Table of Contents

STEP 3 – DETAILED SYSTEM PLANNING AND DESIGN

The main objectives of Step 3 are to develop system requirements and specifications, develop performance measures for the system objectives, and prepare plans for deployment and subsequent operations and maintenance. The product of this step will be the overall Work Zone ITS System Plan. Sub-steps to developing the plan are depicted in Figure 12. These steps should be done within the context of TMP development, implementation, and evaluation for coordination with other TMP strategies.

Figure 12. Sub-steps to be explored in Step 3.

3.1 Determining system requirements and specifications

The objectives of the ITS work zone application and the manner in which it would operate to achieve these objectives are documented in the concept of operations developed in Step 2. The next step is to develop system requirements. These requirements define what the system will do. System requirements and specifications will be most effective if they also define performance targets and requirements. Typically, a trade-off exists between the amount (and cost) of system features and components (i.e., spacing and coverage of sensors, number and types of information dissemination devices, and services to be provided, etc.). Defining performance targets and requirements provides a basis for deciding what features and components are critical to achieve system objectives. All requirements should link with specific user needs and/or operational policies and constraints established in the concept of operations documents to preserve traceability. No requirement should exist that does not link to a user need, operational policy, or operational constraint, and vice versa.

By conducting a thorough and well-focused requirements generation process, agency staff will better manage stakeholder expectations, ensure that the key needs identified earlier are addressed, and gain consistent understanding of and buy-in for the system, and will be able to develop a more realistic estimate of the project deployment schedule and cost. The level of effort required for this activity depends on whether the agency has used a system of similar capabilities in the past and has past requirements and specifications (its own or from a peer agency) from which to work, and how many unique or unusual objectives exist. The National ITS Architecture[24] can help define requirements and specifications, and should be consulted and followed when designing such systems. For more complex projects, the requirements documentation process should be done in two levels to include first high-level requirements, then detailed requirements.

Some examples of system requirements that have been developed by state DOTs for several types of work zone ITS are available from AASHTO.[25] The examples are from several State DOTs, including Michigan, Minnesota, Missouri, and North Carolina, and cover real-time traveler information systems, speed management, and dynamic lane merge systems. An example of requirements for a work zone ITS are presented in Figure 13 below.

Requirements will necessarily vary for various types of systems, deployments, and agencies. As an example, a Minnesota project team developed this set of physical, functional, system, and maintenance requirements for the deployment of a traffic monitoring system in a work zone.

Physical Requirements1. The system shall be self-contained in a traffic barrel. 2. The traffic barrel shall be indistinguishable from other traffic barrels to passing drivers. 3. The device shall meet crash safety standards for use on the National Highway System.

Functional Requirements

1. The system shall detect speed of vehicles travelling towards the sensor.
2. The system shall detect the volume of vehicles travelling towards the sensor.
3. The system shall have a cellular modem for communication to the central office when cellular access is available.
4. The system shall have a satellite modem for communication to the central office when cellular access is not available.
5. The system shall report speeds within three miles per hour of actual speeds.

6. The system shall be configurable to report data every minute.
7. The system shall be configurable to operate in a continuous data collection mode.

System Requirements

1. Data requirements
    a. The system shall report data in real time.
    b. Real time data shall be available from a designated website.
    c. The system shall report data to the central office.
    d. The system shall report adjustable binned historical data.
        i. System shall report 85th percentile speed data.
        ii. System shall report 50th percentile speed data.
        iii. System shall provide a binned speed curve.
    e. Binned historical data shall be downloadable from a designated website.
        i. Historical data shall be downloadable in Microsoft Excel format.
    f. The system shall be capable of providing per vehicle speed records.
2. Website requirements
    a. Data recorded by the device shall be available on a designated website.
    b. Historical data on the website shall be password protected.
    c. The website shall provide a mapping function that pictorially illustrates the location of the devices.
    d. The website shall provide a mapping function that pictorially displays speed data in a color-coded format.
    e. The website shall provide both graphed and tabular historical data.
    f. The website shall produce an XML feed that can be parsed by the DOT's traffic management software.

