



Intelligent Transportation Systems (ITS) Systems Engineering Joint Process Review

Final Report

By

Federal Highway Administration (FHWA) Washington Division

Washington State Department of Transportation (WSDOT) Traffic Operations Division

July 2009

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Executive Summary

The purpose of this review was to examine the existing WSDOT intelligent transportation system (ITS) project delivery process and determine whether federally funded WSDOT ITS projects are complying with federal ITS Systems Engineering requirements contained in 23 Code of Federal Regulations (CFR) Part 940. While the primary purpose was to check compliance with federal regulations, a secondary purpose was to identify opportunities for better incorporating Systems Engineering practices into the WSDOT ITS project delivery process. The ultimate goal of this review is to ensure that WSDOT has a project delivery process that allows ITS projects or projects that contain ITS elements to be implemented successfully and minimize the risk of failure.

Following is a brief summary of the primary observations and recommendations from this process review. More detail is available in the remainder of the report.

Observation #1: WSDOT has a documented process in the *Design Manual* Chapter 1050 that complies with the systems engineering requirements in 23 CFR Part 940. However, implementation of the process is not consistent from project-to-project.

Recommendation: Better ensure the *Design Manual* Chapter 1050 systems engineering requirements are being followed and the "ITS Project Systems Engineering Review Form is being completed for all ITS projects through the following:

1. Provide clear language in *Design Manual* Chapter 1050 that systems engineering is required on all ITS projects regardless of funding source or program.
2. Add the "ITS Project Systems Engineering Review Form" to the Project Design Documentation Checklist.
3. Reference the "ITS Project Systems Engineering Review Form" in appropriate sections of *Design Manual* Chapter 300.
4. Perform outreach and education to the Region Traffic Engineers and FHWA Washington Division Area Engineers that the "ITS Project Systems Engineering Review Form" needs to be submitted to the FHWA Division Office for federal ITS projects or projects that contain ITS elements prior to construction authorization.

Observation #2: The level of systems engineering should be commensurate with the scale of the project scope. In particular, higher risk and complex ITS projects should more rigorously follow the "V" diagram than low risk, straight-forward ITS projects. Beyond the "ITS Project Systems Engineering Review Form," *Design Manual* Chapter 1050 does not provide specific guidance on how to determine and document the appropriate level of systems engineering for ITS projects.

Recommendation: Modify *Design Manual* Chapter 1050 to provide clear guidance on how to determine and document the appropriate level of systems engineering based on the complexity, risk, and scope of ITS projects:

1. Provide definitions of categories of ITS projects based on level of risk, complexity, and scope.
2. Provide guidance on how to classify an ITS project into one of these categories.
3. Provide guidance on how to apply systems engineering, including the steps of the "V" diagram, for each project category. Identify any documentation required (e.g., checklists or forms), checkpoints when the documentation is required, any approvals needed, and how the documentation should be filed.

Observation #3: The current WSDOT project development process makes it difficult to deliver ITS projects using the systems engineering "V" diagram. Based on WSDOT staff experience, the Q Program has inherent flexibilities that allow the "V" diagram process to be followed, whereas ITS projects in the I and P Programs have difficulty following the "V" diagram due to the limitations of the traditional project development process.

Recommendation: ITS projects that require a more rigorous systems engineering analysis (i.e., higher risk, complex ITS projects as discussed in Recommendation #2) should be given the flexibility needed to complete the steps of the "V" diagram, which is often not the case when programmed under the I or P Programs. This flexibility can be achieved by programming complex ITS projects under the Q Program. However, further investigation of recent I Program ITS projects (e.g., SR 167 HOT Lanes and I-90 VSL projects) that successfully completed the steps of the "V" diagram is needed to better understand how the inherent inflexibilities of the I and P Program can be overcome. The bottom line objective is to structure the ITS project development process in a way that places the individuals most knowledgeable of the ITS being deployed in the key decision making roles in the process to ensure effective project delivery.

In addition, incorporating core ITS elements into the WSDOT Design Matrix procedures, *Design Manual* Chapter 1100, should be considered to allow ITS to be scoped early in the project development process, which will allow a proper systems engineering analysis to be completed. The objective is to institutionalize ITS, as set out in the WSDOT ITS Statewide Plan, as a standard component to the Highway Construction Program.

Observation #4: There are no on-going and accessible systems engineering training opportunities currently available to WSDOT staff. This training is critical to successful implementation of systems engineering on ITS projects.

Recommendation: Leverage the following opportunities to increase the availability of systems engineering training to WSDOT staff:

1. FHWA can provide periodic funding for systems engineering training, such as the training given as part of this process review, through the ITS Peer-to-Peer Program or the FHWA Washington Division office.
2. Web-based systems engineering courses are available through the ITS Professional Capability Building Program (http://www.pcb.its.dot.gov/) and the

Consortium for ITS Training and Education (CITE) (http://www.citeconsortium.org).

3. Systems engineering concepts can be incorporated into current WSDOT ITS training classes.
4. Professional groups such as ITS Washington or the Institute of Transportation Engineers (ITE) can potentially organize training opportunities.
5. Expertise at the University of Washington or other universities can potentially be used to provide local training.
6. A National Highway Institute (NHI) course should be developed on systems engineering and be made available on an on-going, as-needed basis.

Purpose of Review

The purpose of this review was to examine the existing WSDOT intelligent transportation system (ITS) project delivery process and determine whether federally funded WSDOT ITS projects are complying with federal ITS Systems Engineering requirements contained in 23 Code of Federal Regulations (CFR) Part 940. While the primary purpose was to check compliance with federal regulations, a secondary purpose was to identify opportunities for better incorporating Systems Engineering practices into the WSDOT ITS project delivery process. Specifically, the objectives of this review were to:

- Determine whether the existing WSDOT ITS project delivery process contained in the WSDOT *Design Manual* complies with federal ITS systems engineering requirements contained in 23 CFR Part 940.
- Determine whether the federal ITS systems engineering requirements (23 CFR Part 940) are being met on individual federally funded WSDOT ITS projects.
- Identify opportunities for improvement in the WSDOT ITS project delivery process to better incorporate systems engineering practices.
- Identify process strengths and best practices that can be shared with other states and/or local agencies.

Systems engineering is a systematic process that was developed specifically for complex technology projects. The systems engineering process, often referred to as the "V" diagram, is shown in Figure 1. As shown in the figure, following the systems engineering process contains a number of steps that are not included in the traditional project delivery process.

Using systems engineering on ITS projects has been shown to increase the likelihood of project success; for example, projects completed on-time and on-budget, meeting stakeholder and project sponsor expectations, and being efficient to operate and maintain. Thus, the ultimate goal of this review is to ensure that WSDOT has a project delivery process that allows ITS projects to be implemented successfully and minimize the risk of failure.

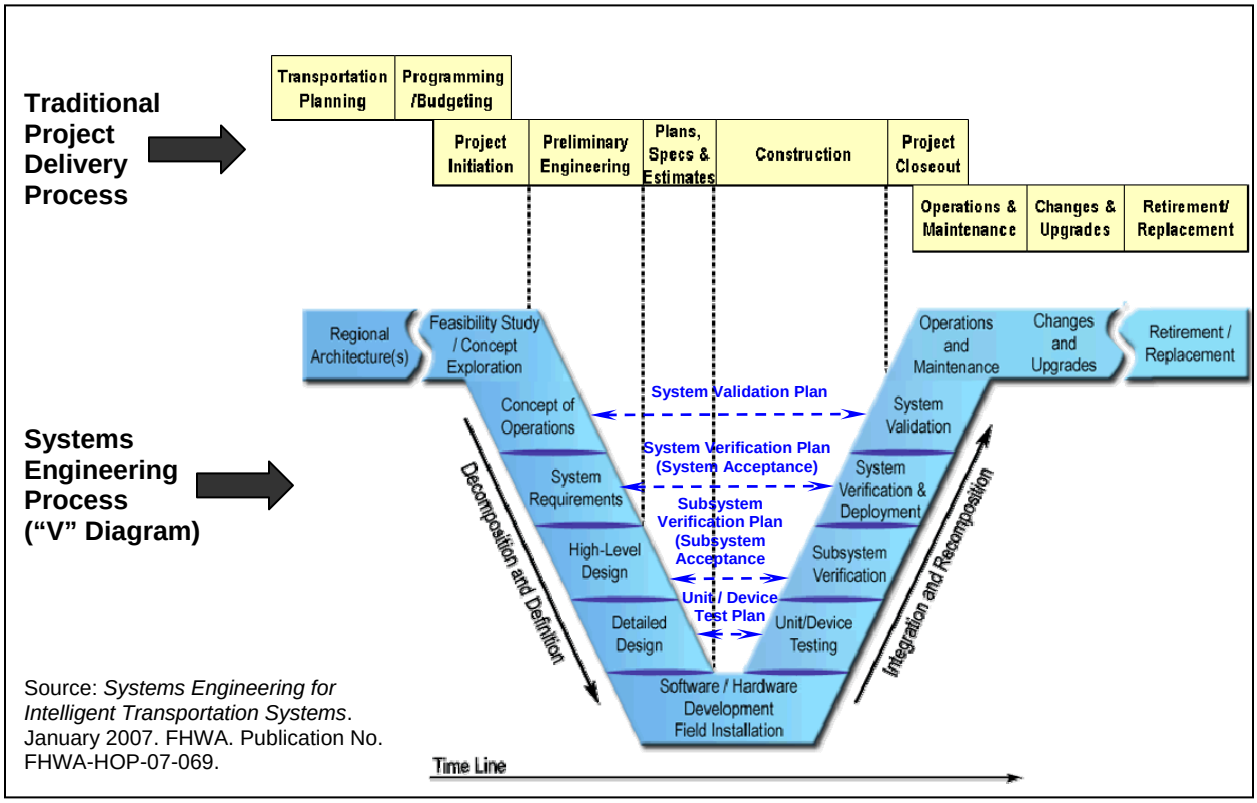

Figure 1. Systems Engineering Activities.

