Issue Paper

Proposed Systems Engineering Approach for ITS Deployments Along Florida's Limited-Access Corridors

Prepared for

Florida Department of Transportation
ITS Office
605 Suwannee Street, M.S. 90
Tallahassee, Florida 32399-0450
(850) 414-4980

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Systems Engineering Approach for ITS Deployment

1. Purpose

The Florida Department of Transportation (FDOT) recently established an Intelligent Transportation Systems (ITS) Office to:

- Coordinate the deployment of statewide communication networks to support ITS;
- Coordinate the deployment of ITS along Florida's limited-access corridors such as I-95, Florida's Turnpike and expressways;
- Coordinate the deployment of advanced traveler information systems (ATIS); and
- Coordinate the development of statewide information sharing for ITS.

Successful deployments of these four objectives will result in one of the largest coordinated deployments of ITS and communication infrastructure programs in the United States. To deploy these services, a comprehensive systems engineering approach is needed to:

- Ensure the deployments are aligned with FDOT's overall mission, goals and objectives;
- Ensure the deployments result in a fully integrated, coordinated, seamless, multimodal, and effective system;
- Ensure public resources are being utilized with maximum cost-efficiency and effectiveness; and
- Ensure maintenance and operation requirements provide for reliability of the system.

The systems engineering approach proposed in this issue paper delineates tasks and responsibilities among the various stakeholders involved in ITS deployments along Florida's limited-access corridors. This systems engineering approach also serves as FDOT's plan for implementing the requirements for systems engineering in the recently promulgated Federal Highway Administration (FHWA) Rule 940, *Intelligent Transportation Systems Architecture and Standards,* for these deployments.

2. What Is Systems Engineering?

The International Council on Systems Engineering (INCOSE) defines systems engineering as follows:

> Systems engineering is an interdisciplinary approach and means to enable the realization of successful systems. It focuses on defining customer needs and required functionality early in the development cycle,

documenting requirements, then proceeding with design synthesis and system validation while considering the complete problem:

- Operations
- Performance
- Test
- Manufacturing
- Cost & Schedule
- Training & Support
- Disposal

> Systems engineering integrates all the disciplines and specialty groups into a team effort forming a structured development process that proceeds from concept to production to operation. Systems engineering considers both the business and the technical needs of all customers with the goal of providing a quality product that meets the user needs. [1]

Systems engineering is not a new discipline and has its origins in transportation systems such as traffic control and high-speed rail systems, military applications, and aerospace programs.[2] Systems engineering approaches have been used in deployments of ITS for several decades; however, no uniform or consistent processes have been adopted within the transportation community as an industry standard.

At the federal level, FHWA Rule 940, *Intelligent Transportation Systems Architecture and Standards,* provides policies and procedures for implementing section 5206(e) of the Transportation Equity Act for the 21st Century (TEA-21), Public Law 105-178, 112 Stat. 457, pertaining to conformance with the National Intelligent Transportation Systems Architecture and Standards. As part of this rule, systems engineering is defined as follows:

> Systems engineering is a structured process for arriving at a final design of a system. The final design is selected from a number of alternatives that would accomplish the same objectives and considers the total life-cycle of the project including not only the technical merits of potential solutions but also the costs and relative value of alternatives.
>
> The systems engineering analysis shall include, at a minimum:
>
> - Identification of portions of the regional ITS architecture being implemented (or if a regional ITS architecture does not exist, the applicable portions of the *National ITS Architecture*);

[1] International Council on Systems Engineering website - http:\\www.incose.org
[2] Shinners, Stanley, *Techniques of Systems Engineering*, McGraw Hill, 1967.

- Identification of participating agencies’ roles and responsibilities;
- Requirements definitions;
- Analysis of alternative system configurations and technology options to meet requirements;
- Procurement options;
- Identification of applicable ITS standards and testing procedures; and
- Procedures and resources necessary for operations and management of the system.

