DEVELOPMENT OF PERFORMANCE ASSESSMENT GUIDELINES FOR VIRGINIA'S WORK ZONE TRANSPORTATION MANAGEMENT PLANS

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ABSTRACT

As America's roadways are becoming more congested and more in need of maintenance and repair, management of traffic through work zones is a major issue for state departments of transportation. To aid this, in 2004, the Federal Highway Administration (FHWA) published its *Final Rule on Work Zone Safety and Mobility*, which mandated that state DOTs develop transportation management plans (TMPs) for all federally-funded roadway construction projects. The Virginia Department of Transportation (VDOT) now requires TMPs for all projects, regardless of funding source. Part of federal and Virginia TMP requirements are to monitor and assess traffic impacts, including a post-construction evaluation of the TMP. Currently, TMPs are not being assessed following individual construction projects, and VDOT does not yet have a formally established process to assess TMP performance throughout its districts and regions.

This project developed a set of guidelines to assist VDOT's work zone personnel and contractors with evaluating TMP performance. The research examines existing literature on work zone evaluation strategies. Thirty state DOTs, as well as personnel within VDOT, were surveyed to explore TMP assessment practices. Finally, two work zone case studies from within the Commonwealth of Virginia were examined. The results of this research effort were used to develop Guidelines for TMP Performance Assessment, with aid and review from a VDOT TMP Performance Assessment Task Group. While these new requirements may add up-front costs to project engineering, VDOT will benefit by having a methodology in place to identify and measure successful strategies to manage safety and mobility impacts from work zones.

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CHAPTER 1: INTRODUCTION, BACKGROUND, AND RATIONALE

1.1 WORK ZONES AND MOTORISTS' EXPOSURE TO WORK ZONES

Automobile ownership, usage, and vehicle-miles-traveled (VMT) have increased at a much faster rate than highway mileage. At the same time, existing highways are aging and in greater need of construction and repair. Agencies and contractors are pressed to complete roadway construction projects as quickly as possible with minimal disruption but also must deal with work zone mobility and safety issues. In 2001, motorists encountered an active work zone one out of every 100 miles driven on the National Highway System (NHS), representing over 12 billion hours of vehicle exposure to work zones *(1)*; this number has likely increased significantly over the past ten years. In 2009, 667 fatalities and over 40,000 injuries resulted from motor vehicle crashes in work zones in the United States *(2)*. As VMT increases and roadway infrastructure ages, work zones have the potential to become more congested and more dangerous. Sound work zone planning and management are thus essential to ensure the safety and efficiency of our roadway transportation system.

1.2 FHWA WORK ZONE POLICY

In order to meet safety and mobility needs during highway maintenance and construction, and to meet the expectations of the traveling public, it is important for state transportation agencies to understand the work zone safety and mobility impacts of projects and take appropriate actions to manage these impacts. In September 2004, the Federal Highway Administration (FHWA) published the *Final Rule on Work Zone Safety and Mobility* (henceforth referred to as the "Final Rule") *(3)*. The Final Rule updated and broadened the former regulation, "Traffic Safety in Highway and Street Work Zones" and applies to all state and local government projects that receive federal-aid highway funding. Transportation agencies were required to comply with the provisions of the Rule by October 12, 2007. Some of the specific requirements *(4)* are to:

- Implement a policy for the systematic consideration and management of work zone impacts on all Federal-aid highway projects. Furthermore, it encourages agencies to implement the policy for non-Federal-aid projects and programs.
- Develop a policy to address work zone impacts throughout the various stages of the project's development and construction. The agency must consider work zone impacts during project development, management of work zone impacts during construction, and assessment of work zone performance after implementation. The agency must also consider communication with the public before and during the project.
- Recognize that state policy may vary based on the characteristics and expected work zone impacts of individual projects or classes of projects.
- Require transportation management plans (TMPs) for all federally-funded roadway construction projects. TMPs are encouraged for all projects, even those without federal funding.

1.3 DEFINITION OF A TMP AND COMPONENTS

A TMP is a set of coordinated transportation management strategies for managing the impacts of a work zone in roadway construction *(4, 5)*. These strategies can include temporary traffic control (TTC), public information (PI) and outreach, or transportation operations (TO) strategies. TMPs need to serve the mobility and safety needs of road users, highway workers, businesses, and the community. The scope, content, and level of detail of a TMP can vary based on the agency's work zone policy and the anticipated impacts of the project. The TMP should identify and assign responsibilities and courses of action, improve public awareness of work zones and impacts, and help maximize project cost-efficiency. Ideally, a TMP should be a written document providing a description of the project, including project background, goals and constraints, a description of the corridor and area, project schedule, and phasing and staging *(4,5)*.

A TMP should also detail existing and future conditions of the work zone and assess predicted work zone traffic impacts. In conjunction with these predicted impacts, work zone impacts management strategies should be selected. Monitoring requirements should also be included "and made part of the construction contract" *(4)*. Part of these monitoring requirements should be an evaluation report for the TMP: "the TMP should include reference to the development of an evaluation report upon completion of construction to document lessons learned and provide recommendations on how to improve the TMP process and/or modify guidelines" *(5)*.

The TMP should also contain any contingency plans for activities that should be undertaken to minimize traffic impacts due to unexpected events. Finally, the TMP should include implementation cost estimates for various strategies to avoid under-allocation of funds. Essentially, a TMP is a more comprehensive approach to managing work zone impacts.

1.3.1 TMP Development

TMP development begins during systems planning and progresses through the design phase of the project. The eleven stages of TMP development that occur during planning, preliminary engineering, and design as suggested by the FHWA are as follows *(4):*

1) Compile Project Material
2) Determine TMP Needs
3) Identify Stakeholders
4) Develop TMP
5) Update/Revise TMP
6) Finalize Construction Phasing/Staging and TMP
7) Re-evaluate/Revise TMP
8) Implement TMP
9) TMP Monitoring
10) Update/Revise TMP Based on Monitoring
11) TMP Performance Assessment

These stages of TMP development are intended to work in an iterative manner where the level of detail progressively increases from planning through preliminary engineering through design, as more project information becomes available.

