sites;

TDOT SmartWay Information System (TSIS) is a system communicating data from TDOT SmartWay devices to a central location and distributing that transportation information to motorists and other interested parties before and while making trips. Information is distributed via TDOT's Web site and through the media. TDOT also provides motorist information on Tennessee 511, a component of TDOT SmartWay.

Information on Weather-Related Road Conditions informs travelers where problems may exist on any state road due to severe weather conditions.

While the potential of ITS is significant, deployment and operation of these systems requires specialized coordination, design, device specifications, procurement / construction, operations management, and maintenance. The TDOT Design Division shall provide implementation plans for ITS and policies for ITS operation.

8.1 23 CFR 940 COMPLIANCE

8.1.1 INTRODUCTION AND SCOPE

These requirements apply to Federal Aid projects, as required by Federal Highway Administration, Department of Transportation 23 CFR Part 940. State-funded projects will follow the same process for consistency.

In accordance with 23 CFR 940, ITS projects funded through the highway trust fund shall conform to the National ITS Architecture and applicable standards. 23 CFR 940 also stipulates that "conformance with the National ITS Architecture is interpreted to mean the use of the National ITS Architecture to develop a Regional ITS Architecture, as applicable, and the subsequent adherence of all ITS projects to that Regional ITS Architecture." This chapter outlines the TDOT procedures for implementing these requirements. The level of documentation should be commensurate with the project scope.

8.1.2 GENERAL CRITERIA

In accordance with 23 CFR 940.3, an ITS project is "any project that in whole or in part funds the acquisition of technologies or systems of technologies that provide or significantly contribute to the provision of one or more ITS user services as defined in the National ITS Architecture". Any reference to the ITS Architecture in this document refers to Statewide and Regional Architectures. Documentation for ITS Projects classified as High Risk, as defined in section 8.1.3, should be completed by staff with qualified ITS experience.

In Tennessee, a project would be considered to be an ITS project if it meets any of the following:

- It requires the integration of multiple separate systems;
- It is a project that has significant potential to involve the integration of technologies on a multi-jurisdictional level;

- It replaces existing or installs new centrally controlled software.

ITS Projects may be either High Risk, Low Risk, or Exempt ITS Projects. The SEA development process is different for each category.

The following describes the categories of ITS projects in Tennessee: **High Risk, Low Risk,** and **Exempt**. The decisive factor in this determination is the scale and complexity of the project. Traffic Signal projects are the most common scale sensitive projects. The nature of the engineering development for ITS projects implies a greater risk and uncertainties to successful completion. Project risk may be defined in terms of schedule, cost, quality, and requirements. These risks can increase or decrease significantly based on several identified factors associated with ITS projects.

The factors are:

- Number of jurisdictions and modes;
- Extent of software creation;
- Extent of proven hardware and communications technology used;
- Number and complexity of new interfaces to other systems;
- Level of detail in requirements and documentation;
- Level of detail in operating procedures and documentation;
- Service life of technology applied to equipment and software.

Generic criteria for the determination of risk are shown in the list below.

- Technology: functions are not fully identified, user interface not right, unrealistic technical requirements, component shortcomings;
- People: personnel shortfalls;
- Physical Environment: external dependencies, device placement;
- Political Environment: adding requirements that are not tied to a need, do you have a champion;
- Contract Issues: unrealistic schedules and budgets, requirements change;
- Additional Risk Factors are shown in Table 8.1.

8.1.3 HIGH RISK ITS PROJECTS

A High Risk ITS project is an ITS project that implements part of a regional ITS initiative that is multijurisdictional, multi-modal, or otherwise affects regional integration of ITS. Multi-jurisdictional does not necessarily mean that a project with termini in more than one city is High Risk ITS. The key criteria is “Regional ITS initiative.”

High Risk ITS projects have ***one*** **(or more)** of the following characteristics:

- Multi-Jurisdictional or Multi-modal;
- Custom software is required;
- Hardware and Communications are “cutting-edge” or not in common use;

- New interfaces to other systems are required;
- System requirements not detailed or not fully documented;
- Operating procedures not detailed or not fully documented;
- Technology service life shortens project life-cycle.

The following are examples of High Risk ITS projects:

- TDOT SmartWay (if additional functionality is to be added);
- Traffic Signal systems scoped to be centrally controlled (Closed loop systems are NOT central control systems);
- Traffic signal projects that require the integration of signal systems with TDOT SmartWay, an Arterial Management System, or RWIS systems;
- An ITS system that involves multiple political jurisdictions;
- Regional Transit Systems;
- Transit Signal Priority Systems.

8.1.4 LOW RISK ITS PROJECTS

Low-Risk ITS projects are often referred to as ITS infrastructure expansion projects.