Maintenance Requirements

1. System setup shall only require one person.
2. System shall be powered with a sealed 12-volt battery.
3. System shall function for a minimum of 14 days on a single battery charge.
4. System battery shall be replaceable in the field without losing data.
5. System shall recharge within a 12-hour period when connected to 120 VAC power.

These requirements can be found at: http://www.dot.state.mn.us/guidestar/2006_2010/icone/iconefinalrequirements.pdf.

Source: Minnesota DOT

Figure 13. Requirements for a work zone ITS deployment in Minnesota.

As part of the system requirements and specifications process, agencies should consider the potential need for, or opportunities of, establishing interoperability and connectivity with other ITS components and transportation management system components in the region. Doing so can result in significant economies of scale and expand the potential range of influence of a work zone ITS. For example, a work zone traveler information system could be designed to feed information to an agency's existing traveler information website or 511 system, rather than establishing a separate website or not making the information available online to the public and others. A work zone incident management system may be best accomplished by installing temporary devices in and around the work zone to monitor and view traffic conditions, and sending the data and images back to the regional TMC already in place, as depicted in Figure 14, rather than developing a separate temporary TMC for the project or relying solely on DOT project staff to monitor the images. The FHWA publication *Designing for Transportation Management and Operations: A Primer* would be a useful resource for these considerations[26].

Work zones are often dynamic and frequently changing throughout a project. Consequently, the system requirements and specification definition process should also address if and how the system must respond to changes in the work zone environment over time. Whether it be a change in device location to accommodate major traffic switches, adjustments in the thresholds being used to activate certain control and management functions, or provisions in a contract that determine when the system is no longer needed, it is important to think through and capture these requirements at this point in the design process. With respect to system duration considerations, work zones can be finished ahead of schedule or be delayed. Consequently, it is often a good idea to include contingency plans within the system design process. Adding a contingency plan could increase costs somewhat, but may be preferable to having to retrofit the system after the fact.

3.2 Developing the system design

Development of the system design will take into consideration much of the documentation assembled in previous steps. The concept of operations from Step 2 describes how the system will work, and system requirements and specifications provide more specific details for what the system needs to do. In this step, the hardware and software interfaces, site plans for the system components, and the integration of the COTS elements are designed. It is important that the design team or contractor has access to all of this documentation when developing the system design, especially if innovative contracting methods are used.

The project team will establish the number and type of technological components during system design, if not already identified through the development of the requirements and specifications in substep 3.1. Alternatively, an agency may choose to allow a contractor to propose all or some aspects of the work zone ITS system design, given the requirements and specifications that the agency has developed. The system design provides additional detail regarding the placement of components within the project area. Strategic placement of components such as sensors and PCMS is important for the work zone ITS deployment to be effective. For example, PCMS used for a queue warning system need to be placed upstream of the maximum expected queue length.

Figure 14. The Las Vegas Freeway and Arterial System for Transportation (FAST) provides regional support for work zone activities.

This is also an appropriate time to consider driver capabilities to verify that the system being planned for and/or designed will be satisfactory from a human factors perspective. Motorists can only process a limited amount of information while driving. It is important that any messages planned for display on CMS follow current guidance to ensure that the information is clear, concise, and credible. Characteristics of the devices and their deployment locations should also be considered. For example, the Manual on Uniform Traffic Control Devices[27] provides specifications for CMS, stipulating that the size of the text on a message display must be sufficiently large and visible (a minimum of 18 inch characters for freeway conditions) so that drivers do not have to slow down to give themselves more time to read. Message boards should be positioned away from obstructions that might limit viewing times, such as piers, abutments, parked construction equipment, etc. In areas with significant truck traffic, the agency should consider whether some message boards need to be on the left as well as the right side of a multi-lane road for visibility. The location should also be far enough upstream of key decision points to allow drivers time to process the information and take appropriate action.

The California DOT “Systems Engineering Guidebook For ITS” may serve as a useful reference during this step.[28]

3.3 Developing a testing strategy

Development of a coherent testing strategy to validate the functionality and accuracy of the ITS is a key component of successful deployment of the system in the demanding environment represented by a work zone. (Note: testing involves validation of the ITS functionality and accuracy before activation, while evaluation assesses the ITS system performance after activation.) The test plan can be prepared by an outside contractor, but should be closely scrutinized by the agency. The test plan does not need to be extensive in all cases; simple validation may be sufficient for a COTS system. Inadequate testing could fail to detect problems in system component operation until after the system is activated for the public.

