Assessing the Effectiveness of Transportation Management Plan (TMP) Strategies

Feasibility, Usefulness, and Possible Approaches

U.S.Department of Transportation
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1. Background & Purpose of Research

1.1 Background

In 2004, the Federal Highway Administration (FHWA) finalized updates to the Work Zone Safety and Mobility Rule. In an effort to improve mobility and safety for motorists and highway workers, the Rule required the development and implementation of a Transportation Management Plan (TMP) for any project that receives Federal funding. TMPs are recommended for other projects as well, regardless of project size, duration, traffic volumes, or work type.

A TMP consists of strategies to manage the work zone impacts of a project. Its scope, content, and degree of detail may vary based upon the State's work zone policy and the expected work zone impacts of a project.[1] While TMPs are required by the FHWA Work Zone Safety and Mobility Rule for all Federal-aid highway projects, States can impose broader policies that address other projects. For example, Rhode Island Department of Transportation (DOT) prescribes the use of TMPs for not only Federal-aid road construction projects, but also for all planned maintenance and other activities requiring a temporary traffic control permit, regardless of size or funding source.[2] Many States see the value in TMPs and develop them for all road projects.

TMPs outline specific strategies to be employed that will help achieve project goals associated with traffic mobility, safety of motorists and workers, and other operational targets. TMPs are important to clearly defining and communicating the comprehensive plan for project management to internal State DOT staff, contractors, the public, and the media.

A large number of TMP strategies were identified in a TMP guide developed by FHWA in 2006. These strategies vary in complexity, ease of use, and cost. The TMP strategies selected for use on any given project are determined based on the unique conditions at the work zone site. For instance, if alternate roadway networks exist in the vicinity of the work zone, a strategy could be to use alternate routes during times of high traffic volumes, or even for the duration of the project.

Many TMP strategies have been implemented by practitioners, but practitioners and researchers are often uncertain of their relative effectiveness. Quantifying TMP strategy benefits can be challenging for a number of reasons, including the transient nature of work zones, the cost of evaluation, and the fact that strategies are rarely implemented in isolation.

Documentation of specific operational and safety factors related to TMP strategies has the potential to help practitioners gauge the strategy's overall success and make determinations of when to use certain strategies. Future use of a strategy could be influenced by its implementation ease/difficulty, cost of

[1] Federal Register, 23 CFR Part 630, U.S. Department of Transportation, Federal Highway Administration, "Work Zone Safety and Mobility." (Washington, D.C.: 2004) Available at: http://frwebgate.access.gpo.gov/cgi-bin/getdoc.cgi?dbname=2004_register&docid=fr09se04-3 (accessed October 2010)

[2] Rhode Island Department of Transportation, "Transportation Management Plans" web page. Available at: http://www.dot.ri.gov/engineering/traffic/tmp.asp. (accessed November 2011)

implementation, and effect on operational and safety performance goals, as well as other factors such as site-specific characteristics.

1.2 Research Purpose

Agencies could develop better, more effective, and more economical TMPs if they had more data on the effectiveness of the potential TMP strategies available for a given project. Effectiveness information could help practitioners better understand which TMP strategies are most likely to improve work zone safety and mobility in various circumstances, and where, when, and how to implement particular strategies to maximize effectiveness. The strategy information included in earlier guidance documents has tended to be more high-level and general, such as a strategy description, suggestions of applicable situations for use of a strategy, general information on possible benefits and challenges, and in some cases a few case study examples. While this information provides a good starting point, for many strategies it could be built upon by having a greater understanding of the usage, effectiveness, and cost effectiveness of each strategy in the field.

Ultimately, work zone practitioners want to know the cause and effect relationship between choosing certain strategies and the corresponding impact those strategies will have on the operational aspects of the project. While selecting and deploying TMP strategies can sometimes be complex, the more that practitioners know how each strategy combines with a set of defined project characteristics and with other strategies, the greater the potential to produce desirable and predictable results.

Research Objectives

- Identify and assess evaluation approaches and scopes.
- Determine data needs.
- Identify relevant work completed to date.
- Recommend approaches and scopes.

State DOTs select specific TMP strategies for several reasons, including:

- The level of certainty that the strategy will perform in a way and at a level that meets the operational and safety goals of the project;
- Federal regulations or industry requirements, such as the MUTCD;
- Relative cost;
- Cost effectiveness;
- Time and effort needed for implementation;
- Project parameters and needs; and
- Political or regional needs.

To assess the potential for capturing and reporting the effectiveness of TMP strategies, FHWA undertook a research effort regarding TMP strategy effectiveness. The objective of this research effort is to identify and assess possible approaches to evaluating TMP strategies, determine what data are needed and available to support an assessment, identify any relevant work completed to date, and provide recommendations on the feasibility and usefulness of, and possible approaches for, conducting an assessment of TMP strategy effectiveness.

The research has been guided by the following four questions:

1. What has been done by agencies to assess the effectiveness of TMP strategies to date?
2. What approaches (e.g., types, scopes) have been tried and/or studied in practice?
3. Does it seem feasible and useful to assess the effectiveness of TMP strategies?
4. Do practitioners and other researchers think it is feasible and useful to assess the effectiveness of TMP strategies?

Using information gathered from published materials and practitioners, researchers assessed the practicality and value of TMP strategy evaluation and potential approaches for assessment.

2. Research Approach and Overview

The research team used several mechanisms to evaluate the feasibility and usefulness of assessing TMP strategy effectiveness.

- ***Literature Review.*** The team reviewed extensive resources on the use and assessment of TMPs and their associated strategies, including existing State DOT policies and practices, academic and consultant research, and guidance developed and promoted by national organizations.
- ***Discussions with Practitioners.*** A sample of work zone practitioners from agencies active in the use and evaluation of TMP strategies participated in telephone question and answer sessions to describe their agency's process for TMP development, selection of TMP strategies, and evaluation of the strategies after implementation.
- ***Online Collaborative Session.*** To encourage discussion among practitioners and share ideas about the use of various TMP strategies and how to evaluate their effectiveness, the research team held an online collaborative session with State, Federal, academic, and consultant work zone experts.

2.1 Literature Review

The research team initially identified the literature most applicable to the topic of TMP strategy effectiveness evaluation, and subsequently reviewed 79 relevant sources. A list of the sources, their relevance, and the strategies they addressed are provided in two tables in Appendix A. Findings showed that States/researchers have used qualitative analysis of the strategies, quantitative analysis, and a combination of the two approaches. The scope of the analysis varied as well, ranging from a case study of a single TMP strategy deployed at one work zone to Statewide evaluations of multiple strategies. The literature review identified several means of analysis that varied by agency and warranted direct discussions with practitioners.

2.2 Practitioner Input

Many practitioners are actively engaged in determining TMP strategy effectiveness based on their first-hand use of these strategies to improve safety and mobility in their jurisdiction's work zones. The research team acquired information from State DOT representatives in two ways. First, the team held one-on-one question and answer sessions by telephone. After the completion of the telephone discussions, the team conducted a peer-to-peer online collaborative session.

2.2.1 Telephone Discussions

Several State DOTs were identified as potential leaders in TMP strategy evaluation techniques. Telephone discussions with these practitioners revealed a variety of TMP development, implementation, and evaluation approaches and scopes. Topics covered in the discussions included how agencies evaluate TMP strategies, such as:

- What qualitative and quantitative evaluation methods have been used in your State?
- How are the data collected and analyzed?
- Does the DOT believe it is feasible to evaluate TMP strategy effectiveness?

In general, agencies thought that measuring the success of TMP strategies is both feasible and necessary. A few States commented that strategies are often implemented differently by project, and as such are evaluated differently. If a study to determine the success of TMP strategies was conducted, these States felt that a strategy could not be deemed successful or unsuccessful without knowing the considerations that went into each strategy's deployment and evaluation. A strategy that is defined as successful based on one measure of effectiveness might score very differently if evaluated from a different point of view. Topics covered during the practitioner telephone discussions are available in Appendix B.

2.2.2 Online Collaborative Session

Work zone experts from six State agencies, one university, FHWA, and the research team came together during an online collaborative session to discuss topics related to TMP strategy effectiveness. Participating agencies varied in size, geographic location, and level of understanding of the subject matter. Topics of discussion included:

- The definition of effectiveness within their respective agencies.
- How TMP strategy effectiveness is categorized today.
- Specific qualitative and quantitative measures of effectiveness (MOEs) used in States.
- Types of TMP strategy evaluation approaches and scopes in use in States.

Practitioners commented that most measurements used to determine the success of a particular TMP strategy are directly related to safety and/or mobility. For example, practitioners noted that one way to identify the safety benefit of a TMP strategy is by comparing work zone crash data to crash data before the work zone was established. Practitioners also noted that mobility benefits are identifiable from before/after comparisons of speed, delay or travel time, queue length, and public perception or satisfaction. Some agencies also include pedestrian mobility and customer satisfaction in their assessment of TMP strategies, but they have yet to define a metric for determining success of these measures. A summary of the online collaborative session is available in Appendix C.

3. Findings

This chapter discusses the findings made as a result of the research activities described in Chapter 2. The initial section presents some key, overarching findings, and subsequent sections present the results of TMP strategy assessments done to date, assessment approach types and scopes that have been used, and research gaps and industry needs.

3.1 Overarching Findings

There are a few key research findings that apply across all strategies, approaches, and scopes.

TMP strategy evaluation is occurring around the country.
Agencies understand the benefit of evaluating the effectiveness of TMP strategies. Based on the research conducted, the research team determined that not only is the evaluation of TMP strategy effectiveness feasible, it is occurring to some degree at the Federal, State, and regional levels. The types of evaluation activities occurring today vary in type and scope, with the most common being research on a specific strategy under specific conditions.

Key Finding
TMP strategy evaluations is occurring at the Federal, State, and local levels.

Having more information about TMP strategy effectiveness would be useful.
Throughout discussions with practitioners, it was apparent that additional guidance on the effectiveness of various TMP strategies would be used. By learning about the effectiveness of strategies used in other locations, practitioners can save time and money by selecting the most effective strategies for use in their jurisdictions.

A variety of MOEs have been evaluated or are of interest for evaluation.
The MOEs used to rate TMP strategies fall into four key areas:

1. Safety;
2. Mobility;
3. Construction efficiency (including cost) and effectiveness; and
4. Public perception and satisfaction.[3]

A list of MOEs is illustrated in Table 1.

Table 1: Effectiveness Criteria

Safety	Mobility	Construction Efficiency and Effectiveness	Public Perception and Satisfaction
• Number and Severity of Work Zone Crashes • Crash Rates • Incident response time • Clearance time	• Speed • Delay • Travel Time • Travel Time Reliability • Queue Length	• Number of Contract Change Orders • Project Duration • Project Cost • Work Zone Inspection Ratings	• Public comments • Type and frequency of legitimate complaints

[3] Scriba and Wood, "Traffic Management Plan Course, Module 9 – Evaluation and Performance," 2011.

Specific measurements for safety include the number and severity of traffic crashes in the work zone, with special consideration for worker-related crashes. Practitioners tend to look at work zone crashes system-wide from year to year to determine the overall success of their efforts. At the project level, examples include comparing the number of crashes (or crash rate) on a corridor during construction to the pre-construction data to determine the relative safety of that project. For mobility effectiveness, practitioners are typically most interested in and most often measure traffic volume/throughput, motorist delay, speed, travel time, and queue length.

The methods of measuring construction efficiency and effectiveness may be completion time, cost-efficiency of the construction methods used, and the quality of work. These constructability considerations can all affect the effectiveness of TMP strategies for the given project and influence future work zones if the quality of the techniques used is sub-standard. Public perception and public satisfaction are often measured by work zone customer surveys, feedback received from customer calls, and discussions held during public meetings.[4]

Stakeholders indicated that crash rates, project duration, project cost, and public comments were the most commonly used effectiveness criteria due to their accessibility to work zone practitioners. Practitioners noted the usefulness of the other effectiveness criteria as well, but because these criteria were not accessible for all work zones, they were used less consistently in TMP strategy assessment.

Feedback from practitioners during the online session confirmed these MOEs have been used in the field, and additional measures were shared as well. For example, the number of contract change orders helped a State determine if the TMP strategies were effective; multiple change orders for temporary traffic control could indicate that the original strategies were not effective in the field. Some practitioners include other types of benefits (e.g., pedestrian mobility) in their definition of effectiveness, but most have not defined a specific measurement for determining success. Other MOEs include total cost to implement and ease of use.

States use a variety of practices for TMP strategy selection, deployment, and evaluation

From the literature review, agency discussions, and an online collaborative session, it was apparent that State practices vary considerably with respect to the following:

- Selection of strategies to be included in TMPs;
- Strategy deployment methods;
- How (or if) data are collected to measure strategy effectiveness;
- Types of data collected;
- Data analysis methods; and
- Information sharing within the agency.

Key Finding

There is no set rule of thumb for selecting TMP strategies.

There are no standard approaches or rules-of-thumb in use for identifying strategies to use on a given project. Several agencies have created their own checklist of strategies for designers, other staff, and consultants to consider on all projects; however, this list is usually not tailored by type of projects and generally does not provide guidance in selecting strategies.

[4] Scriba and Wood, "Traffic Management Plan Course, Module 9 – Evaluation and Performance," 2011.

A few agencies have included possible TMP evaluation/performance criteria in their checklist of strategies. Implementation of these evaluation criteria in TMPs is not yet widespread.