Low Risk ITS projects will have ***all*** of the following characteristics:

- Single jurisdiction and single transportation mode (highway, transit, or rail);
- No software creation – commercial-off-the-shelf (COTS) or proven software;
- Proven COTS hardware & communications technology;
- No new interfaces;
- System requirements fully detailed in writing;
- Operating procedures fully detailed in writing;
- Project life-cycle not shortened by technology service life.

The following are examples of Low Risk ITS projects:

- Traffic signals with emergency vehicle preemption;
- Roadway Weather Information System (RWIS);
- Parking Management Systems;
- Various surveillance or control systems that could functionally be integrated into a Freeway Management System;
- Expanding existing communications systems – this consists of extending existing fiber-optic or wireless communications systems, using the same technology and specifications as the preexisting system;
- Leasing turnkey services only (e.g., website-based information service) – with no hardware or software purchases.

8.1.5 EXEMPT ITS PROJECTS

Exempt ITS projects do not require a Systems Engineering Analysis (SEA). All activities of the traditional roadway project development life-cycle process will be followed. No further ITS-specific action is necessary.

Exempt ITS projects can be classified into two categories:

- An exempt ITS project is one that does not use federal funding;
- ITS System expansions that do not add new functionality. In other words, a project that by itself may have been considered high or low risk, but if the scope of the project simply expands this system it can be considered Exempt.

The following are examples of Exempt ITS projects:

- Upgrades to an existing traffic signal – This may include, for example, adding or revising left turn phasing or other phasing, adding pedestrian-crossing displays;
- Installing an "isolated" traffic signal – This is a signal not connected to any type of external signal-control system, nor likely to be in the future because of its isolation;
- The project adding new intersections could be considered Exempt because it is an expansion of an existing system within the same jurisdiction with no new functionality.
- A signal interconnect project that uses existing software and is on an isolated corridor connecting multiple signals;
- Traffic signal timing projects – This includes all "studies" whose purpose is to change the coordination parameters for controlling a group of signals – but with ***no*** installation of new hardware or software;
- A project to add DMS devices to SmartWay with existing DMS devices could be considered an Exempt project;
- Studies, Plans, Analyses – This includes ITS Master Plans, Deployment Plans, Technology Studies, etc. whose product is only a document, with no new hardware of software installed;
- Routine Operations – This includes operating and maintaining any ITS elements or systems – again with no new hardware or software installed.

	Low-Risk Project Attributes	High-Risk Project Attributes	Risk Factors
1	Single jurisdiction and single transportation mode (highway, transit or rail)	Multi-Jurisdictional or Multimodal	With multiple agencies, departments, and disciplines, disagreements can arise about roles, responsibilities, cost sharing, data sharing, schedules, changing priorities, etc. Detailed written agreements are crucial!
2	No software creation; uses commercial-off-the-shelf (COTS) or proven software	Custom software development is required	Custom software requires additional development, testing, training, documentation, maintenance, and product update procedures - all unique to one installation. This is very expensive, so hidden short-cuts are often taken to keep costs low. Additionally, integration with existing software can be challenging, especially because documentation is often not complete and out-of-date.
3	Proven COTS hardware and communications technology	Hardware or communications technology are “cutting edge” or not in common use.	New technologies are not “proven” until they have been installed and operated in a substantial number of different environments. New environments often uncover unforeseen problems. New technologies or new businesses can sometimes fail completely. Multiple proven technologies combined in the same project would be high risk if there are new interfaces between them.
4	No new interfaces	New interfaces to other systems are required.	New interfaces require that documentation for the “other” system be **complete and up-to-date.** If not (and often they are not), building a new interface can become difficult or impossible. Duplication of existing interfaces reduces the risk. “Open Standard” interfaces are usually well-documented and low risk.
5	System requirements fully detailed in writing	System Requirements not detailed or not fully documented	System Requirements are critical for an RFP. They must describe in detail all of the functions the system must perform, performance expected, plus the operating environment. Good requirements can be a dozen or more pages for a small system, and hundreds of pages for a large system. When existing systems are upgraded with new capabilities, requirements must be revised and rewritten.
6	Operating procedures fully detailed in writing	Operating procedures not detailed or not fully documented	Standard Operating Procedures are required for training, operations, and maintenance. For existing systems, they are often out-of-date.
7	None of the technologies used are near end of service life	Some technologies included are near end of service life	Computer technology changes rapidly (e.g. PC’s and cell phones become obsolete in 2-4 years). Local area networks using internet standards have had a long life, but in contrast some mobile phones that use proprietary communications became obsolete quickly. Similarly, the useful life of ITS technology (hardware, software, and communications) is short. Whether your project is a new system or expanding an existing one, look carefully at **all** the technology elements to assess remaining cost-effective service life.