The test plan should be scheduled to provide sufficient time for resolving any problems that may arise, as well as retesting, in case any part of the system fails the initial testing. Tests should be established for each detailed level requirement defined in Step 2. A table listing all detailed level requirements in one column and corresponding tests in the adjacent column is a useful tool for ensuring that the test plan is adequate. There should be one test for each requirement and a requirement for each test. If either a requirement or a test is missing its corresponding element, the table is not complete.

Acceptance testing typically consists of the following tests:

- **Functional testing** – requirement-by-requirement testing of the system’s ability to meet specifications as envisioned.
- **Performance testing** – evaluates how well the system performs under various conditions
- **Throughput testing** – measures how quickly the system processes a discrete event of data transfer or how quickly the system responds to operator input
- **Storage testing** – measures the ability of the system to store data or handle the operation of multiple programs simultaneously
- **Stress testing** – evaluates system operation under the peak load it is expected to encounter
- **Failure mode testing** – evaluates the system’s ability to diagnose, report, and respond to failures (e.g., field devices, central system computer, power)
- **Operability testing** – tests the system’s ability to operate for long periods without failing (e.g., central software crash).

Test plans for the system should include the following elements:

- Test schedule developed as part of the overall project schedule, including sufficient time for resolving any problems that may arise, as well as retesting in case any part of the system fails the initial test
- Consistent test data used to populate files and databases prior to collection of actual data
- Data sheets used to record test data
- Expected test results including detailed level specifications that define expected system operating parameters (e.g., system reporting every 2 minutes), or other expected results if not called for in the specifications
- Requirements table listing requirements and corresponding tests
- Test reports that tell the project team how well the system performed.

3.4 Planning for operations and maintenance

During the planning step, the agency needs to consider what will be needed for operating and maintaining the work zone ITS. For example, incorporation of work zone ITS components into a permanent ITS deployment may place additional demands on TMC staff. This needs to be recognized during the planning process. Ideally, these types of needs should be addressed as part of TMP development and implementation. Automated systems may require fewer agency operational considerations since operations and maintenance may be handled by the vendor.

The level of effort required for system maintenance planning depends largely on how the ITS portion of the work zone is procured. For example, some DOTs have procured work zone ITS as part of a larger construction contract, and maintenance was the responsibility of the contractor. Operations and maintenance are frequently overlooked in ITS application development.

In general, work zone ITS deployments tend to be concerned primarily with corrective maintenance issues, due to the short life span of these deployments. Short-term maintenance issues include tasks such as replacement of power source for the equipment (e.g., recharging or replacing batteries); minor adjustments of the location of system signs and detectors to reflect queue lengths that are different from what was anticipated; movement of equipment due to work zone configuration changes; and troubleshooting and repairing malfunctions. Longer-term issues, such as system enhancements, are less of a consideration.

Implementing agencies should carefully plan for maintenance needs when determining the response requirements for system uptime and penalties for system downtime. For example, the agency should specify if someone needs to be on-site 24/7, what response times are expected (e.g., within 4 hours, 24 hours), and what penalties will be assessed if a system is down and at what point (e.g., after 2 hours) the penalties will begin.

It is also important that provisions be made to maintain functionality of existing ITS. Many projects result in power (and thus system functionality) being lost, for example, unless special arrangements for maintaining capabilities are made in advance.

Due to the limited duration typical of work zones, operations and maintenance responsibilities can be included with the procurement of the system. For example, an agency can pay a contractor a "per day" fee for the ITS application that includes operation of the ITS. The "per day" fee technique can result in significant staff time cost savings for the agency, as agencies are not required to dedicate staff to these projects or maintain inventories of spare parts. The agency should not be overly prescriptive regarding operational aspects of the ITS, such as requiring that the system process data on-site; vendors may be able to more cheaply process data off-site, and send it back to the field, as needed.

Example: Operations and Maintenance costs – I-70/I-57 Project in Effingham, Illinois.