1.3.2 TMP Components *(4)*

Transportation management strategies for TMPs include TTC, PI, and TO strategies:

- *Temporary Traffic Control* – TTC refers to control strategies, traffic control devices, and project coordination and contracting strategies. According to Section 630.1012 of the Final Rule *(4)*, a TTC plan is required for all TMPs. It should be consistent with Part 6 of the *Manual on Uniform Traffic Control Devices* (MUTCD) *(6)* and work zone hardware recommendations from Chapter 9 of the AASHTO *Roadside Design Guide (7)*. The TTC plan can either be provided by reference (to the MUTCD or agency plans/manuals) or specifically designed for individual projects. Examples include:
    - Control strategies - full roadway closures, lane shifts or closures, one-lane/two-way operation, two-way traffic on one side a divided facility, reversible lanes, ramp closures or relocation, night work, weekend work, work hour restrictions for peak travel, improvements to bicycle/pedestrian access and business access, off-site detours/alternate routes, etc.
    - Traffic control devices - temporary signs (warning, regulatory, guide/info), changeable message signs, arrow panels, channelizing devices, temporary pavement markings, flaggers/officers, temporary traffic signals, lighting devices, and other devices.
    - Additional TTC strategies include coordination with other projects, utilities coordination, right-of-way coordination, and alternative or innovative contracting strategies.

- *Public Information/Outreach* – PI strategies include awareness strategies for the general public and specifically for motorists. The PI strategies utilized for a project vary based on project intensity. Examples include:

  - Public awareness strategies - brochures/mailers, press releases/media alerts, paid advertisements, public information centers, telephone hotlines, web sites, public meetings/hearings, community task forces, coordination with media/schools/businesses/emergency services, work zone education and safety campaigns, rideshare promotions, etc.
  - Motorist information strategies - traffic radio, changeable message signs (CMS) or temporary information signs, highway advisory radio, 511 traveler information systems, transportation management centers, etc.

- *Transportation Operations* – TO strategies typically focus on demand management, corridor or network management, work zone safety management, incident management, and enforcement strategies. Examples of TO strategies include:
  - Demand management strategies - transit service improvements or incentives, shuttle services, ridesharing/carpool incentives, park & ride promotion, HOV lanes, congestion pricing/tolls, ramp metering, parking supply management, variable work hours, telecommuting, etc.
  - Corridor/network management strategies - signal timing/coordination, temporary traffic signals, street/intersection improvements, bus turnouts, turn restrictions, parking restrictions, truck restrictions, separate truck lanes, reversible lanes, dynamic lane closure system, ramp metering or suspension of ramp metering, ramp closures, railroad crossing controls, coordination with adjacent construction sites, etc.

- Work zone safety management strategies - speed limit reductions/variable speed limits (VSLs), temporary traffic signals, temporary traffic barriers, movable barriers, crash-cushions, temporary rumble strips, intrusion alarms, warning lights, automated flagger assisted devices, project task force/committee, construction safety supervisor/inspector, road safety audits, TMP monitor/inspection team, team meetings, on-site safety training, safety awards/incentives, windshield surveys, etc.
- Traffic/incident management and enforcement strategies - intelligent transportation systems (ITS) for traffic monitoring/management, transportation management centers, surveillance (CCTV, detectors, lasers, probe vehicles, helicopters) to detect problems, traffic screens, call boxes, milepost markers, tow/freeway service patrol, total station units (to reduce clearance time for major incidents), photogrammetry, coordination with media, local detours, contract support for incident management, incident/emergency management coordinators, incident/emergency response plans, police enforcement (either paid or cooperative), automated enforcement, increased penalties for work zone violations, etc.

Together, a combination of TTC, PI, and TO strategies can be used to manage traffic impacts from a work zone, depending on the size and complexity of the project. A TMP should document the combination of strategies used, the plan for implementing these strategies, and how these strategies will mitigate adverse safety and mobility impacts to traffic.

1.4 VDOT'S TMP POLICY

In 2005, Cottrell *(5)* developed a set of guidelines for VDOT to use when developing TMPs. Formerly known as "congestion management plans," VDOT has actually been using TMPs since the 1970s. However, Cottrell notes, "In all cases, TMPs were developed on a case-by-case basis without guidelines, processes, or directions on how to proceed." Cottrell developed a systematic procedure to follow in developing plans to lessen the impact of construction projects, especially on limited-access highways. These guidelines were developed from best practices observed in other states, including California, New York, Washington, Illinois, Indiana, and Ohio.

VDOT's TMP Development Guidelines recommend data collection and monitoring of field conditions during construction to compare to predefined performance requirements and predicted work zone impacts. VDOT Regional Traffic Engineers and the contractor should each designate a trained person to implement and monitor the TMP. The TMP should identify the processes that will be used to monitor safety and mobility performance (for example, tracking queue lengths, volumes, travel times, crashes, complaints, etc.). TMP strategy implementation costs should also be tracked and compared to budgeted costs.

The scope, detail, and content of a TMP vary with project complexity; likewise, the level of assessment necessary for a TMP should vary with project complexity. VDOT has three types (or levels) of TMPs and five categories for its construction projects *(8)*.

The following TMP Types are defined in VDOT's TMP Requirements (IIM-LD-241.4) *(8)*:

- *Type A* - no-plan, minimum plan, single phase construction, maintenance projects, utility and permitted work; for example, widening of pavement or adding turn lanes or entrances.
- *Type B* - moderate level of construction activity with the primary traffic impact limited to the roadway containing the work zone; for example, widening of pavement involving lane closures or shifting traffic/detours.
- *Type C* - these types of projects are anticipated to cause sustained and substantial work zone impacts greater than what is considered tolerable based on policy or engineering judgment. These are long-duration construction or maintenance projects (1) on Interstates or freeways, (2) in a designated Transportation Management Area (Northern Virginia, Richmond, and Hampton Roads), and (3) occupying a location for more than three days with continuous lane closures.

