Synthesis of Work-Zone Performance Measures

Final Report
September 2013

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Center for Transportation Research and Education

SWZDI
Smart Work Zone Deployment Initiative

IOWA STATE UNIVERSITY
Institute for Transportation

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Smart Work Zone Deployment Initiative
Federal Highway Administration
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About SWZDI

Iowa, Kansas, Missouri, and Nebraska created the Midwest States Smart Work Zone Deployment Initiative (SWZDI) in 1999 and Wisconsin joined in 2001. Through this pooled-fund study, researchers investigate better ways of controlling traffic through work zones. Their goal is to improve the safety and efficiency of traffic operations and highway work.

About CTRE

The mission of the Center for Transportation Research and Education (CTRE) at Iowa State University is to develop and implement innovative methods, materials, and technologies for improving transportation efficiency, safety, and reliability while improving the learning environment of students, faculty, and staff in transportation-related fields.

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SYNTHESIS OF WORK-ZONE PERFORMANCE MEASURES

Final Report
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CONTENTS

FIGURES

TABLES

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EXECUTIVE SUMMARY

Background

The Federal Highway Administration (FHWA) 2004 Work Zone Safety and Mobility Rule applies to all state and local government agencies that receive federal-aid highway funding after October 12, 2007. This rule was an update to the former regulation (23 CFR 630 Subpart J) to address more-current issues affecting safety and mobility in work zones.

In addition, Moving Ahead for Progress in the 21st Century (MAP-21) emphasizes performance monitoring and performance-based decision-making in order to provide the most efficient investment of transportation funds. MAP-21 focuses on several areas relevant to work zones including safety, congestion reduction, and reduced project delivery delays (FHWA 2013).

Although more focus is placed on performance measures, many agencies are in early stages of selecting and implementing work-zone performance measures.

Project Objectives

The main objective of this research was to identify and summarize how agencies collect, analyze, and report different work-zone traffic-performance measures, which include exposure, mobility, and safety measures. The researchers also examined communicating performance to the public.

Methodology

After conducting and documenting the results of an in-depth literature review to identify effective safety and mobility performance measures and data and reporting needs, the team conducted a survey of seven states surrounding Iowa, as well as Iowa, to provide the most up-to-date information.

These are some of the safety measures that were addressed:

- Crashes (may be stratified by crash type, severity, contributing circumstance)
- Speed
- Work-zone inspection
- Emergency management services
- Surrogate measures

These are some of the mobility measures that were addressed:

- Queue
- Delay
- Capacity
- Speed
- User measures (i.e., surveys, user complaints)
- Work-zone incidents rating

For communicating with the public, the following were examined:

- Missouri DOT TRACKER
- Virginia DOT DASHBOARD
- Washington State DOT Gray Notebook
- Wisconsin DOT MAPSS

The team synthesized the knowledge gathered into this toolbox titled *Synthesis of Work-Zone Performance Measures*.

Key Findings

The selection of which work zones to monitor, the metrics selected, and the frequency of monitoring depends on federal and agency rules and agency and stakeholder needs and priorities. Again, three different types of performance measures are exposure, safety, and mobility or traffic operation measures.

Exposure measures, which include measures such as volume or hours of operation, are used to normalize safety or mobility performance measures to a common denominator so that performance measures can be compared among facilities. For instance, crashes per hour of work-zone operation provide an indication of both number of crashes and amount of time the work zone was present.

Perhaps one of the first steps in collecting data for work-zone performance measures is to collect data that the agency already has. These data can include traffic counts, speed captures, and various other information. Usually, these data can be found in traffic management centers (TMCs) and traveler information systems.

Ways to collect data for work-zone performance measures include both permanent and temporary evaluation systems and devices, traffic management systems, public surveys, and external sources (Margiotta et al. 2006).

The following technologies have been evaluated and found effective for collecting mobility data:

- Automatic license plate recognition (can collect travel times, speeds, vehicle classification)
- Bluetooth (can collect travel times, speeds)
- Magnetic sensor (can collect travel times, speeds)
- Automatic vehicle identification (can collect travel times, speeds)
- Microwave radar (can collect volume, length of vehicles, speeds, vehicle headway)
- Cellular phone (can collect speeds, traffic times)
- Global positioning system (can collect speeds, traffic times) (Chau 2012)

Implementation Readiness and Benefits

The Iowa Department of Transportation (DOT) is working actively to integrate work-zone performance measures into their standard procedures. They are currently involved in research into other state work-zone performance ventures.

The *Synthesis of Work-Zone Performance Measures* that was developed through this research provides up-to-date information and knowledge to help state departments of transportation (DOTs), as well as counties and cities, to better address reporting of work-zone performance. This toolbox also details the resources available on the topic and provides current information and ideas on what other state agencies are doing to report performance to the public.

In essence, this toolbox outlines the different measures that some states are pursuing, options for data collection, and examples of communicating performance to the public.

1. INTRODUCTION

The purpose of this toolbox is to identify common safety and mobility performance measures that are proposed or in use by different agencies nationwide. The review summarizes general information about work-zone performance measures.

1.1 Federal Guidance on Work-zone performance

The 2004 Work Zone Safety and Mobility Rule applies to all state and local government agencies that receive federal-aid highway funding after October 12, 2007. This was an update to the former regulation (23 CFR 630 Subpart J) to address more-current issues affecting safety and mobility in work zones.

The changes mostly encourage broader consideration of the safety and mobility impacts of work zones across the project development phase and strategies that help manage impacts during the project delivery phase. The Work Zone Safety and Mobility Rule is summarized as follows:

"The Federal Highway Administration (FHWA) revised Title 23, Part 630, Subpart J in September 2004. This rule encompassed new regulations that would cause the states to incorporate safety and mobility early on in the project process, instead of only when the work zone is going to be established. To encourage the states to make this change in their approach to projects, the rule also stated that the state agencies had to comply by October 12, 2007 in order to receive federal-aid funding. The procedures/requirements that the state agencies needed to implement are listed below:

- Create an overall state-level work zone safety and mobility policy.
- Develop methods to evaluate and mitigate WZ impacts, necessitate personnel training, incorporate crash and operations data into process improvement, and hold bi-annual performance reviews.
- Define 'significant' projects, which can be accomplished by discovering significant work zone impacts early on in the project development process.
- Create Transportation Management Plans (TMPs) for projects.
- Have suitable characteristics for the TMP of the project. (As in, significant project TMPs should have a Temporary Traffic Control Plan (TTC) as well as Transportation Operations (TO) and Public Information (PI) parts, while other projects should just require a TTC.)
- Observe TMPs and adjust them based upon result.
- Critique and evaluate the crash and operational data of many projects.
- Archive the data and information sources to be used for continuous improvement.
- Work with stakeholders." (Scriba 2005)

For more information regarding the Final Rule on Work Zone Safety and Mobility, see the presentation entitled "The Final Rule on Work Zone Safety and Mobility" presented by Tracy Scriba in February 2005. It is also encouraged to visit the FHWA website regarding this rule at ops.fhwa.dot.gov/wz/resources/final_rule.htm. This website provides various links to other state policies, as well as examples of the implementation of the rule.

1.2 Performance Measures

The objective of work-zone performance measures is to improve safety and mobility in work zones for the traveling public and highway workers. Performance measures are sets of defined, outcome-based conditions or response times used to evaluate success (ATSSA 2011, SAIC 2006).

Work-zone impacts result from the combined effect of design decisions, work phasing and sequencing operations, and mitigation strategies used. Performance metrics are used to assess how planning, design, and construction decisions impact safety and mobility in a work zone (Ullman et al. 2011b).

Work-zone performance measures quantify the impact of work zones on travelers, businesses, and workers. Performance measures and goals are used to define what an agency wants to achieve as follows (ATSSA 2010):

- Increase accountability and transparency
- Efficiently utilize resources
- Improve quality of service for the public
- Document agency goals and objectives
- Assess, document, and communicate agency performance
- Increase accountability and improve decision-making
- Evaluate the effectiveness of new and existing policies, practices, or procedures
- Identify areas of improvement
- Justify incentives or disincentives

The selection of which work zones to monitor, the metrics selected, and the frequency of monitoring depends on federal and agency rules and agency and stakeholder needs and priorities. Three different types of performance measures are exposure, safety, and mobility or traffic operation measures. Exposure measures, which include measures such as volume or hours of operation, are used to normalize safety or mobility performance measures to a common denominator so that performance measures can be compared among facilities. For instance, crashes per hour of work-zone operation provide an indication of both number of crashes and amount of time the work zone was present.

Ullman et al. (2011b) suggests that agencies select a few good measures based on their needs and track them “clearly, seriously, and consistently.” The authors noted that work-zone performance measures should be selected so that they are as follows:

- Related to agency safety and mobility goals
- Consistent with measures used in work-zone planning and design impact analyses
- Characterize the various facets of impacts that occur
- Allow evaluation of the effects of alternative strategies to mitigate work-zone impacts
- Compatible with other agency performance measures

Successful use of performance measures in work zones provides agencies with the ability to accomplish the following (Ullman et al. 2011b):

- Determine whether goals and objectives for work-zone impacts are being met
- Identify specific problems at work zones
- Review and improve work-zone policies and procedures and traffic-impact tools
- Better predict the benefits of work-zone impact strategies
- Provide quantifiable measures to communicate impacts of work zones and effectiveness of mitigation strategies to officials and the public

Performance measures compare work-zone conditions against baseline conditions. For instance, a change in crash rate would be calculated by equation 1-1:

$$\Delta CR = MCR_{wk} - MCR_{bef} \quad \textbf{(1-1)}$$

where:
ΔCR = Change in crash rate
MCR_{wk} = Monthly crash rate for work zone
MCR_{bef} = Monthly crash rate for roadway segment before work zone

As a result, it is necessary to establish baseline conditions as a basis for comparison.

1.3 Level of Performance

Performance measures should have specific measurable thresholds, which are defined as a minimum acceptable level of performance for a particular measure (ATSSA 2011). Performance measures can be qualitative or quantitative with corresponding thresholds. For instance, a particular length of queue can be established as the target for which performance is considered acceptable. The target may be based on the agency's work zone policy on queue lengths that are considered tolerable to road users for example.

Project-level metrics are used to assess the impact of a specific work zone. Program-level metrics are used to assess the impact of a set of work zones. Performance measures can also be applied at the region or district level or policy level.

The American Traffic Safety Services Association (ATSSA 2010, 2011) suggests using a rubric that defines threshold values to distinguish levels of performance as shown Figure 1-1. They also suggest using a range of values.

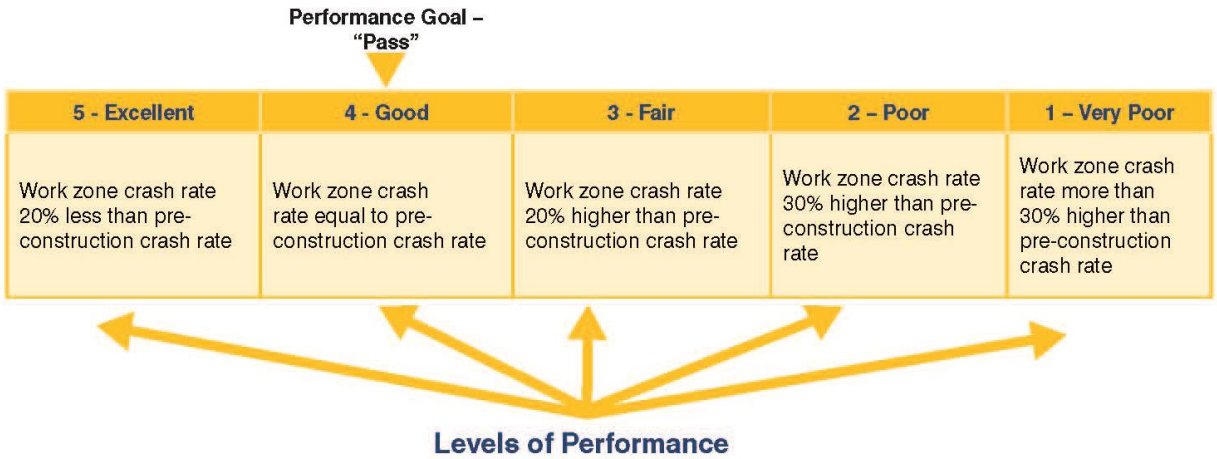


Figure 1-1: Sample levels of performance (ATSSA 2010)

1.4 Data

Sources of data, methods to collect data, and methods to calculate performance measures should be determined once an agency has selected work-zone performance measures. The data and sources depend on the individual performance measure. Agencies should assess the necessary data against available resources to determine which sources are the most appropriate (Ullman et al. 2011b).