Operations and maintenance costs can vary significantly for various reasons. A traffic management system was procured as part of the overall bid by the contractor for a work zone project on the I-70/I-57 interchange in Illinois. This was budgeted at $1,800/month over 25 months ($45,000 total) for 70 devices. IDOT intended for the system to remain operational and used during 3 other contracts that were scheduled to occur within the section over the next several years. The next contract that was let also included this component, but was bid at much a different value: budgeted at $29,767/month over 25 months ($744,187 total) with only a few devices added from the previous contract. Agency and contractor understanding of desired operational conditions is important for requesting and submission of bid requests because the bid costs can vary greatly.

3.5 Determining staff training needs for those using and operating the work zone ITS

The amount of training needed will be determined by the approach that will be taken to procure, operate, and maintain the system. If the system will be leased, operated, and maintained by the vendor or a contractor, training of agency staff will focus primarily on operational aspects of the system. This can be very important as the agency, contractor, and vendor work to fine-tune the system. For example, for a recent work zone ITS deployment in Illinois, the agency, contractor, and vendor worked together to identify ways to improve the queue-end warning system, calibrating it to generate messages from queue length data, and make adjustments as necessary throughout the course of the project. However, if the agency will be responsible for operating and maintaining the ITS, agency staff will need to receive in-depth training on all aspects of the system. Agency staff will need to learn about each component of the system, and how the components work together, as well as system set-up, maintenance requirements, testing techniques, and troubleshooting. The agency will need to determine the most appropriate people to receive the training, which would most likely be provided by the system supplier. Redundancy in staff training should be included to account for staff turnover and absences.

The National Highway Institute (NHI) offers courses addressing a wide variety of aspects of ITS.[29] The curriculum covers several topics of interest to project managers of work zone ITS, including systems engineering, project management, telecommunications, software acquisition, and ITS procurement.

The Consortium for ITS Training and Education (CITE),[30] composed of numerous university and industry partners, offers a wide variety of ITS online courses on topics that include incident and emergency management, transportation management, systems engineering, and rural ITS.

Other resources include ITS courses available through the Local Technical Assistance Program (LTAP).[31] Also, some agencies that operate and maintain permanent ITS have developed their own curriculum.

