Intelligent Transportation Systems (ITS)
Systems Engineering (SE) Requirement

> ***Intelligent Transportation Systems (ITS) means electronics, communications, or information processing used singly or in combination to improve the efficiency or safety of a surface transportation system.***

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Resources

MnDOT

- MnDOT ITS Systems Engineering Website
- Procedures for Implementing HPDP ITS Systems Engineering Requirement: A Quick Reference Guide
- ITS Implementation: Decision Tree for Project Classification and Systems Engineering Requirements
- Minnesota Statewide Regional ITS Architecture
- ITS Initiatives and Project Concepts for Implementation (Implementation Volume of *Minnesota Statewide Regional ITS Architecture*)

Purpose

The purpose of this guidance is to ensure that 23 CFR Section 940 (**Rule 940**) is implemented on applicable Trunk Highway projects. FHWA has established Rule 940 based on FTA policy. The intent of the FTA Policy and Rule 940 is to foster integration of regional ITS systems, which includes the integration of the deployment of regional ITS systems.

Where applicable, **Rule 940** requires that all ITS systems or components be developed based on a Systems Engineering (SE) process (see definition below), and that the scale of the SE process be on a scale commensurate with the project.

Terminology

- Systems Engineering
- ITS Architecture
- Glossary

When ITS SE Process for Rule 940 Compliance Applies

> ***Implementing the ITS SE Process allows projects to move forward, taking proper consideration of interoperability and future expansion needs to enable full integration of ITS.***

- Implementing the ITS SE Process for Rule 940 compliance is required for **All ITS projects funded (in whole or in part) with the highway trust fund** (Includes National Highway System (NHS) and non-NHS facilities).

- In addition, MnDOT requires that the ITS SE Process for Rule 940 compliance is followed on **all State Funded ITS projects** in which ITS component(s) will be connected/integrated to another ITS component, project or system.

The ITS SE Process applies to all ITS Class A-1, A-2, B-1, B-2 and C projects (for definition and identification of project classes, see Which ITS Class is Your Project?).

Implementing ITS SE Process for Rule 940 Compliance on Projects

Project Manager's Responsibilities

1. Coordinate with the District Traffic Engineer or the District State Aid Engineer to determine if the project is an ITS project and/or a project with an ITS component(s).
2. Submit the SE Checklist that has been completed by the Traffic Project Engineer, with the Project Submittal to MnDOT's Pre-Letting Engineer or the District State Aid Engineer (i.e., required for federal authorization).

District Traffic Project Engineer's Responsibilities

1. Determine if the ITS SE Process for Rule 940 compliance applies.
   (See above **When ITS SE Process for Rule 940 Compliance Applies**).
   - If ITS SE Process applies, continue to Step #2
   - If ITS SE Process does not apply, you are done

2. Determine to which ITS class your project belongs.
   See Which ITS Class is Your Project?

3. If your project is a Class B-1, B-2 or C, go to Step #4
   If your project is Class A-1 or A-2: A programmatic SE process was done for all Class A (including Classes A-1 and A-2) projects. A SE process is not required for Class A projects. SE documents (Concept of Operations, Functional Requirements and a Test Plan) are available as references and **shall be reviewed for consistency**.

   a. Prepare and complete the appropriate Class A-1 or A-2 Checklist from the following:

   Class A-1:
   - Traffic Signal Checklist
   - Road Weather Information System Checklist
   - Railroad-Highway Grade Crossing Checklist
   - Weigh in Motion System Checklist

   Class A-2:
   - Dynamic Message Sign Checklist
   - Traffic Detection Checklist
   - Ramp Meters Checklist
   - Video Checklist
   - Communications Checklist
   - Flood Warning System Checklist
   - Slippery Pavement Warning Checklist
   - Reduced Visibility Warning Checklist
   - Dynamic Curve Warning Checklist

   b. Send the completed checklist to MnDOT contact person listed on page 1 for review and electronic approval for 23 CFR 940 compliance.

   c. Certify, sign and provide the completed checklist to the Project Manager.

4. If your project is Class B-1, B-2 or C:
   a. Complete the **Systems Engineering Process** (on page 3)
   b. Prepare and complete the checklist for the Class of your project.
      - Class B-1 Checklist (Freeway Traffic Management)
      - Class B-2 Checklist (Arterial Traffic Management)
      - Class C Checklist (Large Scale/Complex ITS Projects)

   c. Send the completed checklist to MnDOT contact person listed on page 1 for review and electronic approval for 23 CFR 940 compliance.

   d. Certify, sign and provide the completed checklist to the Project Manager.