Each project category is defined as follows:

- Category I – No-plan projects, small, simple and short-duration projects
- Category II – Minimum-plan projects, relatively simple, single-season construction projects
- Category III – Multi-season construction projects of medium complexity
- Category IV – Very large, complex, multi-season projects (generally >$100M)
- Category V – Major projects and multi-contract projects where seamless interaction among contractors is necessary.

Type A TMPs are required for Category I and II projects; Type B TMPs are required for Category III and IV projects; and Type C TMPs are required for Category V projects.

Following the completion of construction, the TMP Development Guidelines recommend that a report should be developed containing an evaluation of the TMP. It should contain successes and failures, changes made to the TMP and the results of those changes, public input, actual versus predicted measures, the cost for implementation of the strategies, and suggested improvements. Specifically, the guidelines suggested the following should be included *(5)*:

- An overall statement reflecting the usefulness of the TMP
- Changes necessary to correct oversights in the TMP
- Changes made to the original plan and their level of success
- Public reaction to the TMP
- The maximum and average delay time encountered (e.g., average queues, slowdowns) during peak and off-peak periods, and delay history over the duration of the project
- Identification of the peak traffic periods
- Frequency of legitimate complaints and the nature of the complaints
- Types and numbers of crashes that occurred during construction
- Types and numbers of safety service patrol assisted incidents
- Level of success and performance log for each implemented strategy of the TMP.
- Suggested improvements or changes for similar future projects

From the guidelines recommended by *(5)*, VDOT's TMP Policy is outlined in an Instructional and Informational Memorandum (IIM) of TMP requirements *(8)*. This directive is applied to all work zone activities regardless of funding source within state right-of-way and on streets and highways within the State Highway System. VDOT's stated goal is "reducing work zone crashes and improving travel time thereby benefitting all citizens of the Commonwealth."

Consistent with the FHWA’s recommendations, the IIM recommends TTC, PI, and TO strategies, noting that all TTC strategies must be in compliance with the Virginia Work Area Protection Manual (WAPM) *(6)*.

VDOT’s TMP Requirements state that Regional Traffic Engineering and Operations should conduct a performance assessment of the TMP including area-wide impacts “during construction as circumstances dictate” *(6)*. A review of the overall effectiveness of the TMP should be completed during the Post-Construction Meeting and included with the Post-Construction Report. Currently, the VDOT TMP Interim/Post-Construction Report is a document that consists of a checklist relating to various work zone activities. Although this requirement and template exists, VDOT’s Regional Operations Directors (RODs) have requested assistance with developing better processes and procedures for evaluating TMP performance.

1.5 PURPOSE AND SCOPE

The rationale behind TMP performance assessment is to determine if the anticipated work zone impacts and changes desired with the implementation of a TMP actually occur in the field. Currently, VDOT is not adequately performing this assessment because a methodology has not been established. Therefore, the purpose of this research effort was to develop a set of strategies to assess TMP performance. Similar to the process used by Cottrell for creating VDOT’s TMP Development Guidelines *(5)*, this project explored best practices recommended by the FHWA, other state departments of transportation, and VDOT’s own districts. In conjunction with these practices, the research team thoroughly examined two case studies of work zones in the Commonwealth to explore current VDOT efforts in assessing TMP performance.

Assessing and managing impacts of work zones due to TMPs has a variety of potential benefits *(9)*. Safety and mobility benefits are possible due to improved traffic flow and road user cost savings. Agencies are able to develop more realistic budgets and better customer acceptance and public relations. Finally, TMP assessment facilitates innovation and continuous improvement in mitigation strategy implementation and reducing work zone impacts. TMP assessment allows for a transportation agency to systematically build off of “lessons learned” from work zones to continuously improve work zone performance.

CHAPTER 2: OVERVIEW OF METHODOLOGY

The following tasks were conducted to achieve the study objectives:

1. A literature review was performed to identify tools and best practices for TMP development, monitoring, and performance assessment.
2. A survey was developed and distributed to other U.S. state transportation agencies examining TMP development, monitoring, and performance assessment practices across the country.
3. A survey was developed and distributed to VDOT's regions examining TMP development, monitoring, and performance assessment practices across the Commonwealth.
4. The research team reviewed VDOT's responses for four consecutive years to a national survey on work zone best practices.
5. Two case studies were conducted on work zones and associated TMPs in the Commonwealth.
6. Guidelines and recommendations were developed for VDOT to enhance its TMP performance assessment practices with review and assistance from an assembled VDOT TMP Performance Assessment Task Group.

2.1 LITERATURE REVIEW

A literature review identified tools and best practices for TMP development, monitoring, and performance assessment. Major areas of the literature review included pre-construction impacts analysis, safety and mobility performance measure development, monitoring and data collection strategies during construction, and post-project evaluation methods. A major guide for identifying best practices came from the FHWA's 2010 Domestic Scan of best practices in work zone data collection, monitoring, and performance assessment from across the nation *(9)*. Results of the literature review are summarized in Chapter 3.

2.2 STATE TRANSPORTATION AGENCY SURVEY

In conjunction with the results of the literature review and Domestic Scan, the research team developed a survey for other state transportation agencies. This survey explored other states' methodologies in developing and assessing work zone safety and mobility performance measures, predicting and assessing work zone impacts, monitoring and collecting data, and assessing TMP performance. This survey is included in Appendix C1. Over 30 states responded to this survey, including all fifteen featured in the FHWA's Domestic Scan. Results of this survey are discussed in Chapter 4.

2.3 VDOT DISTRICT SURVEY

Following the results of the literature review, Domestic Scan, and survey to other state transportation agencies, the research team developed a survey for the five state regions' work zone coordinators to examine the extent of VDOT's work zone policies, processes, and procedures. The survey questions again detailed methodologies in developing and assessing work zone safety and mobility performance measures, predicting and assessing work zone impacts, monitoring and collecting data, and assessing TMP performance. This survey is included in Appendix C2. The research team received responses from all five regions across the state. Results of this survey are discussed in Chapter 4.