Data source resources include the following:

- *Monitoring Work Zone Safety and Mobility Impacts in Texas* (Ullman et al. 2009) summarizes various sources of data
- *A Tutorial on Establishing Effective Work Zone Performance Measures* (Scriba et al. 2011) lists various sources of data
- *Work Zone Safety Performance Measures Training Module* (ATSSA 2011) describes data collection techniques and considerations
- *Best Practices in Work Zone Assessment, Data Collection, and Performance Evaluation: Summary Report* (Ullman et al. 2010) examines and provides recommendations on data collection methods and technology
- *Evaluating the Feasibility of Incorporating Mobility-based Work Zone Traffic Control Performance Measures in Highway Construction Project Specifications* (Chau 2012) details the results of using seven different technologies to collect mobility data
- *A Primer on Work Zone Safety and Mobility Performance Measurement* (Ullman et al. 2011b) defines guidelines and procedures for data collection
- *Work Zone Performance Measures Pilot Test* (Ullman et al. 2011a) provides examples of performance measures collected and the technology that was used

Some sources of these data are summarized in the corresponding performance measures sections, which follow.

1.5 Iowa DOT on Work-Zone Performance

The Iowa Department of Transportation (DOT) is working actively to integrate work-zone performance measures into their standard procedures. They are currently involved in research into other state work-zone performance ventures.

1.6 Developing Performance Measures

Several resources have suggested a list of steps to develop performance measures (ATSSA 2011, Scriba and Ullman 2011). The steps are as follows:

1. Identify stakeholders, which may include traditional and non-traditional partners
2. Set goals based on level of analysis (project level, regional/district level, or state/agency-level)
3. Identify existing work-zone performance measures
4. Identify available data sources
5. Define analysis requirements
6. Hold initial brainstorming sessions to define draft performance goals
7. Organize and categorize performance measures
8. Test, refine, and finalize performance measures, which includes setting baseline measures
9. Assign roles and responsibilities
10. Determine methods to disseminate results
11. Periodically review and refine performance measures

Performance measures also need to include the following (ATSSA 2011):

- Specific measure of effectiveness for the performance measure
- Unit of measure (e.g., hours of delay)
- Method to measure performance
- Frequency and timing to measure performance
- Responsibility for measuring performance (e.g., reported by contractor)

As noted previously, performance measures should relate to the safety and mobility goals and objectives for an individual agency. They should capture the full range of road user impacts so that trade-offs between meeting traveler needs and other project needs, such as time or cost, can be balanced. For instance, one work zone may have a few periods of significant congestion with minor impacts at other times while another work zone has small but persistent congestion. Each will be perceived differently by the public and, as a result, focusing on only one performance measure such as maximum queue length may not adequately address user needs. Therefore, several measures are often needed. In addition, the measures selected should be sensitive to the alternative strategies that are available (Ullman et al. 2011a). SAIC (2006) suggests using the set of questions in Figure 1-2 to assess when a performance measure is realistic.

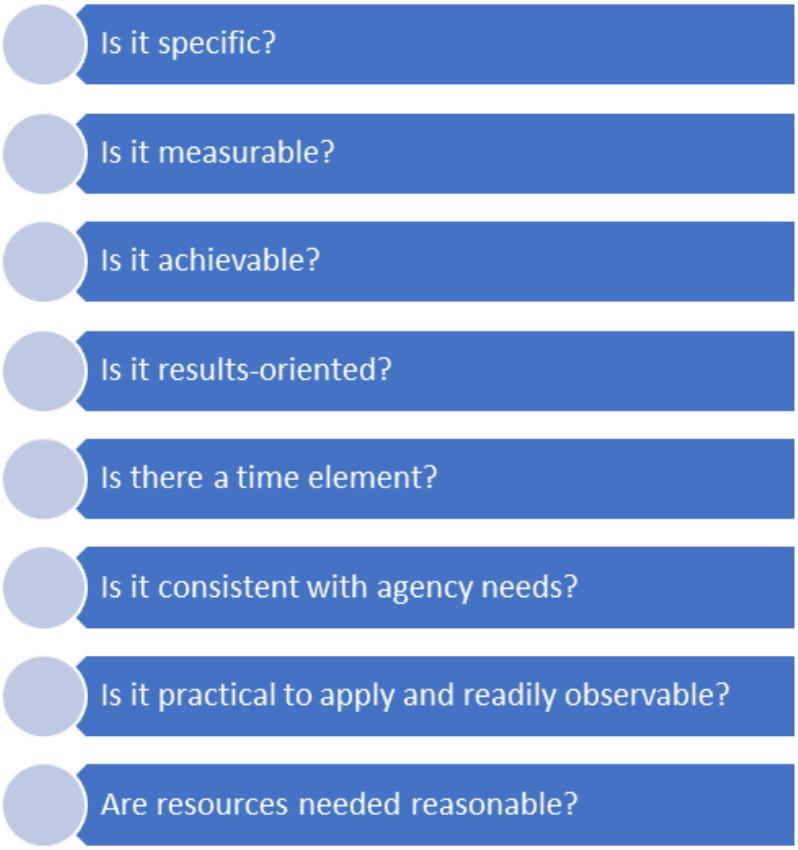


Figure 1-2: SAIC realistic assessment (based on S.M.A.R.T. goals)

SAIC (2006) also provided the graphic in Figure 1-3, which describes a process for development of performance measures.

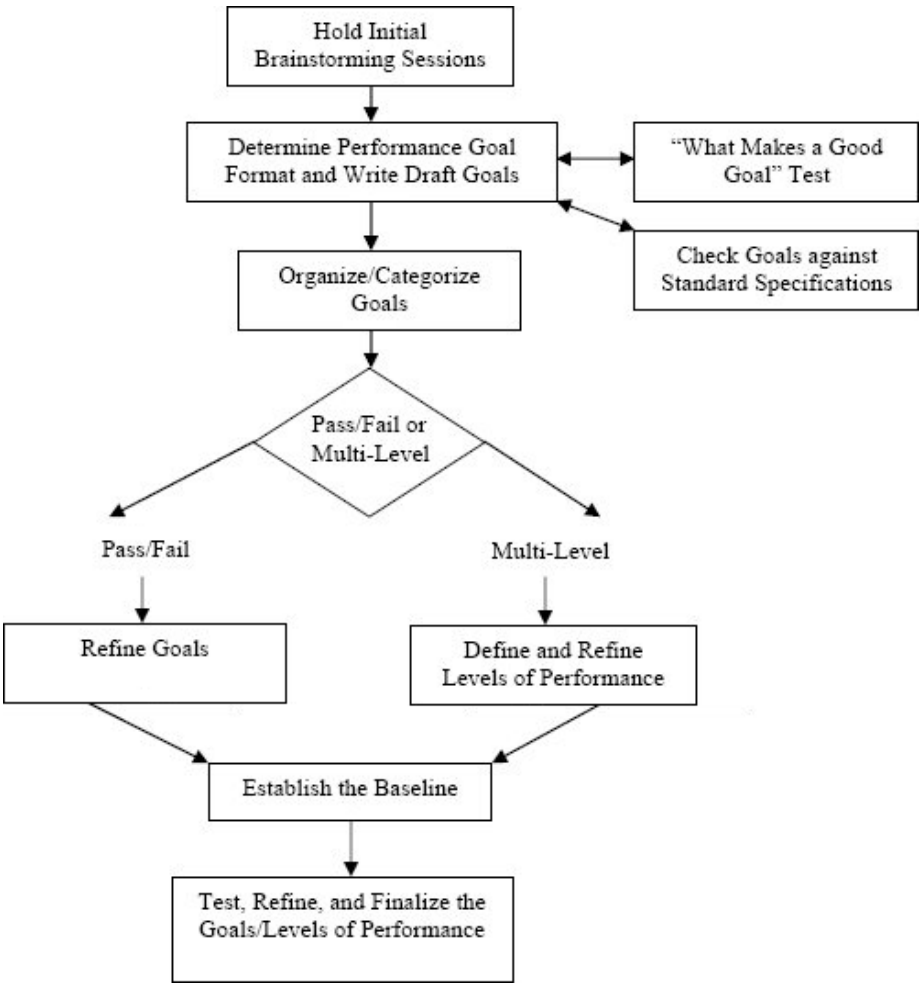


Figure 1-3: Methodology to select performance measures (SAIC 2006)

An example of performance measures in shown in Table 1-1 (based on information from SAIC 2006).

Table 1-1: Sample performance measures (SAIC 2006)

Category	PM	5 - Excellent	4 - Good	3 - Fair	2 - Poor	1 - Very Poor
Congestion	#2	Average travel time through WZ < 10% target	Average travel time through WZ = target	Average travel time through WZ > 10% target	Average travel time through WZ is 20% higher than target	Average travel time through WZ > 20% higher than target

PM stands for performance measure

Scriba and Ullman (2011) suggest selecting a manageable number of performance measures, which are developed in consideration of data needs. They recommend starting with a simple process and then refining and expanding it as additional needs are noted. They also advise reviewing the performance measures periodically to determine whether they are aiding in evaluating progress and whether they point to changes in policies or procedures that need to be made.

Interested readers should refer to the *Work Zone Safety Performance Measures Guidance Booklet* (ATSAA 2010), which provides useful background information on how to conduct brainstorming sessions, set goals and priorities, etc. The booklet is available at www.workzonesafety.org/files/documents/training/fhwa_wz_grant/atssa_performance_measures_guide.pdf. It is also advised that the reader look into the presentation that coincides with the booklet at www.workzonesafety.org/fhwa_wz_grant/atssa/atssa_wz_performance_measures_module.

1.7 Measurement Methodologies

A measurement methodology is necessary for each performance measure selected. Performance measures can be categorized as follows (ATSSA 2011):

- Pass/fail or threshold (i.e., queue length not to exceed 10 vehicles more than 10 percent of the time); some agencies simply state a goal (i.e., goal is no more than 15 minutes of additional delay)
- Subjective (i.e., drivers feel the level of delay is acceptable)
- Policy (i.e., respond to traveler complaints within 24 hours)
- Regional/state/agency level (i.e., 10 percent or less increase in delay system wide)
- Categories (i.e., < 10 minutes of delay is minor; 10 to < 15 minutes of delay is moderate; and ≥ 15 min of delay is major (MoDOT 2013))

The specific measure of effectiveness to be used includes the following:

- Unit of measure
- Measurement method
- Frequency of measuring and reporting
- Person or group responsible for measuring performance

A sample measurement methodology is shown in Table 1-2 (based on ATSSA 2010). Types of data, data collection methodologies, and guidance on how to measure and interpret results are provided in the *Work Zone Safety Performance Measures Guidance Booklet* (ATSSA 2010).

Table 1-2: Sample measurement methodology (ATSSA 2010)

Performance Measure	Measure of Effectiveness	Measurement Unit	Method	Timing	Evaluator
Work zone crash rate = pre-construction crash rate	Work zone crash rate	Crashes per 1000,000 vehicles through work zone	1) Calculate average crashes per month for a 3 year period prior to construction 2) Calculate monthly crash rate during construction 3) Compare to pre-construction rate	End of each month during construction	Project engineer

2. EXPOSURE MEASURES

Exposure is the amount of time, roadway space, or vehicle travel that a work zone affects.

2.1 Types of Exposure Work-Zone Performance Measures

Exposure measures include measures such as hours of lane closure, vehicles per hour (vph), vehicles per day (vpd), vehicle miles traveled (VMT), and so forth. Volume measures such as vpd or VMT are used in the denominator to normalize safety and mobility measures (i.e., crashes/hour of lane closure) (Ullman et al. 2011b). Common exposure measures include the following (Ullman et al. 2011b):

- VMT through the work zone
- Number of vehicles passing in the work zone
- Hours of work zone activity
- Hours of dedicated enforcement in work zone
- Percent of time when work activity occurs
- Average number of work activity hours per day
- Percent of hours when one lane or more lanes are closed

As noted by Ullman et al. (2011b), exposure measures can also include use of technologies to improve work-zone safety or mobility such as number of projects using a concrete barrier to protect workers from errant vehicles or protect travelers from pavement edge drop-off.

Ullman et al. (2011b) summarized potential exposure-related performance measures along with why the measure is needed and considerations for the performance measures as noted in Table 2-1.