TMP strategies are often selected without comprehensive information on a strategy's potential benefits and disadvantages

When identifying specific strategies to include as part of a TMP for a project, practitioners must first determine the potential impacts of the work zone and then determine which strategies to use to remedy or mitigate these impacts to motorists and workers. A host of strategies exist for any known impact, as do their specific deployment techniques. Each strategy's inclusion in the TMP should be based on a desired result that targets one or more of the potential impacts that were identified.

For instance, for public outreach, there are numerous strategies and mechanisms used by States to inform the public. However, to tailor the strategy and deployment mechanism to the needs of a particular project, practitioners must have information on what methods work well in those situations. In some cases that may involve providing instant notifications of work zone delay information on a portable changeable message sign. In other cases, posting information to the project's website or distributing flyers to nearby businesses and their customers – or some combination of all of these strategies – may be more appropriate and effective. Whichever method is used, strategies need to be evaluated during and after implementation to determine if one is a more effective means of communication for future work.

The knowledge level of States varies widely regarding the selection of appropriate TMP strategies compatible with project-specific conditions and desired outcomes. In some cases practitioners said that they select TMP strategies from a toolbox of applications developed by their respective agency, and they employ the strategies without having a good understanding of how the techniques will contribute to mobility and safety nor for which situations the strategies are best used. Most practitioners stated that the main criterion for selecting strategies to be included in a TMP is past experience with using the strategy on similar projects. This past experience can vary from person to person and agency to agency. States with more experience in developing TMPs and assessing TMP strategies generally have a better understanding of how well certain strategies work. In all cases, State practitioners requested improved knowledge transfer with respect to these practices so that each State knows the tools available to them and understands how each strategy may perform in a given set of circumstances.

3.2 Assessments of TMP Strategies to Date

Key Finding

States evaluate strategies using a variety of methods.

The literature review for this project, while not exhaustive, identified 79 published sources that addressed TMP strategy assessment. Some of the literature (19 sources) addressed the development and use of TMPs overall. These sources provided information on TMP development such as purpose, process, and components, but not information on individual strategies. Many of the sources identified through the literature search discussed the use and success of one or more specific strategies. Table 2 provides the number of sources identified and reviewed for various types of TMP

strategies. A list of the sources and a table showing the strategies each source addressed are in Appendix A. Practitioners who participated in the discussions for this project noted that while a higher number of studies can add certainty to results if the studies reinforce each other, not all research results carry equal weight and that the quality of the research is important.

Table 2: Summary of Literature Review Sources Discussing Specific TMP Strategies

TMP Strategy	Number of Sources
Traffic Control Devices	32
Intelligent Transportation Systems (ITS)	22
Speed Management	14
Queue Management	12
Portable Changeable Message Signs (PCMS)	10
Public Outreach	7
Night Work/Off-Peak Work	5
Law Enforcement	4
Detours/Driver Diversion	4
Lane Closures	2
Video Detection	2
Real-Time Crash Data Analysis in Work Zones	2
Incentives/Disincentives	2
Signal Optimization	1
Stage Construction	1

As noted earlier, agencies understand the benefit of evaluating the effectiveness of TMP strategies. Examples below illustrate program-level procedures and guidance developed to document and assess TMP strategy effectiveness.

Key Finding

Methodologies used in the States to evaluate TMP strategies could be applied to future work by FHWA and others.

The California Department of Transportation (Caltrans) recognizes the need to include TMP strategy monitoring and assessment as part of the construction contract. As a lesson learned from implementing TMPs, Caltrans now includes funding for monitoring traffic conditions during construction to track TMP effectiveness. They have standardized practices for monitoring the effectiveness of TMPs in the field to modify deployment techniques for improved efficiency. [5]

Researchers affiliated with the Texas Transportation Institute (TTI) and the City of Frisco, Texas, have developed a matrix that correlates specific performance measure types and indicators to TMP strategies for all project sizes. The matrix not only instructs practitioners on the most relevant TMP strategies, but it also guides them on how to collect and analyze data to evaluate strategy effectiveness.

[5] FHWA, Work Zone Safety and Mobility Web page, "Fact Sheet 11 – Caltrans Transportation Management Plans Reduce Work Zone Congestion," available at: http://ops.fhwa.dot.gov/wz/practices/factsheets/factsheet11.htm (accessed January 2012).

This could prove especially beneficial in determining how a strategy performed under certain conditions and informing decisions regarding future deployment.[6]

The Maryland State Highway Administration recognizes the need to evaluate TMP strategies to assess their potential future use. Their *TMP Guidelines for Development, Implementation and Assessment*[7] document indicates that monitoring for evaluation is important to:

- Assess and fine-tune performance of all TMP strategies and overall performance of the project corridor and alternative routes;
- Track public acceptance;
- Determine cost effectiveness of individual TMP strategies and shift resources from the least to most cost effective strategies; and
- Determine if additional TMP elements are needed or if particular elements need refinement.

In reviewing TMP strategy assessment done to date, certain strategies arose that have been evaluated more often and could be grouped based on their general purpose or function (i.e., what they are trying to accomplish). The following sections provide information on these TMP strategies, highlighting the name of the type of strategy, some examples of how the strategy has been used, and some numerical results, where found and applicable, from specific evaluations previously done for each strategy.

The strategies discussed below include:

- Traffic control devices;
- ITS strategies;
- Speed management (including Law Enforcement);
- Queue management;
- Portable Changeable Message Signs (PCMS);
- Public outreach;
- Nighttime only work zones; and
- Detours/Driver diversion.

3.2.1 Traffic Control Device Strategies

The use of traffic control devices is part of every TMP, serving as a mechanism to convey guidance and navigational prompts throughout the work zone to improve safety and mobility. These devices are implemented differently for various circumstances. Some examples of using this strategy are highlighted below.

Key Finding

Traffic control devices are a common TMP strategy, and their effectiveness is being evaluated.

One device of particular interest is the changeable message sign. The Midwest Smart Work Zone Deployment Initiative conducted 10 evaluations on changeable

[6] Carson, Anderson, and Ullman. "Matrix-Based Decision Support Tools for Construction Activities on High-Volume Roadways" *Transportation Research Record: Journal of the Transportation Research Board*, No. 2081 (2008).
[7] Maryland State Highway Administration, *Transportation Management Plans: Guidelines for Development, Implementation and Evaluation*, November 2006. Available at: http://www.marylandroads.com/OOTS/06TMPGuidelinesRev5.pdf (accessed March 2012)

message signs showing alternate route information and warnings of slow or stopped traffic. Findings from these evaluations varied; some sites achieved traffic diversions of around four percent while others saw little to no change. The authors included lessons learned to address typical geometric issues to make the systems more effective. The placement and visibility of the variable message sign was considered very important in maximizing effectiveness, as drivers must be able to easily see the sign and have time to react to the message (e.g., making a decision to take a detour route). [8]

As part of a study performed by the University of Missouri, sequential warning lights were used at a series of nighttime work zones to determine the effect on driver behavior. MOEs included speed, the number of late taper merges, and the locations where vehicles merged into an open lane from the closed lane. A benefit/cost analysis was also performed to determine if the use of the warning lights contributed to a decrease in societal costs; the analysis estimated the cost of Statewide deployment in relevant work zone locations and the potential savings related to crashes. Results of the study showed reduced speeds for all vehicle types, especially in urban work zones. Researchers documented a statistically significant decrease of 2.21 mile per hour in the mean speed and 1 mile per hour in the 85th percentile speed. Vehicle position data from near the taper demonstrated that sequential lights reduced the number of late taper merges at rural work zone tapers. Researchers found that the number of early merges increased from approximately 53 percent to 65 percent with the use of this strategy. [9]

Researchers at TTI evaluated innovative traffic control devices at short-term rural work zones. Various types of devices were tested at eight work zones, including portable rumble strips, portable variable message signs (VMS), radar drones, fluorescent yellow-green worker vests, retroreflective vehicle visibility improvements, fluorescent orange signs, and speed display trailers. The effectiveness of each device was assessed based on the vehicle speeds in the work zone, the ease of installation and removal, the impact of the device on vehicle conflicts, and worker comments. Analysis of the data collected revealed that the speed display trailer had the largest impact on speeds with the number of speeding motorists reduced by 13 percent before the taper and 6 percent in the work zone. The use of a VMS led to a slight decrease in speed and reduced the occurrence of driver conflicts as they approached the closed lane. The use of a VMS to indicate a closed lane ahead reduced by 20 percent the number of vehicles in the closed lane approaching the taper. The fluorescent orange signs, vehicle visibility improvements, and yellow-green worker vests all acted to improve the conspicuity of workers as documented by both worker and motorist comments. [10]

3.2.2 ITS Strategies

Intelligent transportation systems (ITS) have proved beneficial in numerous facets of the transportation field, including work zone safety and mobility. ITS efforts have been used to share information with motorists on the road; help stakeholders manage traffic in the work zone and determine when

[8] Midwest Smart Work Zone Deployment Initiative. "Real-Time Integrated ATIS Systems," 2005.
[9] Sun, Edara, Hou, and Robertson. "Cost-Benefit Analysis of Sequential Warning Lights in Nighttime Work Zone Tapers," 2011. Available at: http://tig.transportation.org/Documents/SEQ/WZ_SeqLights_Report_June2011.pdf (accessed August 2012)
[10] Fontaine, Carlson, and Hawkins. "Evaluation of Traffic Control Devices for Rural High-Speed Maintenance Work Zones: Second Year Activities and Final Recommendations," 2000. Available at: http://ntl.bts.gov/lib/10000/10400/10477/1879-1.pdf (accessed August 2012)

conditions are conducive to implement predetermined alternate transportation solutions; reduce or eliminate the need for certain resource-intensive activities (e.g., data collection, flagging operations); and monitor contractor performance.

In many cases, States conduct impacts analysis during the planning and design phase of a project to guide the selection of strategies to deploy during construction. Conducting analysis during construction can be critical due to the dynamic nature of traffic patterns. For example, updated analysis conducted during the construction phase may enable contractors to adjust lane closure schedules to ensure safety and mobility goals are met. Analysis may not be done during the construction phase due to a lack of data collection capabilities in a work zone. ITS devices with real-time reporting and data analysis can facilitate the process of analyzing work zones during their implementation phase, which can support TMP strategy effectiveness. This is a current practice in some areas across the country.[11]

Bluetooth probe tracking is an example of using an ITS technology to both provide traveler information and assess TMP strategy effectiveness. The presence of Bluetooth in smart phones, GPS units, and other devices inside vehicles provides researchers and practitioners with a rich set of moving data points inside a work zone. Each device has a unique signature that can be tracked to collect travel times, speed, and other related data. Haseman, Wasson, and Bullock analyzed travel behavior at a work zone in rural Indiana over a 12 week period in 2009, gathering 1.4 million vehicle records cost effectively using Bluetooth technology. By collecting probe data from multiple field collection sites within a single work zone, researchers were able to communicate travel delay times to the motoring public and assess driver diversion rates. When the public was made aware of delay and alternate route information based on real-time data, the motorists were able to make educated travel decisions based on the current traffic situation. Researchers in this study found that it was important to provide both delay information and alternative routes to produce meaningful driver behavior changes.[12]

Saito and Wilson used ITS technologies to deploy variable advisory speed systems (VASS) to provide drivers with advanced notice of upcoming travel speeds. The intent of VASS is to increase flow in work zones by dynamically modifying the posted speed limit based on real-time operating speeds. The three objectives of their study were: 1) Research VASS that can be tested, 2) Select and deploy a VASS in Utah at a long-term work zone, and 3) Perform a statistical analysis on traffic flow characteristics data to evaluate the effectiveness of the VASS. This statistical analysis included analyzing speed data to determine if speeds were reduced when the system was in place. If speeds were reduced, then the researchers considered the VASS implementation successful. Their study concluded that the VASS was effective on weekends during evening peak hours when there was a traffic slow down; however, there was no statistical difference at other times of the week in the absence of

[11] Jeremy Jackson. "Dynamic Work Zone Traffic Management," *ITE Journal*, http://www.ite.org/membersonly/itejournal/pdf/2010/JB10EA26.pdf, 2010.

[12] Ross J. Haseman, Jason S. Wasson, and Darcy M. Bullock. "Real-Time Measurement of Travel Time Delay in Work Zones and Evaluation Metrics Using Bluetooth Probe Tracking," *Transportation Research Record: Journal of the Transportation Research Board*, No 2169 (2010).

reoccurring congestion. Further research is needed to determine if such a system is appropriate for widespread implementation.[13]

3.2.3 Speed Management

As a means of addressing multiple safety and mobility concerns within work zones, practitioners often select strategies that seek to lower motorist speeds and reduce speed differential among vehicles. Types of strategies include traffic control devices, active law enforcement, public information campaigns, and a combination of these efforts.