2.4 VDOT WORK ZONE SELF-ASSESSMENT AND BEST PRACTICES

Each year, the FHWA conducts a national Work Zone Mobility and Safety Self-Assessment (WZ SA), a survey designed to assist agency work zone coordinators in assessing policies, programs, and procedures “against many of the good work zone practices in use today”. The research team obtained VDOT’s responses to the WZ SA from 2007 to 2010. The best practices featured in the WZ SA have been identified by the FHWA and are available in the *Work Zone Best Practices Guidebook (10)*. The WZ SA facilitates communication and sharing of best practices among transportation professionals *(10)*. It allows states/divisions to track their progress in work zone management and identify areas of need or improvement as well as areas of success. Relevant responses to this survey are included in Appendix C3. Results of this survey are discussed in Chapter 4.

2.5 CASE STUDIES

In conjunction with findings from literature and surveys, the research team thoroughly examined two work zones during the 2011 construction season. The research team studied each project’s TMP and pre-construction impacts assessment and met with project staff (both VDOT and contractor) to discuss traffic impacts. For each project, the research team collected volume and travel time data to gauge the extent of resources available as well as the effectiveness of the project TMP. Observations, findings, and lessons learned from these case studies were used to supplement the development of VDOT’s TMP Performance Assessment Guidelines.

The first case study explored was the Interstate 81 Full-Depth Pavement Reclamation project in Augusta County. One of two southbound lanes on the freeway was closed for five five-day periods during the height of construction work. This project featured a unique traffic control plan in which a significant portion of traffic was forced to detour off of the interstate and onto a parallel highway for several miles. The project TMP thoroughly detailed TTC, PI, and TO strategies which were used to mitigate potentially heavy delays. This case study is detailed in Chapter 5.

The second case study explored was Phase I of the Gilmerton Bridge replacement project along Military Highway (US 13/US 460) in the City of Chesapeake. While this project is not expected to be complete until 2014, the first phase of bridge replacement involved a reduction of the highway to one lane in each direction along with a suggested detour route along Interstate 64. As Military Highway and the suggested detour route were both approaching capacity even prior to construction, a pre-construction impacts analysis predicted potentially significant delays. This case study is detailed in Chapter 6.

2.6 DEVELOPMENT OF TMP PERFORMANCE ASSESSMENT GUIDELINES

The researchers assembled a list of findings and recommendations from the results of the literature review, surveys, and case studies. These findings were presented to a TMP Performance Assessment Task Group made up of various work zone personnel from the Commonwealth. The Task Group members are listed in Appendix A. The Task Group provided further guidance and recommendations as the researchers drafted a set of guidelines and forms for assessing TMP performance that VDOT can now utilize. The draft Guidelines for TMP Performance Assessment are presented in Appendix B and are considered the major deliverable from this project.

CHAPTER 3: LITERATURE REVIEW

Effective assessment of work zone impacts is not simply a post-construction process. Work zone impacts assessment is a process that occurs over the life cycle of a project and begins during project development, as noted by the Final Rule (*3)*. For large-scale and potentially disruptive projects, initial traffic impacts should be predicted and subsequent performance measures should be developed prior to construction. During construction, traffic impacts should be monitored and data should be collected to be compared to performance measures or thresholds. Finally, a post-construction assessment should tie in data showing work zone impacts and performance measures, as well as changes made, lessons learned, and applications to future work zones. A literature review was conducted exploring best practices for each of these processes. The following sections detail key sources and findings from the literature review.

3.1 NCHRP DOMESTIC SCAN: BEST PRACTICES IN WORK ZONE DATA COLLECTION, MONITORING, AND PERFORMANCE ASSESSMENT FROM ACROSS THE NATION

A major guide and source of information for this project came from the FHWA's National Cooperative Highway Research Program (NCHRP), which conducted a Domestic Scan of fifteen U.S. state transportation agencies in 2010. This Domestic Scan *(9)* provided numerous examples of best practices in the areas of work zone impacts analysis, performance measure development, data collection methodologies, and utilization of data/performance measures for improving work zone safety and mobility. The Domestic Scan also provided recommendations for state transportation agencies to improve each of these areas. Many of these best practices and recommendations, combined with other literature findings, were included as part of the research team's survey to state DOTs and VDOT districts.

3.2 PERFORMANCE MEASURE DEVELOPMENT

In order to assess the effectiveness of a TMP in regards to work zone safety and mobility, performance measures must be defined and utilized. Performance measures are "sets of defined, outcome-based conditions or response times that are used to evaluate success" *(11).* The Domestic Scan notes that agencies which "have clearly established performance measures tend to effectively track those measures and consider them through the project development process" *(9)*. Agencies use performance measures to specify what they seek to achieve, to communicate goals and objectives in a transparent way, and to document and assess the effectiveness of policies, practices, and procedures. Performance measure development should be an iterative process involving all stakeholders associated with a project or policy. Performance measures must be specific, measureable, and achievable. Performance measures for TMP assessment should focus on safety and mobility impacts to traffic in the work zone area.

3.2.1 Safety Performance Measures

Safety performance is difficult to quantify outside of actual events; that is, crashes and injuries to workers are the generally accepted measure, as well as "legitimate" complaints from users. A survey of user-perceived safety of a work zone could also be assessed but would be more difficult to quantify. Some states, such as New Hampshire, use service/fire dispatch frequency as a safety performance measure; other states, such as Oregon and New York, have quantitative work zone inspection scores that "grade" work zone safety *(9)*. The Domestic Scan notes that most safety performance measures for agencies tend to be at the agency or program level rather than the individual project level *(9)*.

The American Traffic Safety Services Association (ATSSA), associated with the FHWA, developed a *Work Zone Safety Performance Measures Guidance Booklet (11)*. ASSTA provides a sample for safety performance measure development. A 1 to 5 rating system for safety performance in terms of crashes was developed, as shown in Figure 1. A score of 5, with a work zone crash rate being 20 percent less than the pre-construction crash rate, receives the highest score of "excellent." The *performance goal* of a work zone crash rate equal to the pre-existing crash rate is rated as 4, or "good."