Table 8.1
Risk Assessment for ITS Projects

8.2 ARCHITECTURE

8.2.1 GENERAL

In areas served by a Planning Organization, the Planning Organization needs to identify potential Highway ITS projects to TDOT when reviewing local programs for inclusion in the TIP. A preliminary risk assessment will be made at the time of this identification. This information shall be documented in the **Tennessee ITS Project Identification Checklist**, which will be submitted to TDOT. It shall be the responsibility of TDOT to validate if a project is ITS, and if so, to verify the in preliminary risk assessment provided in the checklist. If the determination of whether a project is ITS or Exempt, or whether a project is a High Risk ITS Project or a Low Risk ITS Project is not obvious, the project shall be discussed with the TDOT Design Division to make a determination. TDOT will notify the Planning Organization and the project sponsor of the determination in writing.

A High Risk ITS Project will require a comprehensive effort that analyzes several options for each type of technology selected, since these types of projects tend to be multifaceted. Generally, there are several elements that need to be evaluated and more options are analyzed in a High Risk ITS Project. If a consultant is used for an ITS Project, these efforts should be included in the consultant's Scope of Work..

In areas not served by a Planning Organization, the TDOT Long Range Planning Office representative will perform the ITS project identifying function. This identification will be made with the **Tennessee ITS Project Identification Checklist**. TDOT will notify the project sponsor of the determination in writing.

8.2.2 ARCHITECTURE CONFORMITY

To ensure conformity with **23 CFR 940**, several requirements must be met. The rule stipulates that conformance with the National ITS Architecture is interpreted to mean the use of the National ITS Architecture to develop a Regional ITS Architecture, and the subsequent adherence of all ITS projects to that Regional ITS Architecture.

According to **23 CFR 940.3**, a Regional ITS Architecture is "a regional framework for ensuring institutional agreement and technical integration for the implementation of ITS projects or groups of projects." It documents data flows and subsystems, roles and responsibilities, operating agreements, and ITS standards to be used for a particular region. In Tennessee, Regional ITS Architectures generally encompass a Planning Organization area. A Statewide ITS Architecture is a form of a Regional ITS Architecture. Tennessee has a Statewide ITS Architecture that was completed in December, 2005. Completed Regional ITS Architectures in Tennessee include Chattanooga, Knoxville, Clarksville, Jackson, Cleveland, Bristol, Kingsport, Johnson City, Memphis, and Nashville.

8.2.3 PROJECT LEVEL ITS ARCHITECTURE

A Project Level ITS Architecture, according to **23 CFR 940.3** is a framework that identifies the institutional agreement and technical integration necessary to interface an ITS project with other ITS projects and systems. The Project Level ITS Architecture indicates the data flows and subsystems that the project will implement. To achieve the significant benefits derived from the documentation, Project Level ITS Architectures needs to be developed for all ITS Projects. The project architecture is especially useful in higher risk projects that are implementing new aspects of a region's ITS architecture.

8.2.3.1 FOR PROJECTS WHERE A REGIONAL OR STATEWIDE ITS ARCHITECTURE EXISTS

If an ITS project falls within the boundaries of a Regional or Statewide ITS Architecture, the Project Level ITS Architecture should be developed as follows:

1.) If the project functions exist in the Regional or Statewide ITS Architecture: create a table of references identifying the data flows that will be addressed by the project. This will satisfy the requirements for a project Level ITS Architecture.

2.) If some project functions do not exist in the Regional or Statewide Architecture: The Project Level ITS Architecture must supplement the Regional or Statewide ITS Architecture with any missing data flows. Create a table of references identifying the data flows that will be addressed by the project and add the additional data flows that will be implemented. The Planning Organization maintaining the Regional ITS Architecture or TDOT for the Statewide Architecture also needs to be notified of the changes, for purposes of updating the ITS Architecture.

3.) If none of the project functions exist in the Regional or Statewide ITS Architecture: A Project Level ITS Architecture shall be created utilizing the Regional or Statewide ITS Architecture and the National ITS Architecture as the basis. The Planning Organization maintaining the Regional ITS Architecture or TDOT for the Statewide Architecture shall be notified of the changes, for purposes of updating the ITS Architecture.

The final design of all ITS projects shall accommodate the interface requirements and information exchanges as specified in the Regional or Statewide ITS Architecture. If the final design of the ITS project is inconsistent with the Regional or Statewide ITS Architecture, then the discrepancies shall be reconciled and the ITS Architecture or the project shall be modified as appropriate.

8.2.4 INTERFACING WITH PLANNING AND THE ITS ARCHITECTURE

Intelligent Transportation Systems at the project level are to be consistent with, and leverage from, the ITS architecture. The ITS architecture provides a framework that supports transportation planning and programming for ITS projects. This step describes what to expect from the ITS architecture and how to use the products at the project level. An existing ITS architecture provides products / elements that can be leveraged for concept exploration, feasibility analysis, and project level developments.