3. Systems Engineering Process for ITS Deployments in Florida

3.1 Background

The proposed systems engineering approach for ITS deployments in Florida is based on the *Systems Engineering Compatibility Model* (EIA/IS 731) developed by INCOSE and was tailored to meet the needs of FDOT for ITS deployments. The process fulfills the FHWA Rule 940 requirements. Additional steps (beyond the requirements of FHWA Rule 940) were included that will result in a more robust process that is consistent with the FDOT’s procurement processes and covers the full life cycle of an ITS deployment. This process is also consistent with a number of other systems engineering approaches, including those established by the Institute of Electrical and Electronics Engineers (IEEE) and the Electrical Industry Alliance (EIA).

This issue paper proposes a basic model that summarizes the major activities of the systems engineering approach. Following FDOT acceptance of this basic model, a Systems Engineering Management Plan (SEMP) will be developed that defines each of the sub-processes that make up the activities. This issue paper is intended to be an initial presentation and discussion of the approach and not the final definition of processes or products. It is recognized that some additional tailoring of this proposed systems engineering approach may be needed based on the unique characteristics of a project. Additional detail and guidance on the application of this systems engineering approach will be provided in the SEMP.

3.2 Benefits of the Systems Engineering Approach

The systems engineering approach will provide the following benefits:

- Reduce the time required to move from concept to deployed systems;
- Ensure that the systems deployed meet users’ (of the system and the operators) needs;
- Reduce the costs of deploying systems;
- Ensure the latest proven technologies are used;

- Reduce the number of engineering changes and, therefore, improve the time-reliability, and reduce the costs of deployment;
- Improve system quality, reliability and performance;
- Improve communications during the engineering of the system;
- Improve ability to sustain and upgrade system products after deployment; and
- Reduce development risks.[3]

3.3 Basic Program Areas

Figure 1 illustrates the three basic program areas that make up the proposed systems engineering approach for ITS deployments in Florida. This figure shows that each of the program areas work together with the other program areas to achieve a coordinated approach. The technical/project management program area is the traditional focus of engineering, design and procurement. Program management functions and professional capacity building program areas support that function. Figure 1 also shows the responsibility for each of the activities in the program area. Blue colors indicate an activity led by the District Office. Gray colors indicate an activity led by the ITS Office.