Table 2-1: Types of exposure methods (Ullman et al. 2011b)

Type of Measure	Measure	Why it is Important	Considerations
Volume-based measures	Volume through work zone (can be stratified by work activity or lane closure hours)	Required to normalize performance measures to per vehicle basis (i.e., minutes of delay per vehicle)	Work zones with significant diversion will require continuous counts to be accurate
	% change in vehicles passing through the work zone	May represent traffic diverting from the work zone	Requires continuous counts to be accurate
	VMT through the work zone (may be stratified by work activity/inactivity periods and/or lane closure	Standard measures of exposure for safety assessments	In some cases, total project length may be the appropriate length to use; in other cases length of each closure may be more appropriate
Time-based measures	% days or nights for work-zone activities	Describes intensity of effort to complete the job	Accounts for allowable work days/nights
	Average hours of work per day or night	Can be used to assess contractor utilization of time allowed for work	Overlap of subsequent jobs make it difficult to determine overall start and end time
	% work activity hours with number of lanes closed	Allows queue and delay measures to be stratified by reduction in roadway capacity	Accounts for lanes being closed in sequence
	Average lane closure length	Can be used to evaluate compliance to maximum lane closure length specifications	Closure lengths may change significantly as additional lanes are closed particularly at night
	Lane-mile-hours of closures	Can be used to explain high levels of delay or crash rate increases	Less intuitive than other performance measures
Project-based measures	Number or fraction of projects with certain types of strategies or technologies to reduce safety or mobility impacts	Program-level measure of agency efforts	Usually site specific; may be necessary to stratify measures by type of facility, work, or other site characteristics

2.2 Data Needs for Exposure Performance Measures

Data needs for exposure performance measures include those for project characteristics, work activities, and traffic volumes (Ullman et al. 2011b, Ullman et al. 2008). The data elements needed will vary depending on the performance measures used and include the following.

Project Characteristics

- Length
- Basic project phasing
- Major roadway capacity constraint locations
  - Long-term lane and shoulder closures
  - Lane shifts
  - Detours
  - Narrowed lanes
  - Sections with portable concrete barriers
  - Construction vehicle access points

Work Activities

- Dates and times of work activities
- Short-duration, short-term, or intermediate-term lane closures
  - Dates
  - Installation and removal times
  - Location
  - Number of lanes closed
  - Length
- Number of work activities present during work-activity hours

Traffic Volume/Capacity

- Annual average daily traffic (AADT)
- VMT through work zone
- Percent of VMT when lanes are closed
- Vehicle miles of truck travel
- Hourly counts
- Vehicle classification (percent trucks)
- Peak-hour volume
- Average and total nighttime volume
- Average and total weekend traffic volume
- Total capacity loss in work zone
- Capacity loss per work zone mile
- Sources of Exposure Data (Scriba and Ullman 2011)
- Project plans
- Construction management databases
- Inspector diaries
- Lane closure request databases
- Published AADT values or data from automatic traffic recorders
- Manual traffic counts
- Electronic traffic surveillance

3. MOBILITY MEASURES

Mobility is a measure of how much travel has been impacted for the traveling public. Mobility performance measures typically assess some measure of delay.

3.1 Types of Mobility Work-Zone Performance Measures

Examples of mobility performance measures include the following:

- Queuing measures
- Travel speed
- Delay
- Queue length
- Queue duration
- Average speed
- Volume to capacity
- Level of service
- Volume

3.1.1 Queuing

Queuing affects delay directly and queuing metrics are attractive as measures because they can be measured directly. Queue-related performance measures are usually more specific than just presence or absence of a queue and may include length, duration, and frequency (Ullman et al. 2011b). Advantages of this performance measure include the following:

- Can be quantified easily
- Concept is easily understood by public
- Can be measured directly

The Indiana DOT (INDOT) (2007) and Ohio DOT (ODOT) (2000) define a queue as vehicle speeds reduced to 10 mph or less due to a work zone restriction.

Disadvantages include the following (Ullman et al. 2011b):

- Short, infrequent, or rapidly-changing queues may be difficult to detect without continuous monitoring
- Begin and end of queues are sometimes difficult to detect

Queues that are due to weather or crashes need to be considered separately from queues that are due to work-zone factors. In addition, regular queuing needs to be determined before the work zone is implemented. This establishes baseline conditions that can be compared against queuing created by the actual work zone.

Queuing is affected by fluctuations in traffic demand and other factors. Queuing can also have safety implications when vehicles encounter a queue unexpectantly. As a result, measures to assess how frequently specific levels of queuing are exceeded and by how much are important so that advance signing can be located properly (Ullman et al. 2011a).

Queuing measures can be adjusted by exposure. For instance, queuing measures can be divided by hours of work activity in the evaluation period as shown with equation 3-1:

$$\frac{\sum \text{time when queue length} > 1 \text{ mile}}{\sum \text{hours of work activity in evaluation period}} \quad \textbf{(3-1)}$$

3.1.2 Delay

Vehicle delay is a measure of user cost. Work-zone delay is the additional travel time needed to traverse the work zone or detour around it and includes the following (Mallela and Sadasivam 2011):

- Speed change delay: additional time to decelerate upstream to the work zone speed and then accelerate back to the initial approach speed
- Reduced speed delay: additional time to traverse the work zone due to the lower posted speed
- Detour delay: additional time to traverse an alternate route when a vehicle detours due to the work zone

Queuing and delay are correlated. As a result, use of performance measures should consider whether both are appropriate.

3.1.3 Travel Time Reliability

Travel time reliability may also need to be considered given that work zones can make travel time less predictable or reliable for road users. Ullman et al. (2011a) suggests use of a "buffer" value, which travelers use to plan their departure time according to equation 3-2:

$$Buffer\ Index = \frac{95th\ percentile\ travel\ time - average\ travel\ time}{average\ travel\ time} \quad \textbf{(3-2)}$$

Use of the 95th percentile travel time is used for less-frequent trips and use of the 80th percentile travel time is used for more-frequent trips.

Individual delay can vary significantly hourly and even over the course of a project, so different delay measures may be necessary to capture the range of impacts. Existing delay needs to be determined so that a baseline can be established. Delay due to crashes, vehicle stalls, and weather should be considered separately from delay due only to work zones (Ullman et al. 2011a).

3.1.4 User Satisfaction

Measures of road user satisfaction may also be used to assess work zone mobility (Ullman et al. 2011b). User complaints may provide real-time information about problem areas, but are subjective. Road user survey ratings can also be used to assess travel conditions. However, they should be designed properly to avoid bias.

3.2 Common Mobility Performance Measures

The National Cooperative Highway Research Program (NCHRP) conducted a scan tour (Scan 08-04) on best practices in work zone assessment, data collection, and performance evaluations and found that traffic delay per vehicle, queue lengths, and duration of queues were the most common work-zone mobility performance measures tracked by agencies (Bourne et al. 2010). The California DOT (Caltrans) uses the following different thresholds for delay:

- 0 minute delay for most freeway projects
- < 15 minute delay when an aggressive traffic management project is used
- < 30 minute delay for complex projects
- < 20 minute delay for flagging operations

INDOT uses queue length with the following metrics (Bourne et al. 2010):

- Queues cannot be present > 6 continuous hours or 12 total hours per day
- 0.5 mile < queues < 1.0 miles in 4 continuous hours
- Mile < queues < 1.5 miles in 2 continuous hours
- Queues > 1.5 miles not allowed

User complaints about delay was a commonly-cited measure. Other measures included volume to capacity (V/C) ratio, level of service (LOS), volume, percent of time operating at free-flow speed, and percent of work zones meeting expectations for traffic flow. Some agencies have identified specific maximum threshold measures for delay, queues, and V/C ratios and use these thresholds during impact analysis (Bourne et al. 2010).

Many agencies evaluate mobility project by project. The Wisconsin DOT (WisDOT) and Oregon DOT (ODOT) evaluate mobility from multiple projects along corridors between major cities. The Missouri DOT (MoDOT) uses a rating system during project inspection that assesses the percent of work zones that meet agency expectations for traffic flow (Bourne et al. 2010).

Table 3-1 summarizes common mobility performance measures used by various states. The team attempted to determine measures commonly used by agencies but the table is not all inclusive.

Table 3-1 also shows thresholds, goals, and guidelines when available. In many cases, the threshold or guideline metric is beyond normal traffic conditions.

Table 3-1: Summary of mobility measures used by various agencies

Category	Considerations for Measure	Performance Measure	States Using Measure	Values
Queue	Queue can be measured by hour or per work zone period (peak period, daytime, nighttime, weekend, etc.)	Duration	OH, CA (Bourne et al. 2010)	< 15 min with aggressive TMP < 30 min for complex projects < 20 min on other roadways with flagger (CA)
		Length	AZ, IN, KY, MD, NC, TN, WI (Ullman et al. 2008), OH (Bourne et al. 2010), MI (MDOT 2010), MN (MnDOT 2007), MO (MoDOT 2012), MT (MTDOT 2009), UT (UDOT 2005), WI (WisDOT 2011), MD (Bourne et al. 2010)	threshold = 3 miles (KY) threshold = 1.5 miles above non-work zone queues (IL)
		Total or average delay when queues are present	IL (IDOT 2007), KS (KDOT 2008), ID (ITD 2008), IN (IDOT 2007), KY (KYTC 2011), MI (MDOT 2010), MN (MnDOT 2007), MO (MoDOT 2012), MT (MTDOT 2009), ND (NDDOT 2006), OH (OHDOT 2000), UT (UDOT 2005), WI (WisDOT 2011),	queue < 6 continuous hrs or 12 hrs total; or 0.5 to 1.0 mile < 4 continuous hrs; or 1 to 1.5 mile < 2 continuous hrs; or > 1.5 mile not permitted (IN) 1 to 1.5 miles for with 2+ consecutive hrs queues or > 2 miles is unacceptable (MD) 1.0 to 1.5 miles with delay for 2 hrs or less or > 1.5 mile (IN—interstate) 0.75 to 1.5 miles with 2+ consecutive hrs or queues ≥ 1.5 miles is unacceptable (OH; WI)
		% vehicles encountering a queue	KS (KDOT 2008), IL (IDOT 2007), ID (ITD 2008), IN (IDOT 2007), KY (KYTC 2011), MI (MDOT 2010), MN (MnDOT 2007), UT (UDOT 2005)	
		% lane closures creating a queue > xx miles		
		% lane closures creating a queue > xx minutes		

Category	Considerations for Measure	Performance Measure	States Using Measure	Values
Delay	Delay can be measured by hour or per work zone period (peak period, daytime, nighttime, weekend, etc.)	Total or average delay	AZ, AK, CA, IN, LA, ME, MD, MA, MI, MO, ND, SD, WI, WY (Ullman et al. 2008), MI, NH, NJ, PN, OR (Bourne et al. 2010), IN (INDOT 2007), IL (IDOT 2007), ID (ITD 2008), IN (IDOT 2007), KY (KYTC 2011), MI (MDOT 2010), MN (MnDOT 2007), MT (MTDOT 2009), OH (OHDOT 2000), UT (UDOT 2005), PA (PennDOT 2013)	delay > 10 min is significant (MI; MN) 5 to 10 min delay not preferred & delay > 10 min undesirable (NH) < 15 min for arterials (MD) threshold = 15 min delay (MT; ND; WI; MN; NJ, MO threshold = 15 min urban & 20 min rural (MO) threshold = 20 min for 2 hours over base condition (PA) 15 to 20 min limited to 2 consecutive hrs (PN) delay > 5 min/mile with max 30 min above normal delay (IL) goal is delay < 30 min (KS)
		Delay along defined corridor	OR, WI (Bourne et al. 2010)	project delay < 10% of peak travel time corridor delay < 10% of peak travel time (OR) max of 15 min additional delay between major city nodes (WI)
		Maximum per-vehicle delay	KS (KDOT 2008), IL (IDOT 2007), ID (ITD 2008), IN (IDOT 2007), KY (KYTC 2011), MI (MDOT 2010), MN (MnDOT 2007), UT (UDOT 2005), WA (WSDOT 2013)	
		% vehicles experiencing delay greater than xx vehicles	KS (KDOT 2008), IN (IDOT 2007), KY (KYTC 2011), MI (MDOT 2010)	
	Travel time	Increase in travel time	MN (MnDOT 2007)	> 10 min considered significant (MN, MI)
	Detour	Detour miles	MI (MDOT 2010)	threshold > 3 miles urban or > 10 miles rural (MI)