Team Members

The review team was comprised of individuals from the FHWA Washington Division office and WSDOT Headquarters and Region offices. As this was a joint process review, there were two co-leaders of the team, one from FHWA and the other from WSDOT. The team members were:

- James Colyar, ITS/Mobility Engineer, FHWA Washington Division – Team co-lead.
- Bill Legg, State ITS Operations Engineer, WSDOT Headquarters – Team co-lead.
- Ted Bailey, Signals, Illumination & ITS Engineer, WSDOT Headquarters.
- Steve Kim, Region Traffic Engineer, WSDOT Olympic Region.
- Wendy McAbee, Area Engineer, FHWA Washington Division.
- Matt Neeley, Transportation Technical Engineer, WSDOT Headquarters.
- Ron Vessey, ITS Field Operations Engineer, WSDOT Headquarters.

While the majority of WSDOT team members were from the Headquarters office, the data collection, analysis, and workshop stages (described in the *Scope of Review* section) provided many opportunities for other WSDOT Region offices to give their input and perspectives to the review team.

Scope of Review

The review focused on WSDOT ITS projects authorized after December 2005, when the current WSDOT Systems Engineering guidance was published in the *Design Manual* Chapter 860 Supplement, "Systems Engineering for Intelligent Transportation Systems."[1] The team selected a representative sample of ITS projects for study (e.g., rural and urban projects, small and large projects, projects from various WSDOT Regions). Table 1 shows the ITS projects selected for review.

Table 1. WSDOT ITS Projects Reviewed.

Project	Region	Location	Cost	Completion
Puget Sound Traffic Map Extension	Olympic	Urban	$1,700,000	July 2008
Spokane Traffic Operations for Arterials	Eastern	Suburban	$830,000	October 2008
US 2 Stevens Pass Variable Speed Limit System	North Central	Rural	$580,000	June 2005
Northwest Region Traffic Flow Map Extension	Northwest	Urban	$2,420,000	June 2009

The team assembled and reviewed all available project documents associated with these projects, including but not limited to the ITS federal program project application, Design Documentation File, Design Documentation Package, Project Design Document Checklist, and Work Plan.

The team also assembled and reviewed general WSDOT project delivery process documents, including the *Design Manual* Chapter 300 (Design Documentation and Approval), *Design Manual* Chapter 1050 (ITS and Systems Engineering), Design Documentation Package Checklist, and WSDOT Project Management website (www.wsdot.wa.gov/Projects/ProjectMgmt/Process.htm).

After the data collection phase, the team organized a two-day training and process review workshop as a primary means of analyzing the specific ITS project and general process delivery documents. The workshop was instructed and facilitated by:

- David Binkley, Lockheed Martin, FHWA Systems Engineering Contract Support.
- Ron Ice, Ice & Associates, FHWA Systems Engineering Contract Support.
- Nathaniel Price, FHWA Resource Center and Oregon Division.

The workshop was held March 17-18, 2009 in Lacey, WA and consisted of two parts:

1. Systems Engineering Training – The workshop began with a focused one-day course on systems engineering. It began with general concepts and progressed to

[1] Note: As a result of a major *Design Manual* reorganization in June 2009, this Supplement is now incorporated into the full ITS Chapter, which was changed from 860 to 1050. There were no changes in the language to the systems engineering guidance in this reorganization. This report will hereafter refer to the current systems engineering requirements in Chapter 1050.

specific techniques for applying systems engineering to ITS project development within an organization. There were over 40 attendees from across the state representing WSDOT (Headquarters and all six Regions), local agencies, and metropolitan planning organizations (MPOs).

2. Process Improvement Review – On the second day, a smaller group of participants from FHWA and WSDOT (the Process Review Team and WSDOT representatives for the projects shown in Table 1) applied what they learned about systems engineering to their own ITS project delivery process as they answered a series of process improvement review questions. The questions were structured to explore various aspects of systems engineering and project implementation for ITS projects with a focus on project development. Facilitators and participants worked together to develop a set of recommendations, which are documented in a Workshop Report contained in the Appendix.

The review team then screened the recommendations in the Workshop Report to form a concise, core set of observations and recommendations that are documented in the body of this report. While the review team concluded that all of the recommendations in the Workshop Report are valid and would benefit WSDOT and FHWA, the team also felt it necessary to focus on a handful of key observations and recommendations that were specific to the objectives and goals of this review and were feasible and implementable within a period of a few years.

Process Strengths

WSDOT has a long history of successful ITS projects. For example, the first Traffic Management Center (TMC) in Seattle was built in the late 1960s and the first ramp meter was operational in the early 1980s. This success was built on a foundation of close working relationships within the transportation community, competent WSDOT agency staff, university connections, and skilled consultant support. A number of strengths were identified during the process review:

- **Motivated, experienced people** – WSDOT Traffic and ITS staff from Headquarters and the Region offices have good hands-on experience with developing and deploying ITS projects. WSDOT has a practical, experienced foundation from which to base ITS-related process improvements.
- **Good positive working relationships** – It was obvious from the workshop and review team that there is a good foundation of cooperation and communication within WSDOT. The working relationship between WSDOT and FHWA was also clearly positive and constructive.
- **Good documented processes to build on** – Few state DOTs have a documented ITS systems engineering project development process. WSDOT is a notable exception with its *Design Manual* Chapter 1050. The larger WSDOT Highway Construction Program also has a well-defined Project Management Process.

- **Already performed systems engineering activities** – Figure 2 identifies the steps in the systems engineering "V" diagram that have been performed by WSDOT in previous projects. As shown, taken as a whole, most of the steps in the "V" diagram have been addressed on one or more projects by at least one of the regions. Although activities were isolated on some projects, the comprehensive coverage of systems engineering activities is a clear indication of substantial adoption of good systems engineering processes by the state.

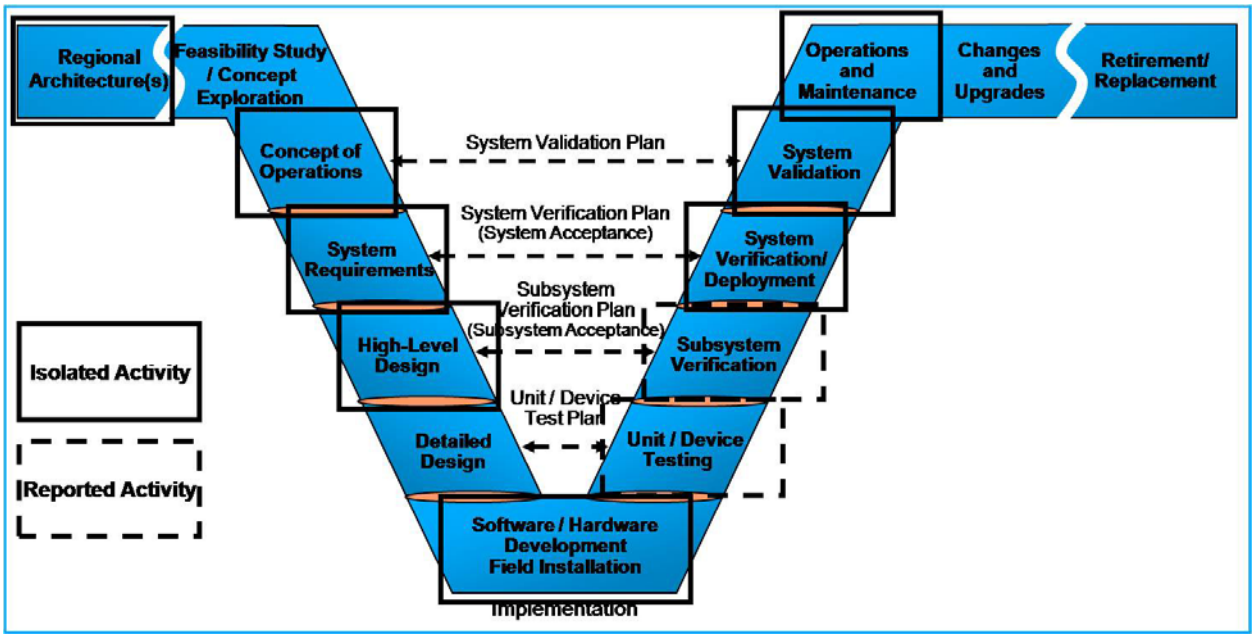

Figure 2. WSDOT Systems Engineering Activities.

Significant Observations and Recommendations

Observation #1: WSDOT has a documented process in the *Design Manual* Chapter 1050 that complies with the systems engineering requirements in 23 CFR Part 940. However, implementation of the process is not consistent from project-to-project.

Discussion: 23 CFR Part 940.11 states that:
"(a) All ITS projects funded with highway trust funds shall be based on a systems engineering analysis.
(b) The analysis should be on a scale commensurate with the project scope.
(c) The systems engineering analysis shall include, at a minimum:
(1) 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);
(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 management of the system."