The University of New Brunswick investigated the effects that certain safety measures had on traffic safety and speed management in rural work zones. In their analysis, they discussed their procedure for data collection and analysis along with their findings on the effectiveness of various safety treatments. MOEs included mean vehicle operating speed, 85th percentile operating speed, and standard deviation of mean operating speeds.[14] The study found that the rumble strips led to the greatest decrease in mean vehicle operating speed (6.9 km/h) and 85th percentile operating speed (9.5 km/h), while the use of PCMS resulted in the most uniform travel speeds, as results showed the smallest standard deviation of mean operating speeds (increase of 0.29 km/h).[15]

The Midwest States Smart Work Zone Deployment Initiative evaluated the long-term effectiveness of speed monitoring displays. Several Midwest States participated in the pooled-fund study to determine if the speed reductions that occurred from deploying the speed monitoring displays during active work zones would persist after the displays were removed or after the work zone. Researchers were able to determine that the speed management techniques were not only successful during the active work zones, but had residual effects on motorist speeds after the work zone was no longer in operation. During the active work zones, 2-7 mph reductions in 85th percentile speeds were observed. The study discussed that after the speed monitoring displays were removed, speeds increased, but not to the level of the pre-study conditions.[16]

The presence of law enforcement at a work zone is designed to make motorists more aware of the work zone and increase compliance with speed limits, increasing motorist and worker safety. Chen, Qin, and Noyce conducted a speed enforcement study on a long term work zone project in Wisconsin. To decrease the occurrence of potential speeding-related crashes, the Wisconsin DOT in conjunction with the University of Wisconsin, studied methods of controlling speed in work zones. The strategies included dynamic speed display boards, a dynamic late merge system, and active law enforcement. Evaluation of each strategy took place to determine the effectiveness of each in reducing the number of motorists violating the posted speed limit and improving speed uniformity. Results of this study found that mobile enforcement achieved the highest speed reduction during the day, and intensive stationary

[13] Saito and Wilson. "Evaluation of the Effectiveness of a Variable Advisory Speed System on Queue Mitigation in Work Zones," 2011. Available at: http://ntl.bts.gov/lib/38000/38000/38071/VASS_Udot_Report_Final_04052011.pdf

[14] Hildebrand, Wilson, and Copeland. "Speed Management Strategies for Rural Temporary Work Zones," *Proceedings of the Canadian Multidisciplinary Road Safety Conference XIII*; June 8-11, 2003; Banff, Alberta. Available at: http://ssom.transportation.org/Documents/SpeedManagementStrategiesforWorkZones03.pdf

[15] See additional discussion on PCMS installations in Section 3.2.5.

[16] Midwest Smart Work Zone Deployment Initiative. "Radar Actuated Speed Displays," 2005.

enforcement achieved the highest speed reduction at night. With these results, researchers recommended using a combination of both mobile enforcement and stationary enforcement to produce a maximum reduction in speed during both daytime and nighttime conditions.[17]

3.2.4 Queue Management

Researchers and practitioners have found that queue management strategies not only reduce delay and increase motorist mobility, but they can improve safety by mitigating back-of-queue crashes, especially in situations with limited sight distance. Through the use of effective queue management, primary and secondary crashes in work zones can be reduced. Data collected through a deployment of a queue management system in Texas highlighted a reduction of sudden braking to avoid rear-end collisions (7 percent reduction), forced lane changes (5 percent reduction), and other erratic maneuvers (3 percent reduction). Additionally, the variance in speed among vehicles was reduced. The evaluation results of these metrics indicate an overall improvement to traffic safety.[18]

Michigan DOT and researchers from Wayne State University worked together to evaluate the dynamic late lane merge system (DLLMS), a strategy to reduce driver confusion at the merge location in work zones. MOEs included the mean travel time delay, the mean travel speed, and the crash frequency. Researchers also performed a benefit/cost analysis to determine the economic viability of this type of system on freeway work zones in Michigan.[19] It was found that the DLLMS had positive impacts on the mean travel delay (i.e., reduced delay) and the mean travel speed (i.e., higher travel speed), with no significant changes to crash frequency. During congested time periods, researchers recorded travel speeds of 47.6 miles per hour in the pre-taper zone at the test site using DLLMS, while speeds at the control site were 29.5 miles per hour in the pre-taper zone.

A second, similar study was also conducted in Michigan to evaluate an early lane merge traffic control system for three- to two-lane transition areas in work zones. This dynamic merge system intends to help smooth traffic flow and reduce aggressive driving just prior to the transition into the construction area. The system monitors traffic flow and queuing, and it sends a message to drivers ("Do Not Pass" when flashing and "Merge Left/Right" with arrow) by means of changeable message signs (CMS). The MOEs considered for evaluation included travel time, number of stops due to work zone congestion, motorist delay, travel speed, number of aggressive driving maneuvers, and number of crashes. The study indicated a decrease in aggressive maneuvers and average peak period travel time. The system was deemed particularly effective in situations where peak hour traffic volumes are approximately 3,000 to 3,500 vehicles per hour during construction for a three- to two-lane merge.[20]

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[17] Yali Chen, Xiao Qin, Davidand Noyce. "Evaluation of Speed Management Strategies in Highway Work Zones," *Proceedings of the 86th Annual meeting of the Transportation Research Board*, Washington, DC, January, 2007. Available at: http://www.workzonesafety.org/files/documents/database_documents/07-2468.pdf

[18] Pesti, Wiles, Cheu, Songchitruksa, Shelton, and Cooner. "Traffic Control Strategies for Congested Freeways and Work Zones," 2007. Available at: http://tti.tamu.edu/documents/0-5326-2.pdf

[19] Datta, Hartner, and Grillo. "Evaluation of the Dynamic Late Lane Merge System at Freeway Construction Work Zones," 2007. Available at: http://www.michigan.gov/documents/mdot/MDOT_Research_Report_RC1500_Part1_209842_7.pdf

[20] Datta, Schattler, Kar, and Guha. "Development and Evaluation of an Advanced Dynamic Lane Merge Traffic Control System for Three to Two Lane Transition Areas in Work Zones," 2004. Available at: http://www.michigan.gov/documents/mdot_RC-1451_97846_7.pdf

3.2.5 Portable Changeable Message Signs (PCMS)

PCMS are often used in work zones to display information to passing motorists, including work zone conditions ahead, real-time delay information, potential detour routes, or upcoming changes to the work zone. PCMS are often useful to practitioners because they are relatively inexpensive in comparison to other strategies and are easily set up and taken down when their role has been completed. A drawback of PCMS is that their effectiveness tends to diminish over time.

Researchers and practitioners have found success in improving work zone safety and mobility through the use of PCMS. The Maryland State Highway Administration has documented average driver speed reductions of 1 to 7 miles per hour, and a reduction in speeding drivers from 2 to 3 percent through the use of a PCMS with a speed display. Maryland recommended that because the effectiveness of PCMS diminishes over time, periodic police enforcement should be used to supplement the signs if a PCMS will be deployed for more than four weeks.[21]

Researchers have also attempted to determine which message sets displayed on a PCMS were best understood by motorists and were the most effective at achieving the desired result. One study evaluated which message sets produced the best adherence to the speed limit through a work zone. Of the four message sets tested in a driving simulator (steady SLOW DOWN 45, flashing SLOW DOWN 45, steady SPEED LIMIT 45 and steady SPEED LIMIT 65) drivers best maintained the speed limit prior to entering the work zone and through the work with the flashing SLOW DOWN 45 message.[22]

3.2.6 Public Outreach

Informing the public of disruptions to their normal transportation options or commuting route can lead to significant changes in driver decisions, such as whether some local drivers decide to alter their commute route, schedule, or mode. Public outreach efforts may be targeted at certain subsets of drivers, such as commuters, long distance drivers passing through the area, or commercial vehicles. Methods to deliver public outreach include advertising on public radio or in newspapers, producing printed materials, coverage in local media reports, and using the Internet and social media as a channel to disseminate work zone related information. A number of these methods have been evaluated and generally show at least some benefits and sometimes provide major benefits, for a typically modest cost.

For example, Caltrans launched an extensive outreach campaign to inform motorists of the construction of the I-10 Long-Life Pavement Project. In the campaign, Caltrans suggested alternate routes for road users. This TMP strategy led to an estimated 57 percent decrease in traffic demand along the corridor and reduced the total vehicle hours of delay and queue lengths significantly below

[21] Maryland State Highway Administration. *Work Zone Safety Toolbox,* "Use of Portable Changeable Message Signs to Improve Speed Compliance," 2005. Available at: http://www.marylandroads.com/OOTS/02PCMR.pdf

[22] McAvoy, Deborah. "Work Zone Speed Reduction Utilizing Dynamic Speed Signs," 2011. Available at: http://www.otc.uakron.edu/docs/Dynamic%20Speed%20Sign%20Final%20Report_OU[1].pdf

the original projections.[23] This reduction of traffic volumes led to improved safety and mobility through the work zone, further proving the effectiveness of this public outreach effort.

Wisconsin DOT instituted a similar public outreach campaign by publishing frequent project briefs on the heavily traveled I-94 reconstruction project between Milwaukee and the Illinois State line. The briefs were distributed to inform motorists of project progress and subsequent construction activities, enabling motorists to decide whether to drive through the work zone or choose alternate routes or means.[24]

Key Finding

Social media and other innovative platforms are becoming a regular tool for providing work zone information to the public.

Ohio DOT has developed project-specific Facebook pages and Twitter accounts for major construction projects to share information about the projects and allow the public to provide input. In addition, several State DOTs (including Missouri, Ohio, and Washington) have general Twitter accounts that provide followers with information about construction projects and potential impacts.

Oregon DOT conducts annual surveys to determine public attitudes on transportation-related topics. To assess how much the public noticed and remembered Oregon DOT's public awareness campaign, questions ask if the public has seen or heard advertising or public service announcements regarding Oregon's laws when driving through work zones. Results from the 2008 survey show that 34 percent of respondents had seen or heard such advertising or public service announcements. Though the effectiveness of Oregon DOT's public awareness program has not been formally assessed to date, information like this could be used as part of an evaluation in the future.[25]

3.2.7 Nighttime Only Work Zones

To minimize safety and mobility effects of a work zone on the traveling public, practitioners may conduct work zone activities during the night when fewer vehicles are on the road. Night-only work zones are being used more often today than in the past, but their evaluation in practice has been limited (see Appendix A).

NCHRP Report 475 provides guidelines for implementing nighttime work zone activities and provides examples and illustrations to show, on a qualitative basis, how to select the most cost-effective plan for work zone activities.[26] The study also applies a cost-effectiveness analysis on a set of work zone strategies. Factors that contribute to cost are traffic control, lighting, and construction staging. For effectiveness, MOEs included community/traffic impact, safety, and constructability. NCHRP 475 provides a sample worksheet to guide the user in weighting and rating the objectives and dividing the weighted effectiveness by the total cost to calculate a ratio of effectiveness/cost values. These results can help practitioners determine the relative effectiveness of different night-time strategies.

[23] Scriba, Symoun, and Beasley. "To Lessen Work Zone Impacts: Try TMPs." *Public Roads*, September/October 2010, 74(2). Available at: http://www.fhwa.dot.gov/publications/publicroads/10septoct/02.cfm
[24] Ibid.
[25] Ross and Pietz. "Maximizing Investments in Work Zone Safety in Oregon," Oregon Department of Transportation, SR 500-380, 2011. Available at: http://ntl.bts.gov/lib/38000/38500/38513/500_380_WZSafetyweb.pdf
[26] Bryden, James; Mace, Douglas. "NCHRP Report 475: A Procedure for Assessing and Planning Nighttime Highway Construction and Maintenance," 2002. Available at: http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_475.pdf

3.2.8 Detours/Driver Diversions

Depending on the roadway and work zone activities, driver detours or providing information on alternate routes and traffic conditions to enable voluntary diversion may be one of the most viable TMP strategies. Before diverting drivers from their normal and planned path, practitioners must determine how information about these routes will be communicated to the drivers. Common methods of informing drivers of a diversion include temporary traffic signs and PCMS.

Researchers at the University of California, Berkeley, studied the use of 18 extended full-closures during 24-hour construction operations on a major freeway in California.[27] To prepare for this effort, practitioners developed a website to provide real-time information to the public, news media, and others on traffic conditions during construction. Additionally, a combination of closed-circuit television monitors and traffic monitoring stations were used to monitor traffic and both portable and permanent changeable message signs displayed real-time information on traffic and detours to passing motorists. The results of this effort included a reduction of up to 18 percent of peak hour demand on the roadway, intentional major increases in volume on the planned detour routes, and much lower anticipated maximum delay measurements (average of 50 minutes versus the expected 90 minutes).

3.3 Assessment Approach Types in Practice

Key Finding

Quantitative analyses with hard data are preferred for measuring effectiveness.

The practitioner group provided significant input on the topic of evaluation approaches during the online session, leading to insights on their current efforts and needs. True assessment of a TMP strategy is not necessarily intuitive. Measurements intended to indicate the performance of a certain strategy may actually measure the performance of a different strategy, or in some cases, the measurements provided no true measurement of effectiveness for any strategy. For example, an agency wants to know whether an ITS deployment at a work zone is successful in diverting traffic when alerts about delay are placed on PCMS. Measuring the volume of traffic driving through a work zone and comparing that to pre-work zone volumes might indicate traffic diversion due to the PCMS messages (effectiveness of the actual strategy), or it might indicate reduced demand due to good advance public outreach done via flyers or email (effectiveness of another strategy), or it might be due to congestion leading up to the work zone that reduces the rate of traffic flow through the work zone (not effectiveness at all).

Even so, States and researchers are performing evaluations of their deployed strategies with marked success, allowing for the implementation of strategies with some confidence of a strategy's performance on future projects.

Table 3 summarizes the merits, concerns, and recommendations for the three evaluation approaches studied as part of the research.

[27] Lee and Kim. "Automated Work Zone Information System (AWIS) on Urban Freeway Rehabilitation: California Implementation," Presented to the Transportation Research Board 85th Annual Meeting January 22-26, 2006, Washington, D.C. Available at: http://www.workzonesafety.org/files/documents/database_documents/Research3075.pdf

Table 3: Matrix of Evaluation Approaches

Evaluation Approach	Merits	Concerns
Qualitative	• Depth of review beyond just numbers. • Subjective assessment by field experts close to the project.	• Subjectivity can include inaccuracies. • Not always useful to compare across projects or agencies.
Quantitative	• Hard numbers eliminate anecdotal issues. • Quantity of data could provide statistical significance to the conclusions.	• Collecting data can require costly equipment. • Data collection can be inconvenient to the contractor since much of the data needed for analysis must be collected during work activity. • Numbers do not tell the entire story.
Hybrid	• Able to take advantage of the best of both approaches: o Subjective depth of information o Objective, hard data • Limits the cost while still providing some quantitative information.	• Challenging to manage parallel quantitative and qualitative approaches. • Increased costs compared to a purely qualitative approach; however, the presence of some subjectivity may still lead to some inaccuracy or less confident results.