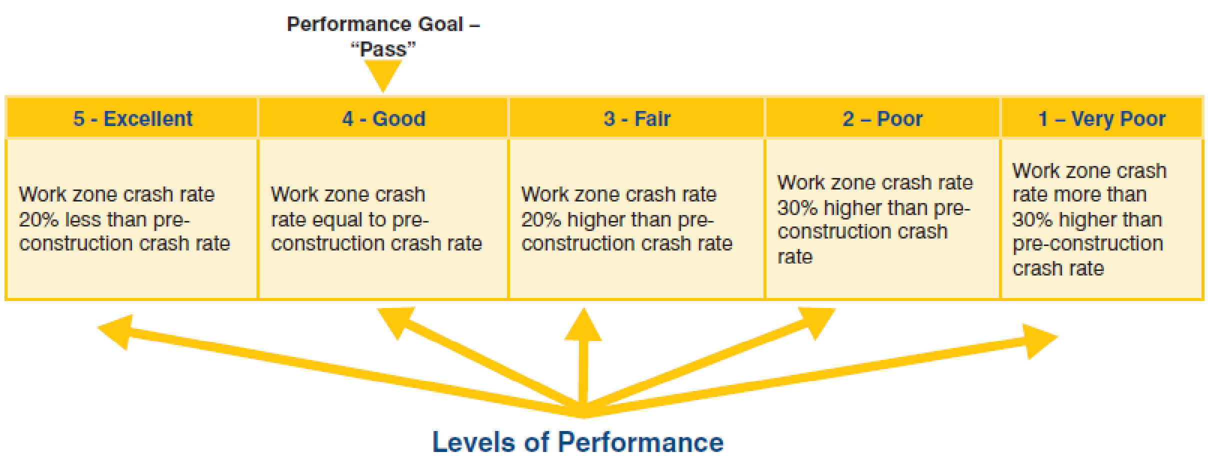


Figure 1. Example performance measure levels for crash rate *(11)*.

Depending on the duration of a project, safety can be evaluated during construction or post-construction. If a project lasts for several months, crash rate can be assessed monthly and compared to a previously measured existing crash rate (based on 3 years of crash data). Ohio DOT often uses "near real-time comparison" of crash frequencies of specific locations during projects to identifying trends, hotspots, and underlying causes *(9)*. Figure 2 displays an example of the development process for safety performance measurement by crash rate. This process allows safety performance to be assessed at the individual project level.

Performance Goal	Measure of Effectiveness	Unit of Measure	Measurement Method	Frequency and Timing	Evaluator
Work zone crash rate equal to pre-construction crash rate	Work zone crash rate	Crashes per month (other options are crashes per 100,000 VMT, crashes per 100,000 vehicles through the work zone)	Compute the average number of crashes per month for a 3-year period prior to construction. During construction, record the number of crashes for each month and compare that to the pre-construction rate.	End of each month during the construction period	State DOT Project Engineer

Figure 2. Example of safety performance measure development *(11)*.

3.2.2 Mobility Performance Measures

Mobility performance measures provide indications of how easy or difficult travel can be along a corridor or in a region *(12)*. Roadway mobility can be quantified in numerous ways through a variety of data collection techniques; the Domestic Scan suggests that mobility performance is typically measured at the project level in contrast to safety performance *(9)*. Mobility performance measures can range from being simple and easy-to-understand for everyday motorists to complex and abstract. Mobility performance measures can tell us about not only how efficiently vehicles are moving through a corridor but also how variable this movement is. Agencies must choose which measures are most reflective of a roadway's mobility, which measures are most cost-efficient and easy to collect, and which measures can best be quantified into monetary values.

Quiroga *(13)* discussed three types of mobility measures and strengths of each. The first types are *Highway Capacity Manual* (HCM) measures – computed measures derived from other data such as volume to capacity (V/C) ratio and level of service (LOS). These values can be “somewhat abstract to the traveling public” and “difficult to use for long-range planning because concepts such as capacity and speed-flow relationships change over time”. HCM measures are usually easier and more relevant for localized analyses rather than area-wide analyses.

The second type of measure, queuing-related measures, includes queue length, duration, and lane occupancy. While the authors suggest that queues can best reflect the traveling public’s perception of congestion, measuring queues can be difficult and site- and time-specific. However, the FHWA recently developed a Primer on Work Zone Performance Measurement *(14)*, which details methodologies for measuring queues or estimating queue lengths from spot speed data. Queue length measurement is important from a safety perspective as well so that drivers can be alerted to downstream congestion.

Quiroga’s preferred method of mobility performance measures are travel-time based measures, such as vehicle travel time, speed, and delay *(13)*. These are easy to understand to both professionals and the public, flexible, and applicable across modes. Travel-time measures can be applied to specific locations, corridors, or regions. Perhaps most importantly (especially to decision-makers), travel-time based measures translate easily into costs. Travel time data can be collected either through vehicle techniques such as the “floating car method” or roadside techniques using sensors. Roadside techniques are becoming more popular and preferable today, such as utilizing Bluetooth sensors that track how long it takes a vehicle to move from one sensor to the next. This data can be sold to agencies seeking to understand the mobility performance of their facilities. Inrix is one such vendor that sells travel time data to agencies; a significant amount of travel time data for links within the Commonwealth of Virginia is now available to VDOT.