Before the project level development begins, groundwork is laid in the planning process and the development of an ITS architecture. The ITS architecture includes a list of stakeholders, a system inventory, an identification of the needs and transportation services that meet those needs, a high-level operational concept, functional requirements, and interconnections and information exchanges. The project will refine and expand products from the ITS architecture. For example, it may expand an agency-level stakeholder to identify maintenance, IT, and operations divisions that were not specified at the regional or statewide level. As the project is defined, additional needs and approaches may be identified that were not envisioned at the regional or statewide level. Providing feedback to the planning process and the ITS architecture is essential so that the ITS architecture continues to provide an accurate high-level depiction of ITS implementation and vision for the region.

Tennessee has developed Architectures. These architectures provide a good starting point for project development and must be used to support project systems engineering analysis, per the FHWA Rule / FTA Policy. In some cases, more than one ITS architecture may apply. For example, a major metropolitan area may be included in a statewide architecture, a regional architecture for the metropolitan area, and sub-regional architectures that are developed for a particular agency or jurisdiction. Identify the ITS architecture that applies to the project, coordinating with the architecture maintainers in the region as necessary. Coordinate with the TDOT Design Division, the Planning Organization or architecture maintainer, to take advantage of all previous work that has been done.

Any given ITS project will implement only a small subset of the ITS architecture. The ITS architecture will most likely address many needs and issues that are outside the scope of the project. For example, in a simple signal system that does not interface with freeway devices, the aspects of the ITS architecture that address freeways are not relevant. The first step is to identify the portion of the ITS architecture that applies to the project. Using this subset of the ITS architecture, document any constraints that the architecture may place on the design, including ITS standards that are identified that may be applicable to the project.

Using an ITS architecture will provide a project that is consistent with other systems in the area, meets requirements for federal funding, and can be developed more efficiently and quickly using the ITS architecture content to get started. A good ITS architecture will provide region-level information that can be used and expanded in the project development, providing a good starting point for concept exploration and initial project development.

Confirm that the project fulfills a portion of the ITS architecture. If the project provides capabilities beyond the ITS architecture, the ITS architecture should be updated to more accurately reflect the ITS project. These changes should be submitted to the maintainer of the architecture.

8.3 SYSTEMS ENGINEERING ANALYSIS (SEA)

8.3.1 GENERAL

Systems engineering is a systematic process that was developed specifically for complex technology projects. Systems engineering processes are required on all highway trust fund projects, as noted in 23 CFR 940.11. Systems engineering processes shall be used on all ITS projects regardless of the funding source.

Systems Engineering is a process-oriented means of deploying a system that leads to reduced risk, controlled cost and schedule, improved system quality, and a resultant system that meets user needs.

Using systems engineering on ITS projects has been shown to increase the likelihood of project success. Projects that are completed on-time and on-budget meet stakeholder / project sponsor expectations, and are efficient to operate and maintain.

There are multiple ways to represent the systems engineering process. One way, the Systems Engineering "V" Diagram (refer to Figure 8.1), represents the typical life cycle of any system or project. Whether the system being deployed consists of a basic computer-aided dispatch (CAD) system for a transit agency, or a more complex interface between a traffic management center and a public safety agency, all systems will follow some variation of this life cycle.

This process is shown as it relates to the traditional Project Development Process. As shown in the figure, the systems engineering process contains a number of stages that are not included in the traditional project delivery process.