Program Management

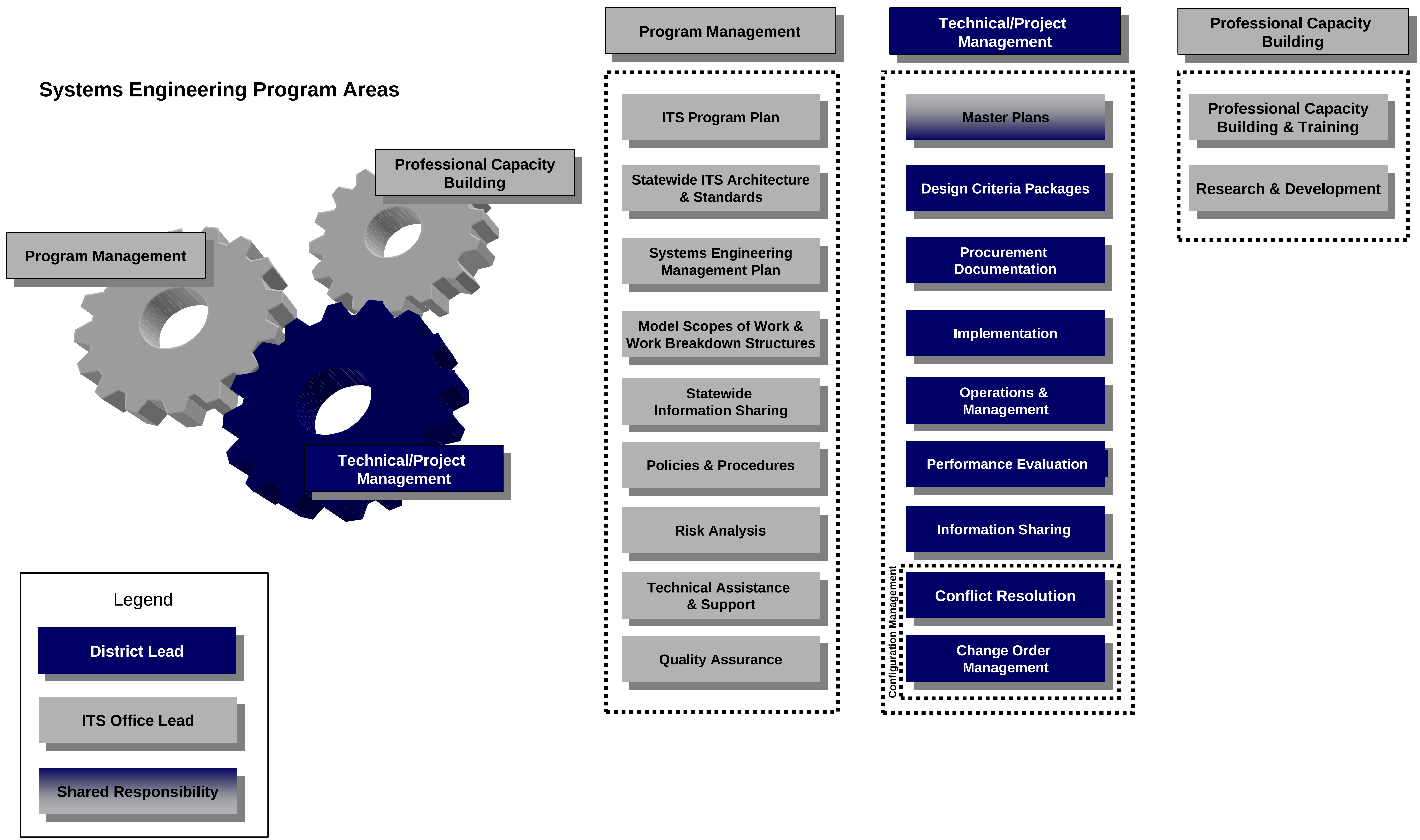
The program management functions support the deployment of ITS through the strategic, long-range planning of ITS, process definition, configuration management and information management. The activities associated with this program area are intended to promote efficiency and cost-effectiveness through establishment of best-management practices, coordination of deployments, development and maintenance of the statewide ITS architecture, adoption of statewide ITS standards, development and maintenance of the SEMP, providing model scopes of work and work breakdown structures, developing an integrated master schedule for program activities, supporting statewide information sharing, developing and adopting statewide policies and procedures, conducting risk analysis, providing technical assistance and support on projects, and quality assurance for processes used in deployment.

Technical/Project Management

The technical/project management functions support the technical development of the individual ITS projects deployed in Florida. The activities associated with this program area are intended to ensure that individual ITS projects are deployed in a cost-effective and efficient manner. This program area addresses the requirements of the FHWA Rule 940 for systems engineering and fully satisfies the IEEE Std. 1220-1998, *Standard for Application and Management of the Systems Engineering Process*. This program area is the traditional emphasis of the systems engineering process for requirements analysis and definition, design, validation, construction engineering, and inspection and maintenance to ensure the requirements are met. The activities associated with technical/project management include: conceptual design, engineering/design, deployment, operations and management (which includes maintenance), information

[3] Adapted from the *Systems Engineering Compatibility Model* (EIA/IS 731).

Figure 1 - Systems Engineering Management Plan For The Five Principal FIHS Corridors



sharing for ATIS and 511/Interactive Voice Response Systems (IVR), performance evaluation, conflict resolution, and change order management.