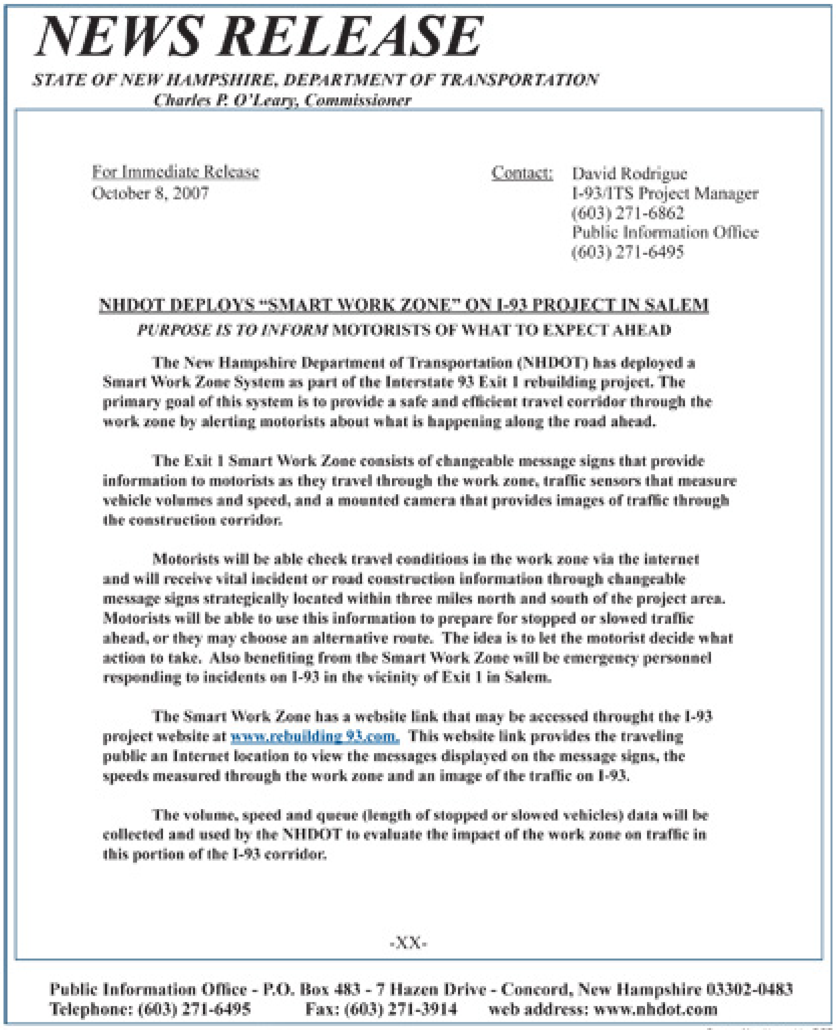
3.6 Planning for public outreach

An important step in the planning process is to determine the amount and type of public outreach that the agency wants to pursue to alert local residents and businesses to the system and its capabilities, including web-based information. For example, how useful would it be to display real-time traffic information on a website if nobody knew that the website existed or how to access it? Carefully prepared press releases and involvement in community meetings are some of the strategies employed with success by state agencies.[32] A number of agencies have learned that proactively working with the media has been a highly successful means of reaching out to the public. The media provides the agency with a free means of disseminating information to the public. It is important to plan for public interaction throughout the course of the project and should be done within the context of TMP development, implementation, and evaluation for the project, in order to keep the public informed and receive their feedback. An example of a press release is exhibited in Figure 15.

The FHWA offers a guide about "Work Zone Public Information and Outreach Strategies" that is designed to help agencies plan and implement effective public information and outreach campaigns to mitigate the negative effects of work zones.[33]

Tip: It is important to use a proactive approach in building public awareness of the project and the information that the ITS application will provide.

Successful techniques include holding press conferences, issuing news releases, and keeping local media (especially those the public turns to for traffic information) up to date.



NEWS RELEASE

STATE OF NEW HAMPSHIRE, DEPARTMENT OF TRANSPORTATION
Charles P. O'Leary, Commissioner

For Immediate Release
October 8, 2007

Contact: David Rodrigue
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NHDOT DEPLOYS "SMART WORK ZONE" ON I-93 PROJECT IN SALEM
PURPOSE IS TO INFORM **MOTORISTS OF WHAT TO EXPECT AHEAD**

The New Hampshire Department of Transportation (NHDOT) has deployed a Smart Work Zone System as part of the Interstate 93 Exit 1 rebuilding project. The primary goal of this system is to provide a safe and efficient travel corridor through the work zone by alerting motorists about what is happening along the road ahead.

The Exit 1 Smart Work Zone consists of changeable message signs that provide information to motorists as they travel through the work zone, traffic sensors that measure vehicle volumes and speed, and a mounted camera that provides images of traffic through the construction corridor.

Motorists will be able check travel conditions in the work zone via the internet and will receive vital incident or road construction information through changeable message signs strategically located within three miles north and south of the project area. Motorists will be able to use this information to prepare for stopped or slowed traffic ahead, or they may choose an alternative route. The idea is to let the motorist decide what action to take. Also benefiting from the Smart Work Zone will be emergency personnel responding to incidents on I-93 in the vicinity of Exit 1 in Salem.

The Smart Work Zone has a website link that may be accessed throught the I-93 project website at www.rebuilding 93.com. This website link provides the traveling public an Internet location to view the messages displayed on the message signs, the speeds measured through the work zone and an image of the traffic on I-93.

The volume, speed and queue (length of stopped or slowed vehicles) data will be collected and used by the NHDOT to evaluate the impact of the work zone on traffic in this portion of the I-93 corridor.

-XX-

Public Information Office - P.O. Box 483 - 7 Hazen Drive - Concord, New Hampshire 03302-0483
Telephone: (603) 271-6495 Fax: (603) 271-3914 web address: www.nhdot.com

Source: New Hampshire DOT

Figure 15. Example press release for a work zone in New Hampshire.