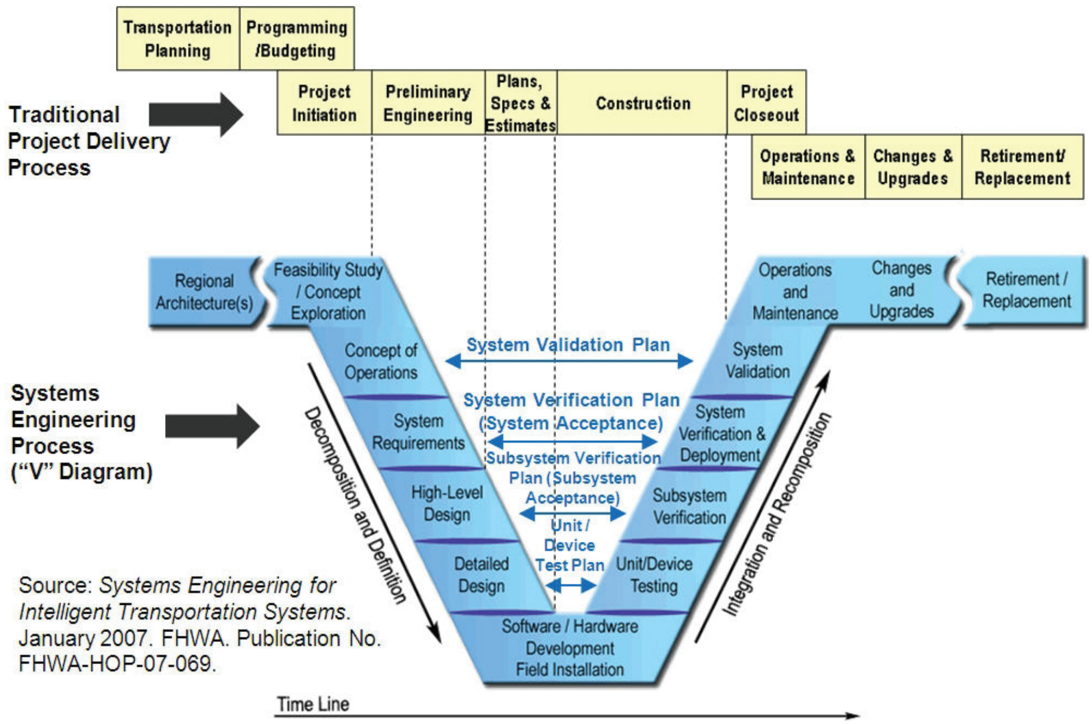

Figure 8.1 – Systems Engineering in Relation to the Project Development Process

Stage 1: Concept of Operations – The manner in which the system will be used is defined.

Stage 2: Requirements – High-level and detailed requirements define what the system will do.

Stage 3: Design – High-level and detailed specifications define how the system will meet the requirements.

Stage 4: Implementation – The components are built or deployed.

Stage 5: Integration & Testing – As each component of the system is completed, it is integrated into the overall system and tested to ensure that the specifications are satisfied.

Stage 6: System Verification – also called acceptance testing; this step ensures that the overall system is consistent with the design, and that it meets the requirements.

Stage 7: Operations & Maintenance – This stage represents the ongoing process of using the system in the manner in which it was intended (and validating that it can be used in this way) and maintaining the system.

An ITS project begins in the upper left side of the "V" diagram and progresses down the "V" and up the right side. Upon reaching the upper right corner, reverse the process to ensure the project being completed meets the initial requirements.

During the “Component Level Design,” specific subsystems and / or components (such as wireless communications, variable message signs, cameras, roadway weather information systems, highway advisory radio systems, or software) should be identified as requiring specialized knowledge and skills. These issues are to be coordinated between the Project Engineer and the TDOT Design Division.

Construction oversight and approvals are addressed in the systems engineering process as you validate / verify the right side of the “V” diagram with the left side. The key to successful construction oversight is traceability. Trace each step on the right side of the “V” diagram back to a requirement on the left side.

Completing the TDOT SEA Form (available on the TDOT Design Division website as outlined in Section 8.3.4.) will fulfill the minimum requirements for a project. However, the level of systems engineering used for a project should be on a scale commensurate with the scope, size, and risk of the project. High-risk ITS projects (such as developing a new custom software system for sharing control of traffic signal systems across multiple agencies) should follow and document each step of the “V” diagram by completing the Systems Engineering Management Plan.

Include all ITS systems engineering documentation in the Design Documentation Package. All systems engineering documentation requires TDOT Design Division approval. As each phase of an ITS project is completed, the SEA document is to be submitted to the TDOT Design Division.

Systems engineering costs are to be estimated and incorporated into the construction engineering (CE) and preliminary engineering (PE) portions of the construction estimate.

Since the SEA documentation is a “living document” as the project progresses, early stages of the documentation shall be updated and submitted with the current submission.

8.3.2 LEVEL OF DOCUMENTATION

The figure below outlines the procedures that should be followed in identifying the level of documentation necessary to meet the requirements for compliance.