Category	Considerations for Measure	Performance Measure	States Using Measure	Values
Capacity		Volume to capacity	MI (Bourne et al. 2010), MN (MnDOT 2007), ND (NDDOT 2006), WI (WisDOT 2011)	V/C > 0.8 considered significant (MN, MI)
		Level of service	IN, MI (Bourne et al. 2010), ND (NDDOT 2006), FL (Margiotta et al. 2006), WA (WSDOT 2013)	drop in LOS < 2 levels LOS no worse than D (MI)
		Limit on lane closure amount and length	FL (Bourne et al. 2010), KS (KDOT 2013)	
Speed	Speed is relatively easy to measure	Average speed	UT (UDOT 2005), FL (Margiotta et al. 2006)	
User measures		Road user complaints	ID (ITD 2008), IN (IDOT 2007), MD (MSHA 2006), MI (MDOT 2010), MN (MnDOT 2007), MO (MoDOT 2012), MT (MTDOT 2009), ND (NDDOT 2006), WI (WisDOT 2011), UT (Scriba 2005), WA (WSDOT 2013), OR (ODOT 2011), VA (VDOT 2013)	
	Requires some type of survey	Road user survey (percent satisfied)	MO (Bourne et al. 2010), ID (ITD 2008), IN (IDOT 2007), MD (MSHA 2006), MI (MDOT 2010), MN (MnDOT 2007) , MT (MTDOT 2009), ND (NDDOT 2006), WI (WisDOT 2011), UT (Scriba 2005), PA (Margiotta et al. 2006), FL (Margiotta et al. 2006), WA (WSDOT 2013), OR (ODOT 2011), VA	Percent increase in overall satisfaction and timeliness (MO), it is not stated what percent is desirable
Work-zone incidents		Frequency of incidents	IN (IDOT 2007), ID (ITD 2008), MD (MSHA 2006), MI (MDOT 2010), MO (MoDOT 2012), MT (MTDOT 2009), ND (NDDOT 2006), OH (OHDOT 2000), UT (UDOT 2005), WI (WisDOT 2011), VA (VDOT 2013)	
		Average and total duration of incidents	IN (IDOT 2007), MD (MSHA 2006), MI (MDOT 2010), MO (MoDOT 2012)	
	Used during project inspection	Average duration of blockage	IN (IDOT 2007), MD (MSHA 2006), MI (MDOT 2010)	
		Lane-hours lost	IN (IDOT 2007), MD (MSHA 2006), MI (MDOT 2010)	
		% of work zones meeting work zone expectations for traffic flow	MO (Bourne et al. 2010)	

3.3 Data Needs for Mobility Performance Measures

Data needs for mobility performance measures include the following:

- Queue characteristics (beginning and end time, location, direction of travel)
- Travel time and delay (time, location, direction of travel)
- Agency rating scores

NCHRP Scan 08-04 (Bourne et al. 2010) summarized data collection practices for 15 states. Some states use a sampling approach and manually collect travel time and queue length. Some use visual inspections by project engineers and inspector although this can be somewhat subjective. The Pennsylvania DOT (PennDOT) attempted using law enforcement personnel to record queue length.

When portable intelligent transportation system (ITS) devices are deployed within a work zone, they have been used to collect volume, speed, and occupancy data. Other sources of data include the following:

- Manual or electronic visual inspection of travel conditions
- Manual sampling of travel time, queuing, and speed
- Electronic monitoring of volume, speed, and lane occupancy
- User complaints

MoDOT has an online survey that invites road users to answer questions via the DOT webpage. Travelers can respond to questions such as “Did you make it through the work zone in a time manner?” and provide an explanation as a comment.

Other sources of mobility data include the following (Scriba and Ullman 2011):

- Electronic traffic surveillance
- Observations by field personnel
- Travel time data collection by agency
- Agency inspection scores
- Road user survey responses
- Road user complaint files

4. SAFETY MEASURES

Safety is measured as crash risk for travelers, enforcement personnel, or agency and contractor personnel working on the site. Safety performance measures assess how crash frequency and severity risk has changed due to the work zone. Work-zone safety is measured against the expected crash risk without the work zone present (Ullman et al. 2011b).

4.1 Types of Safety Work-Zone Performance Measures

Crash statistics can be tracked at the project level although many states currently record work-zone fatalities on an annual basis statewide. Given that crashes are a somewhat rare occurrence, measures can be tracked over time to determine trends.

Crash severity and crash type are also often tracked so that problem areas can be identified (Ullman et al. 2011a). Some measure of exposure, such as vpd, is usually included. Crashes rates in terms of crashes per million vehicle miles traveled (MVMT) or crashes per hour of work activity are common metrics used as safety performance measures.

NCHRP conducted a scan tour (Scan 08-04) on best practices in work zone assessment, data collection, and performance evaluations and found that work-zone crash measures were the most common work-zone safety performance measures tracked by agencies (Bourne et al. 2010). Most agencies tracked crash frequency (annual, quarterly, or monthly) while a few considered crash severity or crash type.

It was noted that use of simple crash counts was problematic given that work-zone exposure influences crash frequency. To compensate, some agencies compare the percentage of certain types of crashes occurring outside of work zones to those within the work zone, which serves as an indicator of potential problems. However, it does not account for exposure.

The Ohio DOT (ODOT) uses annual construction budget as an exposure measure and compares total annual work zone crash frequency to annual construction budget as shown in Figure 4-1 (Bourne et al. 2010).

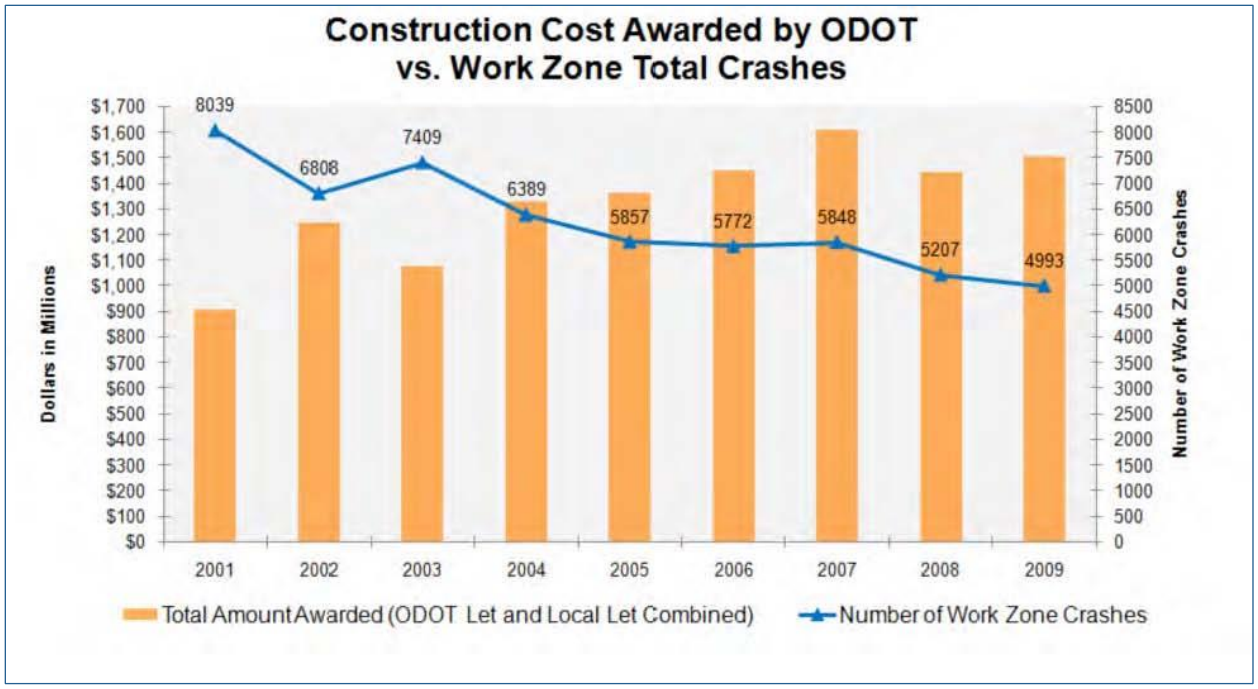


Figure 4-1: Ohio DOT comparison of crashes versus construction costs (Bourne et al. 2010)

also evaluates crash rate for a select number of significant projects. They use ADT to estimate work-zone crash rate before and during a selected project and then compare the change in crashes per million vehicle miles. Unit and societal costs are also applied. In addition, ODOT compares near real-time crash frequency for certain on-going projects where historical crash trends are available prior to construction. Comparisons of crash frequency before and after allows ODOT to identify unusual trends and investigate hot spots further so the agency can make improvements.

The New Hampshire DOT (NHDOT) examines freeway service patrol and fire department dispatch calls for work zones to monitor safety performance. They compare service calls for a work zone against the normal rate of calls to a location. Higher-than-average calls indicate a safety problem. NHDOT is also able to monitor service calls by time-of-day and day-of-week to evaluate trends (Bourne et al. 2010).

The Oregon and New York State DOTs (ODOT and NYSDOT) use work-zone quality inspection scores as a measure of safety. These two agencies convert inspections into a formal rating for several different topics, which allows them to compare the metrics across contractors or agency regions or districts as shown in Figure 4-2 (Bourne et al. 2010).

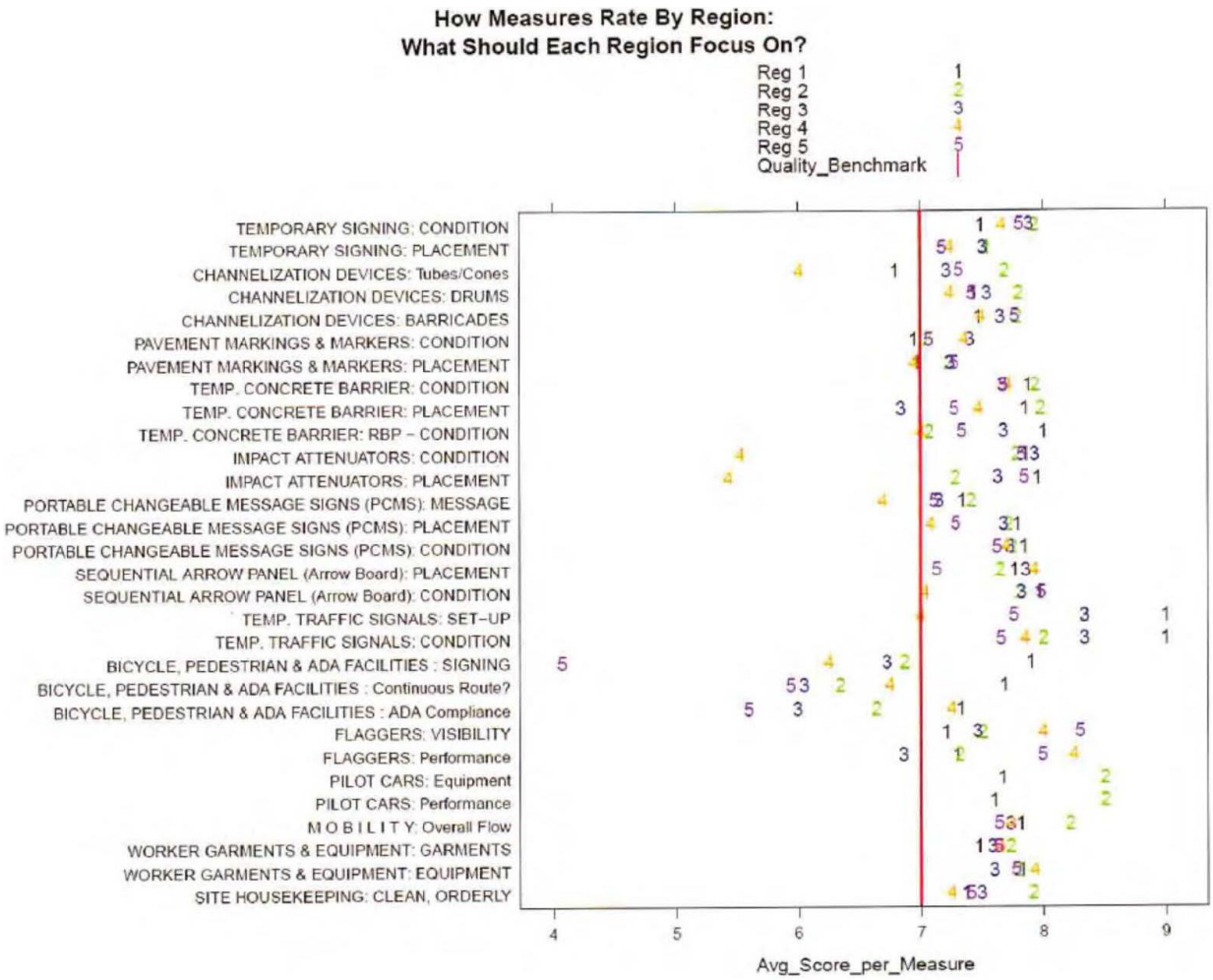


Figure 4-2: Sample work-zone inspection scores (Bourne et al. 2010)

NYSDOT uses a score between 0 and 5 for each topic for each work zone. A 0 indicates that topic is missing and a 5 indicates the topic is in excellent condition. Their goal is for all ratings of 4 or higher. Each work zone is then assigned a letter grade (i.e., A = 95 to 100 percent of topics rated met the goal) and projects receiving a D are targeted for immediate remedial action. The number of inspected work zones that meet the goal of having all topics rated 4 or higher is also used as a metric.

The methodology for the Oregon DOT (ODOT) is similar. MoDOT also uses inspection scores as a safety performance measure. Trained personnel rate a sample of work zone projects. The rating focuses on several items, such as devices used to guide drivers, which measure visibility in the work zone. Ratings are combined to assess whether a work zone meets expectations for adequate visibility.