Many methods exist for determining the performance of a TMP strategy after its implementation as either a stand-alone treatment, or a treatment used in combination with other strategies. Discussions with practitioners indicated that quantitative analyses with hard data are preferred for measuring effectiveness, but that the information necessary often does not exist. As such, informal qualitative reviews were more common.

3.3.1 Qualitative Approach

By definition, a qualitative approach to measuring effectiveness of TMP strategies relies on the assessment of practitioners, inspectors, users, or other stakeholders without the benefit of numerical data. Qualitative data may take the form of customer feedback, a visual assessment of flow and traffic control usage in a work zone, or insight from a work zone expert with deep experience using work zone strategies to improve the safety and mobility of work zones. A variety of sources can provide helpful information. Qualitative information on how TMP strategies are working can come from project staff, road users, and the media:

- ***Feedback from Agency Field Staff.*** Qualitative feedback is often received from agency field staff during construction and in post-construction meetings. Law enforcement officials are also considered a useful source of information. In some cases, contract change orders are used to indicate the effectiveness of temporary traffic control strategies, as practitioners have stated that multiple change orders to temporary traffic control could indicate the original strategies

were not effective. Internal work zone inspection forms are widely used as a means to subjectively measure compliance with a traffic control plan.

- ***Feedback from Road Users.*** State agencies often receive comments from the public related to TMP strategies that can help practitioners recognize a need that can be resolved in the field. Sources include website work zone surveys, messages from social networking sites, complaints received via phone, phone surveys through customer service centers, and public meetings. This type of feedback can quickly connect the DOT to its customers, and it helps the DOT see the work zone from the motorists' perspective.
- ***Coverage in the Media.*** Both positive and negative press can provide an indication of how TMP strategies are working. Media coverage can come through sources such as radio traffic reports, blog posts, and newspaper articles or columns.

Key Finding

Though not readily available in the literature review, the research team found substantial unpublished qualitative evaluations occurring at State highway agencies.

While the majority of published literature identified focuses on the quantitative evaluation approach, practitioners responded that they often use a qualitative approach to evaluating TMP strategy effectiveness. Qualitative information is generally available to practitioners; however, due to how many State DOTs are organized, there is often no formal mechanism for sharing lessons learned within the State on a regular basis. Because of staff or budget constraints, many of these lessons learned are shared informally at project debriefing meetings where only project staff are present or at meetings of one discipline such as State traffic meetings, and may not reach other staff such as designers who will work on future projects and may not be documented anywhere. Ideally, the insights gained should be shared among districts, regions, and divisions of the agency, including public outreach personnel, and documented so that they are available for future reference and to future staff. Standardized and easy-to-use documents, checklists, or a database are one way to increase the documentation and sharing of lessons learned throughout a single State DOT and among other States.

Key Finding

Formal mechanisms to share lessons learned among highway agencies would increase practitioners' ability to access TMP strategy effectiveness information.

State Example. Rhode Island DOT (RIDOT) has developed a set of qualitative TMP performance monitoring strategies comprised of varying levels of documentation, dependent on project complexity. On all projects RIDOT requires a post-construction work zone assessment of the following:

- Description of the areas of the TMP that had successful implementation and why;
- Description of the areas of the TMP that had less than successful implementation and why;
- Summary of changes that were necessary to correct oversight of the original TMP;
- Summary of effectiveness of each change made to the TMP;
- Summary of the type and frequency of legitimate complaints received;
- Description of the road user mobility impacts observed during the work;
- Summary of crashes and incidents that occurred during the work;

- Description of road safety impacts that were observed during the work; and
- Suggestion of changes or improvements to TMPs on similar future projects.

RIDOT's post-construction work zone assessment methods are mostly qualitative in nature, as project-specific safety and mobility data are described rather than quantified and are based on observations at the site by agency staff, contractor staff, or motorists.[28] Due to funding and resource constraints, this method has only been used on a small number of projects in the State.

Advantages and Disadvantages. Qualitative feedback was often found to be a significant rationale for TMP strategy effectiveness by stakeholders, as it includes the practitioner experience lacking in numbers-only analyses. In addition, while quantitative data is not always available, staff feedback, public comments, and designer experience typically are. Work zone practitioners stated that qualitative evaluations were often used in practice.

The main disadvantage of qualitative analysis is its subjectivity, which can limit the information's applicability between locations due to differences such as terrain, traffic conditions, or how it is implemented. States may not always accept qualitative evaluations done in other States or jurisdictions. Additionally, driving habits differ in different regions of the state (e.g., urban versus rural), which may affect projects in those regions differently.

3.3.2 Quantitative Approach

Quantitative evaluation of TMP strategies used in work zones often necessitates greater effort than what is needed for a qualitative evaluation because of the types of data collection and analysis. The approaches generally used by States to collect work zone data are to require it from the contractor as part of the project, rely on law enforcement to collect crash data through uniform accident reports, require field staff traveling through the work zone to note observations or log periodic travel times or queues, or deploy data collection equipment on site for automated recording of traffic conditions. The value of quantitative evaluation is its objectivity. Hard numbers provide value to practitioners that subjective opinions of TMP effectiveness lack. For a quantitative approach, the data collected may include the number and severity of crashes, travel times, queue lengths, vehicle speeds, and speed differential, among others.

MOEs vary greatly among States and across studies, which can make correlating results difficult. MOEs and their targets need to be defined clearly. Higher speeds or greater throughput are generally desirable for a TMP strategy focused on improving mobility, but would be undesirable for a strategy focused on speed management or traffic diversion, respectively. In addition, the findings from different evaluations can lead to varying conclusions. For example, one study may show a statistically significant reduction in speeds from using speed feedback monitors while another study shows very modest, non-significant speed reductions using the same strategy.

[28] Rhode Island DOT. "Level 1 Transportation Management Plan – Significant Project Template." Available at: http://www.dot.ri.gov/documents/traffic/DPM%20450.05%20RIDOT%20Level%201%20TMP%20Template%20Rev.%2011-06-09.xls (Accessed January 2012).

Simulation models have been used by practitioners and researchers to assess the safety and mobility impacts of TMP strategies. The literature search found 11 sources that made use of simulation/modeling to assess TMP strategy effectiveness. The sources found that simulation/modeling is a low risk and low cost tool that can be useful in assessing potential impacts to traffic safety and mobility from the use of various TMP strategies. Models can be run for various scenarios to obtain an indication of the effectiveness or relative effectiveness of different strategies. Practitioners can use simulation in a structured process to obtain reasonable and quantifiable estimates on specific MOEs (e.g., travel time, delay, maximum queue lengths, number of crashes) corresponding with individual TMP strategies. This information can be used to develop benefit-cost relationships for the different strategies, at least on a relative basis, and select the most beneficial strategy based on site conditions of the planned work zone rather than selecting strategies considering only past experience on similar projects.

Key Finding

When properly used, simulation/modeling can be a useful, low cost tool for assessing the potential impacts of various TMP strategies.

State Examples. A number of practitioners and researchers are tailoring their data collection and analysis methods to quantitatively measure the effectiveness of TMP strategies.

Michigan DOT uses peer teams independent of the project to review TMPs and the TMP strategies that are being proposed for a given project before construction begins. MDOT also concurrently collects and analyzes crash data prior to construction to serve as "before" data for the work zone corridor under consideration. The "before" data is compared to crashes that take place within the active work zone as a method of evaluating the TMP strategy's effect on safety. Operational data, such as delay and queue length, are collected during the construction phase and recorded for future evaluation.[29]

During the Woodrow Wilson Bridge Project, Virginia DOT used variable speed limits as a means to lessen the impact of construction to motorists. The DOT recognized that appropriate MOEs would be key to assessing the impact and usefulness of the VSL system. MOEs included speed limit compliance, credibility of the posted speed limit, crash rates, traffic flow observations, queue creation and dissipation rates, travel times, and diversion rates. Data were obtained prior to deployment, during baseline conditions, and after deployment to gauge the effectiveness of the VSL system.[30] Changing site conditions did not allow researchers to conduct a direct before-and-after comparison and made it difficult to determine any conclusive effects of the VSL system, so researchers turned to simulation to evaluate the VSL system effectiveness. This analysis indicated that VSL systems could be effective in improving mobility if demand did not exceed capacity by a large amount.[31]

[29] Scriba, Symoun, and Beasley. "To Lessen Work Zone Impacts: Try TMPs." *Public Roads*, September/October 2010, 74(2). Available at: http://www.fhwa.dot.gov/publications/publicroads/10septoct/02.cfm

[30] Virginia DOT: Examples of Temporary Traffic Control Plans and TMP Templates. Available at: http://www.extranet.vdot.state.va.us/locdes/electronic%20pubs/iim/Examples%20of%20Temporary%20Traffic%20Control%20Plans.pdf

[31] Fudala and Fontaine. "Work Zone Variable Speed Limit Systems: Effectiveness and System Design Issues." Virginia Transportation Research Council, 2010. Available at: http://www.virginiadot.org/vtrc/main/online_reports/pdf/10-r20.pdf

Some researchers have evaluated how well microsimulation models produce reliable outputs that approximate actual conditions in the field. Researchers utilized the simulation models QUEWZ, QuickZone, and CA4PRS to model locations along Interstate and State routes in New England. The comparison of field observations with simulation results focused on queue lengths and travel time. Researchers found that simulation models can produce an accurate prediction of field conditions. Researchers showed that QUEWZ and QuickZone provided reasonable order of magnitude queue length estimates similar to those observed in the field for interstate highways. However, the study authors noted that users of these simulation models should have a strong foundation in highway capacity analysis and traffic flow fundamentals to understand simulation results and realize when results are not realistic.[32]

North Carolina DOT and North Carolina State University are developing a tool called FREEVAL-WZ that will model freeway lane closures and full closures to identify how the closures will impact traffic and affect the ability of the DOT to close lanes. The FREEVAL-WZ software tool allows the analyst to predict the operational impacts of work zones, including impacts from capacity reductions, lane closures, reduced speed limits, and traffic diversions. The tool includes a planning-level feature that enables a quick assessment of work zone impacts, while still allowing for additional, more detailed operational analysis.

Advantages and Disadvantages. Quantitative evaluation is the approach most preferred by practitioners and researchers; however, it is also the most difficult to conduct. During the online session, practitioners shared that quantitative data provide hard evidence of whether or not strategies work, and these numerical findings can be easily shared within a single agency or among multiple agencies; however, this information can be difficult to get in real-time, is sometimes costly or time-consuming to collect, and sometimes it is not clear what data should be collected for the evaluation. In order to be truly effective, resources need to be allocated towards data collection and analysis. Additional advantages of quantitative analysis include transparency and objectivity, compared to the subjectivity of qualitative evaluation.

Disadvantages include the cost of data collection and lack of funding or staff allocated to collect and analyze the data. Other considerations that can be advantages or disadvantages include the ease of data analysis once the data is collected (e.g., hard copy crash reports are more difficult to analyze than records from an electronic crash records system) and the timeliness of those data necessary for usefulness. Several practitioners pointed out that in some cases data are plentiful, but analysis and reporting are not completed, in part due to resource limitations, so the information is not useful to practitioners.

[32] Collura, Heaslip, Moriarty, Wu, Khanta, and Berthaume. "Using Simulation Models to Assess the Impacts of Highway Work Zone Strategies: Case Studies along Interstate Highways in Massachusetts and Rhode Island," Transportation Research Board Annual Meeting, Washington, D.C., on January 13-17, 2008. Available at: http://www.workzonesafety.org/files/documents/database_documents/Publication9955.pdf

3.3.3 Hybrid Approach

A hybrid approach to strategy evaluation has both qualitative and quantitative aspects. Both qualitative and quantitative information are collected, usually using different mechanisms, and can be collected simultaneously or in a similar timeframe. Typically, qualitative information such as public opinion appraisals or agency feedback can be collected and reviewed with relative swiftness when compared to the collection and evaluation of numerically driven measures. This short-term component gives practitioners the advantage of making positive changes in a work zone before the working conditions have been altered. A more formal quantitative evaluation can be conducted to supplement the qualitative evaluation.

With a hybrid evaluation, a degree of subjectivity is inherent to the analysis. This may especially be the case when determining the effectiveness of multiple strategies deployed simultaneously.

State Examples. Indiana DOT encourages engineers to monitor and evaluate TMP effectiveness throughout the duration of each significant construction project. They suggest monitoring traffic volume, travel time, queue length, delay, number of incidents, incident response and clearance rates, contractor incidents, community complaints, user costs, and cumulative impacts from adjacent construction activities. During post-construction evaluations, the Indiana DOT suggests that each TMP undergo an evaluation to identify successes and failures, changes made to the TMP during construction and the associated results, feedback from the public, expected traffic conditions compared to actual traffic conditions, total cost associated with the TMP, and suggested improvements.[33]

The Maryland State Highway Administration suggests the following list of topics to be covered in the post-project evaluation:[34]

- Overall statement reflecting the usefulness of the TMP;
- Successes and failures;
- Areas of the TMP that were successfully implemented;
- Changes made to the original TMP and results of those changes;
- Public reaction to the TMP;
- Frequency of legitimate complaints and nature of complaints (or compliments);
- Actual measures of conditions versus what was predicted (for example, predicted and encountered delay time);
- Cost for implementation of the strategies;
- Number and types of crashes that occurred during construction; and
- Suggested improvements or changes for similar future projects.