3.7 Investigating system security

Agency staff need to take system security into consideration to ensure that access to the ITS application is protected from unauthorized intrusion. System security is especially critical for systems providing traveler information. Most COTS and permanent ITS deployments rely on a multi-level architecture that grants varying levels of access to the system, depending on the attributes of the user. Some users, for example, will be granted the ability to review the system operating conditions on a website, but not be able to change operational strategies or access more detailed data. Other user may be designated managers of the system, and be allowed to make certain changes to the system. Typically, one or two users may be designated as the system administrator, with the greatest level of access and control privileges granted to them.

In addition, agencies also need to consider the vulnerability of the system's physical components. Sturdy locks and strong passwords should be placed on cabinet doors and computer access points, respectively, where possible. All keys and passwords for the equipment should be stored away from the devices. Also, many agencies position devices in locations where it is difficult for thieves to access and steal the device. Although these are basic security procedures, several locations around the country have experienced security violations where PCMS were programmed to display a false message (see Figure 16), which was made possible by easily guessable or visible system passwords. Easily portable components, such as solar panels, trailer tires, and barrels with sensors have also been stolen. Advances in global positioning satellite (GPS) and other technology in recent years has made monitoring and tracking of equipment easier, reducing theft and vandalism problems.

Figure 16. PCMS in several states have been illegally accessed and had messages changed.

Example: Work Zone ITS Security Issues.

Vandalism was a problem on the I-40 reconstruction project in West Memphis, Arkansas. Although securely locked, the control center trailer was broken into by vandals, who ripped the system wires from their connections and destroyed the monitor for the computer. The vandalism resulted in several days of downtime while a replacement computer was sent from the system developer, and damaged wiring was reconnected.

At a separate project in Illinois, a set of portable traffic sensors was stolen. However, officials used the location tracking technology built into the device to identify their location in the thief's garage, making apprehension and recovery of the equipment by local law enforcement personnel very easy.

3.8 Planning for evaluation

Evaluation is the rational assessment of how well system goals and objectives are being achieved, and it is an essential ingredient in good project management. The most effective evaluations occur when the goals and objectives for a work zone ITS are explicitly stated, measurable, and agreed to by all stakeholders. Considerations for evaluation at the early stage of the project, particularly during concept development and development of requirements, can greatly facilitate subsequent evaluation of the system. Although evaluation should be considered during each step of the process, formal planning for evaluation cannot occur until the system is well defined.

The primary purposes of evaluations are to:

- Identify changes needed to fine tune and optimize existing system operation or design and improve performance. In this way, the deployment is more likely to meet or exceed established goals and objectives.
- Understand and quantify the benefits of the system, which can help to identify future work zone ITS investment decisions (by documenting conditions for a successful implementation).
- Document lessons learned.

Planning for evaluation should begin with a determination of the appropriate scope for the evaluation. The scope for the evaluation establishes the extent of the assessment (e.g., effort, level of detail, how frequently evaluation will be done for the project) and might be based on the complexity of the system, as well as the duration and scale of the project.

Quantifying benefits need not be overly complex: for example, a North Carolina Smart Work Zone system was observed to have fewer crashes compared to other work zones without the technology.[34] Another example of quantified benefits was documented in the case of a California automated work zone information system that reduced traffic demand through the work zone, having a maximum average peak delay 50 percent lower than expected.[35] Public satisfaction is also valuable, and comments and feedback from the public can be a useful gauge of the value of a system. In Little Rock, Arkansas, for example, 82 percent of drivers surveyed agreed that an Automated Work Zone Information System improved their ability to react to slow or stopped traffic.[36]

An evaluation includes, at a minimum, periodic monitoring of the data and analysis of performance measures, which necessitates a plan to collect and archive relevant data to adequately assess system performance. For example, an evaluation of a traveler information website might include counting hits or user sessions. Tracking visitor sessions or "visits" to the website is recommended as a tool to easily compare between sites. Trends on website usage may also assist in evaluating other facets of the work zone project, such as the effectiveness of a public awareness campaign and whether a website is a good investment that should be included on future ITS deployments.