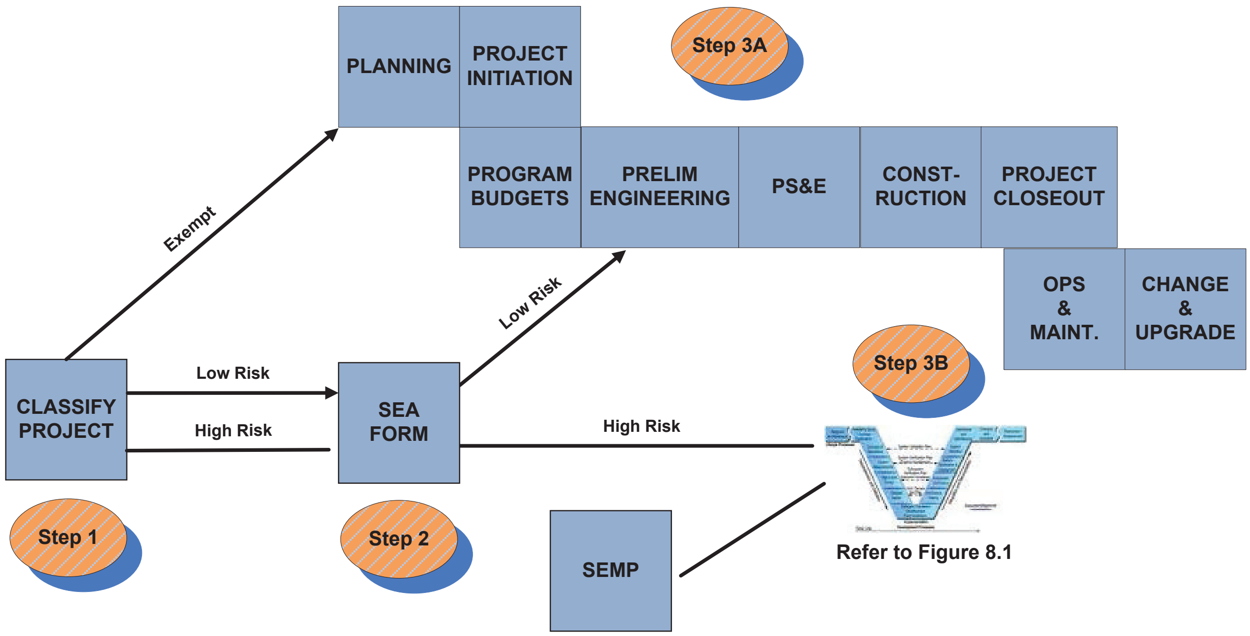

Figure 8.2 – Steps to ITS Compliance

Step 1

All ITS projects must be listed on the STIP / TIP prior to obligation of funds. However, many ITS projects are not required to be listed individually, since they are classed as air quality exempt. Such projects may be lumped together in the program. If a traditional roadway design project contains an ITS element, then the requirement for STIP / TIP listing is determined by the overall project.

Because of this variation in project classification, projects with ITS elements may not be identified. For this reason, the Planning Organization is encouraged to coordinate with the TDOT Design Division (project sponsors) to “flag” ITS projects, or at least note the High-Risk ITS projects, within their STIP submittal to TDOT / FHWA.

By using the guidelines contained in this chapter the TDOT Design Division will make a preliminary classification of the project’s risk as exempt, low, or high.

If the project is considered Exempt, then all activities of the traditional roadway project development life-cycle process will be followed. Exempt projects are not considered “ITS” for purposes of these procedures and no further ITS-specific action is necessary.

Step 1 occurs when the ITS project is added to the Transportation Improvement Program (TIP). The Design Division makes a preliminary classification of the project as High-Risk, Low-Risk, or Exempt. If the project is Exempt, then the remainder of the process is exactly the same as for a traditional road building project. Low-Risk and High-Risk projects proceed to Step 2.

Step 2

This step occurs when initial funding is requested. The Project Manager must fill out applicable sections of the Systems Engineering Analysis Form, which consists of 12 questions. This Form is available on the TDOT Design Division website as outlined in Section 8.3.4. Based on the level of detail, the project is classified as Low-Risk or High-Risk, then proceed accordingly.

Step 3a

For Low-Risk projects, the remainder of the process (after FHWA approval) is exactly the same as for a traditional road building project. However, as the project progresses all remaining undocumented questions shall be completed.

Step 3b

For High-Risk projects, the traditional road building process is not appropriate. Instead, the best approach is usually a Systems Engineering process. This is definitely the case for projects that include software development. A Systems Engineering Management Plan (SEMP) must be completed during the first funding cycle to help manage the implementation and testing. A sample template, along with a checklist, is available on the TDOT Design Division website as outlined in Section 8.3.4.

The required SEA documentation and information to be included at the appropriate Plans Submittal stage are outlined below:

a. Preliminary SEA Document
    i. Submitted during conceptual phase
    ii. Includes SEA Items 1 thru 4
b. 30% SEA Document
    i. Includes SEA Items 1 thru 4 and 10
c. 30% Plans
    i. Preliminary device locations
    ii. Communication alternatives
    iii. Possible power service locations
    iv. Sufficient right-of-way (ROW) to make a determination of proposed location
    v. Utility providers identified
d. 60% SEA Document
    i. Includes SEA Items 1 thru 7 and 10
e. 60% Plans
    i. Survey completed

ii. Detailed survey and device placement
iii. Communication and electric routing shown
iv. ROW determined
v. Bucket truck surveys completed
vi. Ongoing utility coordination
vii. Typical and communication details developed
viii. Utility conflicts identified
ix. Permit review information compiled
x. Erosion control plan
xi. Preliminary estimate in electronic format

f. 90% SEA Document
   i. Includes SEA Items 1 thru 12
   ii. Change management document outlining changes through prior phases

g. 90% Plans
   i. Final details
   ii. Final communication plans
   iii. Final items and quantities
   iv. Final special provisions
   v. Final bid documents

All ITS projects shall be based on a Systems Engineering Analysis (SEA). The scale of the analysis should be on a scale commensurate with the project scope of the ITS portion of the project.