[33] Jeannotte and Chandra. *Developing and Implementing TMPs for Work Zones*, Federal Highway Administration, FHWA-HOP-05-066 (Washington, DC: 2005). Available at: http://ops.fhwa.dot.gov/wz/resources/publications/trans_mgmt_plans/index.htm.

[34] Maryland State Highway Administration, *Transportation Management Plans: Guidelines for Development, Implementation and Evaluation*, November 2006. Available at: http://www.marylandroads.com/OOTS/06TMPGuidelinesRev5.pdf

While these agencies and some other States include TMP evaluation elements in their policies or guidelines, implementation of these efforts is generally still in the early stages.

Advantages and Disadvantages. The hybrid approach is able to take advantage of the benefits of both the qualitative and quantitative approaches without relying solely on either. Practitioners can gain the advantages of the easier-to-collect qualitative data and of the more objective output of a quantitative analysis Objective, hard data can be collected and analyzed, and then combined with in-depth knowledge of the situations by field experts. The disadvantage of the hybrid approach versus doing just a quantitative or qualitative evaluation is that it can be challenging to manage parallel quantitative and qualitative approaches. Another potential disadvantage is that there could be situations where the qualitative and quantitative information conflict, making it difficult to make conclusions on the effectiveness of a TMP strategy.

3.4 Evaluation Scope Types in Practice

States are evaluating TMP strategy effectiveness using a number of different scopes. For the purposes of this document, "scope" is defined as the extent or bounds under which the evaluation is occurring.

Key Finding

Each evaluation scope has merits and limitations that affect its evaluation effectiveness.

Scopes fall into the following categories:

- Full-scale evaluation of all strategies on a project;
- Agency-wide evaluation of a single TMP strategy;
- Research evaluation of multiple agency deployment of a single strategy;
- Case study of a single strategy at one location; and
- Process review.

Table 4 summarizes the merits, concerns, and recommendations for each evaluation scope. Table 5 illustrates the evaluation scopes commonly used in different States, as noted by practitioners during the research project's stakeholder outreach.

Table 4: Matrix of Evaluation Scopes

Evaluation Scope	Definition	Merits	Concerns
Full Scale Evaluation of all Strategies on a Project	A project is evaluated across all of the strategies that are deployed, taking a comprehensive look at the strengths, weaknesses, and lessons learned.	• Significant information gathered about the varying strategies. • Ability to learn how strategies relate to each other.	• Feasible for only a small number of projects. • Difficult to assess the effectiveness of a specific strategy, as it will be evaluated in combination with others.
Agency-wide Evaluation of a Single TMP Strategy	A single strategy is evaluated across multiple projects within an agency to identify patterns and quantify the impacts of using a given strategy.	• Provides detailed information about the TMP strategy selected for evaluation. • Can detect levels of effectiveness in varying scenarios (conditions). • Most States responded that this type of evaluation is most valuable.	• Only feasible for a small number of strategies due to the effort necessary. • Focusing on a single strategy could leave out important information about its effectiveness when used with other strategies.
Research Evaluation of Multiple Agency Deployment of a Single Strategy	Evaluation of a single strategy involving its use across more than one agency	• May shed light on how to select a strategy dependent on multiple factors.	• A particular strategy may lose its identity when reviewed in tandem across multiple agencies' projects.
Case Study of a Single Strategy at One Location	A single focus on the impacts of one application of one strategy at one location.	• Allows for study depth because of the limited scope.	• Application may not be transferable to other scenarios outside the exact study parameters. • States commented that it is difficult to determine if results would be applicable to them in non-identical situations.
Process Review	Broad-based assessment of using various strategies within an agency. Likely conducted as part of a larger review required by the Work Zone Safety and Mobility Rule.	• Could bring up important information not discussed in project-level evaluations.	• TMP strategy assessment might be only a small part of the process review, so it may not provide sufficient analysis of strategy effectiveness.

Table 5: Commonly Used Evaluation Scopes

State	Full-scale Project Evaluation	Agency-wide TMP Strategy Evaluation	Case Studies	Process Review
California	✓	✓		✓
Delaware	✓			✓
Illinois	✓		✓	✓
Maryland	✓	✓	✓	✓
Michigan	✓		✓	✓
New Jersey	✓			✓
Ohio			✓	✓
Oregon		✓		✓
Wisconsin			✓	✓

Note: States were not asked if they commonly use the Research Evaluations Based on Multiple Agency Deployment scope.

3.4.1 Full-scale Project Evaluation

A full-scale project evaluation has the potential to determine how a set of TMP strategies interplay under a specific set of conditions. Through an in-depth focus on one project, the evaluators should have a more detailed understanding of the project conditions, how the strategies were used, what operations were like in the work zone, and why certain strategies were selected during project development and implementation. It may also be more feasible to collect more comprehensive quantitative data, such as for longer periods or for a greater number of MOEs.

Schrock and Maze conducted a full-scale project evaluation in Iowa to test a methodology for evaluating alternative delay-reducing work zone TMP strategies. The work zone used in the study experienced queues on 34 days between May and September, 1997. The traffic conditions on those days were modeled using CORSIM to determine the average delay for six alternate traffic control plans. The average delay was then converted into a societal cost and used to rank the theoretical effectiveness of each alternative work zone TMP strategy.[35]

When attempting to assess individual strategies, it may be difficult to attribute success or failure to a single strategy due to the environment under which this evaluation is performed. Instead, the evaluation may need to assess the combined effectiveness of all TMP strategies. Because of this, effort

[35] Schrock and Maze. "Evaluation of Rural Interstate Work Zone Traffic Management Plans in Iowa Using Simulation," Iowa Department of Transportation, 2000. Available at: http://www.intrans.iastate.edu/reports/traffic6.pdf

should be taken to determine how the relationships between strategies influenced their effectiveness. Additionally, due to the high level of effort required on full-scale project evaluations, highway agencies may find such evaluations are only feasible for a small number of projects.

3.4.2 Agencywide TMP Strategy Evaluation

This type of evaluation can lead to an understanding of how a single strategy can perform under a wide range of circumstances, and it provides an opportunity to decipher how the strategy may combine with other strategies. When agencies evaluate a single strategy under a wide variety of field conditions and constraints – and possibly in combination with other strategies – there is potential to learn how effective the strategy can be in many of the possible scenarios that will be encountered on future projects. During the online session, most States responded that this type of evaluation is most valuable; participants felt that this scope would allow for a true measurement of the single strategy being tried, especially when evaluated in coordination with other strategies and compared. However, this scope was the least used among the types of evaluations discussed because the completion of an agency-wide TMP strategy evaluation generally requires more coordination and resources than other evaluation methods.

Key Finding

States consider agency-wide evaluation of a single TMP strategy to be the most valuable type of evaluation.

Michigan DOT's Statewide work zone unit compiles safety and mobility performance results, as they relate to pre-construction season objectives, at the end of each season. These data are analyzed and compiled to help determine which TMP strategies are performing at an acceptable level. Michigan DOT uses the performance rating to help determine future strategy usage on a statewide level by sharing the information internally throughout the State.[36]

Wisconsin DOT collects best practices throughout the State regarding TMP strategies and shares the results at annual statewide conferences and training opportunities. Strategies are deemed "best practices" based on feedback received from the DOT field staff.

In an agency-wide evaluation, there may be a tendency to lump the evaluation conditions together, losing valuable circumstantial information that may attest to a strategy's success or failure on future projects. Similar to the full scale evaluation of a single project, the agency-wide evaluation of a single TMP strategy is only feasible on a small number of strategies due to the level of effort necessary for such a study.

In some cases an agency-wide deployment and evaluation may not provide clear results due to the wide variety of scenarios under which the TMP strategy was evaluated. Differing results could occur in the following situations:

- Urban versus rural settings;
- Areas where a variation of traffic volumes and/or user types exist;
- Locations with different speed limits;
- Sites with differing levels of pre-project crash rates; and
- A variety of topographic and geometric conditions.

[36] "To Lessen Work Zone Impacts: Try TMPs." http://www.fhwa.dot.gov/publications/publicroads/10septoct/02.cfm

3.4.3 Research Evaluation Based on Multiple-Agency Deployment

This evaluation scope can highlight real-world examples of a single strategy's performance in varying settings, and differs from the *Agency-wide Evaluation of a TMP Strategy* as defined in the previous section in two ways. This evaluation type consists of a collaboration of multiple agencies and its scope often includes support from consultants or researchers. Agencies have particular processes or methods for strategy use, implementation, and review, and an evaluation involving a variety of techniques across projects from different agencies may shed light on how to select a strategy independent of these factors.

This evaluation scope is useful in assessing a TMP through multiple lenses as this scope contains information gathered from various agencies and locations. The range of information collected through this evaluation scope can enable the evaluation to provide a broader review of the strategy and maximize the applicability of the assessment. This evaluation scope often involves the use of professional researchers (e.g., consultants or universities) that may be able to conduct more robust data analysis than some public agencies. However, it should be noted that this evaluation scope may produce conflicting results causing a particular strategy to lose its identity when reviewed in tandem across multiple agencies and additional funding may be needed if outside researchers are used.

An example of this type of evaluation is a series of studies conducted on portable traffic monitoring devices (PTMD) at multiple sites in California and North Carolina. The PTMDs utilized were work zone barrels fitted with technology to record real-time speed and volume data. These PTMDs were set up in a variety of configurations, allowing practitioners to document related safety, mobility, and queuing patterns to the traffic control configuration and qualitatively assess each configuration's effectiveness. The USDOT conducted a multi-State qualitative evaluation of the effectiveness of these devices through interviews with State DOT staff. [37]

3.4.4 Case Study

Case studies focus on one strategy at a single location, allowing for study depth as follows:

- How the strategy performs under finite field conditions;
- How the strategy is affected by other implemented strategies; and
- How changes to the strategy affect its performance.

A speed reduction strategy tested by researchers at the University of Kansas showed that effectiveness of the strategy varied based on the vehicle type and temporary traffic control measure being used. The case study measured the speed reduction in three vehicle class types as motorists reacted to portable changeable message signs (PCMS) and static signs. Researchers found that static signs were more effective at reducing speeds in passenger cars and semi-trailers in this study, while PCMS had more effect on passenger trucks. The researchers concluded by recommending the use of both PCMS and

[37] Chandler, Rephlo, and Beasley. "National Evaluation of the SafeTrip-21 Initiative: I-95 Corridor Coalition Test Bed Final Evaluation Report: North Carolina Deployment of Portable Traffic-Monitoring Devices," Research and Innovative Technology Administration, FHWA-JPO-10-058, 2010. Available at: http://ntl.bts.gov/lib/34000/34000/34005/index.htm; also see: Chandler, Rephlo, and Beasley. "National Evaluation of the SafeTrip-21 Initiative: California Connected Traveler Test Bed Final Evaluation Report: California Deployment of Portable Traffic-Monitoring Devices," Research and Innovative Technology Administration, FHWA-JPO-10-059, 2010.

static signing in work zones to capture all motor vehicle users when attempting to reduce driver speed.[38]

While case studies may provide precisely-measured effectiveness, they are not widely accepted by practitioners as a realistic evaluation tool for specific TMP strategies due to the need for a controlled environment. These environments are rarely available, and there is concern that fully-controlled results would not reflect real-life field conditions. States commented that it is difficult to determine if the case study method would work if any of the variables changed in the field. Even in a case where the strategy was deemed effective (or ineffective) at a particular location, practitioners expressed concern that the same strategy may perform differently in their jurisdiction.

3.4.5 Process Review

A process review related to TMP strategy effectiveness is a broad-based assessment of the use of various strategies within an agency. It is likely to be conducted as part of a larger work zone process review, such as the one required every two years by the Work Zone Safety and Mobility Rule. The objective of the currently performed process reviews is to evaluate Statewide work zone policies, practices, and processes to assess the current situation and identify appropriate improvements to the agency's policies and procedures regarding safety and mobility. Typically, the process review is carried out using both State-level work zone data and samples of project-level data. The agency may be able to define statewide trends in TMP practices and strategies, which could lead to adjustments in policy, guidelines, and required training of employees and its contractors. This broad-based assessment could reveal important information that would not have been discussed if only the specific TMP strategies were evaluated at the project level.

One concern when using this scope to evaluate TMP strategies is how much attention will be given to TMP strategy use and effectiveness during a larger process review. A review may not provide sufficient analysis of strategy effectiveness unless TMP strategies were chosen as a focus area for the review.

The Vermont Agency of Transportation requires the construction engineer to submit a summary of TMP effectiveness and recommendations for improvements at the end of the construction season based on the work zone documentation provided by the regional engineers. The Work Zone Safety and Mobility Committee, comprised of representatives from multiple sections within the Agency of Transportation, meets annually to discuss these summaries. The summaries serve to identify successful and unsuccessful TMP practices. The State's Work Zone Safety and Mobility Guidance document and supporting documentation are revised to reflect the field evaluation summaries for future use.[39]

As a portion of the New York State Department of Transportation's 2010 Work Zone Safety and Mobility Process Review, all Regions were provided with the list of "Strategies to Consider" from

[38] Bai, Finger, and Li. "Analyzing Motorist's Responses to Temporary Signage in Highway Work Zones," *Safety Science*, Vol. 48, No. 2, pp. 215-221, February 2010.