Evaluation can benefit the agency responsible for the deployment of the work zone, as well as the traveling public. The lessons learned can be used for adjustments to the current system and can also be incorporated into future work zone applications. By framing a plan for a robust evaluation early, an agency can plan data collection activities, rather than piecing together available shreds of data after the project. This is also a time to consider data needs for agency process review. In addition, evaluation results can serve as a valuable resource for other agencies and planners. In general, the need exists for more data collection to better quantify benefits. Ensuring that work zone ITS will archive data in a format and level of completeness to allow the analyst to drill down to detailed impacts will allow agencies to better quantify those types of impacts, and develop strategies to minimize their occurrence in the future.

Several FHWA documents provide useful guidance for the use of work zone safety and mobility performance measures. First, *A Primer on Work Zone Safety and Mobility Performance Measurement*[37] offers information for understanding data requirements for generating useful performance measures. A companion document, the *Work Zone Performance Measures Pilot Test*[38] summarizes lessons learned through the identification and testing of a candidate set of work zone mobility-related performance measures at five projects nationwide. A third document, *Guidance on Data Needs, Availability, and Opportunities for Work Zone Performance Measures*[39] provides more in-depth information and guidance on the usefulness of various measures, and the data necessary to develop and use them effectively.

Tip: Helpful hints for planning an evaluation.

- Evaluations can be either qualitative or quantitative; however, the best evaluations employ a combination of both types of information.
- The most effective evaluations occur when the goals and objectives for a work zone ITS are explicitly stated, measurable, and agreed to by all stakeholders.
- Examining the role of research in the evaluation step of the project will help clarify the types of analyses that can be performed to produce benefits data.
- It is helpful to provide a mechanism for the public to offer feedback on the project. Several agencies have used comment sections on the project websites to collect this feedback.
- The formality and magnitude of an evaluation should match the level of the ITS deployment. An informal evaluation may be sufficient for simple systems, while a more formal evaluation would be better suited for a larger-scale deployment.

The ITS JPO at USDOT has developed a six-step process for evaluating ITS projects, which is shown graphically in Figure 1y, and should be considered at this stage of the project. Some of these steps will be carried out later during and after system deployment, but the planning should occur now.

Figure 17. Overall evaluation process for ITS applications in work zones.

The *ITS Evaluation Resource Guide*[40] contains a more detailed explanation of this six-step process, as well as a discussion of evaluation measures that correspond to overall ITS goal areas – safety, mobility, efficiency, productivity, environmental impacts, and customer satisfaction. Sample evaluation strategies, evaluation plans, test plans, and final reports are also available for downloading from the website. Table 8 presents some example criteria that might be used for a work zone ITS evaluation.

Table 8. Example evaluation criteria.

Evaluation Objective	Hypothesis	Measures of Effectiveness	Required Data
Mobility – Reduce delay and optimize travel times through the construction corridor by providing advanced traveler information.	The ITS will reduce travel time through the corridor during construction.	• Change in travel time over baseline conditions in the primary direction during construction. • Change in the overall corridor-wide travel time reliability • Change in travel time on recommended or viable alternate routes	• Observed corridor travel time during construction • Observed travel time variability • Observed alternate route travel times during construction • Observed queue lengths before and after ITS on

			mainline routes
Safety – Improve traveler safety in the construction corridor	The ITS implementation will reduce crash risks during construction.	• Changes in the number of crashes or crash severity occurring in the corridor • Changes in speed variability along the corridor during construction • Change in the number of conflicts that occur in the corridor during construction	• Historical crash data • Real-time crash data • Observed speed variability during construction • Observed number of conflict situations occurring during construction
Customer Satisfaction – Improve travel satisfaction for corridor users during construction	The ITS will result in improved satisfaction among corridor users.	• Corridor traveler perceptions • Corridor traveler behavioral response to system components • Update frequency and perceived accuracy of provided information	• Opinions of corridor travelers serving on a panel survey • Traffic volumes on alternate routes and mainline • Wide distribution of customer satisfaction surveys
Institutional – Improve coordination among implementing agencies.	The ITS will result in improved coordination among implementing agencies.	• Number of institutional issues	• Documented institutional issues

3.9 Estimating system benefits and costs

A key part of system planning is estimating system benefits and costs. In estimating the benefits that the system will have on traffic, mobility and safety are both key factors to consider. Estimation of these impacts will become easier as results become available from more ITS in work zone deployments. At present, traffic modeling and traffic flow theory can be used to estimate impacts on delay through factors such as diversion of traffic around the work zone. The level of effort spent to evaluate potential system impacts should be proportional to the size, duration, and complexity of the work zone. A complex 25-mile, 3-year work zone would require a more extensive evaluation of system impacts than that for a simple 1-mile, 2-month work zone. In estimating system impacts, it is important to consider the whole area that the ITS deployment will influence (see Figure 6).