An SEA is a process or a structured approach which can control costs, lead to reduced risks, maintain the project schedule, satisfy user needs, and meet the requirements of TDOT and the Federal regulation. The SEA effort will vary based on the complexity of the project and the type of ITS project.

An SEA will provide a description of the scope of the ITS project (the general location, conceptual alternative, and logical termini or service area of the proposed project), a concept of operations that identifies the roles and responsibilities of participating agencies and stakeholders in the operation and implementation of the ITS project, functional requirements of the ITS project, interface requirements and information exchanges between the ITS project and other planned and existing systems and subsystems, and identification of applicable ITS standards.

The SEA is broken into twelve items to be addressed. The twelve items are discussed in **Section 8.3.3.1 Required Systems Engineering Analysis Documentation for Low Risk and High Risk Projects**.

8.3.3 ITS STANDARDS IN THE SYSTEMS ENGINEERING PROCESS

National ITS Standards are primarily used in the design stage of the systems engineering process, after a high-level design (project architecture) has been developed. During the detailed design phase, specific messages, data elements, communications profiles, and design options are defined.

The systems engineering process is used during the development of ITS standards, as well. Some standards include sections which document this process to help ITS deployers with interpreting and using the standard. For example, the concept of operations developed for an ITS standard may help ITS project designers to conceptualize how messages might be exchanged between systems, such as the order in which control information is sent to a field device and the type of status returned. Additionally, the high-level and detailed requirements developed for an ITS standard might be used to create system functional requirements that could also be used later during system verification.

Standards can be included in a procurement specifications by documenting all of the standards applicable to the ITS systems deployment. You must also specify the definitions, references, options, and requirements, where applicable, for each standard to be used in the system. The procurement specifications will also include the standards conformance and acceptance tests that the systems must pass. Vague statements to the effect that the systems must be "ITS standards compliant" or must "conform to" specific standards are not sufficient. Resources that can be used for assistance with procurement specifications are:

- The NTCIP Guide available at:
  http://www.ntcip.org
- USDOT's ITS technical assistance resources available at:
  http://www.standards.its.dot.gov/deploy_Technical.asp

8.3.3.1 REQUIRED SYSTEMS ENGINEERING ANALYSIS DOCUMENTATION FOR LOW RISK AND HIGH RISK PROJECTS

All submissions required by the TDOT Project Development Process shall also be required for ITS projects. A Project Level ITS Architecture and a Systems Engineering Analysis (SEA) are required for any ITS project, whether High Risk ITS or Low Risk ITS. The documentation will be more extensive for High Risk ITS projects than for Low Risk ITS projects, and is expected to be commensurate with the scope of the ITS work. Both the Project Level ITS Architecture and the SEA must be completed and approved prior to authorization of construction funding. The SEA will consist of items 1 through 12, listed below. A SEA Form is available on the Design Division website as outlined in Section 8.3.4.

SEA Item #1 – Define the scope of work for the project (PIN#, State / Federal Project #, the general location, conceptual alternative, level of development and logical termini or service area of the proposed project). Scoping shall also include inter-agency coordination and possible effects on neighboring jurisdictions.

Include the location, project description, description of the ITS work, and the project background (summary of purpose and need).

Be as descriptive as possible and briefly address any proprietary equipment / software requirements.

SEA Item #2 – Identify portions of the Regional or Statewide ITS Architecture being implemented.

If the portion does not exist in the Architecture, identify applicable portions of the National ITS Architecture. Include identification of the ITS User Services which will apply to the project and a graphic from the Architecture illustrating the data flows that will be incorporated.

Inclusion of SEA Item #2 will satisfy the Project Level ITS Architecture requirements. The use of the FHWA software product *Turbo Architecture* is required by TDOT.

SEA Item #3 – Provide a list of all stakeholders that have a direct role in the project, including the roles and responsibilities of each, their Concept of Operations, and Operational Concept.

Provide an Operational Concept. The Operational Concept is a high level description of the roles and responsibilities of the primary stakeholders and the systems they operate.