Systems Engineering Process

Use the Systems Engineering (SE) process to develop, design and implement the ITS Project or project with an ITS component. The SE analysis should be on a scale commensurate with the project scope.

The basic (minimum) steps required for a full SE process are as follows:

1. Coordination with regional ITS architecture:
    a. **From the Minnesota Statewide Regional ITS Architecture**, identify the portions of the regional ITS architecture being implemented, and:
        i. Ensure that the final design accommodates the interface requirements and information exchanges specified in the regional ITS architecture.
        ii. The regional ITS architecture can be updated as so that the project and the regional architecture have accommodating interface requirements and information exchanges.

    b. **If the Minnesota Statewide Regional ITS Architecture does NOT contain the ITS project concept**:
        i. Create a project-level architecture that coordinates with the development of the regional ITS architecture. Please refer to MnDOT CAV-X contact for guidance.

        ii. Ensure that the final project-level ITS architecture coordinates with the development of the regional ITS architecture so that the project will accommodate the interface requirements and information exchanges in the completed regional ITS architecture.

2. Identify the roles and responsibilities of participating agencies;

3. Define requirements;

4. Analyze alternative system configurations and technology options and determine what best meets requirements;

5. Identify procurement options;

6. Identify applicable ITS standards and testing procedures;

7. Identify procedures and resources necessary to operate and manage the system.

SE Process Resources

- CFR 940.11
- FHWA Systems Engineering for ITS
- Systems Engineering Guidebook for ITS
- Model Systems Engineering Documents for Adaptive Signal Control Technology (ASCT) Systems

Which ITS Class is Your Project?

Minnesota ITS Projects are divided into five (5) classes:

- Class A-1: Programmatic ITS Applications for Standard Traffic Signals, Road Weather Information Systems, Weigh-in-Motion Systems, and Railroad-Highway Grade Crossings;
- Class A-2: Programmatic ITS Applications for Dynamic Message Signs, Traffic Detection, Video, Ramp Meters, Communications, Flood Warning Systems, Slippery Pavement Warning, Reduced Visibility Warning, and Dynamic Curve Warning;
- Class B-1: Freeway Traffic Management;
- Class B-2: Arterial Traffic Management; and
- Class C: Large Scale/Complex ITS Projects.

Tools and resources to assist with identification of project classes and SE requirements are available on the MnDOT ITS Systems Engineering Website.

The applications in each Class are as follows:

Class A-1 Programmatic ITS Applications

- Traffic Signals, including:
  - Basic traffic signals
  - Flashing yellow arrows
  - Advanced warning flashers
  - Railroad preemption
  - Emergency vehicle preemption (localized without control center oversight)
  - Transit signal priority (localized without control center oversight)
  - Enforcement lights (e.g. blue lights)
  - Vehicle presence detection
  - Traffic signal interconnects (closed loop systems)
- Road Weather Information Systems, including:
  - Environmental sensor stations
  - Communication system for data transfer
  - Central hardware and software to collect and disseminate field data
  - Video tools (e.g. Pan-tilt-zoom (PTZ) cameras)
- Railroad-Highway Grade Crossings, including:
  - Flashing light signals
  - Standard crossing gates
  - Four quadrant gates
  - Traffic signal preemption
- Weigh-in-Motion (WIM) Systems for CVO weight screening and sorting
- MnDOT Systems Engineering Documentation for Class A-1 Programmatic ITS Applications can be accessed on the MnDOT ITS Implementation for CAV Readiness Project web page.

Class A-2 Programmatic ITS Applications

- Dynamic Message Signs (DMS)
- Traffic Detection
- Ramp Meters
- Video
- Communications
- Flood Warning Systems
- MnDOT Systems Engineering Documentation for the above Class A-2 Programmatic ITS Applications can be accessed on the MnDOT Systems Engineering for ITS and CAV Readiness Project web page.
- Slippery Pavement Warning
- Reduced Visibility Warning
- Dynamic Curve Warning
- MnDOT Systems Engineering Documentation for the above three Class A-2 Programmatic ITS Applications can be accessed on the MnDOT Systems Engineering for Work Zone Data Initiatives (WZDI) and Warning Systems Project web page.