[39] Vermont Agency of Transportation. "Work Zone Safety and Mobility Guidance Document," 2007. Available at: http://www.aot.state.vt.us/progdev/Publications/DocumentsPUBLICATIONS/WorkZoneSafetyMobilityGuidanceDocument.pdf

FHWA's *Developing and Implementing Transportation Management Plans for Work Zones*. The regions then selected a total of 21 work zones which occurred throughout the year and documented which of the TMP strategies were used on each project. The process review discovered that there were a substantial number of strategies deployed on New York work zones, with the most frequent being PCMS, transportation management center (TMC) coordination, lane shifts or closures, and temporary traffic signals. The frequency that these strategies were being deployed could be a surrogate for strategy effectiveness (i.e., ineffective strategies would not be deployed at the same rate as effective strategies).[40]

Ohio officials performed an extensive review of crash rates at a sample of work zones compared to non-construction sites during free flow operation. Based on review of this data, Ohio DOT identified specific locations at a few work zones where the crash rates at work zones were much higher than crash rates were prior to construction. Field investigation at these locations enabled Ohio DOT to identify contributing factors such as insufficient off-ramp length, inadequate ramp merges, and lack of paved shoulders. Ohio DOT also concluded that the situation was compounded by drivers speeding through work zones. After these factors were identified, Ohio DOT took action to reduce the work zone crash rates with infrastructure solutions, including requiring minimum ramp lengths and paved shoulders in work zones. Ohio DOT intends to use additional crash analyses to identify other characteristics that contribute to the number and severity of crashes in work zones.[41]

Tennessee DOT has chosen a systems-level approach to satisfy the requirements of FHWA's Work Zone Safety and Mobility Rule by establishing a Standing Committee on Work Zones that provides the structure for assessing its work zones annually. Topics that the Committee evaluates include:

- Procedures to differentiate between significant projects and non-significant projects;
- Development of TMP strategies;
- Training of work zone personnel;
- Roles and responsibilities of performing work in a work zone;
- Procedures to assess active and completed work zones; and
- Data that quantify work zone TMP strategy success (delay, crashes, and other data collection).

In the annual report, the Committee generates an ordered list of implementation recommendations, starting with the most critical. Those recommendations are the primary driving force to motivate work zone policy change for the next year.[42]

Most States perform annual work zone traffic control inspections to assess compliance with traffic control requirements. While these inspections are not as comprehensive as a process review, they often

[40] New York Department of Transportation. "NYSDOT 2010 Work Zone Safety and Mobility Process Review." 2010.
[41] Holstein. "Work Zone Crash Analysis & Traffic Management in Work Zones –The ODOT MOT Process." Available at http://ssom.transportation.org/Documents/ohio.pdf.
[42] Tennessee DOT. "Work Zone Safety and Mobility Manual," available at: http://www.tdot.state.tn.us/Chief_Engineer/assistant_engineer_design/design/TDOTWorkZoneSafetyMobilityManual.pdf.

result in valuable findings about what is occurring in the field on projects and may provide opportunities for learning about TMP strategy effectiveness.

3.5 Research Gaps and Industry Needs

While research and discussions with practitioners have found that assessing TMP strategy effectiveness is feasible and useful, remaining challenges prevent wide scale adoption. Gaps still exist with respect to the following:

- Standard definitions of strategies and performance measures;
- Comparing effectiveness and identifying suitable strategies for various project features:
  - Methodology and/or tools to compare TMP strategy evaluations that use different measures of effectiveness,
  - Determination of the relative cost effectiveness of TMP strategies,
  - Anticipation of results when combining multiple strategies;
- Identification of a mechanism for information exchange on sharing best practices for TMP strategy selection, deployment, and evaluation and for sharing the results of evaluations; and
- Increasing the use of simulation and modeling tools for TMP strategy evaluation.

3.5.1 Need for Standard Definitions of Strategies and Performance Measurements

Defining TMP Strategies. TMP strategies generally consist of three categories: temporary traffic control plans, public information, and transportation operations elements. Additionally, each of these three categories can be further broken down into subgroups of TMP strategies. While there are many strategies used across the different agencies, commonly used strategies vary by State, and thus ways of grouping strategies and assessment techniques may need to be tailored to the State or region to ensure they are accounting for the variations of strategies that may be deployed.

Defining Measures of Effectiveness. In general, effectiveness criteria can be grouped into four subject areas: safety, mobility, construction efficiency and effectiveness, and public perception and satisfaction. However, measures used to assess the effectiveness of TMP strategies vary from agency to agency and from strategy to strategy, and in some cases effectiveness criteria for a single strategy vary. For example, while one State may use travel time as a performance measures for some strategies, other States use queuing for measuring effectiveness of the same strategies. It can be difficult to compare assessments of a single strategy between agencies if different effectiveness criteria are used on each assessment.

Even within the same jurisdiction, effectiveness measurement can be challenging. TMP strategies in different categories do not typically have the same MOEs, complicating efforts to make cost-effective decisions. For example, using travel time as an MOE to compare a work zone that employed a nighttime work strategy to one that used other scheduling strategies (e.g., weekend work or construction phase/staging) would be feasible. On the contrary, comparing nighttime work to strategies in other categories (e.g., a public information strategy such as 511 traveler information systems or a public website that provides work zone updates) would be much more difficult. While an agency will need to use some scheduling strategy for every project and would never replace that with public outreach, it may be able to use a less expensive but more disruptive or more intensive schedule if it

implements an aggressive public outreach campaign. In this way, there would be some benefit to being able to weigh strategies across different categories.

This quantity and range of effectiveness criteria is needed due to the varying types of analysis, but in order to conduct a comparison of TMP strategies across projects or agencies, it would be beneficial to determine a standard set of effectiveness criteria as well as to which analyses each criteria apply. A standard set of effectiveness criteria tied to specific TMP strategies would facilitate future comparisons.

3.5.2 Challenges with Comparing Effectiveness and Identifying Suitable Strategies

Many challenges exist to measuring the effectiveness of TMP strategies and successfully comparing their many attributes accurately. There is a need for a better understanding of how TMP strategy effectiveness varies for given project features to enable better identification of suitable strategies to achieve desired results. For example, it would be helpful to know that using dynamic lane merge would reduce congestion and increase throughput on a six-lane urban freeway prior to applying the strategy in the field. To gain this understanding, the below challenges need to be addressed and more strategy evaluations need to be completed.

Project-specific Characteristics. Confounding factors to measuring the effectiveness of a TMP strategy are project-specific characteristics such as the location of the work zone and type of roadway. Work zone practitioners noted that the use and effectiveness of TMP strategies differ in urban and rural environments depending on numerous factors, such as the availability of detour routes and public transit options. To better measure the effectiveness of a TMP strategy, the project characteristics and geographic conditions surrounding the evaluation should be included as part of a strategy effectiveness assessment.

Dynamic Nature of Work Zones. Queue lengths, travel times, and delay are often captured and recorded in the resident engineer's diary, but these measures are not analyzed unless there is a need, due to the relative difficulty in accessing logs (often in paper format) and the dynamic nature of work zones. By the time a formal analysis would be completed, the work zone may not have the same issues that warranted the analysis. Practitioners noted that additional ITS equipment in work zones could improve an agency's ability to collect quantitative data and conduct analysis of TMP strategy effectiveness, but this equipment is generally not available due to funding constraints. Even if this data were available, practitioners noted that there is no staff available to analyze it.

Connect Public Outreach with Driver Behavior. Further research is needed to determine a correlation between public information strategies and driver behavior, specifically strategies that seek to notify the motorist in advance of the work zone to encourage detours. Public information strategies can be some of the most effective and least costly methods to increase work zone safety and mobility; this is especially true if a given strategy results in a decision to detour around the work zone at the beginning of a trip. Work zone practitioners noted that they can collect quantitative data showing the number of motorists who requested work zone updates or viewed work zone information online, but they typically have not correlated that data to the number of drivers who avoid the work zone.

Use of Multiple Strategies Simultaneously. Work zones are dynamic in nature, and depending on the size and scope of the project, a work zone can have multiple TMP strategies deployed simultaneously. While researchers have had some success isolating and assessing the effectiveness of single TMP strategies in case studies, practitioners often do not have that possibility on ongoing projects. Additionally, even after the effectiveness of a single TMP strategy is quantified through a research case study, the question remains: How will this effectiveness change when the single strategy is coupled with others in a real-world work zone? Understanding the anticipated results of combining multiple strategies is an industry need to enable work zone practitioners to assess TMP strategies more effectively.

3.5.3 Need to Share Evaluation Results and Best Practices

Throughout discussions with practitioners, it was apparent that guidance on the effectiveness of various TMP strategies can and would be used. By learning about the effectiveness of strategies used in other locations, practitioners can save time and money by adopting those strategies found to be most effective in other locations. For example, Illinois DOT has been under pressure to minimize road closures and detours due to public response, and a compilation of strategy effectiveness could assist in justifying future road closures.

The usefulness of information on TMP strategy effectiveness highlights the need for sharing best practices within agencies and among agencies, researchers, and other practitioners. Multiple States cited the need for internal collaborative meetings designed to share experiences related to project-specific TMP strategy selection, implementation, operation, and evaluation. States suggested that communicating the use and application of TMP strategies on a nationwide level would assist States in determining which strategies to implement in appropriate cases, and it would help them recognize the outcomes that could result from appropriate strategy implementation. Conveying this information would help guide the States on how and when to implement appropriate strategies without committing the State DOTs to evaluate each strategy themselves. The development of a national database of effective strategies for selection and inclusion in TMPs is one way in which this information could be successfully shared.

3.5.4 Increasing the Use of Simulation and Modeling for TMP Strategy Evaluation

Simulation and modeling tools are important to consider when conducting TMP strategy assessments. These tools have the potential to enable work zone practitioners to evaluate strategies before construction begins and without the constraints of real-world deployments and their associated resource, data collection, and field conditions.

Throughout the literature review, 11 publications were identified where researchers have successfully used simulation and modeling to evaluate TMP strategies. However, during the stakeholder outreach task, many of the practitioners did not mention the use of simulation or modeling to evaluate TMP strategies. If mentioned, practitioners noted that the use of these tools was limited to large and significant projects. Reasons for the limited use include the following:

- Lack of trained staff and lack of time and resources to properly code and analyze each scenario make it difficult to obtain useful information.

- The “black box” effect of many simulation and modeling tools can intimidate unfamiliar users.
- Minor errors in the input data, coding, or calibration of the tools can produce dramatic differences in the final output.

As these tools continue to evolve and improve, practitioners should consider the potential they offer to support TMP strategy assessments. Additional training in how to use these tools for TMP strategy assessment may be helpful to increase this type of application.

4. Conclusion

This report presents the results of research done to identify and assess possible approaches to evaluating TMP strategies; determine what data are needed and available to support an assessment; identify any relevant work completed to date; and provide recommendations on the feasibility and usefulness of and possible approaches for conducting assessment of TMP strategy effectiveness.

Practitioners expressed their desire for information that would facilitate the assessment of TMP strategies. If TMP strategies are more regularly and thoroughly assessed, practitioners would be able both to share their experiences and learn from their peers. Disseminating this knowledge gained from TMP strategy assessment would further advance a practitioner's ability to design and implement a successful work zone by confidently selecting and deploying TMP strategies that had been well-assessed and had produced positive results.

Both the literature review and the stakeholder outreach effort revealed that most important MOEs fall into one of the four following categories:

1. Safety;
2. Mobility;
3. Construction efficiency (including cost) and effectiveness; and
4. Public perception and satisfaction.

Many State DOTs are already collecting data (qualitative and quantitative) in work zones for the purpose of TMP strategy evaluation. This report provides examples of assessments that have been done on traffic control devices, ITS strategies, speed management (including law enforcement), queue management, PCMS, public outreach, nighttime only work zones, and detours/driver diversions.

As validated through research, one or more of these three approaches is typically used to assess TMP strategies:

1. Qualitative evaluation;
2. Quantitative evaluation; and
3. Hybrid evaluation.

Each TMP strategy assessment can be conducted through one of the following five evaluation scopes:

1. Full scale evaluation of all strategies on a project;
2. Agency-wide evaluation of a single TMP strategy;
3. Research evaluation of multiple agency deployment of a single strategy;
4. Case study of a single strategy at one location; and
5. Process review

This report provides successful application examples of the various assessment approaches and scopes listed above. Each evaluation approach has its own advantages and disadvantages, which researchers and public agencies should to consider when selecting how to conduct TMP strategy assessments. It is likely that in order to find the best evaluation approach and to determine the most effective TMP strategy for a work zone, practitioners will apply a combination of these methods and scopes.

Lastly, the following areas should be addressed in order to facilitate more widespread adoption of TMP strategy assessment:

1. Standard definitions of strategies and performance measures;
2. Comparing effectiveness and identifying suitable strategies for various project features:
    a. Methodology and/or tools to compare TMP strategy evaluations that use different measures of effectiveness,
    b. Determination of the relative cost effectiveness of TMP strategies,
    c. Anticipation of results when combining multiple strategies;
3. Identification of a mechanism for information exchange on sharing best practices for TMP strategy selection, deployment, and evaluation and for sharing the results of evaluations; and
4. Increasing the use of simulation and modeling tools for TMP strategy evaluation.

Despite these challenges, practitioners expressed that widespread assessment of TMP strategies is feasible and would provide valuable information to support TMP strategy selection in work zones.

Appendix A: Identified Resources in Literature Review

This appendix includes a list of the 79 resources identified and reviewed by the research team for this project, sorted by relevance (High, Moderate, or Low) in Table 6. Additionally, Table 7 lists each resource as well as which TMP strategies were evaluated within the resource.