Design Manual Chapter 1050.06-07 also requires these seven elements for federal ITS projects as summarized in Exhibit 1050-2a in a form called the "ITS Project Systems Engineering Review Form." As such, the WSDOT project delivery process as documented in the *Design Manual* complies with the systems engineering requirements in 23 CFR Part 940. However, our review of specific ITS projects (see Table 1) and discussions in the workshop revealed that systems engineering is not being applied consistently from project-to-project. Further, the "ITS Project Systems Engineering Review Form" is not being completed for all ITS projects. There are multiple reasons for this, including:

- Due to the focus of 23 CFR Part 940 systems engineering is only being followed for federal projects (as opposed to state funded projects) or specific types of ITS projects (such as ITS earmark projects). Due to the apparent benefits of the Systems Engineering process, there needs to be clear language in Chapter 1050 that systems engineering, including the "ITS Project Systems Engineering Review Form," needs to be applied to all ITS projects or projects that contain ITS elements.
- The "ITS Project Systems Engineering Review Form" is not recognized and integrated into the broader WSDOT project delivery process. For example, the form is not mentioned in *Design Manual* Chapter 300 (Design Documentation and Approval) nor is it included in the Design Documentation Package Checklist.

In addition, 23 CFR 940.13 states that compliance with systems engineering needs to be demonstrated before authorization of the construction phase. Chapter 1050 is consistent with this by stating that the "ITS Project Systems Engineering Review Form" should be submitted to FHWA with the construction authorization request for federal ITS projects. However, this is currently not being done consistently from project-to-project. Thus, outreach and communication of this requirement should be undertaken to make the Region offices aware that this is a requirement both in 23 CFR Part 940 and the *Design Manual* Chapter 1050. The FHWA Washington Division Area Engineers should also be made aware of this requirement, as they typically approve construction authorizations for FHWA on individual projects, including ITS projects.

Recommendation: Better ensure the *Design Manual* Chapter 1050 systems engineering requirements are being followed and the ITS Systems Engineering Review Form is being completed for all ITS projects through the following:

1. Provide clear language in *Design Manual* Chapter 1050 that systems engineering is required on all ITS projects regardless of funding source or program.
2. Add the "ITS Project Systems Engineering Review Form" to the Project Design Documentation Checklist.

3. Reference the "ITS Project Systems Engineering Review Form" in appropriate sections of *Design Manual* Chapter 300.
4. Perform outreach and education to the Region Traffic Engineers and FHWA Washington Division Area Engineers that the "ITS Project Systems Engineering Review Form" needs to be submitted to the FHWA Division Office for federal ITS projects prior to construction authorization.

Observation #2: The level of systems engineering should be commensurate with the scale of the project scope. In particular, higher risk and complex ITS projects should more rigorously follow the "V" diagram than low risk, straight-forward ITS projects. Beyond the "ITS Project Systems Engineering Review Form," Chapter 1050 does not provide specific guidance on how to determine and document the appropriate level of systems engineering for ITS projects.

Discussion: Both 23 CFR Part 940.11 and the *Design Manual* Chapter 1050 state that the systems engineering analysis should be commensurate with the scale of the project scope. Per 23 CFR Part 940.11, the seven elements included in the "ITS Project Systems Engineering Review Form" are considered the minimum level of systems engineering needed for ITS projects. While these seven elements may be sufficient for low risk ITS projects, current guidance and practice indicates that higher risk, complex ITS projects should more rigorously follow the steps in the "V" diagram.[2,3]

Other states have developed guidance and processes on how to determine an appropriate level of systems engineering tailored to the complexity and scope of an ITS project. For example:

- California/Caltrans – ITS projects are categorized as exempt, minor, or major. Exempt projects do not require systems engineering, minor projects can follow a traditional project development process, and major projects use the "V" diagram process. Major projects also require a Systems Engineering Management Plan that documents how the "V" diagram will be implemented.
- Virginia/VDOT – Has a User Guide for Systems Engineering and ITS Architecture that explains how systems engineering is incorporated into VDOT projects and incorporates a checklist that guides a project team through systems engineering compliance.

In Washington, the Integrated Corridor Management (ICM) and Active Traffic Management (ATM) projects are recent examples of ITS projects that appropriately followed a more rigorous systems engineering process following the "V" diagram. However, our review revealed that these more rigorous systems engineering activities are often done in isolation within a project and not consistently from project-to-project. This is due to the fact that there is no guidance in Chapter 1050 or elsewhere that would

[2] *Systems Engineering for Intelligent Transportation Systems*. January 2007. FHWA. Publication No. FHWA-HOP-07-069. Located at: http://ops.fhwa.dot.gov/publications/seitsguide/index.htm.
[3] *California Systems Engineering Guidebook for ITS.* January 2007. FHWA California Division and Caltrans. Located at http://www.fhwa.dot.gov/cadiv/segb/.

aid a project team in determining when and how to undertake a more rigorous systems engineering analysis beyond the "ITS Project Systems Engineering Review Form."

Recommendation: Modify *Design Manual* Chapter 1050 to provide clear guidance on how to determine and document the appropriate level of systems engineering based on the complexity, risk, and scope of ITS projects:

1. Provide definitions of categories of ITS projects based on level of risk, complexity, and scope.
2. Provide guidance on how to classify an ITS project into one of these categories.
3. Provide guidance on how to apply systems engineering, including the steps of the "V" diagram, for each project category. Identify any documentation required (e.g., checklists or forms), checkpoints when the documentation is required, any approvals needed, and how the documentation should be filed.

Observation #3: The current WSDOT project development process makes it difficult to deliver ITS projects using the systems engineering "V" diagram. Based on WSDOT staff experience, the Q Program has inherent flexibilities that allow the "V" diagram process to be followed, whereas ITS projects in the I and P Programs have difficulty following the "V" diagram due to the limitations of the traditional project development process.

Discussion: The Q Program is used for many ITS projects in the state. This has allowed the ITS group within WSDOT to establish a project development process that aligns with the systems engineering "V" diagram for complex stand-alone and software integration-type projects.

I and P Program projects are for more traditionally funded transportation projects that follow the traditional development processes. ITS elements that are part of I and P Program projects have experienced difficulty in following a "V" type systems engineering process due to the limitations of the traditional processes. The challenge is seen especially in the testing and validation phases when the construction group wants to shut the project down but more regression testing might be needed on some of the electronics and software.

However, the Northwest Region has recently completed a series of complex ITS projects, such as the SR 167 High Occupancy Toll (HOT) Lane project and I-90 Variable Speed Limit (VSL) project, programmed under the I Program. These projects generally followed each step of the "V" diagram. These projects should be investigated further to see if there were staffing, scheduling, or funding-related issues related to the I Program that made it more difficult to deliver these projects.

Funneling ITS projects through the Q Program would likely be more conducive to the systems engineering process, but may not be feasible for every project. The difference being, for example, a project that is scoped primarily as ITS versus a project that is a paver or is intended to add capacity that also happens to include some new ITS elements or enhancements to the existing system. I and P program projects are

primarily scoped, designed, and constructed by offices other than the Traffic Offices and are also tied to the traditional project delivery mindset, which does not typically require the V diagram. For the installation of low risk ITS components (e.g., junction boxes, conduits, camera poles, and electrical services), it may be more efficient to use the traditional project development processes present in the I and P Programs. However, for complex and high risk ITS projects, such as software integration and other ITS projects that are laden with a myriad of complex ITS elements, it may be more practical and cost effective to direct project development through the Q Program due to its inherent flexibility and ability to adhere to the systems engineering "V" diagram.

Recommendation: ITS projects that require a more rigorous systems engineering analysis (i.e., higher risk, complex ITS projects as discussed in Recommendation #2) should be given the flexibility needed to complete the steps of the "V" diagram, which is often not the case when programmed under the I or P Programs. This flexibility can be achieved by programming complex ITS projects under the Q Program. However, further investigation of recent I Program ITS projects (e.g., SR 167 HOT Lanes and I-90 VSL projects) that successfully completed the steps of the "V" diagram is needed to better understand how the inherent inflexibilities of the I and P Program can be overcome. The bottom line objective is to structure the ITS project development process in a way that places the individuals most knowledgeable of the ITS being deployed in the key decision making roles in the process to ensure effective project delivery.

In addition, incorporating core ITS elements into the WSDOT Design Matrix procedures, *Design Manual* Chapter 1100, should be considered to allow ITS to be scoped early in the project development process, which will allow a proper systems engineering analysis to be completed. The objective is to institutionalize ITS, as set out in the WSDOT ITS Statewide Plan, as a standard component to the Highway Construction Program.

Observation #4: There are no on-going and accessible systems engineering training opportunities currently available to WSDOT staff. This training is critical to successful implementation of systems engineering on ITS projects.

Discussion: WSDOT is a national leader in professional training and certification for its professional staff. However, WSDOT does not routinely provide training on systems engineering, and systems engineering is not well understood by the civil engineering/ transportation community because it is not typically taught in civil engineering university programs.

On-going systems engineering training is needed for WSDOT staff to successfully implement systems engineering in the state. Even if a project is sourced outside WSDOT, staff needs to understand what the contractor is doing and know how to review work products in order to provide a meaningful check-and-balance to the process.