Class B-1 Freeway Traffic Management Applications

- Traffic Observation and Detection, including:
  - Video*
  - Traffic detection*
  - Condition reporting system
  - Weather sensors and provision of current and forecast weather conditions
  - Automatic vehicle location (AVL) for FIRST, maintenance and State Patrol vehicles
- Traffic Control Systems including:
  - Lane control signs
  - Ramp meters*
  - Electronic toll collection*
  - Automated gate closure systems
- Data Processing and Response Formulation (Manual and Automated) including:
  - TMC software (i.e. ATMS) and data extract tool
- Infrastructure Support Tools including:
  - Landline communication (fiber, copper, telephone lines, DSL lines)*
  - Wireless communication (point-to-point and cellular)*
  - Power
- Information Sharing including:
  - Dynamic message signs (DMS)*
  - Radio broadcasts
  - Web pages for construction and traveler information
  - 511 phone system and 511 mobile app
  - Computer Aided Dispatch (CAD) for FIRST, maintenance and State Patrol vehicles

- MnDOT ITS Concept of Operations for Freeway Traffic Management

Programmatic SE analysis has been developed for ITS applications specific to MnDOT implementation and are identified with asterisks (*). The SE documents for these applications can be used by other agencies as references for performing SE analysis for their deployments. Please refer to the MnDOT contact person listed on page 1 for more information.

Class B-2 Arterial Traffic Management Applications

- Central Traffic Signal Control Systems
- Adaptive Signal Control System and Automated Traffic Signal Performance Measures (ATSPM)
- Traffic Observation and Detection, including:
  - Video*
  - Traffic detection*
  - Condition reporting systems
- Local Area Arterial Traffic Control and Traveler Alerts, including:
  - Dynamic speed display signs
  - Emergency vehicle preemption (with or without control center oversight)
  - Red light running systems
  - Transit signal priority (with or without control center oversight)
- Data Processing and Response Formulation (Manual and Automated), including:
  - TMC software (e.g. central traffic signal control software*) and data extract tool
- Infrastructure Support Tools, including:
  - Landline communication (fiber, copper, telephone lines, DSL lines)*
  - Wireless communication (point-to-point and cellular)*
  - Power
- Information Sharing (Travelers, Media & Other Agencies), including:
  - Dynamic message signs (DMS)*
  - Web pages for construction and traveler information
  - 511 phone system and 511 mobile app
- MnDOT ITS Concept of Operations for Arterial Traffic Management

Programmatic SE analysis has been developed for ITS applications specific to MnDOT implementation and are identified with asterisks (*). The SE documents for these applications can be used by other agencies as references for performing SE analysis for their deployments. Please refer to the MnDOT contact person listed on page 1 for more information.

Class C Large Scale/Complex ITS Projects (This is the full list for Class C applications)

- Integrated Corridor Management (ICM)
- Bus Rapid Transit (BRT)
- Communications (for example, fiber network)*
- TMC (Transportation Management Center)
- Incident management systems
- Intersection conflict warning systems

- Infrastructure-based safety systems
- Truck priority
- Smart work zone
- Other Complex applications not listed above and not listed in Class B-1 or B-2

SE analysis has been developed for MnDOT specific Communications implementation. The programmatic ITS application of Communications is identified with an asterisk (*). The SE document for this application can be used by other agencies as a reference for performing SE analysis for their deployments. Contact MnDOT contact person listed on page 1 for more information.

Minnesota Statewide Regional ITS Architecture

The **Minnesota Statewide Regional ITS Architecture** is shared vision of how each agency's system works together with the systems of other agencies by sharing information and resources to enhance transportation safety, efficiency, capacity, mobility, and security. The information exchange among the many transportation stakeholders helps illustrate various integration options, gain consensus on cost-effective ITS technologies and systems to be considered prior to investing in the design, development and deployment of ITS.

The latest architecture version includes a detailed Operational Concept for each service and identified need, providing more information on how a system will be used and what stakeholder will use it.

Minnesota Statewide Regional ITS Architecture Version 2018, Implementation Volume
This document provides a full list of near term and future ITS projects which were defined by state and local transportation agencies in 2018. The Implementation Volume provides all necessary information and references for developing ITS projects while complying with 23 CFR 940.