4.2 Surrogate Measures of Safety

Safety may also be measured using surrogate measures, such as speed, risky maneuvers (tailgating, passing on the shoulder), and so forth. Although direct correlations between safety surrogates and crash risk are often unknown, it is assumed that reductions in risky behaviors will result in a corresponding decrease in crashes. Risky behaviors can also have an impact on traffic operations.

Hallmark et al. (2011) evaluated merge behavior at a freeway work zone and identified several behaviors that had potential negative impacts on safety. These behaviors included forced merges, late merges, lane straddling, and queue jumping.

Queue jumping occurs when a driver already in the open lane decides to jockey for a better position by moving to the closing lane and passes one or more vehicles before merging back to the open lane. In a number of instances, queue jumping caused late and forced merges and appeared to evoke aggressive behavior by other drivers, which was manifested by lane straddling and, in some cases, vehicles physically trying to block queue jumpers.

Forced merges are a safety problem because a driver behind a forced merge has to slow or, in some cases, take some evasive action to avoid colliding with the merging vehicle. Forced slowing and braking cause operational problems because traffic flow is interrupted.

Speed is the simplest surrogate safety measure. It has been correlated with crash likelihood although the relationship between work-zone crashes and speed has not been well established.

4.3 Summary of State Practices

State practices were reviewed and are summarized in Table 4-1.

The team attempted to determine measures commonly used by agencies but the table is not all inclusive. As noted, the majority of states use crashes or crash rate. Several agencies use speed or work-zone inspections as performance measures.

Table 4-1: Summary of safety performance measures used by various agencies

Safety Performance Measures	Description	Considerations for Measure	States Using Measure	Range
Crashes May be stratified by crash type, severity, contributing circumstance	• Requires access to timely crash data • Crash rate requires exposure data • Cost incorporates crash frequency and severity	Total crashes	OH (Bourne et al. 2010), WA (WSDOT 2013), NE (NEDOR 2012), MO (MoDOT 2013), WI (WisDOT 2013), ID (ITD 2008)	reduce work zone crashes 5% from previous year (ID) goal is Towards Zero Deaths (TZD) (KS; MO; ND) goal is ratio of 2% work zone to on-system crashes (NE) 10% annual reduction in work zone related fatalities & crashes (PA)
		Crash rate (per year, per month, per 100 million VMT, etc.) Specific measures may include: % of projects exceeding baseline crash rate	CN, GA, OR, PN, TN (Ullman et al. 2008), OH (Bourne et al. 2010), WA (WSDOT 2013), WI (WisDOT 2013), OR (ODOT 2011)	
		Crash cost Specific measures may include: % change in work zone crash costs	OH (Bourne et al. 2010), MI (MDOT 2010)	
		Number of highway worker injuries or worker injury rate per hours worked	WA (WSDOT 2013), OR (ODOT 2013)	0 traffic related worker fatalities (ID)
Speed	Assumes correlation between safety and speed	Average or 85th percentile speed	MO (MoDOT 2013)	
		Speed variability		
		% exceeding speed limit		
		Speed citation frequency		
Work-zone inspection	• Some agencies have standardized criteria so that inspections can be used to assess safety • Assumes correlation with crash risk	Number performed		
		Score Specific measures may include: number of topics receiving a score of 4	OR, NY, MO (Bourne et al. 2010)	goal is for topics to be 4 or 5 (NY)

Emergency management services (EMS)	• Often correlated to crash data (if available may be faster than obtaining crash data) • Need to exclude non-crash responses such as stalled vehicles	Increase in EMS dispatches to work-zone area Specific measures may include: number of freeway service dispatch calls	NH (Bourne et al. 2010)	
Surrogate measures	• Assumes some correlation with crash risk	Frequency of work-zone intrusions		

4.4 Sources of Data for Safety Performance Measures

Data needed for safety performance measures varies by the specific performance measure but generally include the following (Scriba and Ullman 2011):

- Traffic crashes (number, severity, type, contributing factors, direction of travel)
- Worker accident and injuries due to traffic crashes (time, location, type, severity)
- Number and results of work-zone inspection scores
- Road user complaints

NCHRP Scan 08-04 summarized practices for 15 states and indicated that most states use police crash reports as one of the primary data sources while a number track injuries to employees at the job site (Bourne et al. 2010). They note that one of the major problems with use of crash data is the lag time between when the crash occurs and when the crash data are available, which can be as long as one year. States with electronic crash reporting have reported a much shorter lag time. Some states still using hard copy crash reports collect crash reports regularly from the police and create their own database. Other sources of data include the following:

- DOT supplemental crash data
- Police crash report forms
- Inspection reports
- Service patrol/fire department calls
- Traffic management center (TMC) incident reports
- Road user complaints
- Emergency management dispatches (time, location, type of response)
- Occupational safety records
- Agency field reviews
- Service patrol or emergency management services (EMS) dispatch logs

5. COLLECTING DATA

One of the first steps in collecting data for work-zone performance measures is to collect data that the agency already has. These data can include traffic counts, speed captures, and various other information. Usually, these data can be found in traffic management centers (TMCs) and traveler information systems. In NCHRP Report 97, Margiotta et al. (2006) described five ways to collect data for the measures:

- Permanent evaluation systems and devices
- Temporary evaluation systems and devices
- Using labor, resources, and traffic management systems
- Surveys of the public
- External sources outside of the agency

Most agencies are already familiar with sources such as automatic traffic recorders (ATR) and data from traffic management centers. Several other methods which have been utilized by agencies to collect data are described in the following sections.

5.1 Mobility Data

Chau (2012) evaluated technologies that can be used to collect mobility data as shown in Table 5-1.

Table 5-1: Technologies for collecting mobility data (Chau 2012)

Technology	Data Collection Uses
Automatic license plate recognition	Travel times, speeds, vehicle classification
Bluetooth	Travel times, speeds
Magnetic sensor	Travel times, speeds
Microwave radar	Volume, length of vehicles, speeds, vehicle headway
Cellular phone	Speeds, traffic times
Global positioning system	Speeds, traffic times

These technologies were evaluated by the Utah DOT (UDOT) and Chau (2012) for measuring performance. Chau (2012) further describes the methods and how UDOT and other states implemented them. The performance measures used were the same as those in *A Primer on Work Zone Safety and Mobility Performance Measurement* (Ullman et al. 2011b). Overall, Chau (2012) found all of the technologies were effective for measuring performance.

5.1.1 Automatic License Plate Recognition

Automatic license plate recognition (ALPR) uses cameras and character recognition software to read license plates. A system can be set up to record and timestamp license plates at different locations around a work zone. Vehicle plate numbers can be matched between the different locations and average speed and travel time can then be determined. Vehicle class can also be collected using ALPR.

The advantage of ALPR is that a large sample of data can be obtained. The systems can be placed unobtrusively and no modifications to the pavement need to be made (as for inductive loops). The system can also be set up to record at multiple locations. According to Ullman et al.

in the FHWA *Work Zone Performance Measures Pilot Test* project, an ALPR was employed to capture travel time in an Arizona work zone and was very successful. (Ullman et al. 2011b)

The main disadvantage of ALPRs is that the systems can be expensive and may not be reliable under adverse weather conditions (Chau 2012). In addition, when drivers are aware that the system is in place, there may be concerns about privacy. Another concern is that the success of the system depends on the efficiency of the system to recognize license plates, as well as the spacing of the sensors to detect queues (Ullman et al. 2011b).

5.1.2 Bluetooth

Bluetooth detectors are used to detect signals from motorists with Bluetooth-enabled devices. Each device has a unique address, which the device transmits within a short range. Detectors can be placed at several locations. Signals from a particular vehicle are recorded at each location and readings matched between locations. This information is used to determine speed and travel time. Bluetooth sensors are portable and non-intrusive and, as a result, can be placed at a variety of locations. In addition, the Bluetooth address is not linked to a specific user so privacy issues are not a concern.

The main disadvantage to this technology is that sample size is dependent on the number of vehicles in the traffic stream with Bluetooth devices (TTI 2013). Ullman et al. affirmed this disadvantage and added that, in order to measure queues, there need to be multiple sensors with close spacing. (Ullman et al. 2011b). Singer et al. (2013) brought up the limitation that the Bluetooth detection range was about 328 feet.

5.1.3 Magnetic Sensors

Magnetic sensors detect the presence of a metallic object by detecting perturbations in the earth's magnetic field. Vehicle signatures at consecutive sensors are matched using timestamps and speed and travel time are collected (FHWA 2013). Two advantages to installing these sensors are that they have a high detection rate and that they self-calibrate (Singer et al. 2013). Other advantages of these sensors are that they are unaffected by the weather on the road and they do not always need pavement cuts for installation.

Magnetic sensors can be sensitive and may require pavement cuts, boring, or coring (FHWA 2013). Another disadvantage noted by Klein et al. (2006) is that, if vehicles are stopped on top of the sensors, they will not detect the vehicles unless the sensors are set out a certain way with the right software. In addition, it is resource intensive to set up multiple data collection points.

5.4.1 Microwave Radar

5.4.1a Truck Transponders

The FHWA Office of Freight Management and Operations currently collects data from transponders located in truck carrier cabs across the US. This data includes geographic positioning system (GPS) information and radio frequency identification, as well as network status details and more (Wolf et al. 2009). Two advantages to using the transponder data is that it does not force the agency to buy or maintain the equipment.

The major disadvantage to using the transponders is the volume of truck traffic on the road being insufficient in providing useful data. Another disadvantage would be that data might have to be purchased from a third-party source (Ullman et al. 2011b). It would be wise to work with the FHWA Office of Freight Management and Operations to optimize the benefits of the transponder data.

5.4.1b iCone

The iCone consists of a highway construction barrel that has a GPS and radar sensor. The system also has networking capability so that several iCones can be linked. The system is capable of collecting speed and density. If several iCones are placed strategically, queue presence and length can be inferred. The system can also detect which lane is closed. The system has been crash tested and is currently being evaluated by seven state transportation agencies (iconeproducts.com/index.php/about-icone).

The main advantage is that the system is unobtrusive and can be integrated easily at strategic points within the work zone. Other advantages to the iCones are that the agency can monitor traffic from anywhere with an internet connection and they measure the average speed of vehicles accurately. The latter advantage was affirmed by a CalTrans study (Ravani et al. 2012).

The main disadvantages are cost and the potential for damage to the system from errant vehicles.

Caltrans developed portable traffic monitoring devices (PTMDs), which are similar to the iCone technology. Data collection devices are placed in a traffic chanelizer, which is crash compliant. The system consists of a radar unit, which can collect speed or volume, GPS, battery, and modem, which is used to transmit the data real-time (Chandler et al. 2013).

5.1.5 Cellular Phone

The tracking of cellular phones is quite widespread. Most phones have a “Location” function that mechanically sends data to cellular network switching centers, for example, when a user travels out of range of one tower and into the range of another. By using this capability, the information gathered can include the location of the phone, its speed, and other details (Singer et al. 2013). One advantage would be the large sample size available. Singer et al. (2013) also stated some advantages to cell phone tracking, such as the data are indiscriminate in terms of identifying the user, as well as being accurate in measuring travel time.

The main disadvantages are that obtaining these data may require agreements from third-party vendors and that the sample size is very reliant on the volume of traffic present (Ullman et al. 2011b).

5.1.6 Video Data Collection

A number of agencies use video data detection to collect mobility data. Software can extract speed and volume measures. Several agencies, such as NHDOT (2011) use a configuration of cameras to detect queue length and provide dynamic messages to drivers as shown in Figure 5-1.

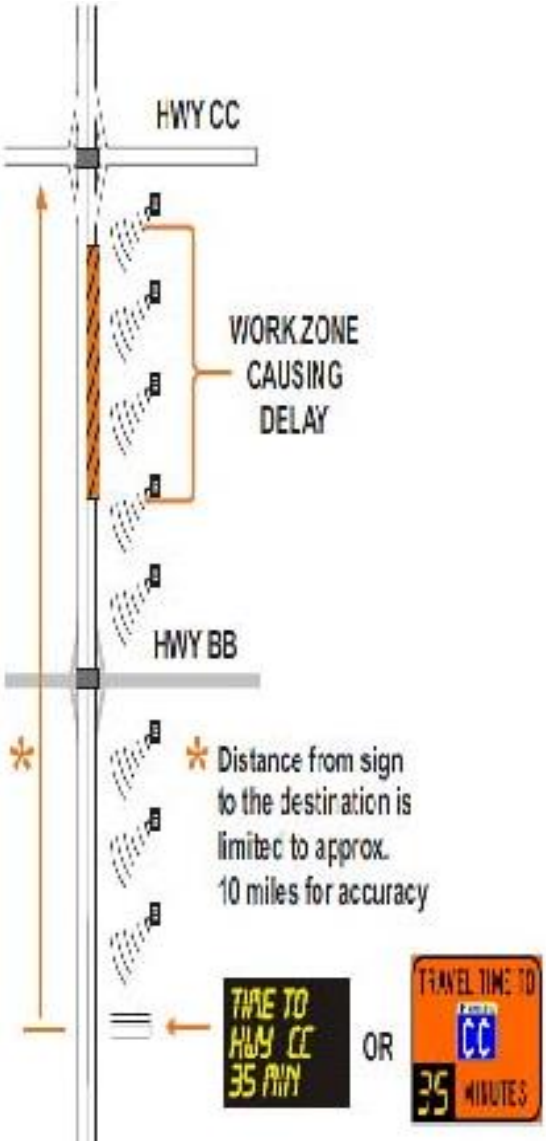


Figure 5-1: ITS system to detect delay and queues (NHDOT 2011)

5.1.7 Other Mobility Data Collection

Several agencies have used other methods to collect mobility data. PennDOT tried using law enforcement personnel to collect queue length while also providing enforcement (Bourne et al. 2010). Some agencies have used chase cars to collect and monitor travel time, speed, and queuing.