3.3 PRE-CONSTRUCTION IMPACTS ANALYSIS

Traffic impacts analysis allows a transportation agency to predict impacts such as queue length and delay to users of highway facilities and develop a TMP to mitigate these impacts. This impacts analysis is used to determine the extent of lane closures, including how many lanes can be closed and for how long they can be closed. The Domestic Scan noted that it is optimal to consider work zone impacts as early in the project development process as possible. TMPs are developed from the work zone impacts assessment and should serve as a dynamic guide that can change based on the actual observed impacts during construction *(9)*. There exist a variety of tools to predict work zone impacts. Smadi and Baker *(15)* conducted a study of several traffic analysis tools examining how accurately various tools can predict work zone conditions, taking into account cost and practicality of each tool. They describe three types of analysis tools:

- Sketch planning tools provide general estimates of travel demand and operations at the project level. These tools are usually the simplest, most cost-effective, and least time-consuming. However, they lack some of the features and capabilities of more complex tools. Examples of sketch planning tools include QuickZone, QUEWZ, and CA4PRS. Sketch planning tools include spreadsheet-based queue analysis tools *(9)*, of which many states have created their own.
- Analytical tools are software programs utilizing the *Highway Capacity Manual* methodologies and formulas. These tools are best suited to isolated facilities, as their output is unable to account for network performance.
- Simulation analysis tools provide the highest levels of detail but are also the most time-consuming and costly. These tools can range from microscopic tools, such as VISSIM, Dynasim, and CORSIM, which model the dynamic and stochastic behavior of individual

vehicles, to macroscopic tools, such as Synchro, which model vehicle movements in platoons using speed/volume and demand/capacity relationships.

3.3.1 Literature pertaining to specific tools

- QuickZone was developed by the FHWA and utilizes Excel to estimate work zone delays, queue lengths, and user costs. This software allows transportation agencies and contractors to compare the effects of doing work at night versus during the day or diverting traffic to alternate routes. Effects can be estimated for durations as short as one hour or as long as the entire length of the project *(16).* Inputs are network data (nodes, links), project data (duration, phasing, capacity reduction), travel demand data (AADT, seasonal variations, TOD variations), and corridor management data (congestion mitigation strategies, resulting capacity changes). The software utilizes a simple deterministic queuing model; outputs are queue lengths, delays, travel behavior, and user costs in an Excel workbook *(15).*
- Construction Analysis for Pavement Rehabilitation Strategies (CA4PRS) supports integrated analysis of project alternatives for different pavement designs, construction logistics, and traffic operations. It is designed to help agencies and contractors develop construction schedules that minimize delay, extend service life of pavement, and reduce agency costs *(16).*
- Road User Costs (RUCs) evaluations are gaining popularity in pre-construction impacts assessment *(9).* The New Jersey Department of Transportation places a significant emphasis on RUCs; their goal is for each project to be “invisible” to the public in terms of the adverse impacts it creates. Wisconsin DOT is currently developing a process for selection of impact mitigation strategies (such as various TTC strategies) based in

comparison of RUC benefits to strategy costs. It is likely that RUCs will need to be approximately six to ten times the cost of a mitigation strategy for that strategy to be considered for implementation *(9)*.

- Aktan, Mohror, and Schnell *(17)* conducted research for Ohio DOT comparing HCM software, Synchro, CORSIM, NetSim, QUEWZ-92, and a spreadsheet developed by the agency. ODOT sought to determine the most accurate commercially available tool for modeling work zones and if these models could be calibrated to predicted accurate queue length and delay for freeway work zones. After studying four different work zones, the study found QUEWZ-92 the most optimal for estimating capacity and the ODOT spreadsheet the most optimal for estimating queue lengths (when provided with an adequate capacity estimate from QUEWZ-92). Interestingly, the study concluded that microscopic simulation tools could not be calibrated to the oversaturated conditions of work zones.
- Kaja-Mohideen, Chitturi, and Benekohal *(18)* did not find that *any* analysis tools gave a reasonable and consistent representation of observed field data. This research included a survey to state DOTs, most of which were generally unsatisfied with the analysis tools they used. The most common tools found for capacity estimation were HCM software and QUEWZ, and the most common tools for queue length and delay estimation were QUEWZ, QuickZone, and HCS.
- Smadi and Baker *(15)* examined the abilities of QuickZone, Dynasim, and VISSIM to predict network conditions for a case study involving a construction project along I-29 in Fargo, North Dakota. Wavetronix sensors were utilized to collect before- and during-construction data. The QuickZone model "took only a few hours to complete" and was

> "by far the easiest software program with which to work"; the researchers noted that the biggest drawback to the software was a limit of 100 links and 200 nodes in a network. The Dynasim model, in contrast, had approximately 3000 links and connectors; a one-hour simulation took approximately 24 hours to complete. Errors had to be re-addressed and the network had to be re-calibrated after each simulation. Both the Dynasim and VISSIM models were based off of a Synchro model; however, the Dynasim model required that the Synchro model first be imported into Cube and then exported to Dynasim. The VISSIM model could be imported directly from Synchro, but the modeling process was still quite extensive. Entire network construction, calibration, and simulation took approximately 960 hours (120 8-hour days, or approximately three months). The researchers concluded that "for large work zones with several access points such as interchanges, VISSIM would be ideal" and that microscopic simulations are preferred for conducting a thorough evaluation of work zones. Dynasim was not recommended for a large network.

Agencies should specifically define where impacts assessment fits into their project development process and scale the TMP planning effort to the level of impacts that are anticipated *(9)*.

3.4 MONITORING STRATEGIES AND DATA COLLECTION DURING CONSTRUCTION

The FHWA specifically states that "work zone performance assessment is not intended to require agencies to embark on a large data collection, storage, and analysis effort…the goal is to improve work zone safety and mobility by making effective use of the available data and information sources" *(19)*. These sources could include project logs, field observations, crash records, operations data from traffic management centers (TMCs) and ITS, enforcement, or public input. The Domestic Scan notes that "in terms of monitoring during project implementation, the activity of both safety and mobility performance measures is much more of a sampling activity at the project level, with emphasis placed on those work zones where impacts are expected to be most significant" *(9)*. Data collection techniques and equipment used should vary based on performance goals, the budget, the geometry of the work zone, and the availability of permanent data collection infrastructure. Data that is collected should be tied to performance measures, and performance measures should be developed based upon the availability of certain data.

3.4.1 Safety Data Collection

The most common source of safety data are crash reports. Crash reports are usually collected by local law enforcement; project logs can keep track of these as well *(9, 11)*. A major issue with safety data collection is the lag time between the time of a crash and when that crash data actually becomes available *(9).* Additional sources of safety data include inspection reports, service patrol calls, TMC incidents, and complaints.