Provide a Concept of Operations. The Concept of Operations is a more detailed description of how the system will be used. It should discuss what the project is to accomplish, including identifying stakeholder needs and resources that stakeholders can provide. It is non-technical and provides a bridge between the needs motivating the project and the specific technical requirements. The greater the expected impact on operations, the more detailed explanation will be required. For complex projects, operational scenarios may be necessary to illustrate the operations.

SEA Item# 4 – Define the functional requirements of the project.

The functional requirements of the project describe how the project will be built and operated. High level functional requirements should be listed and can further be used to develop specific contract specifications language.

Provide interface / communication requirements for all stakeholders in the project. This includes the existing systems already deployed in the region.

Functional requirements are statements of the capabilities that a system must have "functions", geared to addressing the business needs that a system must satisfy. Business needs are the objectives for which the system is built. These functional requirements will be traced through the life of the project.

A key aspect of the functional requirements is that they address what a system must do, but does not address how the system should accomplish the "what". In other words, a functional requirement should not go into the details of how to implement the function.

SEA Item# 5 – Provide analysis of alternative system configurations and technology options to meet requirements, including rationale for technology selection.

Describe the basis of the project scope and how it was developed. Identify any proprietary items and explain the necessity and rationale for these items. Show the link between the system design concept and the operations and maintenance of the constructed project.

SEA Item# 6 – Provide analysis of procurement methods considered including rationale for selected option.

Describe possible procurement methods for the design, construction, and operations / maintenance (as applicable) of the project and why the preferred method was selected. In some cases, the procurement methods may be determined by State law.

SEA Item# 7 – Identify the existing applicable ITS Standards that will be used in the project. An explanation is required for not using the applicable standards.

ITS Standards are available on-line from the FHWA website. List all ITS Standards which may be applicable to the project, indicate if the Standard is to be used in the project and if not used, and provide an explanation of why they are not being used. For more information, visit FHWA web page: http://www.standards.its.dot.gov/learn_Application.asp. Turbo Architecture includes a listing of the applicable standards to a region or project based on the interfaces selected. (Most regional architectures include this report, but it can be tailored further for a project.)

SEA Item# 8 – Identify the testing procedures to verify compliance with the standards as well as the requirement for interoperability.

The testing procedures verify the individual elements of the project comply with the project specifications. The specifications are based upon the high level functional requirements identified in SEA Item #4.

SEA Item# 9 – Provide a traceability matrix for documenting compliance with SEA #8.

The traceability matrix provides a mechanism for ensuring that each functional requirement is tested and that each item to be tested has been addressed in the specifications. It is meant to provide a trace from needs to requirements to design and verification

A sample traceability matrix can be found on the TDOT Design Division website as outlined in Section 8.3.4.

The traceability matrix will be included in the contract documents for use during construction.

The completed traceability matrix will include the results of the test and any necessary work needed to address failures during the test and will be included in the project construction records.

SEA Item# 10 – Provide change management control.

Provide a description of the change management control. Describe what changes were made during project development, how changes were accommodated, and how change orders will be processed and managed during construction, including identifying necessary approvals. In many cases, standard procedures used by TDOT will incorporate many of these items.

This item requires documentation of changes in design, construction, and operations.

SEA Item# 11 – Provide a Maintenance Plan and a funding analysis for the maintenance and operation of the system after completion. This includes an analysis of cost, personnel, software, utilities, and anything further required to maintain and operate the system, typically on an annual basis.

SEA Item# 12 – Provide documentation for revising the ITS Architecture after construction. This should highlight existing data flows (ones that currently exist), planned data flows (as part of this project), and future data flows (flows that are still planned to be implemented sometime in the future).

This information can be shown by utilizing a different line style representing the data flows between elements.

Contact the appropriate Planning Organization for preferred or required formats for submitting this information.

8.3.4 ADDITIONAL REQUIREMENTS

For TDOT managed projects, it is anticipated that the required documentation will be prepared by the TDOT Design Division.

Forms, templates, and checklists are provided on the TDOT Design Division website for use in the preparation of the SEA at the following address:

http://www.tdot.state.tn.us/Chief_Engineer/assistant_engineer_design/design/TDM_Chapter_8_ITS_Templates_and_Checklists.zip.

The forms, templates, and checklists provided have been customized for TDOT and are based on the documents provided by the U.S. DOT Federal Highway Administration in the Systems Engineering Guidebook for ITS. This site is available at the following address:

http://www.fhwa.dot.gov/cadiv/segb/views/checklist/index.htm.

Documentation shall be submitted electronically.

In addition, when the project is covered by a ITS Architecture, the as-built Project Level ITS Architecture with any modifications noted, shall be submitted by the local agency to the appropriate planning organization for updating the Regional ITS Architecture.

If any uncertainty exists regarding design requirements, standards, forms, project risk category, or other ITS requirements, the project sponsor should contact the TDOT Design Division.

INDEX