Agencies/Organizations

Agencies/Organizations	Description
Federal Highway Administration (FHWA)	Regulates Federally funded ITS projects and provides full oversight of ITS projects
MnDOT – Office of Connected & Automated Vehicles (CAV-X)	Provides guidance and technical assistance for all ITS projects and projects with an ITS component, including guidance on the SE process.
Metropolitan Council and Greater Minnesota MPOs	Manages planning for ITS Projects in accordance with MnDOT Family of Plans, including the Minnesota Statewide Regional ITS Architecture. Adoption of Minnesota Statewide Regional ITS Architecture

Approvals

Types of Projects	Approval Agencies
Local Projects	MnDOT SALT (State Aid for Local Transportation)
Trunk Highway Projects	MnDOT – CO Traffic, District Traffic or RTMC (Regional Transportation Management Center)
Transit Projects	MnDOT Office of Transit
Railroad Projects	MnDOT OFCVO (Office of Freight & Commercial Vehicle Operations)
Weigh-in-Motion (WIM)	MnDOT Transportation System Management - Traffic Forecasting & Analysis and/or District Office
Road Weather Information System (RWIS)	MnDOT CO (Central Office) Maintenance

Glossary

23 CFR – Code of Federal Regulations, Title 23, Highways, Subchapter K, Part 940 – Intelligent Transportation System Architecture and Standards.

Concept of Operations (**Con Ops)** – A narrative description of how a system should work.

Intelligent Transportation Systems (ITS) – The electronics, communications, or information processing used singly or in combination to improve the efficiency or safety of a surface transportation system.

ITS Architecture – Both the logical architecture and physical architecture (infrastructure) designed to satisfy a defined set of user services. The logical architecture provides a common framework for ITS interoperability. ITS Architecture includes the functions and activities of Intelligent Transportation Systems, and provides a framework for planning, defining, and integrating these systems.

- **National ITS Reference Architecture (also "Architecture Reference for Cooperative and Intelligent Transportation" or "ARC-IT")** – Maintained by the United States Department of Transportation (DOT) and available at https://local.iteris.com/arc-it/.
- **Regional ITS architecture** – A regional framework for ensuring institutional agreement and technical integration for the implementation of ITS projects or groups of projects. Regional ITS architectures help guide the integration of ITS components. During development of a regional ITS architecture, agencies that own and operate transportation systems must together consider current and future needs to ensure that today's processes and projects are compatible with future deployments of ITS projects/systems.
- **Project level ITS architecture** – A framework that identifies the institutional agreement and technical integration necessary to interface a major ITS project with other ITS projects and systems.

ITS Project – 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.

Major ITS Project – Any ITS project that implements part of a regional ITS initiative that is multi-jurisdictional, multi-modal, or otherwise affects regional integration of ITS systems.

National ITS Reference Architecture (also "national architecture") – See **ITS Architecture**

Project level ITS architecture – See **ITS Architecture**

Region – The geographical area that identifies the boundaries of the regional ITS architecture and is defined by and based on the needs of the participating agencies and other stakeholders. In metropolitan areas, a region should be no less than the boundaries of the metropolitan planning area.

Regional ITS architecture – See **ITS Architecture**

Systems Engineering (SE) – 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 (i.e. Concept of Operations), documenting requirements (i.e. Functional or System Requirements), then proceeding with design synthesis and system validation while considering the complete problem. 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 technical needs of all customers with the goal of providing a quality product that meets the user needs.

Compare Processes – SE and HPDP

For ITS projects the SE procedures complements the traditional DOT planning, pre-design, final design and construction QA/QC with a series of activities that are more appropriate for technology projects.