Many states are committed to collecting up-to-date safety data in work zones. Ohio DOT collects crash data from major projects approximately every two weeks; agency personnel manually code police crash reports into a database to allow for near real-time safety tracking. New York State DOT has "probably the most formalized process" for collecting safety data, as all types of work zone traffic crashes and worker accident data are gathered by project staff and entered into a database for trend analyses *(9)*. When agencies such as Michigan DOT gather supplemental crash data, they use a specific form to ensure data consistency and collection quality *(7)*. More states are moving toward electronic coding of crashes *(9)*.

3.4.2 Mobility Data Collection

Sources of mobility data for work zones include both manual and electronic methods. Manual methods include visual inspection or manual sampling. Michigan DOT has a specific mobility data collection form to sample peak-period traffic *(9).* Electronic sources include detectors for speed/volume/occupancy monitoring such as loop detectors or Wavetronix radar-based data collection devices. The Domestic scan notes that manual/visual inspections remain popular as “smart” work zones can be expensive; however, New Hampshire DOT is finding value in ITS deployments and tracks a number of mobility-related measures via portable ITS devices that look like orange barrels in work zones *(9)*. These ITS “Smart Barrels” can be used to collect volume and speed data, as well as estimate queue length *(20)*. Many states also rely on TMCs to help manage work zones and track mobility impacts such as queue lengths. In areas where TMCs are not available, third-party data sources are making it easier to obtain mobility data in work zones. Private sector travel-time data can significantly expand an agency’s ability to monitor work zone mobility; however, issues exist with linking private-sector travel time links to work zone extents *(21)*. Integrating data from an archived private-sector travel time database can also require significant expertise and time. Finally, many state agencies, such as California DOT (Caltrans), the Illinois Tollway Authority, and Missouri DOT are reaching out to the general public using customer surveys to assess mobility impacts. For example, Missouri DOT has a website with a “Tracker” tool for assessing how it delivers services and products to its customers; measures include percentage of work zones meeting expectations for traffic flow and visibility and a nine-question survey for non-technical MoDOT personnel and the general public *(9)*.

3.4.3 Domestic Scan Recommendations for Data Collection

The Domestic Scan's overarching finding from successful states was that support from upper management for collecting and analyzing data is critical. The Scan notes that not all agencies explicitly address or require data/performance measurement monitoring as part of a TMP; many agencies rely on project staff (as opposed to the contractor) for monitoring impacts *(9)*. Many agencies still face challenges in connecting data collection and performance measures; that is, data availability often affects which performance measures that agency chooses to use.

Generally, agencies with solid work zone safety and mobility data management systems tend to make better use of their data. Electronic database systems are becoming more popular as a tool to quickly store and analyze data. Electronic crash data significantly speeds up the availability of safety data; for example, in Indiana, 86% of safety data is available within 5 days *(9)*. Many agencies, such as Maryland State Highway Administration (SHA) have also found development of an electronic database system to track and approve current/future lane closures very useful *(9)*.

3.5 UPDATING TMPS/WORK ZONES DURING CONSTRUCTION

Once performance measures have been established and data is collected from work zones, what are transportation agencies doing with this data in relation to the TMP and predicted work zone impacts? The Domestic Scan found specific examples of agencies that utilize safety and mobility data to identify deficiencies or gaps in their approach to project delivery and make improvements. A common way in which agencies utilize work zone mobility data is to establish acceptable times of day when one or more travel lanes can be closed for work activities. Ohio DOT makes regular changes to design standards, specifications, and other documents based on work zone data. For example, by comparing during-construction safety data with pre-construction data, agency personnel were able to locate a “problem spot” for median egress from a work zone for large vehicles and altered their standards to provide greater sight distance for these vehicles. Access to real-time data correlates to an agency’s ability to modify or update work zones in a timely manner *(9)*. At the same time, a lack of timely data prevents agencies from responding more quickly to work zone conditions.

The Domestic Scan notes that not all agencies have gone through a full policy and process review cycle as required by the Rule *(9).* Not all agencies have fully explored the availability and usefulness of data available for work zone safety and mobility improvement due to a number of reasons, such as a lack of expertise, time, and funding. While a lack of resources is an issue for many agencies, the Scan suggests that more can be done with available data. The Scan recommends that agencies constantly improve how data is analyzed and continuously improve processes and procedures *(9).*

3.6 POST-PROJECT EVALUATION

Post-construction, agencies should incorporate lessons learned for use in future projects. For example, Michigan DOT has used “pilot projects” with similar characteristics from prior projects with successfully implemented strategies. Michigan also tracks results of lane closures closely and records when predicted impacts do not correspond to actual impacts *(9).* Currently, few states conduct post-project evaluations for individual construction projects. New York State

DOT conducts regional traffic control inspections for a "representative sample" of work zones and assigns a score from 0 to 5 to various work zone traffic control components. Traffic control components scoring lower than "3" require a follow-up report to be submitted *(22).* Similarly, Illinois DOT conducts a work zone traffic control project review every other year (alternating with years to perform *process* reviews). This review involves a "random selection of projects" sampled for drive-through inspection *(23).* After both of these states conduct their regional/district work zone sample inspections, follow-up meetings are held to discuss lessons learned.

For individual projects, Illinois DOT has TMP performance assessment guidelines for safety and mobility *(23)*. A safety performance assessment is required if a fatal crash occurs within the project limits and summarizes crash information, any changes made to traffic control as a result, and/or recommendations to change IDOT's standards or policies. Mobility performance assessments are only required for significant, long-term projects. IDOT requires the Resident Engineer to submit a Work Zone TMP Summary Report summarizing TMP strategies including changes made, successes and failures, descriptions of traffic operations due to the work zone, and any recommendations for changes to IDOT standards or policies *(21)*.

The FHWA released a guide on Work Zone Impacts Assessment *(19)* designed to help transportation agencies develop and/or update their own policies, processes, and procedures for assessing and managing the work zone impacts of road projects throughout different program delivery stages. Work zone impacts assessment is a process that begins during Systems Planning but proceeds throughout the entire project. The FHWA states that this should include conducting a performance assessment to develop recommendations for improving work zone policies, processes, and procedures and incorporating work zone impacts assessment and management in maintenance and operations *(19)*.