5.2 Safety Data

Most agencies use crash data. When crash reports are collected or filed electronically, access to data is much timelier. The Ohio DOT (ODOT) developed a real-time crash analysis tool to collect and track crashes for selected work zones. Data are collected via electronic queries or bi-weekly visits to law enforcement agencies. Collection of this near real-time data allows ODOT to identify and address safety issues while the work zone is active (Chandler et al. 2013).

The Kansas DOT (KDOT) has policies that require law enforcement agencies to notify authorized personnel of all work zone related crashes within a set timeframe. Work zone supervisors are required to fill out forms when a crash occurs in a KDOT work zone (Chandler et al. 2013).

NHDOT reviews freeway service patrol and fire department dispatch calls in key work zones to monitor safety. An unusually large dispatch volume is used as an indicator of a safety problem in the work zone (Ullman et al. 2008)

5.3 User Satisfaction

A number of agencies collect user satisfaction information. MoDOT (2013) has a customer survey that road users can access through a web site. MoDOT asks whether signing provided sufficient and clear warning, whether channelizers provided proper guidance, whether travel was timely, and whether the road user felt safe in the work zone. Information is compiled quarterly. MoDOT also conducts mass mailings around work zone projects. They received 1,783 customer surveys in 2012.

The Illinois Tollway used highway signs to solicit feedback from customers as shown in Figure 5-2. They also used focus groups, email surveys, and outreach to determine how well the public thought the system was performing.

Figure 5-2: Construction sign soliciting feedback (Bourne et al. 2010)

6. COMMUNICATING PERFORMANCE TO THE PUBLIC

The objective of work-zone performance measures is to improve safety and mobility in work zones for the traveling public and highway workers. Performance measures are outcome-based conditions which are used to evaluate success. Key to that success is communicate work zone status and improvement to policy makers and the traveling public. Good communication with the public can lessen congestion since road users can make informed choices as they plan trips. Additionally, keeping the public informed can to improved safety if drivers are more aware of prevailing road conditions. Finally, communication of work-zone performance can inspire confidence in the system and shows good stewardship on the part of the roadway agency.

Several states have developed innovative strategies to communicate performance to the public and are described in the following sections. Although not necessarily specific to work zones, these examples illustrate different ways to present information to the public. Two of the examples are graphical illustrations and two are report based.

Work zones are included in the various performance measures but the information is usually aggregated to show general safety and mobility measures. However, the information could be tailored to show work zone and the examples are simply provided to illustrate how different agencies communicate performance measures.

6.1 Virginia Department of Transportation DASHBOARD

The Virginia DOT (VDOT) uses a "dashboard" on their website to inform the public how the agency is performing in terms of congestion performance, safety, condition of roadways, finances, project timetables, citizen survey results, and VDOT management performance. Figure 6-1 shows their DASHBOARD, which provides a visual graphic for performance measures of interest (VDOT 2013).

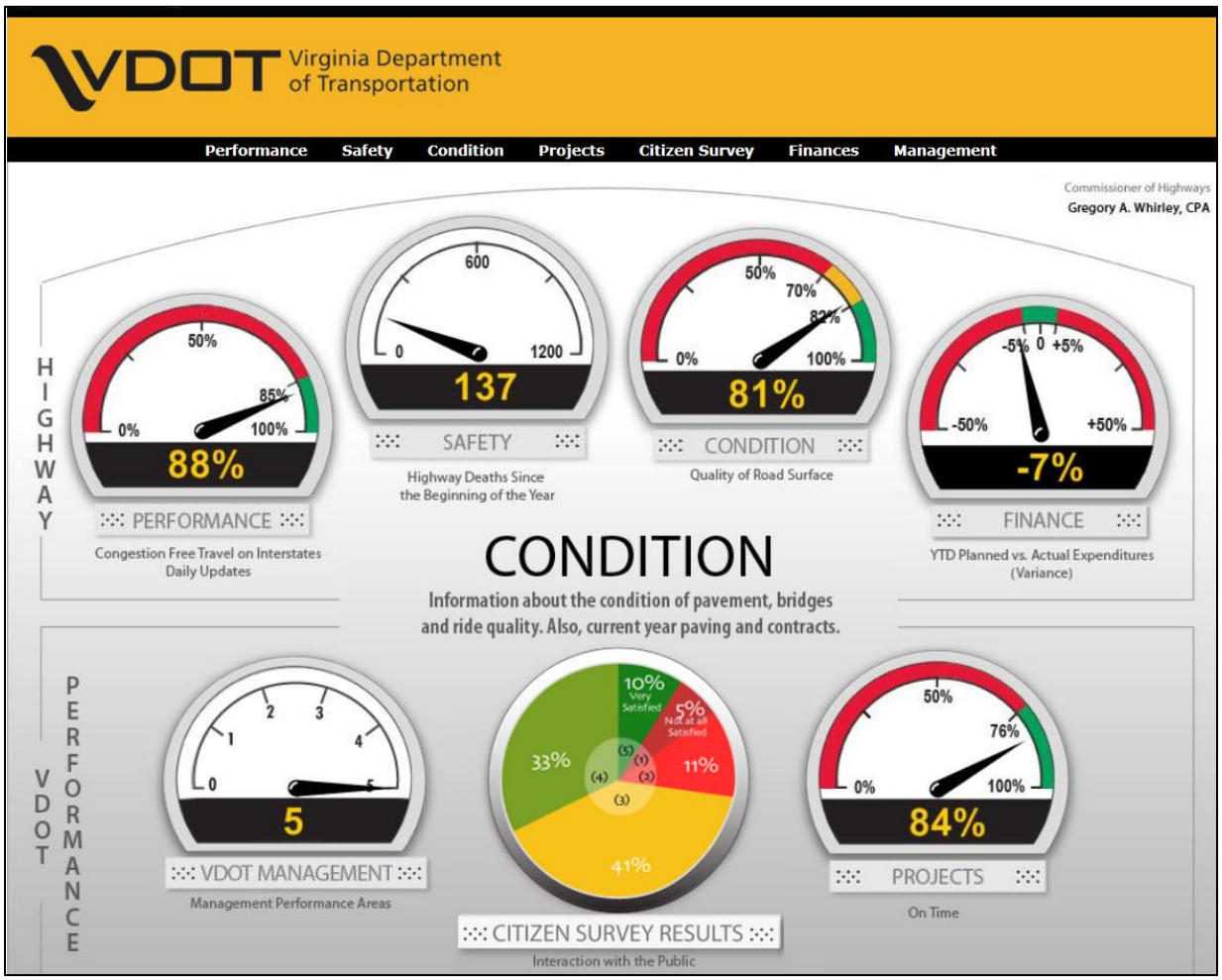


Figure 6-1: VDOT DASHBOARD on first visit (VDOT 2013)

One way that VDOT makes this DASHBOARD even more effective is by creating links to the specific topic when the visitor moves their cursor over one of the dials and clicks. The website then displays a page like the one shown in Figure 6-2.