Professional Capacity Building

The professional capacity building functions support the sustainable execution of the systems engineering process and align the program management and technical/project management program areas with FDOT and with ITS stakeholders. The activities are strategically oriented to improve the understanding and effectiveness of ITS deployments. The activities associated with the professional capacity building area include training for all aspects of ITS deployment, research and development, and mainstreaming ITS with other Department activities and transportation partners.

3.4 Focus On Technical/Project Management

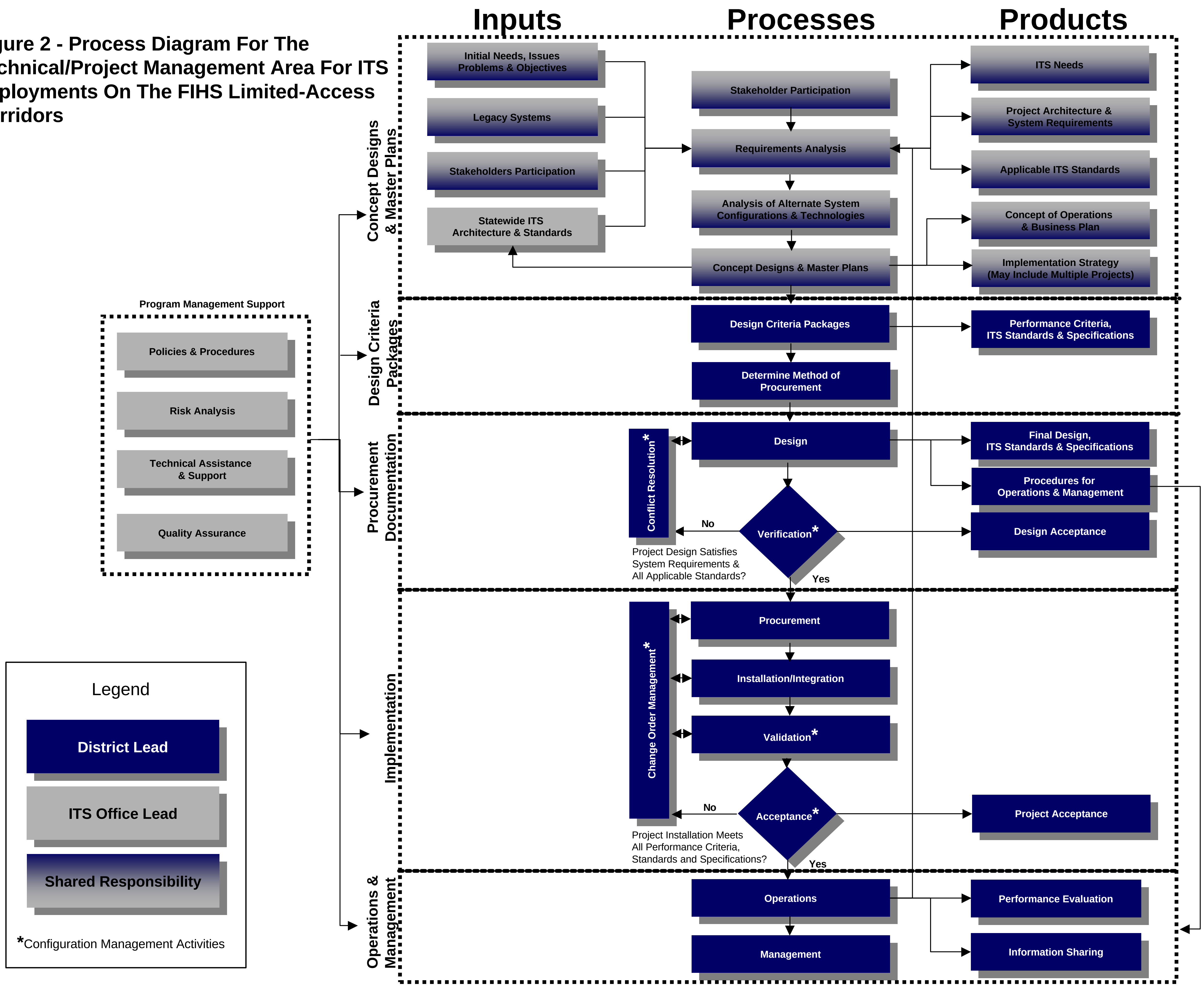
Since the technical/project management program area is the major program area in the systems engineering process, a separate process diagram was developed and is provided in Figure 2. The requirements of FHWA Rule 940 are addressed in this program area. The process diagram covers all of the major activities that are applicable to any ITS deployment but may need to be tailored for specific types of projects (such as software). This process diagram is oriented to the coordinated corridor deployments for the limited-access corridors in Florida.