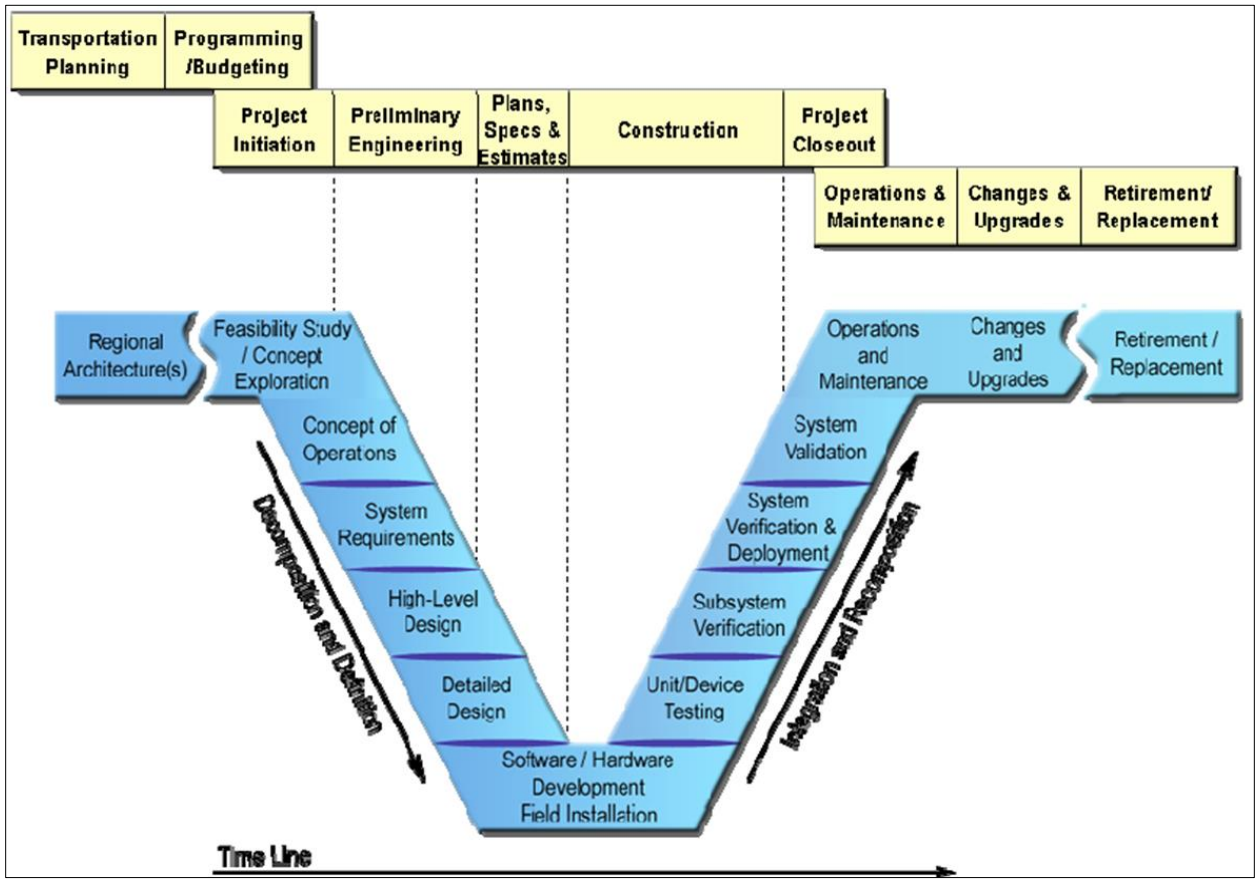
Systems Engineering (SE) is a structured process for arriving at a final design of a system after reviewing a number of alternatives. It considers the total life-cycle of the project including the technical merits of potential solutions and also the costs and relative value of alternatives.

For ITS, the SE process begins with the development and implementation of an ITS architecture. It continues by outlining the steps and level of detail of each phase of project deployment, from high-level tasks such as establishing a Concept of Operations to very detailed component design, installation, and testing. The purpose of the SE process is to ensure that a well-planned foundation is in place and then to affirm the requirements of an ITS system.

SE reduces risk and errors in developing complex projects. It is a cyclical process of planning, designing, implementing, testing, operating, and maintaining a system or project throughout its useful life.

The diagram shows the relationship of SE to the typical DOT project phases.

Process Comparison Diagram



Guidelines/Regulations

- Federal Register 23 CFR Parts 655 and 940
  - http://ops.fhwa.dot.gov/its_arch_imp/docs/20010108.pdf
  - http://ops.fhwa.dot.gov/its_arch_imp/docs/fta-pol.pdf
- US DOT RITA/ITS Joint Program Office: http://www.its.dot.gov/
- FHWA ITS Architecture Implementation Program: http://www.ops.fhwa.dot.gov/its_arch_imp/