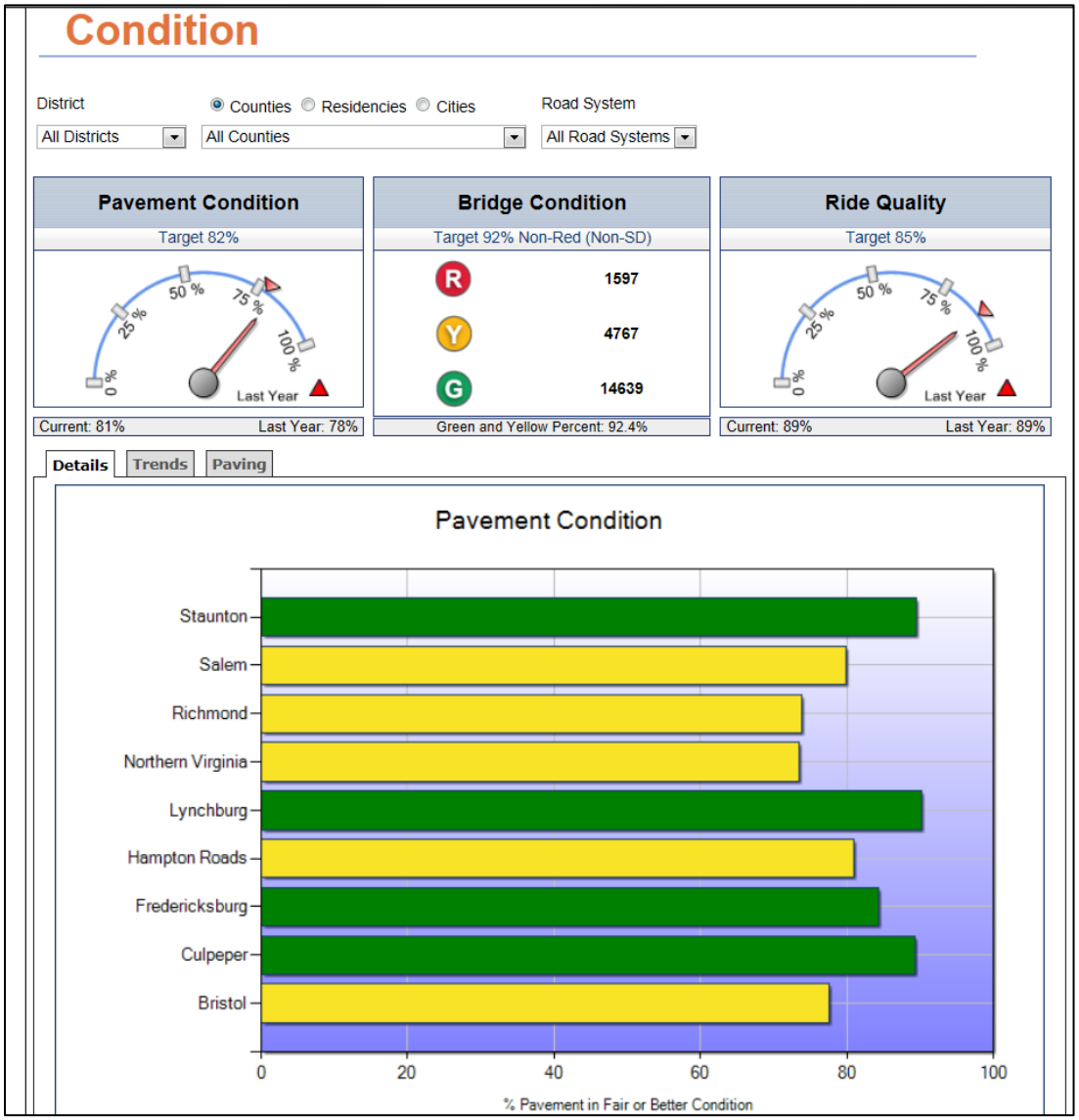


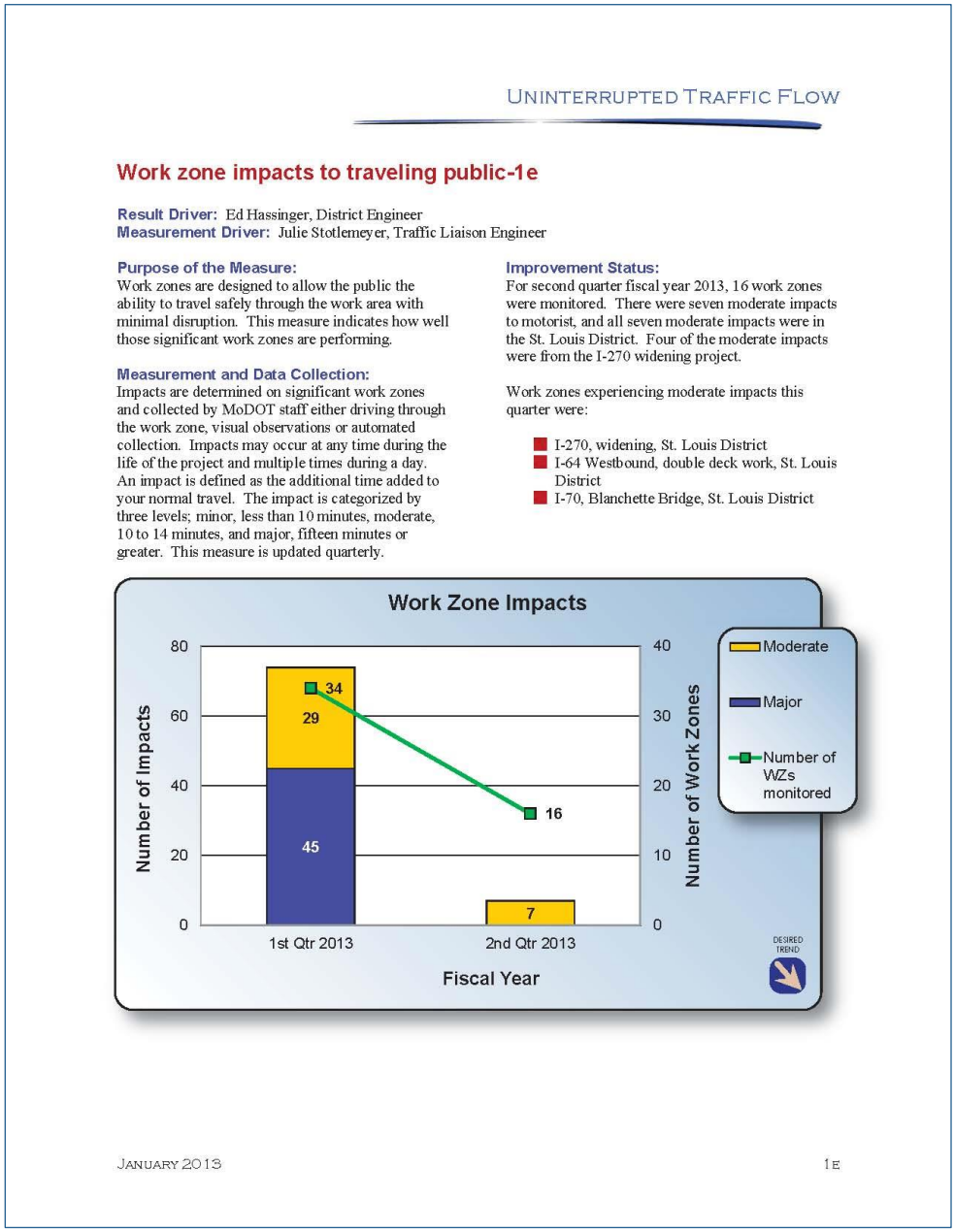
Figure 6-2: VDOT DASHBOARD after clicking on the Condition dial (VDOT 2013)

By clicking on a dial, the user is then provided with a wealth of information. VDOT also posted the last year's numbers so the user can compare them to today's statistics. The visitor can also focus in on a district, county, and road system. Overall, this could be one of the easiest ways to communicate agency efficiency to the public with easy-to-understand visual aids.

6.2 Missouri Department of Transportation TRACKER

MoDOT created TRACKER to let the public know about how the DOT performed in their services and products provided to road users. MoDOT publishes this report on a quarterly basis. The performance measures that the state uses are defined and focused to correlate to the mission and value statements of the agency.

A number of the measures are for general mobility and safety and illustrate methods of presenting this type of information. Several are specific to work zones. Results are provided in a graphical format as shown in Figure 6-3.



UNINTERRUPTED TRAFFIC FLOW

Work zone impacts to traveling public-1e

Result Driver: Ed Hassinger, District Engineer
Measurement Driver: Julie Stotlemeyer, Traffic Liaison Engineer

Purpose of the Measure:
Work zones are designed to allow the public the ability to travel safely through the work area with minimal disruption. This measure indicates how well those significant work zones are performing.

Measurement and Data Collection:
Impacts are determined on significant work zones and collected by MoDOT staff either driving through the work zone, visual observations or automated collection. Impacts may occur at any time during the life of the project and multiple times during a day. An impact is defined as the additional time added to your normal travel. The impact is categorized by three levels; minor, less than 10 minutes, moderate, 10 to 14 minutes, and major, fifteen minutes or greater. This measure is updated quarterly.

Improvement Status:
For second quarter fiscal year 2013, 16 work zones were monitored. There were seven moderate impacts to motorist, and all seven moderate impacts were in the St. Louis District. Four of the moderate impacts were from the I-270 widening project.

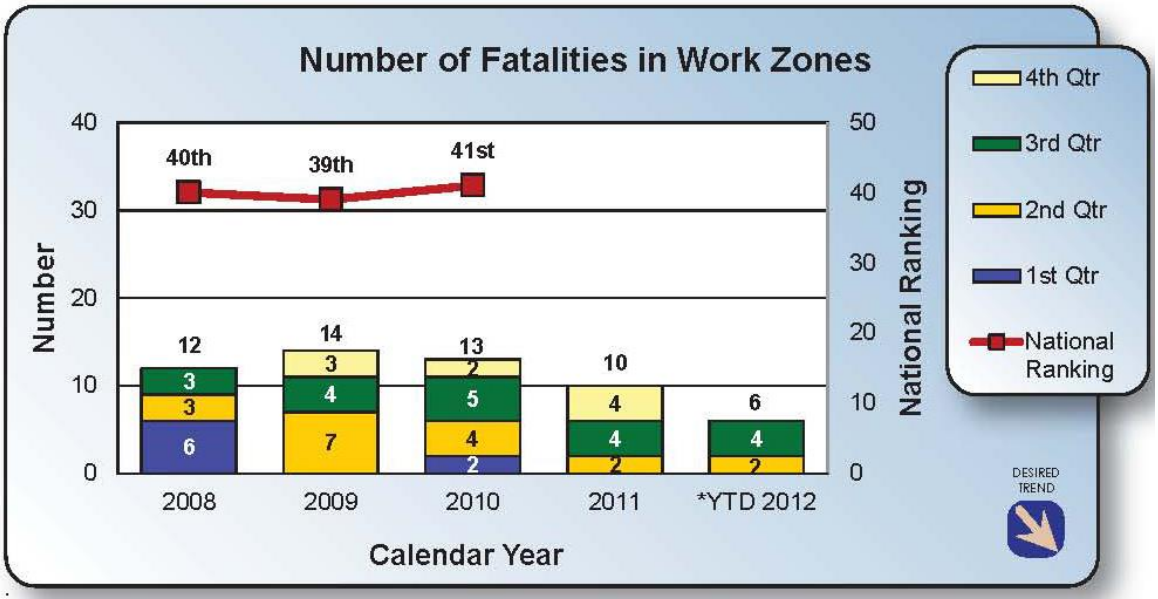
Work zones experiencing moderate impacts this quarter were:

- I-270, widening, St. Louis District
- I-64 Westbound, double deck work, St. Louis District
- I-70, Blanchette Bridge, St. Louis District

JANUARY 2013 1E

Figure 6-3: MoDOT TRACKER work-zone mobility measures (MoDOT 2013)

Missouri also shows fatalities in work zones by quarter in a graphical format as shown in Figure 6-4. The information is presented by quarter and compared against the national ranking for work-zone fatalities.



*YTD 2012 – Due to a backlog of crash reports into STARS, the fatality, disabling, minor injury and work zone crash measures will only illustrate first, second and third quarter data derived from TMS.

Figure 6-4: MoDOT TRACKER work-zone safety measures (MoDOT 2013)

6.3 Wisconsin Department of Transportation MAPSS

WisDOT created the *MAPSS Performance Improvement Report* to help the public understand how the DOT is performing in five areas: mobility, accountability, preservation, safety, and service (MAPSS). Each section has specific performance measures that describe how the DOT measures it, the current level, the goal that was set for the measure, whether the goal was met, the trend of the measure, and comments regarding the measure. This report is published quarterly as well (Figure 6-5).

July 2013

Wisconsin Department of Transportation

MAPSS Performance Scorecard

✓ Goal has been met ↑ Performance is trending in a favorable direction ↔ Trend is holding ↓ Performance is trending in a unfavorable direction

Performance measure	How we measure it	Current report period	Goal	Goal met	Trend	Comments
Mobility: Delivering transportation choices that result in efficient trips and no unexpected delays.						
Urban freeway congestion Calendar year 2012	Percent of urban freeway with serious congestion	15.0	10.0		↑	The measure is based on the percent of urban freeway miles at a mid-level of service (LOS D) or worse (a lower value is better).
Transit availability Calendar year 2012	Percent of population served by transit	54.0	75.0		↓	Economic factors affecting this measure include rate of inflation in relation to funding.
Bicycle accommodation Calendar year 2012	Percent of state highway miles with bicycle accommodation	69.0	100 percent, except where prohibited		↑	Increasing percentage of bicycle accommodations is mostly due to the paving and widening of shoulders.
Incident response Calendar year 2012	Average time to clear full closures on the interstate	4 hrs. 09 min.	Decrease response time by 5 percent compared to the prior year.	✓	↑	From 2011 to 2012 average incident clearance time was reduced 10 percent, exceeding the annual target.
Winter response State fiscal year 2013	Average time to bare/wet pavement after snow/ice event	–0.43 hrs.	2.00 hrs.	✓	↑	It was an unusual spring. Late spring multi-day storms with wet snow meant that on average a bare/wet pavement was achieved before the storm ended. (A lower number is better.)
Accountability: The continuous effort to use public dollars in the most efficient and cost-effective way.						
Transportation Economic Assistance Grants Calendar year-to-date 2013	Jobs created and retained through TEA grants	1,640	15 grants, 2,700 jobs and 100 percent compliance		↑	In 2013, we aim to increase the number of grants and jobs by 50 percent, and achieve 100 percent compliance with reporting requirements.
Timely scheduling of contracts State fiscal year 2012	Percent of highway program funding scheduled in the first six months of the fiscal year	43.2	60.0		↓	Monthly snapshots compare actual funding programmed with targets.
On-time performance Calendar year 2011	Percent of highway projects completed on-time	90.0	100.0		↓	Factors affecting this measure include adverse weather, plan changes, material shortages and utility work delays.
On-budget performance State fiscal year 2013	Final highway project cost as percent of original contract amount	102.0	100.0		↑	Costs are impacted by quality and completeness of project designs, field conditions, weather and contract oversight (a lower number is better).
Surplus property management State fiscal year 2013	Dollar value of surplus land sold	4.37 mil.	2.75 mil.	✓	↑	Fiscal year 2013 goal of $2.75 million surpassed.
DMV efficiency 2011–2012 calendar year average	Number of DMV products issued per employee hour worked	9.3	9.0	✓	↔	Self-service options and technologies are being used to shorten processing times.

The Wisconsin Department of Transportation MAPSS Performance Scorecard reviews five key goals and over-arching performance measures that guide us in achieving our mission "to provide leadership in the development and operation of a safe and efficient transportation system." Establishing goals and measuring results is essential to running a successful organization and meeting public expectations.

For more information on MAPSS, visit www.mapss.wi.gov

1

Figure 6-5: WisDOT MAPSS Performance Improvement Report (WisDOT 2013)

6.4 Washington State Department of Transportation Gray Notebook

From the beginning of its quarterly accountability report, *The Gray Notebook*, back in 2001, WSDOT began this initiative to help the public gain a greater perspective of what the DOT was accomplishing. Each edition of The Gray Notebook (Figure 6-6) provides articles ranging from reports on major projects to pavement preservation, as well as a "lite" version, which summarizes the notebook's topics.