There are a number of systems engineering training opportunities that can be leveraged in the state:

1. FHWA can provide periodic funding for systems engineering training, such as the training given as part of this process review, through the ITS Peer-to-Peer Program or the FHWA Washington Division office.
2. Web-based systems engineering courses are available through the ITS Professional Capability Building Program (http://www.pcb.its.dot.gov/) and the Consortium for ITS Training and Education (CITE) (http://www.citeconsortium.org).
3. Systems engineering concepts can be incorporated into current WSDOT ITS training classes.
4. Professional groups such as ITS Washington or the Institute of Transportation Engineers (ITE) can potentially organize training opportunities.
5. Expertise at the University of Washington or other universities can potentially be used to provide local training.
6. A National Highway Institute (NHI) course should be developed on systems engineering and be made available on an on-going, as-needed basis.

Recommendation: Leverage the opportunities listed above to increase the availability of systems engineering training to WSDOT staff.

Implementation Plan

Based on the recommendations documented above, an implementation plan was developed that provides a framework for ensuring that the recommendations are not forgotten over time, but are instead implemented within a certain time frame and tracked to measure success of the process review. Table 2 shows the implementation plan as developed by the review team. The implementation plan is considered living, in that it can be refined over time as agreed to by the review team.

Progress on the implementation plan will be documented by the FHWA Washington Division Office. Progress will be tracked through informal quarterly updates by the WSDOT review team members. Communication amongst the review team and those responsible for implementing the recommendations will be the key to achieving the objectives of this process review.

In order to implement many of the recommendations multiple WSDOT programs beyond Traffic Operations will need to be included throughout the decision making process. Strategic Planning and Programming, Design, Construction and Maintenance will be consulted along with outreach to ITS stakeholders statewide within WSDOT. In addition, many of the recommendations will involve significant changes to the WSDOT *Design Manual* which will involve FHWA concurrence and approval. Due to the number of decision making bodies involved a relative time schedule as noted below is recommended as a starting point. As the implementation plan moves forward, more

precise completion dates will be determined. For this report, three broad timeframes were considered for each recommendation:

- **Near Term**: Recommendation implemented by June 30, 2011.
- **Mid Term**: Recommendation implemented by June 30, 2012.
- **Long Term**: Recommendation implemented by June 30, 2015.

Table 2. Implementation Plan

Recommendation	Person(s) responsible	Timeframe	Comments
Recommendation 1: Better ensure the *Design Manual* Chapter 1050 systems engineering requirements are being followed and the "ITS Project Systems Engineering Review Form is being completed for all ITS projects through the following:			The recommendations outlined here will need to be implemented and revised multiple times as the Systems Engineering Process evolves and becomes clearer over time. The Near Term implementation date will spread the work about the current process while WSDOT simultaneously begins the process to increase guidance and direction in the *Design Manual.*
1. Provide clear language in *Design Manual* Chapter 1050 that systems engineering is required on all ITS projects regardless of funding source or program.	Ted Bailey	Near Term	
2. Add the "ITS Project Systems Engineering Review Form" to the Project Design Documentation Checklist.	Ted Bailey	Near Term	
3. Reference the "ITS Project Systems Engineering Review Form" in appropriate sections of *Design Manual* Chapter 300.	Ted Bailey	Near Term	
4. Perform outreach and education to the Region Traffic Engineers and FHWA Washington Division Area Engineers that the "ITS Project Systems Engineering Review Form" needs to be submitted to the FHWA Division Office for federal ITS projects prior to construction authorization.	Ted Bailey and James Colyar	Near Term	Ted Bailey will provide outreach and education to the Region Traffic Engineers. James Colyar will provide outreach and education to the FHWA Washington Division Area Engineers

Recommendation	Person(s) responsible	Timeframe	Comments
Recommendation 2: Modify *Design Manual* Chapter 1050 to provide clear guidance on how to determine and document the appropriate level of systems engineering based on the complexity, risk, and scope of ITS projects:			The time frames for these recommendations are primarily contingent upon the level of detail in guidance pursued. Other states such as California and Virginia will be used as a guide. See the following link for more information: http://www.fhwa.dot.gov/cadiv/segb/.
1. Provide definitions of categories of ITS projects based on level of risk, complexity, and scope.	Ted Bailey Matt Neeley Ron Vessey James Colyar	Near Term	
2. Provide guidance on how to classify an ITS project into one of these categories.	Ted Bailey Matt Neeley Ron Vessey James Colyar	Near Term	
3. Provide guidance on how to apply systems engineering, including the steps of "V" diagram, for each project category. Identify any documentation required (e.g., checklists or forms), checkpoints when the documentation is required, any approvals needed, and how the documentation should be filed.	Ted Bailey Matt Neeley Ron Vessey James Colyar	Mid Term	

Recommendation	Person(s) responsible	Timeframe	Comments
Recommendation 3: 1. ITS projects that require a more rigorous systems engineering analysis (i.e., higher risk, complex ITS projects as discussed in Recommendation #2) should be given the flexibility needed to complete the steps of the "V" diagram, which is often not the case when programmed under the I or P Programs. This flexibility can be achieved by programming complex ITS projects under the Q Program. However, further investigation of recent I Program ITS projects (e.g., SR 167 HOT Lanes and I-90 VSL projects) that successfully completed the steps of the "V" diagram is needed to better understand how the inherent inflexibilities of the I and P Program can be overcome to use the steps of the "V" diagram. The bottom line objective is to structure the ITS project development process in a way that places the individuals most knowledgeable of the ITS being deployed in the key decision making roles in the process to ensure effective project delivery.	Ted Bailey; WSDOT Strategic Planning and Programming; WSDOT Design; James Colyar	Long Term	Institutionalizing ITS has been a topic of discussion for a long time. It is anticipated that multiple discussions will be necessary to determine if and how this concept could be implemented into a core part of WSDOT business. An underlying mid term goal would be to determine the feasibility of this recommendation and level of support from the many stakeholders.
2. In addition, incorporating core ITS elements into the WSDOT Design Matrix procedures, *Design Manual* Chapter 1100, should be considered to allow ITS to be scoped early in the project development process, which will allow a proper systems engineering analysis to be completed. The objective is to institutionalize ITS, as set out in the WSDOT ITS Statewide Plan, as a standard component to the Highway Construction Program.	Ted Bailey; WSDOT Strategic Planning and Programming; WSDOT Design; James Colyar	Long Term	

Recommendation	Person(s) responsible	Timeframe	Comments
Recommendation 4: Leverage the following opportunities to increase the availability of systems engineering training to WSDOT staff:			The recommendations outlined here will need to be implemented and revised multiple times as the Systems Engineering Process evolves and becomes clearer over time.
1. FHWA can provide periodic funding for systems engineering training, such as the training given as part of this process review, through the ITS Peer-to-Peer Program or the FHWA Washington Division office.	James Colyar	Near Term	
2. Web-based systems engineering courses are available through the ITS Professional Capability Building Program (http://www.pcb.its.dot.gov/) and the Consortium for ITS Training and Education (CITE) (http://www.citeconsortium.org).	James Colyar	Near Term	Options 1, 2, 4, 5 & 6 under this recommendation will be indentified and made available through WSDOT ATMS training system and/or communicated statewide to ITS Stakeholders through a variety of methods.
3. Systems engineering concepts can be incorporated into current WSDOT ITS training classes.	Ted Bailey	Mid Term	WSDOT resources for conducting in-house ITS training are limited and given the current economic forecast may continue to be on-hold throughout the 09-11 biennium.
4. Professional groups such as ITS Washington or the Institute of Transportation Engineers (ITE) can potentially organize training opportunities.	James Colyar	Near Term	
5. Expertise at the University of Washington or other universities can potentially be used to provide local training.	James Colyar	Near Term	
6. A National Highway Institute (NHI) course should be developed on systems engineering and be made available on an on-going, as-needed basis.	James Colyar	Near Term	

Appendix

Systems Engineering for ITS Workshop Recommendations Report

Acknowledgements: The Review Team would like to acknowledge the efforts of Mr. David Binkley from Lockheed Martin (FHWA Systems Engineering Contract Support). Mr. Binkley was the primary moderator for the Systems Engineering Workshop held in March 2009 and primary author of this Workshop Recommendations Report. Mr. Ron Ice from Ice & Associates (FHWA Systems Engineering Contract Support) and Mr. Nathaniel Price from the FHWA Resource Center also made significant contributions to the Systems Engineering Workshop. Finally, the Review Team would like to acknowledge Mr. Emiliano Lopez from the FHWA Office of Operations and Mr. Steve Sill from the ITS Joint Program Office for providing funding support for the Systems Engineering Training and Workshop.

Purpose of Report

This report documents the results of the Systems Engineering for Intelligent Transportation Systems (ITS) Workshop that was conducted with the Washington State Department of Transportation (WSDOT) on March 17-18, 2009. This workshop combined systems engineering training with a process improvement review that explored WSDOT's current use of systems engineering.

This report identifies WSDOT's successes and analyzes areas of its ITS project development process that could benefit from improved usage of systems engineering approaches. All of the recommendations that are offered were identified during the workshop by the workshop participants in an open-discussion forum. These recommendations are intended to further strengthen the process for the development of ITS projects in the state.