By this stage, the general cost estimates developed in Step 2 can be refined based on better-defined system characteristics. When refining cost estimates, agencies should be sure to consider ancillary costs such as required training, agency labor, outreach activities, and system maintenance. It is also recommended that agencies include a reserve or contingency fund to pay for unexpected items, such as fixing system integration and communications problems (e.g., costs for cellular modems and pagers, etc.).

System costs will vary widely depending on whether the system is purchased or leased, and whether labor associated with operating and maintaining the system is provided internally by agency staff or by an outside contractor. These procurement options and issues will be discussed further in the next section.

The ITS JPO maintains an ITS Benefits and Unit Cost Database to assist users with estimating system and unit costs of ITS elements and deployments across the country.[41]

Key takeaways

- The main products of Step 3 are detailed system plans that build on the concept of operations from Step 2. The concept of operations describes the objectives of the system and how it would operate to achieve the objectives. Step 3 develops the system requirements and specifications that define what the system will do and ideally include performance targets.
- Documentation should include plans for system testing, operating the deployed system, the staffing approach, any necessary public outreach, system security considerations, and evaluation throughout and at the conclusion of the project. It is important to plan for each of these aspects to avoid issues later with system deployment and to ensure that data will be available for system evaluation.
- The most effective evaluations occur when the goals and objectives for a work zone ITS are explicitly stated, measurable, and agreed to by all stakeholders. Then it is much easier to pick appropriate performance measures for evaluation and to know what data to collect to best determine system success and value.

[24]For more information, see: http://www.iteris.com/itsarch/

[25]The AASHTO work zone ITS website can be found at: http://ssom.transportation.org/Pages/ITSinWorkZones.aspx.

[26]This document can be found at: https://ops.fhwa.dot.gov/publications/fhwahop13013/index.htm. [27]Available at: http://mutcd.fhwa.dot.gov.

[28]Available at: http://www.dot.ca.gov/newtech/docs/se_guidebook_ver1-12_14_05.pdf

[29]More information about the ITS curriculum is available on the ITS Professional Capacity Building (PCB) Program website at: http://www.pcb.its.dot.gov.

[30]More information at: http://www.citeconsortium.org.

[31]The LTAP resource database can be searched at: http://www.ltap.org/resources/searchdbs.php.

[32]Note that the Manual of Uniform Traffic Control Devices (MUTCD) prohibits the display of website addresses on CMS and PCMS.

[33]This guide is available online at: https://ops.fhwa.dot.gov/wz/info_and_outreach/public_outreach_guide.pdf.

[34]Additional information can be found at: http://www.itsbenefits.its.dot.gov/ITS/benecost.nsf/ID/AAD0A64995FF6FFA8525733A006D5298?OpenDocument&Query=Home.

[35]Additional information can be found at: http://www.itsbenefits.its.dot.gov/ITS/benecost.nsf/ID/F1F2919AE17E081285257172005C8569?OpenDocument&Query=Home.

[36]Additional information can be found at: http://www.itsbenefits.its.dot.gov/ITS/benecost.nsf/ID/76C9F2DE2BF5DB1D85257603004E031D?OpenDocument&Query=Home.

[37]This is available online at: https://ops.fhwa.dot.gov/wz/resources/publications/fhwahop11033/fhwahop11033.pdf.

[38]This is available online at: https://ops.fhwa.dot.gov/wz/resources/publications/fhwahop11022/.

[39]FHWA-HOP-13-011, February 2013, https://ops.fhwa.dot.gov/wz/decision_support/performance-development.htm.

[40]Available online at: http://www.its.dot.gov/eval/eguide_resguide.htm.

[41]The database is available online at: http://www.benefitcost.its.dot.gov; the website has instructions on how to contribute.