Each of the activities outlined in the technical/project management program area will be outlined in detail in the SEMP and is not discussed in detail in this issue paper. The overall intent of the process is to ensure that stakeholder requirements are defined early in the process, design is driven by these requirements, services are integrated, validation is performed to ensure the requirements outlined early in the process were met in the deployment, and operations and management of the system are accomplished successfully.

Included in these activities is the introduction of a configuration management approach for ITS deployments in Florida. With large or complex ITS systems, configuration management is needed to support effective system deployment and management through conflict resolution in design and change order management in the procurement process. These processes ensure:

- System components are clearly identified in design through preparation of conceptual engineering (analogous to Phase I design in FDOT’s Roadway Plans Preparation Manual).
- Control processes are implemented to ensure that the final design reflects the requirements identified in conceptual design based on procedures prepared by the ITS Office in cooperation with the Districts.
- Documentation is provided to support operations and management, enhancements and integration through “as-built” plans, software and technology documentation

Figure 2 - Process Diagram For The Technical/Project Management Area For ITS Deployments On The FIHS Limited-Access Corridors



- Formal testing and acceptance procedures are developed and implemented to ensure the quality of the deployment through its life-cycle

The roles for the ITS Office and District Office identified are proposed to provide a balanced approach where best practices are developed cooperatively with the ITS Office servicing as facilitators and are implemented in deployments at the local level. For the limited-access corridors, the ITS Office is documenting the plans prepared by the Districts and expressway authorities for the limited-access facilities, assessing statewide needs for traveler information, data systems and software; recommending statewide priorities for programming in cooperation with the Districts; maintaining an integrated master schedule of ITS-related activities; working with the Districts to determine the method of procurement for projects and providing technical assistance as requested. When requested by the Districts, the ITS Office may provide design/criteria packages, preliminary design services, final design services or participate in the configuration management processes that include, conflict resolution, change order management, validation, testing and acceptance. On other ITS projects, the Districts (e.g., arterial management systems) or the ITS Office (e.g., communication networks) may lead any or all of the technical/project management functions. This systems engineering process is designed to manage the challenges and opportunities presented with changing stakeholders and requirements throughout the course of a project. Processes, procedures and practices will be identified in the Systems Engineering Management Plan to support these efforts.

3.5 Mapping of Requirements And Roles

Table 1 summarizes the mapping of the requirements of the systems engineering approach proposed in this issue paper to other professionally accepted techniques including FHWA Rule 940 and the *Systems Engineering Compatibility Model.* The basic process was also mapped to the *Florida Statutes* to document the authority of FDOT to develop this systems engineering approach.

Table 1 also summarizes the proposed roles of the major stakeholders for ITS deployments along the limited-access corridors: FHWA, ITS Office, Districts, and metropolitan planning organizations (MPOs).

4. Summary and Next Steps

The systems engineering approach proposed in this issue paper identifies the major activities needed to ensure FDOT optimizes the resources committed to ITS deployments along the limited-access corridors. The approach ensures that the projects identified are driven by stakeholder requirements and that the final deployment meets these requirements. The systems engineering approach emphasizes three areas: program management, technical/project management, and professional capacity building to promote cost-efficient and effective deployments that will be fully integrated and seamless.