Better systems engineering processes will improve WSDOT's capability to deliver ITS projects. The goal is to continue WSDOT's successes by systematically applying systems engineering to higher risk ITS projects so that they are on-time and on-budget and are efficient to operate and maintain as they meet stakeholder expectations. In addition to these benefits, adopting the recommendations will also enable WSDOT to meet the systems engineering analysis requirements that are identified for ITS projects by 23 Code of Federal Regulations (CFR), Subchapter K – ITS, Section 940.11 (a.k.a. *Rule 940*).

To summarize the Key Recommendations:

- Expand applicability of WSDOT *Design Manual* Supplement on Systems Engineering for ITS to include all projects, regardless of funding source
- Incorporate Core ITS elements into the WSDOT Design Matrix Procedures
- Program the project appropriately based on risk
- Expand the use of Systems Engineering Process Review Form for ITS Projects
- Work with FHWA To Provide statewide/regional ITS architecture training
- Expand the documentation of roles and responsibilities of each stakeholder during the project scoping process in the ITS Project Systems Engineering Review Form.
- Expand the documentation of need for the project at the beginning of the project development process in the ITS Project Systems Engineering Review Form
- Expand the documentation of project requirements and relate these requirements to the needs for the project in the ITS Project Systems Engineering Review Form
- Create a configuration management process and use this process to manage ITS project changes to scope, budget and schedule for large and complex ITS projects
- Work with FHWA to Increase Systems Engineering training

These will be discussed in more detail later in this report.

Background

In 1998, Congress passed the Transportation Equity Act for the 21st Century. Section 5206(e) of that law required USDOT to develop regulations to implement the ITS program. The FHWA went through the rule making process and developed the regulations contained in 23 CFR, Sec. 940. This rule requires use of a systems engineering analysis on all federally funded ITS projects.

Over the last century, a robust, systematic process for developing traditional roadway projects has evolved. WSDOT, like most DOTs, has a rigorous set of procedures that define how these projects are developed. The more recent introduction of ITS adds a new level of complexity to transportation projects that cannot be managed in the same way that more traditional construction projects are managed. Systems engineering is a systematic process that was developed specifically for complex technology projects. Good technical control of ITS development using systems engineering is critical to project success.

The Systems Engineering for ITS Workshop focuses on the ***application*** of systems engineering to the existing project delivery process. The workshop covers: 1) the benefits of using systems engineering, 2) how to satisfy the Federal requirements for systems engineering as documented in Rule 940.11, and 3) how to apply systems engineering to an agency's existing project delivery processes.

As shown in Figure A-1, WSDOT project delivery documentation was reviewed prior to the workshop. This documentation review allowed the workshop facilitators to familiarize themselves with WSDOT's current process and tailor the workshop. During the workshop, the facilitators and participants worked together to review WSDOT's ITS project development process and identify process improvement recommendations. Following the workshop, this report was prepared by the facilitators and FHWA.

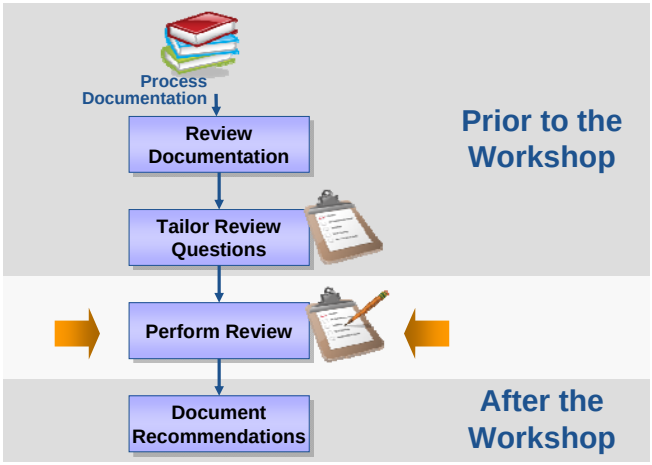

Figure A-1: SE Process Review Process

Data Collection and Review

Workshop participants did an excellent job of providing documentation prior to the workshop. General process documentation and strategic planning documents were provided along with documentation for four ITS projects. The documents that were reviewed are listed in Table A-1. This documentation was reviewed by the workshop facilitators prior to the workshop and was the subject for the discussions on day 2 of the workshop.

Table A-1: Reviewed Documentation

Project/Area	Document Name
WSDOT General Process Information	*Design Manual*, Chapter 860 – Supplement for ITS Systems Engineering, 12/30/05
	Design Documentation Package Checklist
	Design Manual, Chapter 330 – Design Doc, Approval, & Process Review
	WSDOT Project Management Website (http://www.wsdot.wa.gov/Projects/ProjectMgmt/Process.htm)
WSDOT Olympia Region, Puget Sound Traffic Map Extension	Design Documentation File, April 2007
WSDOT Eastern Region, Spokane Traffic Operations for Arterials	Work Plan
	ITS Partnership Agreement Between FHWA & WSDOT for Spokane Regional TMC Integration
	ITS Integration Program Application – Project Description
	ITS Standards Testing Program, Test Site Profile Information
	ITS Evaluation Interviews – Assistant Traffic Eng and the former TMC Manager
	Letter to FHWA
	Phase III Work Plan (Contract Amend 5)
WSDOT North Central Region, US 2 Stevens Pass VSL System	FY03 Integration Program - US2 Stevens Pass Variable Speed Limit Proposal
	Design Document Package
	Project Related Email
	Other correspondence, files
WSDOT North West Region, Traffic Flow Map Extension	Design Documentation Package Approval Memo SR 18 – XL2289 PIN 101800H/FA project # ITS-2005(033)
	Design Documentation Package Design Approval
	DDP Estimate (spreadsheet)
	DDP Memo
	Ramp Evaluation Upgrade Memo
	Project Design Document Checklist (spreadsheet)

Workshop Summary

The two-day workshop was held March 17 and 18. The first day's training was held at the Gwinwood Center in Lacey, WA. The second day was conducted at WSDOTs Materials Lab Conference Room in Tumwater, WA. The workshop included two parts:

- Systems Engineering Training – The workshop began with a focused one-day course on systems engineering. The training course assumed no previous systems engineering knowledge. It began with general concepts and progressed to specific techniques for applying systems engineering to ITS project development and within an organization. That day involved over 40 stakeholders from across the state including members of local planning agencies and municipal traffic departments.

- Process Improvement Review – On the second day, a smaller group of participants from WSDOT applied what they learned about systems engineering to their own ITS project delivery process as they answered a series of process improvement review questions. The questions were structured to explore various aspects of systems engineering and project implementation for ITS projects with a focus on project development. Facilitators and participants worked together to develop a set of recommendations that are presented in this report.

The WSDOT workshop was unique in that the first day was opened up to a larger group of stakeholders – providing everyone a chance to be introduced to general Systems Engineering and ITS project management concepts. The second day focused on just WSDOT personnel either from the ITS group at headquarters but also representatives from the regions whose projects were part of the review. A list of workshop participants is included in Attachment A.

Workshop Findings

This section identifies WSDOT's strengths and specific challenges that were identified during the workshop.

Process Strengths

Washington has a long history of successful ITS projects. This success was built on a foundation of close working relationships within the DOT community and competent agency staff, university connections, and consultant support. A number of strengths were identified during the workshop:

- **Motivated, experienced people** – Participants from WSDOT had hands-on experience with ITS projects. Participants were engaged in the workshop and eager to share their experiences – good and bad – with ITS projects. WSDOT has already started to develop their project development process and has an experience base upon which to mature that process. Process improvement requires a champion and Ted Bailey was invaluable in preparing for the workshop and will be critical to future process improvements in the DOT.
- **Good positive working relationships** – It was obvious from the workshop participants that cooperation and communication within WSDOT is quite good. The working relationship between the regions and headquarters was also clearly positive and constructive.
- **Proactive desire to improve** – WSDOT and the FHWA Washington Division Office formed a group called the "ITS Systems Engineering Process Review Team" several months prior to the workshop to begin discussions and to follow through. Their charter says that their purpose is to "Ensure that WSDOT complies with the federal ITS Systems Engineering requirements when implementing ITS projects." This proactive leadership should be a model for other states.
- **Good documented processes to build on** – Very few DOTs have a good documented ITS project development process. WSDOT is a notable exception with

its supplement to the *Design Manual* Chapter 860, "Systems Engineering for Intelligent Transportation Systems". This included use of an "ITS Project Systems Engineering Review Form" for all new projects to indicate compliance with the basic requirements from FHWA's Rule 940 for ITS projects. The discussions on day 2 revolved around how to make that more effective and applicable to all types of ITS projects. The larger WSDOT Highway Construction Program also has a well-defined Project Management Process. The focus of the recommendations will be to ensure that the ITS processes and the overall WSDOT processes are aligned well and supportive to overall project success.

- **Already performed systems engineering activities** – Figure A-2 below identifies the steps in the Systems Engineering V that have been performed by WSDOT in previous projects. As shown, taken as a whole, most of the steps in the V have been addressed on one or more projects by at least one of the regions. However, these activities were sometimes isolated in that they weren't performed consistently on every project and were frequently disconnected from other activities on the same project. It should be noted the process review team intentionally selected two projects that started before and after Rule 940 was identified in the ITS Systems Engineering *Design Manual* Supplement, dated December 30, 2005. The purpose of this decision was to evaluate both urban and rural projects from multiple WSDOT regions while providing insight into WSDOTs project delivery improvements in regards to systems engineering as a result of the *Design Manual* Supplements new requirements. Although isolated, the comprehensive coverage of systems engineering activities is a clear indication of substantial adoption of good systems engineering processes by the state.