Table 6: Identified Resources by Relevance

Ref #	Title	Year	Author(s)	Relevance
1	To Lessen Work Zone Impacts: Try TMPs	2010	Scriba, Symoun, Beasley	High
6	Work Zone Crash Analysis & Traffic Management in Work Zones –The ODOT MOT Process		David Holstein	High
7	RIDOT TMP Templates	2009	RIDOT	High
8	VDOT TMP Template and Woodrow Wilson Bridge Project TMP Example	2007	VDOT	High
9	Developing and Implementing TMPs for WZs	2005		High
11	Streamlined Strategies for Faster, Less Traffic-Disruptive Highway Rehabilitation in Urban Networks	2008	Eul-Bum Lee, Kunhee Choi, and Seungwook Lim	High
12	Caltrans Transportation Management Plans to Reduce Work Zone Congestion	2007	Caltrans	High
13	TMP Course, Module 9 - Evaluation and Performance	2011	FHWA (T. Scriba, K. Wood)	High
20	Revised Process for Work Zone Decision Making Based on Quantitative Performance Measures	2009	Hartmann, T.; Hawkins, G.	High
25	A Performance Assessment of Virginia's Traffic Management Plans	2012	Virginia Transportation Research Council	High
26	Techniques for Effective Highway Construction Projects in Congested Urban Areas	2011	Thomas R. Warne (consultant)	High
27	TMP Guidelines for Development, Implementation and Assessment	2006	MdSHA	High
30	Work Zone Safety and Mobility Manual(Tennessee)	2007	Tennessee DOT	High
33	Cost-Benefit Analysis of Sequential Warning Lights in Nighttime Work Zone Tapers	2011	Carlos Sun, Praveen Edara, Yi Hou, Andrew Robertson	High
35	Construction Area Late Merge (CALM) System	2004	Eric Meyer	High
37	Evaluation of the Dynamic Late Lane Merge System at Freeway Construction Work Zones	2007	Tapan Datta, Catherine Hartner, and Lia Grillo	High
39	Development and Operational Analysis of Highway Alternating Merge Transition Zones	2009	Wakeel Idewu	High
40	Evaluation of Traffic Control Devices for Rural High-Speed Maintenance Work Zones: Second Year Activities and Final Recommendations	2000	Michael D. Fontaine, Paul J. Carlson, and H. Gene Hawkins, Jr.	High
44	Evaluation of Data from Test Application of Optical Speed Bars to Highway Work Zones	2000	Eric Meyer	High
45	Evaluation of Work Zone Speed Advisory System	2004	Geza Pesti, Patrick T. McCoy, Mark D. Meisinger, and Vijayakumar Kannan	High
61	ITS in Work Zones, A Case Study: Work Zone Travel Time System	2004	Unknown	High
62	Deployment of Smart Work Zone Technology in Arkansas	2002	Lorie H. Tudor, Alan Meadors, Robert Plant, II	High

65	Development and Evaluation of an Advanced Dynamic Lane Merge Traffic Control System for three to two Lane Transition Areas in Work Zones	2004	Tapan Datta, Kerrie Schattler, Puskar Kar and Arpita Guha	High
66	Michigan DOT TMP Template		Michigan DOT	High
67	TMPs in Wisconsin	2011	Alicia Dougherty	High
72	Traffic Control Strategies for Congested Freeways and Work Zones	2007	Geza Pesti, Poonam Wiles, Ruey Long (Kelvin) Cheu, Praprut Songchitruksa, Jeff Shelton, Scott Cooner	High
73	Project Level Transportation Management Plan (TMP) Guidance Document	2010	Oregon DOT	High
74	Maximizing Investments in Work Zone Safety In Oregon	2011	Ross, J.; Pietz, A.	High
75	New York State DOT Work Zone Safety and Mobility Process Review Report August 2010	2010	New York State DOT and FHWA - New York Division Office	High
76	Work Zone Safety and Mobility Program Review	2010	Iowa DOT and FHWA Iowa Division Office	High
77	Request for Exception to Compliance with the Work Zone Safety and Mobility Rule	2011	Illinois DOT	High
78	Evaluation of the Effectiveness of a Variable Advisory Speed System on Queue Mitigation in Work Zones	2011	Mitsuru Saito, Aaron Wilson	High
79	Work Zone Speed Reduction Utilizing Dynamic Speed Signs	2011	Deborah S. McAvoy	High
2	Simulation Models for Assessment of the Impacts of Strategies for Highway Work Zones	2010	Collura, J.; Heaslip, K.; Moriarty, K.; Wu, F.; Khanta, R.; Berthaume, A.	Moderate
3	Work Zone Design and Operation Enhancements	2010	John A. Gambatese and Michael Johnson	Moderate
5	Analyzing motorists' responses to temporary signage in highway work zones	2009	Yong Bai, Kris Finger, Yue Li	Moderate
10	Matrix-Based Decision Support Tools for Construction Activities on High-Volume Roadways	2008	Jodi L. Carson, Stuart D. Anderson, and Gerald L. Ullman	Moderate
15	Work Zone Safety and Mobility (Delaware)	2007	Delaware DOT	Moderate
16	Work Zone Safety and Mobility (Vermont)	2007	Vermont DOT	Moderate
17	Work Zone Safety and Mobility (Idaho)	2008	Idaho DOT	Moderate
18	Time Measurement of Travel Time Delay in Work Zones and Evaluation Metrics Using Bluetooth Probe Tracking	2009	Haseman, R.; Wasson, J.; Bullock, D.	Moderate
19	NCHRP 475 - A Procedure for Assessing and Planning Nighttime Highway Construction and Maintenance	2002	Bryden, J.; Mace, D.	Moderate
21	Caltrans TMP Fact Sheet	2007	FHWA	Moderate
22	Transportation Management Plan Guidelines	2004	Caltrans - Division of Traffic Operations	Moderate
23	Estimation of Traffic Mobility Impact - State of the Practice	2006	Praveen K. Edara, Benjamin H. Cottrell, Jr.	Moderate
24	Evaluation of Rural Interstate Work Zone Traffic Management Plans in Iowa Using Simulation	2000	Steven D. Schrock and T.H. Maze	Moderate
28	Dynamic Work Zone Traffic Management	2010	Jeremy Jackson	Moderate
31	Work Zone Transportation Management Plan Development Course	2009	Caltrans	Moderate

32	Transportation Management Plan (TMP) Monitoring-DelDOT's Experience	2010	Adam Weiser	Moderate
34	Development and Eval of an Advanced Dynamic Lane Merge TCD for 3-2 Lane Transition Areas in WZs	2004	Tapan Datta, Kerrie Schattler, Puskar Kar and Arpita Guha	Moderate
36	Evaluation of Speed Management Strategies in Highway Work Zones	2006	Yali Chen, Xiao Qin, David Noyce	Moderate
38	Effectiveness of Dynamic Messaging on Driver Behavior for Late Merge Lane Road Closures	2009	Robert Sperry, Tom McDonald, Shashi Nambisan, Ryan Pettit	Moderate
42	Advanced Notification Messages and Use of Sequential Portable Changeable Message Signs in Work Zones	2005	Gerald L. Ullman, Brooke R. Ullman, Conrad L. Dudek, Alicia Williams, and Geza Pesti	Moderate
46	Guidelines for the Application of Removeable Rumble Strips	2007	Eric Meyer	Moderate
47	Identification and Testing of Measures to Improve Work Zone Speed Limit Compliance	2005	Marcus A. Brewer, Geza Pesti, and William H. Schneider IV	Moderate
48	Low-Volume Highway Work Zone Evaluation of Temporary Rumble Strips	2011	Sun, Carlos; Edara, Praveen; Ervin, Kyle	Moderate
50	Radar Speed Display	2003	Eric Meyer	Moderate
51	Low-Cost Portable Video-Based Queue Detection for Work-Zone Safety	2011	Morris, Ted; Schwach, Jory A.; Michalopoulos, Panos G.	Moderate
52	Speed Monitor Display	2000	Tom Maze	Moderate
53	Speed Management Strategies for Work Zones	2003	Eric D. Hildebrand, Frank R. Wilson, James J. Copeland	Moderate
54	Real-Time Integrated ATIS Systems	2005	Midwest Smart Work Zone Deployment Initiative	Moderate
55	Radar Actuated Speed Displays	2005	Midwest Smart Work Zone Deployment Initiative	Moderate
56	Intelligent Transportation Systems in Work Zones: A Cross Cutting Study	2002	FHWA	Moderate
57	Long-Term Effectiveness of Speed Monitoring Displays in Work Zones on Rural Interstate Highways	2001	Geza Pesti, Patrick McCoy	Moderate
58	Speed Control Through Work Zones: Techniques Evaluation and Implementation Guidelines	1987	Errol C. Noel, Conrad L. Dudek, Olqa J. Pendleton, Huqh W. McGee, Ziad A. Sabra	Moderate
59	Traffic Control Strategies for Congested Freeways and Work Zones	2007	Geza Pesti, Poonam Wiles, Ruey Long (Kelvin) Cheu, Praprut Songchitruksa, Jeff Shelton, and Scott Cooner	Moderate
60	Reducing Work Zone Crashes by Using Emergency Flasher Traffic Control Device	2009	Yingfeng Li and Yong Bai	Moderate
63	Automated Work Zone Information System on Urban Freeway Rehabilitation: California Implementation	2006	Eul-Bum Lee, Changmo Kim	Moderate
64	Criteria for Portable ATIS in Work Zones	2005	Vikas Lachhwani and Alan J. Horowitz	Moderate

68	Evaluation of the Late Merge Work Zone Traffic Control Strategy	2004	Andrew Beacher, Michael Fontaine, Nicholas Garber	Moderate
70	Comparing Three Lane Merging Schemes for Short Term Work Zones - A Simulation Study	2010	Rami Harb, Essam Radwan, Vinayak Dixit	Moderate
71	Study on Intelligent Lane Merge Control System for Freeway Work Zones	2007	Pei Yulong, Dai Leilei	Moderate
4	Commuter Impacts and Behavior Changes during a Temporary Freeway Closure: The Fix I5 Project in Sacramento, California	2010	Liang Ye, Patricia L. Mokhtarian, Giovanni Circella	Low
14	Tracker, Measures of Departmental Performances	2011	Missouri DOT	Low
29	Work Zone Safety and Mobility Manual - TMP Workbook (Tennessee)		Tennessee DOT	Low
41	Wider Lane Lines	2005	MdSHA	Low
43	Experimental Alternative Highway Merge Sign	2004	Eric Feldblum	Low
49	Use of Portable Changeable Message Signs to Improve Speed Compliance	2005	Maryland State Highway Administration	Low
69	Guidelines for Using Late Merge Traffic Control in Work Zones	2005	Andrew Beacher, Michael Fontaine, Nicholas Garber	Low

Table 7: Relevant Strategies Evaluated in Each Literature Review Resource

	Strategies															Strategy Selection Tools	
Name of Resource	Queue Management	Public Outreach	ITS	Traffic Control Devices	Night Work/Off-Peak Work	Speed Management	Law Enforcement	Detours/Driver Diversion	Lane Closures	Signal Optimization	Stage Construction	PCMS	Video Detection	Real-Time Crash Data Analysis in Work Zones	Incentives/ Disincentives	Simulation and Modeling	Decision-Making Matrices
01: To Lessen Work Zone Impacts: Try TMPs																	
02: Using Simulation Models to Assess the Impacts of Highway Work Zone Strategies: Case Studies along Interstate Highways in Massachusetts and Rhode Island																X	
03: Work Zone Design and Operation Enhancements				X													
04: Commuter Impacts and Behavior Changes during a Temporary Freeway Closure: The Fix I5 Project in Sacramento, California		X						X								X	
05: Analyzing motorists' Responses to Temporary Signage in Highway Work Zones			X	X													
06: Work Zone Crash Analysis & Traffic Management in Work Zones –The ODOT MOT Process	X													X			
07: RIDOT TMP Templates and Example																	
08: Examples of Temporary Traffic Control				X													

	Strategies															Strategy Selection Tools	
Name of Resource	Queue Management	Public Outreach	ITS	Traffic Control Devices	Night Work/Off-Peak Work	Speed Management	Law Enforcement	Detours/Driver Diversion	Lane Closures	Signal Optimization	Stage Construction	PCMS	Video Detection	Real-Time Crash Data Analysis in Work Zones	Incentives/ Disincentives	Simulation and Modeling	Decision-Making Matrices
Plans and TMP Templates																	
09: Developing and Implementing TMPs for Work Zones																	
10: Matrix-Based Decision Support Tools for Construction Activities on High-Volume Roadways																	X
11: Streamlined Strategies for Faster, Less Traffic-Disruptive Highway Rehabilitation in Urban Networks		X			X										X	X	
12: Caltrans Transportation Management Plans Reduce Work Zone Congestion			X														
13: Traffic Management Plan Course, Module 9 – Evaluation and Performance			X														
14: Tracker, Measures of Departmental Performance																	
15: Work Zone Safety and Mobility – Delaware																	
16: Work Zone Safety and Mobility – Vermont																	

	Strategies															Strategy Selection Tools	
Name of Resource	Queue Management	Public Outreach	ITS	Traffic Control Devices	Night Work/Off-Peak Work	Speed Management	Law Enforcement	Detours/Driver Diversion	Lane Closures	Signal Optimization	Stage Construction	PCMS	Video Detection	Real-Time Crash Data Analysis in Work Zones	Incentives/ Disincentives	Simulation and Modeling	Decision-Making Matrices
17: Work Zone Safety and Mobility – Idaho		X	X	X													
18: Real-Time Measurement of Travel Time Delay in Work Zones and Evaluation Metrics Using Bluetooth Probe Tracking	X	X	X														
19: NCHRP Report 475 - A Procedure for Assessing and Planning Nighttime Highway Construction and Maintenance				X	X												
20: Revised Process for Work Zone Decision Making Based on Quantitative Performance Measures																	
21: Caltrans Transportation Management Plans Reduce Work Zone Congestion	X	X															X
22: Transportation Management Plan Guidelines																	
23: Estimation of Traffic Mobility Impact - State of the Practice																X	
24: Evaluation of Rural Interstate Work Zone Traffic Management Plans in Iowa Using Simulation	X															X	
25: A Performance Assessment of Virginia's											X						