The following next steps are needed:

- Achievement of consensus among the Districts and ITS Office on the basic program areas, activities and roles and responsibilities proposed in this issue paper.
- Completion of the SEMP plan that will define and document the tasks and deliverables associated with each of the activities outlined in the system engineering approach.
- Development of training programs on the systems engineering process and systems engineering management plan for all of the key stakeholders in the process. Following delivery of the training with the Districts and ITS Office, the training should be extended to the consultant community.
- Implementation of the systems engineering process.

Table 1. Mapping of Systems Engineering Approach Activities to Rule 940 Requirements, Systems Engineering Compatibility Model, Authority in Florida Statutes and Roles and Responsibilities

	Proposed Systems Engineering Process For ITS Deployments In Florida	Rule 940 Requirements (FHWA Docket, April 8, 2001)	Systems Engineering Compatibility Model (International Council on Systems Engineering)	Florida Statutes (Authority)	Roles and Responsibilities: FHWA Role	FHWA Resp.	ITS Office Role	ITS Office Resp.	District Role	District Resp.	MPO/Local Role	MPO/Local Resp.
ITS Architecture Conformity in Rule 940 for Regions	Initial Needs, Issues Problems & Objectives	Describe/define the region	1.1 Define Stakeholders	334.044(12), 334.044(10)(a)	♦	⊙	□	❍	■	●	□	⊙
	Legacy Systems and Stakeholders	Identification of participating agencies and other stakeholders	1.1 Define Stakeholders	334.044(12), 334.044(10)(a)	♦	⊙	□	❍	■	●	□	⊙
	Stakeholders Participation	Identification of participating agencies and other stakeholders	1.1 Define Stakeholders	334.044(12), 334.044(10)(a)	♦	⊙	□	❍	■	●	□	⊙
	Concept of Operations and Business Plan	Development of an operational concept that identifies roles and responsibilities	1.1 Define System Level Requirements	334.044(12), 334.044(10)(a)	♦	⊙	□	❍	■	●	□	⊙
	Requirements Analysis	Identification of any agreements required for operations for utilization of standards and interoperability	1.1 Define System Level Requirements	334.044(12), 334.044(10)(a)	♦	⊙	□	❍	■	●	□	⊙
	Requirements Analysis	System functional requirements	1.2 Define Technical Problem	334.044(12), 334.044(10)(a)	♦	⊙	□	❍	■	●	□	⊙
	Project Architecture and System Requirements	Interface requirements and information exchanges	1.2 Define Technical Problem	334.044(12), 334.044(10)(a)	♦	⊙	■	●	□	⊙	□	⊙
	Applicable ITS Standards	Identification of ITS standards to support interoperability	1.2 Define Technical Problem	334.044(12), 334.044(10)(a)	♦	⊙	■	●	□	⊙	□	⊙
	Implementation Strategy	The sequence of projects required for implementation	1.3 Define Solution	334.044(12), 334.044(10)(a)	♦	⊙	□	⊙	■	●	□	⊙
Systems Engineering in Rule 940 for Projects	Concept Designs & Master Plans	Identification of portions of the ITS architecture being implemented	1.1 Define System Level Requirements	334.044(12), 334.044(10)(a)	♦	❍	□	⊙	■	●		
	Concept of Operations and Business Plan	Identification of participating agencies' roles and responsibilities	1.1 Define System Level Requirements	334.044(12), 334.044(10)(a)	♦	❍	□	⊙	■	●		