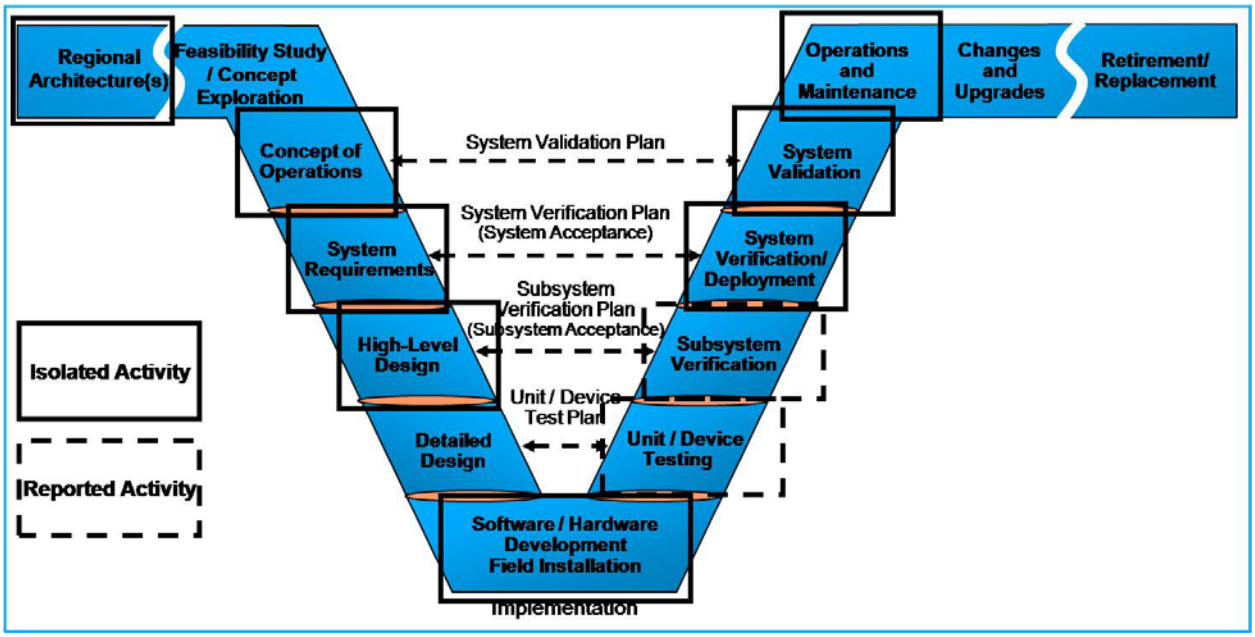

Figure A-2. WSDOT Systems Engineering Activities

Specifically:

- WSDOT and the Metropolitan Planning Organizations (MPOs) have sponsored and materially participated in development of regional ITS architectures as well as a Statewide ITS Plan.
- The federally funded project called the Integrated Corridor Management (ICM) initiative included activities to develop a ConOps and System Requirements. Other projects have included identification of the project participants roles and responsibilities in keeping with the ITS Project Systems Engineering Review Form they are currently using.
- The ICM project included a documented set of Requirements; all projects are required to identify the system requirements per the ITS Project Systems Engineering Review Form. The projects reviewed showed various levels of compliance – usually in the form of a high-level paragraph about the project.
- It was reported that in-house projects for upgrading the TMC software include design documentation. Other WSDOT project files included detailed drawings of the placement of devices and tables showing the types of devices to be procured and installed.
- Although detailed test plans/procedures were not submitted, it was reported that contractors are required to test their products and demonstrate they work satisfactorily on site as part of the acceptance process.

Identified Challenges

During the workshop, participants identified challenges that they have encountered in developing ITS projects. The challenges discussed were:

- **Lack of consistency in applying ITS process documentation and policy** – WSDOT has an ITS Project Systems Engineering Review Form that has been used at a basic level that meets rather than exceeds the Rule 940 requirements.

- **Disconnect between ITS and Traditional processes** – The WSDOT *Design Manual* is meticulously followed for traditional roadway projects. The *Design Manual* and other supplied process documentation do not completely address all ITS project components and ITS elements that deal with deployment of ITS field equipment as a part of a roadway project. The *Design Manual* supplement for WSDOT is a good start but is needs to be applied consistently to all ITS projects, regardless of funding source or whether it is embedded in a larger capital project.

- **Funding Lines lead to different management processes –** The Q Program is used for many ITS projects in the state. This has allowed the ITS group within WSDOT to setup establish a project development process that aligns with the “V” type systems engineering process for complex standalone and software integration type projects. I and P Program projects are for more traditionally funded transportation projects that follow the traditional development processes. ITS elements that are part of I and P Program projects have experienced difficulty in

following a “V” type systems engineering process due to the limitations of the traditional processes. The challenge is seen especially in the testing phases when the construction group wants to shut the project down but more regression testing might be needed on some of the electronics. Funneling ITS projects through the Q program would be more conducive to the systems engineering process, but may not be feasible for every project. For the installation of “Low Risk” ITS components, (e.g. junction boxes, conduits, camera poles, and electrical services) it may be more efficient to use the traditional project development processes present in the I and P Programs. However, for standalone ITS projects, software integration and other ITS projects that are laden with a myriad of complex ITS elements it is more practical and cost effective to direct project development through the Q Program due to its inherent flexibility and ability to adhere to the Systems Engineering Process required by Rule 940.

- **Ability to staff project oversight work** – As a result of RCW 47.28.030 and RCW 47.28.035 WSDOT has a $60k limitation for state force work and material whenever state force labor is included with any component of a project located on State owned highway right-of-way. An aggregate total of materials and labor above the $60k limitation must be contracted out. This arbitrarily limits WSDOTs ability to use in-house resources to oversee and manage integration projects including the ability to develop Concepts of Operations, requirements documents, testing, verification, acceptance plans, etc. during the iterative systems engineering process.

ITS Project Development Process

A high-level diagram of the WSDOT Project Management Process that has been defined for all projects is shown in Figure A-3. This general process was acknowledged by the project managers in the workshop as being representative of their general approach. This process is well defined on the WSDOT Project Management Website (http://www.wsdot.wa.gov/Projects/ProjectMgmt/Process.htm).