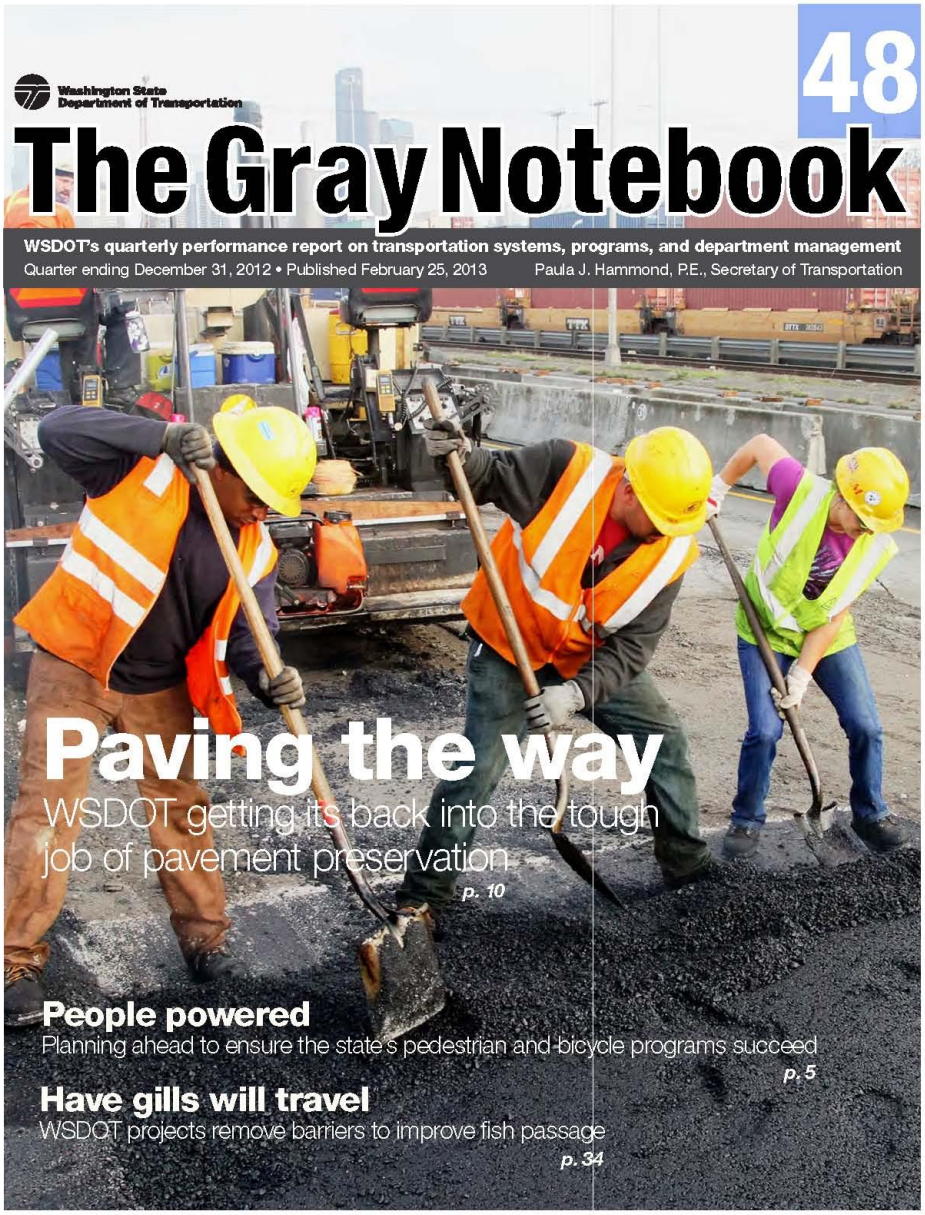


Figure 6-6: WSDOT The Gray Notebook (WSDOT 2013)

7. RESOURCES

This section provides an annotated list of selected resources that may be used to help select work-zone performance measures.

A Primer on Work Zone Safety and Mobility Performance Measurement (Gerald L. Ullman, Timothy J. Lomax, and Tracy Scriba. Washington, District of Columbia: Federal Highway Administration, September 2011.)

This primer was created to assist agencies in understanding and implementing the FHWA Work Zone Safety and Mobility Rule and describes the following:

- What is measured
- How the performance measure is recorded
- Why the measure is being recorded
- The three types of performance measures (exposure, safety, and mobility)
- How these measures work with the agency to improve and promote safety and mobility
- The difference between metrics that measure on a project-level versus a program-level

The primer provides agencies with in-depth discussions and examples of different performance measures, including guidelines and procedures for collecting data for the measures. At the end of the primer, a section dedicated to guiding the agency through each step of these processes can help the agency get a running start on implementing performance measures.

Implementing the Rule on Work Zone Safety and Mobility (Scriba, Tracy, Param Sankar, and Krista Jeannotte. Report No. FHWA-HOP-05-065. Washington, DC: Federal Highway Administration, 2005.)

This report was put together by the FHWA to help state agencies implement the FHWA Work Zone Safety and Mobility Rule. It clearly defines the FHWA rule and provides guidance and examples on incorporating the rule into the agency's structure of operating and planning work zones:

- Describes how the new rule modifies the previous version of the rule
- Describes different ways that agencies can create or adjust their work-zone safety and mobility policy to fit the Final Rule
- Breaks down and describes the four components of agency-level methods and guidelines for work zones (analysis of safety and operations data, training, process reviews, and impact assessment)
- Defines what a "significant" project is and explains how to decide whether and when a project is "significant"
- Details what, how to create, and how to test traffic management plans

Scan 08-04: Best Practices in Work Zone Assessment, Data Collection, And Performance Evaluation. (Bourne, J. Stuart, Chung Eng, Diana Gomez, Dave Holstein, Reynaldo Stargell, Ron Lipps, Denise Markow, K. C. Mathews, Tracy Scriba, Brian Zimmerman, and Gerald L. Ullman. NCHRP 20-68A Scan Team Report, October 2010.)

This study had North Carolina put together a 10 member team along with a subject matter expert (SME) to perform a scan of how other agencies assess their work zones, collect data, and use various performance measures. Fourteen agencies were selected: California DOT, Florida DOT, Illinois Tollway Authority, Indiana DOT, Maryland DOT, Michigan DOT, Missouri DOT, New Hampshire DOT, New Jersey DOT, New York State DOT, Ohio DOT, Pennsylvania DOT, Oregon DOT, Washington State DOT, and Wisconsin DOT. The team came up with the following recommendations:

- Define where and how work-zone safety and mobility impact assessments belong in the development of the project
- Match the amount of the transportation management planning effort of a project to the magnitude of the impacts that are expected
- Quality data should be collected to measure performance effectively
- Transportation management centers should be employed in collecting data
- Performance measures should be chosen in correlation to the agency mobility and safety goals and objectives
- Agencies should be sure to improve their data collection techniques and processes continuously

Work Zone Impacts Assessment: An Approach to Assess and Manage Work Zone Safety and Mobility Impacts of Road Projects (Sankar, Param, Krista Jeannotte, Jeffrey P. Arch, Marcelino Romero, and James E. Bryden. Washington, DC: Federal Highway Administration, May 2006.)

The goal of this guide is to exhibit a basic method for assessing the work zone. Overall, the guide can assist agencies in creating work-zone impact assessments and help them see the effects of their performance measures so they can make changes if necessary.

The guide begins with an overview of what an assessment of work-zone impacts is and displays how the work-zone assessment relates back to the FHWA Final Rule. The document provides a view of the assessment procedure structure and describes how to create and apply a work-zone policy. The document provides various figures and tables to help the agency incorporate the information and dissect the values and methods that can be implemented for assessing work-zone impacts within systems planning, preliminary engineering, design, and construction. The guide depicts how work-zone performance assessment helps the agency understand and gauge the safety and mobility impacts of the work zone and also shows how maintenance and operations can apply the work-zone assessment document.

Guide to Benchmarking Operations Performance Measures (Tarnoff, Philip J., Stanley E. Young, Joshua Crunkleton, and Nezamuddin. Report No. NCHRP 20-7. College Park, Maryland: Center for Advanced Transportation Technology, 2008.)

This study was conducted by the University of Maryland Center for Advanced Transportation Technology (CATT). The team's primary goal was to perfect 12 operations performance measures that the National Transportation Operations Coalition (NTOC) created in 2005. The team evaluated the data collection and analysis methods from pilot tests and created guidance documents for those methods. The operations performance measures were as follows:

- Road user satisfaction
- Extent of congestion (spatial)
- Extent of congestion (temporal)
- Incident duration
- Non-recurring delay
- Recurring delay
- Speed
- Throughput (person)
- Throughput (vehicle)
- Travel time (facility)
- Travel time (reliability)
- Travel time (trip)

These measures are described extensively in the report. It provides guidelines for the implementation of the performance measures, including recommendations on accuracy and minimum sample size. The report also lists traffic-flow performance measures and the data collection methods used, a comparison of data collection methods, examples of sensor spacing, and tables regarding each performance measure and the results from this pilot study.

Guide to Effective Freeway Performance Measurement (Margiotta, Richard, Timothy Lomax, Mark Hallenbeck, Shawn Turner, Alex Skabardonis, Chris Ferrell, and Bill Eisele. Washington, DC: Transportation Research Board, August 2006.)

Report
The report portion of the document was created to document the research that went into developing the guidebook.

Guidebook
The guidebook portion of the document is designed to help provide agencies with guidance on implementing performance measures for freeways, which the authors define as "access-controlled highways characterized by uninterrupted traffic flow." Within the guidebook, the authors provide different approaches to gauging the performance of freeways (both rural and urban). It should be noted that the focus of the performance measures discussed in this guidebook is on congestion and mobility performance. Other performance measures, such as freeway safety, operational efficiency, ride quality, environmental, and road user satisfaction, are discussed as well, although not as thoroughly.

Appendices provide: a list of freeway performance measures that can be implemented, along with how they are used, data required, units of measure, how often to report the data, and a definition of each measure; survey results for the agencies that had already implemented performance measures; and sample questions that were asked of the public to gauge the effectiveness of agency performance.

8. SURVEY OF SURROUNDING STATES

After reviewing documents that were gathered during the literature review, the tables that are in sections 3 and 4 were created. To provide the most up to date information, the team also conducted a survey of the states surrounding Iowa.

State transportation agencies were provided with the initial draft tables and asked to approve or disapprove the findings. The states that were surveyed were Illinois, Iowa, Kansas, Minnesota, Missouri, Nebraska, South Dakota, and Wisconsin. The responses from the agencies are summarized below. Based on these responses, material presented in sections 3 and 4 were updated. If a response was not received from the agency in question, it was assumed that the information was correct.

8.1 Summary of State Surveys

Illinois – Priscilla Tobias, Illinois DOT
The Illinois DOT (IDOT) confirmed the team's findings, and reaffirmed the response referencing to their Work Zone Safety and Mobility policy posted on their website.

Iowa – Dan Sprengeler and Mark Bortle, Iowa DOT
The team's finding that Iowa is in the process of developing work-zone performance measures was confirmed.

Kansas – Kristina Pyle, Kansas DOT
The Kansas DOT (KDOT) affirmed the team's findings, although the DOT has not implemented the performance measures. At this time, KDOT uses its Lane Closure Guide to help decide on mobility mitigation measures.

Minnesota – Kenneth Johnson, Minnesota DOT
The Minnesota DOT (MnDOT) confirmed the team's findings and stated that they are looking to incorporate more performance measures, but they have a long way to go. They also stated that their Metro District (St. Paul/Minneapolis) observes average speeds if there are complaints, and it is not standard practice.

Missouri – Dan Smith and Julie Stotlemeyer, Missouri DOT
No response has been received from the Missouri DOT.

Nebraska
After attempting to contact the Nebraska Department of Roads for several weeks, no response was received.

South Dakota
No response was received from the South Dakota Department of Transportation.

Wisconsin – Jon Shaw, Wisconsin DOT
The Wisconsin DOT (WisDOT) acknowledged the team's findings, although they felt the DOT's measures were overstated. Most of the measurements have been work-zone queue length and delay as well as capacity and delay. Information was adjusted in the tables as appropriate.

9. RESEARCH NEEDS TO ADDRESS WORK-ZONE PERFORMANCE MEASURES

Many states are in the early stages of developing work-zone performance measures. As a result, information is not yet available as to how realistic it is to meet the various performance measures. For instance, several states have proposed the safety goal of Towards Zero Deaths, which may be difficult to meet. Consequently, the one research need that the team identified is the need to survey agencies that developed performance measures early to ask for their experiences in how they have met their goals.

Another area for further research is data collection. For safety performance measures, the main measure is reduction in crashes or reduction in crash rate. The largest difficulty with crash data appears to be obtaining timely access to crash reports. Several agencies have begun working on more timely access through electronic reporting. As a result, the team proposes summarizing information on the utility of more timely access to crash information in preventing additional work-zone crashes. This research summary would assist in assessing value in investing in an electronic reporting system.

The most pressing needs for agencies appear to be better ways to collect mobility data. The team summarized potential future research needs for mobility performance measures, which include the following:

- **Travel Time and Delay:** Various methods are available for collecting travel time and delay including Bluetooth devices, probe vehicles, cameras, and radar technology. As a result, the main research need for travel time is to compare the cost, reliability, and performance of the different methods in being able to produce the necessary data for work-zone performance measures.

- **Queue:** Queuing is a common performance measure. In the planning stages, the queue is estimated using work-zone packages, such as QUEWZ, so that traffic management plans can be used to address significant work-zone projects. However, in the field, it is challenging to monitor queue length. Several methods, such as iCones or cameras, are available. However, detection of work zones requires a number of sensors (as shown in Figure 5-1). This can be resource intensive and may not be practical for many work-zone projects. As a result, one research need is for better technologies to detect and monitor queuing real-time. In addition, it would be useful to compare the cost, reliability, and performance of current systems used to detect queuing.

- **User Satisfaction:** A number of agencies have conducted surveys to assess road user expectations and satisfaction. Case studies summarizing best practices would be useful to agency personnel who are considering implementing these types of studies.

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