	Strategies															Strategy Selection Tools	
Name of Resource	Queue Management	Public Outreach	ITS	Traffic Control Devices	Night Work/Off-Peak Work	Speed Management	Law Enforcement	Detours/Driver Diversion	Lane Closures	Signal Optimization	Stage Construction	PCMS	Video Detection	Real-Time Crash Data Analysis in Work Zones	Incentives/ Disincentives	Simulation and Modeling	Decision-Making Matrices
Traffic Management Plans																	
26: Techniques for Effective Highway Construction Projects in Congested Urban Areas					X				X						X		
27: TMP Guidelines for Development, Implementation and Assessment																	
28: Dynamic Work Zone Traffic Management	X		X														
29: Work Zone Safety and Mobility Manual – TMP Workbook																	
30: Work Zone Safety and Mobility Manual																	
31: TMP Guidelines																	
32: Transportation Management Plan (TMP) Monitoring- DelDOT's Experience			X	X	X		X	X	X	X							
33: Cost-Benefit Analysis of Sequential Warning Lights in Nighttime Work Zone Tapers				X	X	X											
34: Development and Evaluation of an Advanced Dynamic Lane Merge TCD for 3-2 Lane Transition Areas in Work Zones	X		X	X													

	Strategies															Strategy Selection Tools	
Name of Resource	Queue Management	Public Outreach	ITS	Traffic Control Devices	Night Work/Off-Peak Work	Speed Management	Law Enforcement	Detours/Driver Diversion	Lane Closures	Signal Optimization	Stage Construction	PCMS	Video Detection	Real-Time Crash Data Analysis in Work Zones	Incentives/ Disincentives	Simulation and Modeling	Decision-Making Matrices
35: Construction Area Late Merge (CALM) System			X	X										X			
36: Evaluation of Speed Management Strategies in Highway Work Zones				X		X	X										
37: Evaluation of the Dynamic Late Lane Merge System at Freeway Construction Work Zones	X		X	X													
38: Effectiveness of Dynamic Messaging on Driver Behavior for Late Merge Lane Road Closures			X	X													
39: Development and Operational Analysis of Highway Alternating Merge Transition Zones			X	X		X											
40: Evaluation of Traffic Control Devices for Rural High-Speed Maintenance Work Zones: Second Year Activities and Final Recommendations			X	X													
41: Wider Lane Lines				X													
42: Advanced Notification Messages and Use of Sequential Portable Changeable Message Signs in Work Zones			X	X													

	Strategies															Strategy Selection Tools	
Name of Resource	Queue Management	Public Outreach	ITS	Traffic Control Devices	Night Work/Off-Peak Work	Speed Management	Law Enforcement	Detours/Driver Diversion	Lane Closures	Signal Optimization	Stage Construction	PCMS	Video Detection	Real-Time Crash Data Analysis in Work Zones	Incentives/ Disincentives	Simulation and Modeling	Decision-Making Matrices
43: Experimental Alternative Highway Merge Sign				X													
44: Evaluation of Data from Test Application of Optical Speed Bars to Highway Work Zones				X												X	
45: Evaluation of Work Zone Speed Advisory System	X		X	X													
46: Guidelines for the Application of Removable Rumble Strips				X													
47: Identification and Testing of Measures to Improve Work Zone Speed Limit Compliance			X	X		X											
48: Low Volume Highway Work Zone Evaluation of Temporary Rumble Strips						X											
49: Use of Portable Changeable Message Signs with Speed Display in Work Zones				X		X						X					
50: Radar Speed Display						X											
51: Low-Cost Portable Video-Based Queue Detection for Work-Zone Safety	X																
52: Speed Monitor Display			X			X											

	Strategies															Strategy Selection Tools	
Name of Resource	Queue Management	Public Outreach	ITS	Traffic Control Devices	Night Work/Off-Peak Work	Speed Management	Law Enforcement	Detours/Driver Diversion	Lane Closures	Signal Optimization	Stage Construction	PCMS	Video Detection	Real-Time Crash Data Analysis in Work Zones	Incentives/ Disincentives	Simulation and Modeling	Decision-Making Matrices
53: Speed Management Strategies for Rural Temporary Work Zones				X		X						X					
54: Real-Time Integrated ATIS Systems		X	X	X				X				X					
55: Radar Actuated Speed Displays						X						X					
56: Intelligent Transportation Systems in Work Zones: A Cross Cutting Study			X														
57: Long-Term Effectiveness of Speed Monitoring Displays in Work Zones on Rural Interstate Highways						X						X					
58: Speed Control Through Work Zones: Techniques, Evaluation, and Implementation Guidelines						X	X										
59: Traffic Control Strategies for Congested Freeways and Work Zones	X											X	X				
60: Reducing Work Zone Crashes by Using Emergency Flasher Traffic Control Device				X													
61: Intelligent Transportation Systems in Work Zones, A Case Study Work Zone Travel Time System			X										X				

	Strategies															Strategy Selection Tools	
Name of Resource	Queue Management	Public Outreach	ITS	Traffic Control Devices	Night Work/Off-Peak Work	Speed Management	Law Enforcement	Detours/Driver Diversion	Lane Closures	Signal Optimization	Stage Construction	PCMS	Video Detection	Real-Time Crash Data Analysis in Work Zones	Incentives/ Disincentives	Simulation and Modeling	Decision-Making Matrices
62: Deployment of Smart Work Zone Technology in Arkansas			X	X								X					
63: Automated Work Zone Information System on Urban Freeway Rehabilitation: California Implementation		X						X									
64: Criteria for Portable ATIS in Work Zones			X									X					
65: Development and Evaluation of an Advanced Dynamic Lane Merge Traffic Control System for Three to Two Lane Transition Areas in Work Zones				X			X										
66: Michigan DOT TMP Template																	
67: Transportation Management Plans in Wisconsin																	
68: Evaluation of the Late Merge Work Zone Traffic Control Strategy				X												X	
69: Guidelines for Using Late Merge Traffic Control in Work Zones				X												X	
70: Comparing Three Lane Merging Schemes for Short Term Work Zones - A Simulation Study				X												X	

	Strategies															Strategy Selection Tools	
Name of Resource	Queue Management	Public Outreach	ITS	Traffic Control Devices	Night Work/Off-Peak Work	Speed Management	Law Enforcement	Detours/Driver Diversion	Lane Closures	Signal Optimization	Stage Construction	PCMS	Video Detection	Real-Time Crash Data Analysis in Work Zones	Incentives/ Disincentives	Simulation and Modeling	Decision-Making Matrices
71: Study on Intelligent Lane Merge Control System for Freeway Work Zones				X												X	
72: Traffic Control Strategies for Congested Freeways and Work Zones	X			X												X	
73: Project Level Transportation Management Plan (TMP) Guidance Document																	
74: Maximizing Investments in Work Zone Safety in Oregon																	
75: New York State DOT Work Zone Safety and Mobility Process Review Report August 2010																	
76: Work Zone Safety and Mobility Program Review																	
77: Request for Exception to Compliance with the Work Zone Safety and Mobility Rule																	
78: Evaluation of the Effectiveness of a Variable Advisory Speed System on Queue Mitigation in Work Zones	X					X						X					
79: Work Zone Speed Reduction Utilizing						X						X					

	Strategies															Strategy Selection Tools	
Name of Resource	Queue Management	Public Outreach	ITS	Traffic Control Devices	Night Work/Off-Peak Work	Speed Management	Law Enforcement	Detours/Driver Diversion	Lane Closures	Signal Optimization	Stage Construction	PCMS	Video Detection	Real-Time Crash Data Analysis in Work Zones	Incentives/ Disincentives	Simulation and Modeling	Decision-Making Matrices
Dynamic Speed Signs																	
Total:	12	7	22	32	5	14	4	4	2	1	1	10	2	2	2	11	2

Note: Some sources discuss multiple strategies, so they are marked for every applicable strategy.

Appendix B: Practitioner Discussion Questions

TMP Strategies - General

1. Who typically develops the TMP and selects strategies for a project?

2. How does your agency identify potential problems/needs related to work zone safety and mobility?

3. How does your agency select TMP strategies?

4. Which TMP strategies are used most often in your agency?

5. How many TMP strategies are used regularly on your agency's projects?

6. Does your agency have a list of recommended TMP strategies or standard strategies for certain types of projects?

7. Have you removed TMP strategies from the list of agency-recommended options? If so, why?

TMP Strategy Effectiveness Evaluation - Qualitative

8. How would you define "effectiveness" as it relates to TMP strategies?
    a. What are your performance measures?

9. How do WZ practitioners find out about the effectiveness/ineffectiveness of particular work zone strategies?

10. Is there a formal process for sharing lessons learned within your agency related to TMP strategy effectiveness?
    a. If yes, please explain.

11. Is there a feedback mechanism for the public to provide input on their experience? How is that information used by the agency?

TMP Strategy Effectiveness Evaluation – Quantitative

12. What types of quantitative data analysis have you completed to determine TMP strategy effectiveness or benefits?
    a. (Examples: Queue lengths, travel times, delay, number of crashes, Level of Service)

13. How is this data collected? By whom?

14. How is this data analyzed? By whom?

15. What challenges have you encountered when attempting to analyze the effect of WZ strategies?

16. What additional data would you most like to have to improve your ability to conduct quantitative analysis of TMP strategy effectiveness?

TMP Strategy Effectiveness Evaluation – Hybrid

17. Please share an example of a TMP strategy you evaluated using both qualitative and quantitative information.

Evaluation Scope

18. Describe situations when you evaluated TMP strategies using the following scopes:
    a. Full-scale, project-level evaluation of all TMP strategies

    b. In-depth review of a single TMP strategy at multiple locations

    c. Case studies (one/small number of TMP strategies on a single project or set of projects)

    d. Process Review – General evaluation of TMP process and procedures

Overall

19. Would you/your agency find it useful to have more information on the effectiveness of various TMP strategies?

20. Do you think it is feasible to rate the effectiveness of TMP strategies?

Appendix C: Online Collaborative Session – Executive Summary

Executive Summary

The online session involving work zone practitioners focused on the strategies used by highway agencies to determine TMP effectiveness. Practitioners discussed how best to measure effectiveness, capture useful strategies for future implementation, and include them on future projects. Practitioners were asked to comment on how effectiveness is measured in their organization and how the results of their findings are disseminated for use in current and future projects.

Defining Effectiveness

TMP effectiveness is typically defined by two overall measurable categories: mobility and safety. By analyzing crash data and its surrogates (e.g., queue length, speed through the work zone), safety benefits of the TMPs can be realized. Mobility benefits are often determined through analyses of speed, delay, travel time, or public satisfaction, among other measures. Factoring in the cost of strategies (e.g., through benefit/cost calculations) can support decision makers in choosing the most cost effectiveness treatments. Several agencies also mentioned other considerations, such as ease of use and whether project staff wants to use the strategy, as indicators of effectiveness. Some agencies include pedestrian mobility and customer satisfaction in their TMPs, but have yet to define a measurement for determining success.

Throughout the session, participants provided information on the measurements States considered important and how specific strategies were evaluated. Some practitioners shared specific metrics, while others have yet to define their measures or techniques. For example, it was apparent that public satisfaction is extremely important, but difficult to quantify.

Qualitative Evaluation

Internally, qualitative feedback is often received from field staff during construction and in post-construction meetings. Enforcement officials were considered a useful source of information by a number of session participants, as were internal staff responsible for the field review of work zones. In some cases, contract change orders were used to determine if changes to temporary traffic control were effective as participants stated that multiple charge orders to temporary traffic control could indicate the original strategies were not effective. Internal work zone inspection forms are widely used.

Externally, States often receive comments from the public related to TMP strategies. Sources include website work zone surveys, messages from social networking sites, phone surveys through customer service centers, newspaper editorials, and public meetings. Often, calls from the public can provide information about issues and can be quickly resolved in the field.

Quantitative Evaluation

To determine quantitatively the success of TMP strategies used in construction projects, data collection needs are greater than with qualitative evaluation. Data collected can include the

number and severity of crashes, travel times, queue lengths, and any modifications made to temporary traffic control elements to improve safety and mobility during the project.

States collect and analyze work zone data by requiring it as part of the project, relying on law enforcement to collect through enforcement forms, having field staff travel through the work zone, or by using technology within the work zone.

According to session attendees, quality data provide hard evidence that strategies are either working or not. Not only are these data measureable and identifiable, they can also be shared among other practitioners. However, data can be difficult to get in real time and are sometimes costly to collect. In order to be truly effective, resources need to be allocated towards data collection and analysis.

Evaluation Scope/Type

With regard to the scopes/types of quantitative analyses that take place, most States responded that evaluating one strategy at multiple locations is most valuable, but this strategy was the least used among the types of evaluations mentioned during the session. Participants felt that this method would allow for the true measurement of the single strategy being tried, especially when evaluated in coordination with other strategies and compared. Project level evaluation of TMP strategies was the second favored method and had above average use. When discussing project level evaluation, States agreed that it's an effective tool for assessment and would like to see a short summary of the evaluation for use and communication.

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