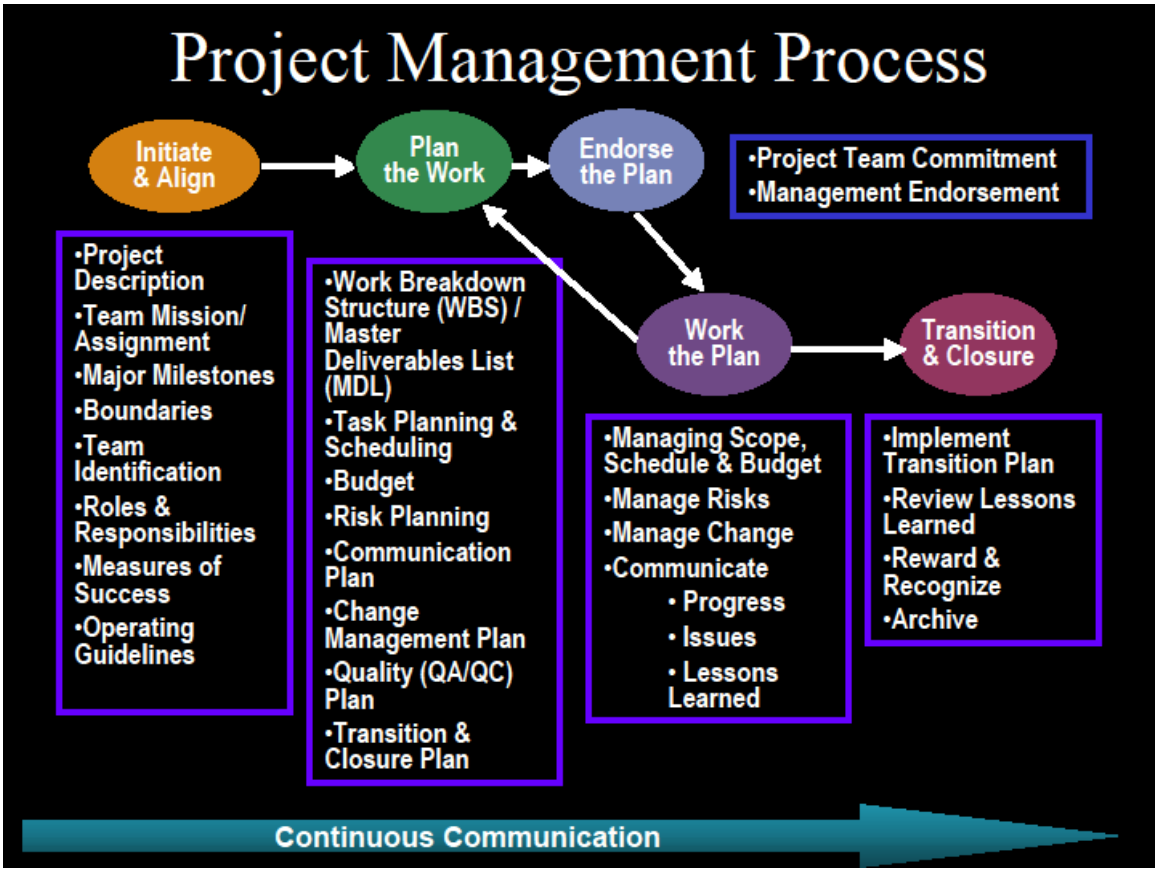

Figure A-3: High-Level WSDOT Project Management Process

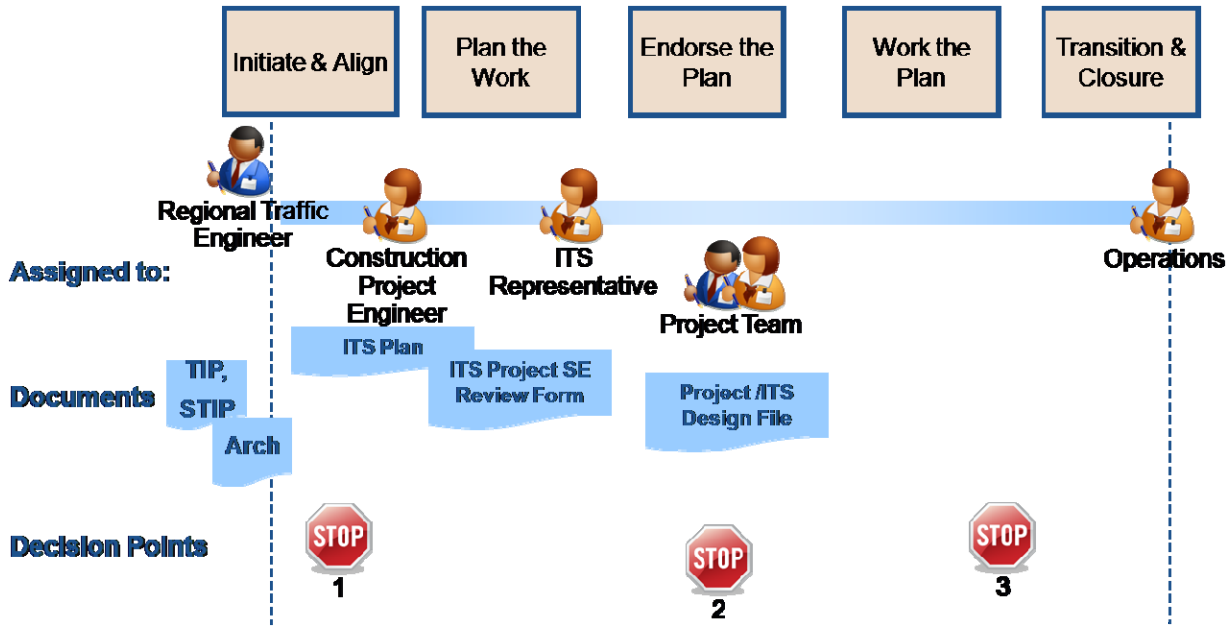

Figure A-4: High-Level WSDOT ITS Project Processes (in-progress)

Figure A-4 above is a similar high-level diagram that was created on day 2 of the workshop to relate the high-level WSDOT management processes to the ITS process described in the WSDOT *Design Manual* Supplement for ITS. This process diagram was not completed in the interest of time, but the preliminary version supported initial discussion of where an ITS Project Systems Engineering Review Form would be completed and some of the traditional project outputs (e.g., the work plan) that could be used to address selected systems engineering requirements. Note that the pure "V" process that is shown in the *Design Manual* Supplement should be reconciled with the acquisition process (something akin to Figure A-4) that is typically used by the agency. Identification of the connections between the "V" process and the agency acquisition process will facilitate integration of systems engineering activities with traditional WSDOT project development activities and the *Design Manual*.

Recommendations

This section lists all of the recommendations that were identified during the workshop by workshop participants. These recommendations are intended to further strengthen the process for the development of ITS projects in Washington. The key recommendations that could be prioritized by WSDOT during the coming biennium's are highlighted with a star (★). Discussion that occurred during the workshop follows each recommendation.

General Process Recommendations

★ **Expand applicability of WSDOT *Design Manual* Supplement on Systems Engineering for ITS to include all projects, regardless of funding source.** The group agreed that the systems engineering approach described in the *Design Manual* Supplement should be followed regardless of funding source; whether federal or state sources are used.

★ **Incorporate Core ITS elements into the WSDOT Design Matrix Procedures.** The Design Matrices covers all aspects of a traditional construction project. Project scoping is driven by the design matrices. Adding ITS to the matrices will make sure it is considered along with other aspects of design, e.g. traffic signals and illumination. This will ensure that ITS doesn't fall through the cracks. Get ITS into the solutions being considered for any roadway or corridor improvement. Currently ITS is seen as an add-on to a project or a stand-alone special project. ITS needs to be more central to the overall process. FHWA division office approves changes to the design matrices.

★ **Program the project appropriately based on risk.** Low risk projects can remain in larger highway construction projects and follow the established traditional processes of the I and P Programs while higher risk projects should follow the Systems Engineering "V" process best facilitated by the Q Program.

★ **Expand the use of Systems Engineering Process Review Form for ITS Projects.** It has been used to date at basic level that meets rather than exceeds the Rule 940 requirements. It should be used to guide the development of the project,

serving as a reminder to the manager of what tasks to include and what questions to ask as plans are made, concept of operations and specifications written, and tests completed.

- **Work with FHWA to Provide statewide/regional ITS architecture training.** FHWA, WSDOT HQ and Regions should collaborate to ensure that everyone involved in ITS project development is equipped to access and interpret the statewide and regional architectures to be able to relate them to ITS projects.

- **Continue Coordinating regional ITS architectures with the Statewide ITS Strategic Plan.** The WSDOT Regions and MPOs have developed ITS architectures based around MPO boundaries. The statewide ITS projects have all been documented in the statewide strategic plan. However, there may be places where the two efforts are not in sync – e.g. MPOs planning for ITS projects incompatible with WSDOT's plans and vice versa.

- **Communicate process review recommendations to DOT management.** Ted Bailey has been instrumental in developing the *Design Manual* Supplement and should continue to lead the effort to integrate ITS into other WSDOT processes.

Technical Process Recommendations

- **Expand the documentation of roles and responsibilities of each stakeholder during the project scoping process in the ITS Project Systems Engineering Review Form.** Stakeholder roles and responsibilities should be defined and documented for all large and complex ITS projects. A concept of operations should also be developed for large and complex projects that includes roles and responsibilities. This activity should be included in the ITS project development process so that roles and responsibilities are defined consistently. Currently it is being covered very generically in the completion of the ITS Project Systems Engineering Review Form. Roles and Responsibilities should be firmly established for large and complex, "High Risk", ITS projects.

- **Expand the documentation of need for the project at the beginning of the project development process in the ITS Project Systems Engineering Review Form**. The practice of defining the project needs during project initiation should continue to be institutionalized so that needs are developed and documented for all projects. Particularly for complex or risky projects, the development of a detailed Concept of Operations (ConOps) should be considered to define the operational needs in more detail. Every large and complex ITS project should have a documented set of needs that are agreed to by project stakeholders since the needs form the basis for the systems engineering process. WSDOT currently defines needs through a collaborative effort during project initiation but this practice needs to be expanded into the documented project development process at WSDOT.

- **Expand the documentation of project requirements and relate these requirements to the needs for the project in the ITS Project Systems Engineering Review Form**. WSDOT has some projects that have documented requirements but not in a formal way nor is it consistent across projects. Some ITS Project Systems Engineering Process Review Forms included a bulleted list of required functionality, which for a project should include more detailed shall statements to govern the technical aspects of the project. WSDOT should continue formalizing the process to ensure that 1) requirements are documented in a timely fashion, and 2) requirements are validated by stakeholders to address (trace to) project needs.

- **Continue to include regular participation by operations and maintenance personnel as the project is being developed.** Personnel who will be responsible for operating and maintaining the completed system should be involved throughout project development, including IT personnel where applicable. These personnel should have input during initial project phases including project planning, RFP and Concept of Operations development and also be involved as the consultant/contractor designs, builds, and delivers the system. In WSDOT, Maintenance and operations are part of the in-process validation. Other departments are brought in as necessary: environmental, bridge, geotech, IT, wireless, etc.

- **Continue institutionalizing the process for regional ITS architecture use.** While ITS projects are still in the concept phase, it is important for the portion of the applicable ITS architecture (either statewide or a regional) to be identified so that other stakeholders, interfaces, etc. in the architecture can be explored. In the past when ITS was directed through earmarked projects it was part of the projects earmark application but then the box may have been checked with no backup or a single diagram representing the whole project. A process for architecture use should be documented to reduce the reliance on single points of contact at HQ and to ensure that it is applied consistently across projects and regions.

- **Regional Architecture (RA) and SE checklist should be required for Congestion Mitigation and Air Quality (CMAQ) projects –** Currently, it is unknown if CMAQ projects have been using the SE checklist or mapping to the architecture. As federally funded programs, they are required to follow the same Rule 940 requirements as other ITS projects.

- **Define a consistent set of reviews for ITS projects –** Just like the Plans, Specification and Estimate (PS&E) milestone reviews that are a standard part of construction projects, a set of standard checkpoint reviews should be defined for large and complex ITS projects. WSDOT should develop standard contract language that requires specific reviews with guidelines for participation, deliverables to be reviewed, actions and outcomes. These checkpoint reviews should occur at the conclusion of each major project development step and provide an opportunity for project stakeholders to review and approve key deliverables before progressing

to the next project step. For example, a review at the completion of the system design step allows WSDOT, other stakeholders, and the consultant/contractor to verify that the project design elements meet the contract requirements and validate that needs are still being met. Checkpoint reviews provide an opportunity for stakeholders to monitor project status and identify and remedy problems while the problems are more manageable.