	Design Criteria Packages, Performance Criteria, ITS Standards and Specifications	Requirements definition	1.2 Define Technical Problem	334.044(12), 334.044(10)(a), 287.055	♦	❍	□	⊙	■	●		
	Analysis of Alternate System Configurations & Technologies	Analysis of alternate system configurations and technologies	1.3 Define Solution and 1.4 Assess and Select	334.044(12), 334.044(10)(a)	♦	❍	□	⊙	■	●		
	Determine Method of Procurement	Procurement options	1.4 Assess and Select	334.044 (5), 334.044 (6), 334.044(7)	♦	❍	□	⊙	■	●		
	Statewide Performance Criteria, ITS Standards and Specifications	Specifications and standards to be utilized	1.5 Integrate System	334.044(12), 334.044(10)(a)	♦	❍	■	●	□	⊙		
	Statewide Testing Requirements	Testing requirements	1.6 Verify and 1.7 Validate System	334.175	♦	❍	■	●	□	⊙		
	Statewide Procedures For Management and Operations	Procedures necessary for management and operations	2.2 Monitor and Control	334.044(13), 334.044(17)	♦	❍	■	●	□	⊙		
Additional Steps Required For Technical/Program Management Systems Engineering & Configuration Management	Risk Analysis		2.5 Manage Risk	334,044(3), 334.044(4)	♦	❍	■	●	□	⊙		
	Verification of Design/Design Acceptance		1.6 Verify and 1.7 Validate System	334,044(3), 334.044(4), 334.175	□	❍	■	●	□	⊙		
	Validation/Project Acceptance		1.6 Verify and 1.7 Validate System	334,044(3), 334.044(4), 334.175	□	❍	□	⊙	■	●		
	Information Sharing		2.6 Manage Data	334.063, 334.24	♦		□	⊙	■	●		
	Performance Evaluation		2.2 Monitor and Control	334,044(3), 334.044(4)	♦		■	●	□	⊙		
	Conflict Resolution		2.7 Manage Configurations	334,044(3), 334.044(4)	♦		□	⊙	■	●		
	Change Order Management		2.7 Manage Configurations	334,044(3), 334.044(4)	♦		□	⊙	■	●		
	Operations		2.7 Manage Configurations	334.044(13)					■	●		
	Management		2.7 Manage Configurations	334.044(13)					■	●		
Systems Engineering Program Management & Professional Capacity Building	ITS Program Plan		2.1 Plan and Organize and 2.3 Integrate Disciplines	334.044(1), 334.044(12)	♦		■	●	□	⊙	□	
	Maintain Statewide ITS Architecture		3.1 Define and Improve the Systems Engineering Process	334.048(4)	♦		■	●	□	⊙	□	
	Systems Engineering Management Plan		2.1 Plan and Organize and 2.3 Integrate Disciplines	334.044(10)(a), 334.044(10)(b)	♦		■	●	□	⊙		
	Statewide Rules, Policies and Procedures for ITS		2.2 Monitor and Control	334.044(2), 334.048(3)	♦		■	●	□	⊙		
	Model scopes of work and Work Break Down Structures		2.3 Integrate Disciplines	334.048(4)	♦		■	●	□	⊙		
	Review Products for Consistency with ITS		2.4 Coordinate with Suppliers	334.044(10)(a), 334.044(10)(b)	♦		■	●	□	⊙		
	Quality Assurance Processes and Reviews		2.5 Manage Risk and 2.8 Ensure Quality	334.048(4)	□	⊙	■	●	□	⊙		
	Statewide Information Sharing		2.6 Manage Data	334.063, 334.24	♦		■	●	□	⊙		
	Professional Capacity Building and Training		3.2 Manage Competency	334.044(9)	□	⊙	■	●	□	⊙		
	Research and Development of New Technologies		3.3 Manage Technology	334.044(20), 334.044(21)	□	⊙	■	●	□	⊙		
	Statewide Technical Assistance and Support		3.4 Manage Systems Engineering Support	334.044(21)	□	⊙	■	●	□	⊙		

Roles
- ■ Lead
- □ Participate
- ♦ Advise

Responsibilities
- ● Perform
- ⊙ Review/Concurrence
- ❍ Approve