- **Continue to Require documented test plans and test results as part of the project deliverables –** WSDOT should continue to require their contractors to use systematic testing processes for all large or complex ITS projects. Tests should be tied specifically to project requirements to ensure that all requirements are adequately tested. An ITS project RFP should require test plans and test results that confirm that the project meets all the project requirements.

- **Document process for doing alternatives analysis for large and complex ITS Projects** – WSDOT involves various stakeholders and includes multiple vendors to provide show-and-tell early on in a project. To aid ITS project managers, consider including a standard process for performing alternatives analysis when ITS project development processes are documented.

Project Management Recommendations

- **Create a configuration management process and use this process to manage ITS project changes to scope, budget and schedule for large and complex ITS projects.** WSDOT has a project control reporting form for changes to scope, budget, and schedule. Changes to design and other aspects are maintained in the Project Files; even email correspondence is used to document key decisions on a project. For earmark projects, which are no longer used, there was an informal process to inform FHWA of the need for a change to get their buy-in. This hasn't been done for CMAQ projects but it should be the same process. WSDOT should establish criteria that defines when formal change management is required in terms of 1) when in the project development process it is required, and 2) the magnitude of change that requires formal change management.

- **Create a work plan for all large and complex ITS projects.** An ITS project manager should begin by developing a plan that defines the scope of work, budget and resources, and project schedule. The project should then be managed per the plan. WSDOT project managers are good about doing this for projects in the regions involving field device installations. A work plan should be well documented for all large and complex ITS projects.

- **Continue to Document a procurement planning process for ITS projects.** The procurement strategy for ITS projects should be tailored based on project risk and WSDOTs experience with the specific type of project. WSDOT has successfully used a variety of procurement approaches to meet project delivery needs. (e.g. General Administration and Department of Information Services Contacts,

Proprietary and Sole Source equipment Identification, and Performance Specifications).

- **Document a risk management process that includes risk identification and monitoring.** WSDOT manages ITS project risks informally as part of the Project Management Plan (PMP). Also, for internally developed projects they are able to mitigate risks as they arise by separating intermediate modules to keep the functionality during switch over of each element. Consider documenting a more formal risk management process once each agency gains more experience. The documented risk management process should ensure that all large and complex ITS projects include risk identification and monitoring during development with participation by the agency, other stakeholders, and contractor for outsourced projects.

- **Define a standard set of programmatic reviews that support cost and schedule monitoring in conjunction with technical reviews.** WSDOT traditional project management process has a fairly mature process for reviews during a project: Quarterly, Monthly, Weekly reviews at varying levels along with PS&E reviews. The milestones are defined in the PMP and loaded into the Project Delivery Information System (PDIS) for tracking. For large and complex ITS Projects SE-type tasks should also be loaded into that system with metrics that can be used to monitor ITS project progress.

- **Further Develop testing procedures for ITS devices.** WSDOT should further develop formal testing procedures for ITS projects including deployment of field devices and then archive and reuse these tests for future installations. Currently, there is a statewide proprietary products list for products that have been previously tested. Testing procedures have also been developed through special provisions included in ITS project contracts. IT software development also has protocols to test any software before it touches their network.

Support Environment Recommendations

- **Work with FHWA to Increase Systems Engineering training.** WSDOT is a national leader in professional training and certification for its professional staff. In-house or consultant led Systems Engineering training should continue to be made available to project managers and others involved in the development of projects. Even if a project is sourced outside WSDOT, staff needs to understand what the contractor is doing and know how to review their SE work products in order to provide a meaningful check-and-balance to the process.

- **Conduct lessons learned meetings as part of project closeout for large and complex ITS projects and make lessons learned accessible to project managers.** WSDOT should make it a standard practice to conduct and document a lessons learned meeting with the project team at the end of large and complex ITS projects, while the lessons are still fresh. At the meeting, the following questions should be asked:

  - Did you develop any useful workarounds or solutions to problems?
  - For unresolved problems, what preventative measures would have helped?
  - What went so well that it should be considered a new best practice?

  Create a mechanism so that lessons learned will be applied to the next project. For example, create an easily accessible repository for lessons learned.

- **HQ support to the regions.** The HQ group is already helping with some monitoring of budgets and project status, primarily for the Q Program projects. HQ can supplement this by educating the region on how to use the *Design Manual* Supplement and on how to apply the ITS Project Systems Engineering Process Review Form.

Attachment A. Workshop Attendees

Name	Organization	Title	Contact #	Email
Ted Bailey	WSDOT	Signal, Illumination & ITS Engineer	360-705-7286	baileyte@wsdot.wa.gov
Stan Markuson	WSDOT SWR	Traffic Ops Engineer	360-905-2241	markuss@wsdot.wa.gov
Michael Novak	WSDOT	ITS Supervisor	360-905-2017	novakm@wsdot.wa.gov
Robert Stull	WSDOT	ITS, Signals	509-667-3079	stullr@wsdot.wa.gov
David Kieninger	WSDOT NCR	Asst Traffic Engineer	509-667-3081	kienind@wsdot.wa.gov
James Todd Daley	WSDOT SCR	ITS Engineer	509-577-1992	daleyt@wsdot.wa.gov
Tony Leingang	WSDOT OR	Freeway Ops Mgr	360-239-0843	leingaa@wsdot.wa.gov
Stephanie Rossi	PSRC	Senior Planner	206-971-3054	srossi@psrc.org
Diane Hilmo	WSDOT	Project Manager	206-440-4399	hilmod@wsdot.wa.gov
Scott Nutter	City of Auburn	Traffic Operations	253-804-5068	snutter@auburn.wa.gov
Dave Rosen	City of Olympia Public Works	Project Engineer	360-753-8576	drosen@ci.olympia.wa.us
Jim Johnstone	WSDOT	Signal Ops Engineer	360-357-2707	johnsja@wsdot.wa.gov
Ken Burt	WSDOT	Signal Operations	360-704-3216	burtk@wsdot.wa.gov
July Dizon	WSDOT	ITS Design	360-357-2756	dizonj@wsdot.wa.gov
Ray Crumbley	WSDOT OR	Asst Traffic Design	360-704-3206	crumbld@wsdot.wa.gov
Fred Housman	City of Seattle	TMC Manager	206-684-5122	fred.housman@seattle.gov
Fay Schafi	City of Issaquah	Sr ITS Engr	425-837-3422	fays@ci.issaqua.wa.us
Raid Tirhi	City of Bellevue	Sr Transp Engr	425-452-6052	rtirhi@bellevue.wa.gov
Jesse Hannahs	City of Federal Way	Sr Trafffic Engr	253-835-2744	Jesse.hannahs@cityoffederalway.com
Richard Gamble	County – Clark County	Traffic Engr	360-397-6118	Richard.gamble@clark.wa.gov
Sanjeev Tandle	City of Puyllup	Traffic Engr	253-841-5591	standle@ci.puyallup.wa.us
Michael Villnave	WSDOT	Traffic Ops Engr	360-357-2683	villnam@wsdot.wa.gov
Dick Adams	City of Lynnwood	Traffic Engr	425-361-6803	Dick.adams@atecorp.net dadams@ci.lynnwood.wa.us

Name	Organization	Title	Contact #	Email
Ken Kakuk	City of Camas	GIS Coordinator	360-817-1561	kkakuk@ci.camas.wa.us
Ali Eghtedari	City of Vancouver	Traffic Engr	360-487-7705	ali.eghtedari@ci.vancouver.wa.us
Becky Spangle	WSDOT	Traffic Supervisor	509-324-6560	spalglb@wsdot.wa.gov
Larry Frostad	WSDOT ER	Asst Traffic Engr	509-324-6194	frostal@wsdot.wa.gov
Anthony Dorrovah	WSDOT	Traffic Engr	360-357-2787	dorrova@wsdot.wa.gov
Steve Kim	WSDOT	Region Traffic Engr	360-357-2670	kims@wsdot.wa.gov
Ron Vessey	WSDOT	ITS Field Operations Engr	360-705-7942	vesseyr@wsdot.wa.gov
Matt Neeley	WSDOT	ITS Engineer	360-705-7297	neeleym@wsdot.wa.gov
Scott Davis	County – Thurston County Public Works	Traffic Engr	360-709-3034	davissa@co.thurston.wa.us
Martin Hoppe	City of Lacey	Transportation Manager	360-491-5600	mhoppe@ci.lacey.wa.us
Vinh Dang	WSDOT	Freeway Ops Engr	206-440-4462	dangv@wsdot.wa.gov
Wendy McAbee	FHWA WA Div	Area Engineer	360-753-9025	Wendy.mcabee@dot.gov
James Colyar	FHWA WA Div	ITS Mobility Engineer	360-753-9408	James.colyar@dot.gov
Nathaniel Price	FHWA OR Div + Resource Center	ITS Engineer	503-587-4709	Nathaniel.price@dot.gov
David Binkley	Lockheed Martin	Systems Engineer	703-367-3148	David.binkley@lmco.com
Ron Ice	Ice & Associates	Systems Engineer	714-692-0180	ronice@ronice.com