3.7 LITERATURE REVIEW CONCLUSIONS

The literature review results emphasize that TMP performance assessment is a process that begins during project development and should be programmed to fit the project's complexity. Performance measures must be agreed upon and be able to be tied to available data. A pre-construction impacts assessment is necessary to verify actual work zone impacts. Real-time safety and mobility data can greatly aid in updating TMPs or agency policies, processes, and procedures. Data collection methodologies can be catered to fit the complexity of the project. Finally, the post-construction evaluation should tie together the observed data and performance measures as well as compare these measures to predicted impacts. Additionally, this evaluation should detail lessons learned and successes and failures as suggested by the data. The results of this literature review were used in developing surveys for state DOTs and VDOT personnel, as well as in recommendations for the newly-developed TMP Performance Assessment Guidelines.

CHAPTER 4: STATE AGENCY AND VDOT SURVEY RESPONSES

This chapter details the results of three separate surveys related to TMP monitoring and assessment, the first two of which were conducted by the research team. The results of each survey provided the research team with a better understanding of TMP-related best practices both across the country and within VDOT. The research team learned how VDOT compares to other states in TMP development, monitoring, and assessment and used these findings to develop recommendations to further improve VDOT's TMP assessment procedures.

4.1 STATE TRANSPORTATION AGENCY SURVEY RESPONSES

The research team received responses from representatives of 33 state transportation agencies, including all 15 states who participated in the Domestic Scan. Some responses were quite detailed and included attached TMP-related files for the research team to utilize; other responses were not completed fully. The following sections summarize responses to various segments of the survey. The full survey can be found in Appendix C1.

4.1.1 Safety Impacts of Work Zones

A large number of states establish safety performance measures at the agency/program level, while some establish safety performance measures at the individual project level. The Domestic Scan suggested that agency/program level safety performance measurement is much more common than agency/program level mobility performance measurement, as safety performance lends itself to an agency's overall policies and practices, not just one specific project. In addition, crash data is often not available within the time frame of a construction project. Many states also evaluate safety performance measures in addition to establishing them. The most popular safety performance measure was number of crashes; many states also used crash rate (which incorporates the number of crashes). Worker injuries, complaints, and a subjective rating of safety were also used by several states. All states who responded use crash records to collect safety data; other popular methods of collecting safety data include visual inspection/inspection reports and project logs.

4.1.2 Mobility Impacts of Work Zones

Approximately the same number of states said that they establish mobility performance measures at the agency level as states who said that they establish mobility performance measures at the individual project level (16 at the agency level; 15 at the project level). The Domestic Scan, on the other hand, suggested that mobility performance measurement was much more common at the individual project level. Some states (Michigan, Missouri, Montana, New Hampshire, Oregon, and Washington) said that they establish mobility performance measures on both levels. Four states (Michigan, Missouri, Montana, and New Hampshire) said that they establish safety and mobility performance measures on both levels. Nearly two-thirds (20) of the states who responded said that they also evaluate these mobility performance measures.

Figure 3 displays mobility performance measures preferred by agencies. There was no overwhelming consensus for the most popular mobility performance measures. The responses suggest that “maximums” may be more popular than “averages” but also suggest that there is no agreed-upon “best” mobility performance measure.

8. What types of performance measures does your agency use with regard to operational impacts of TMPs? (check all that apply)

	Response Percent	Response Count
Average queue length	36.4%	8
Maximum queue length	45.5%	10
Volume to capacity (V/C) ratio	40.9%	9
Average delay	45.5%	10
Maximum delay	**63.6%**	**14**
Travel time	40.9%	9
Subjective rating of delay/congestion	36.4%	8
	Other (please specify)	3
	answered question	**22**
	skipped question	**13**

Figure 3. Mobility performance measures used by state DOTs.

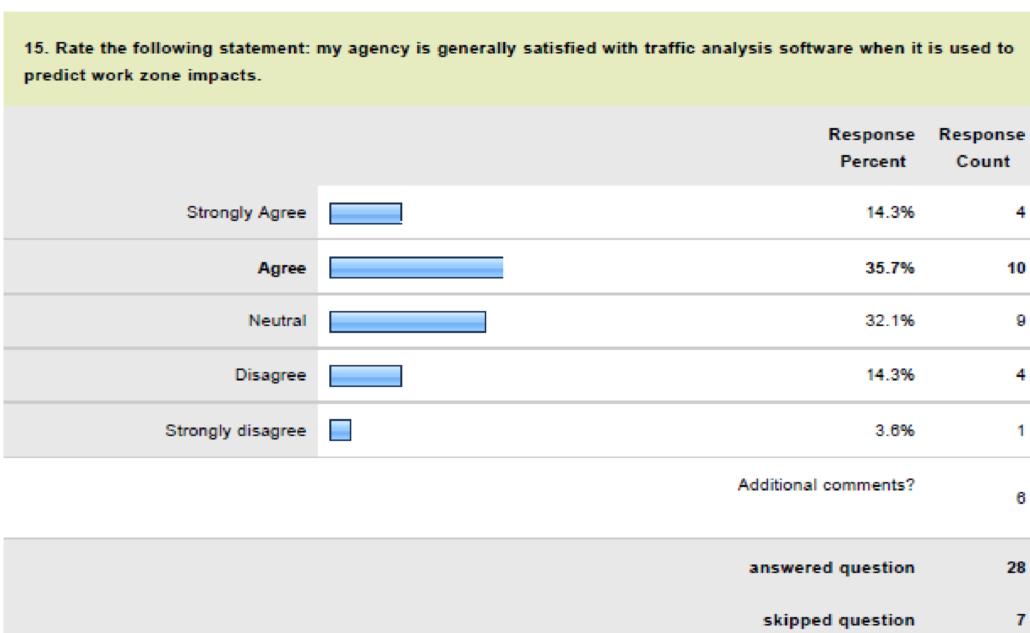
Similarly, the survey results suggested that there is no consensus as to the “best” ways to collect mobility data. Eleven states utilize project logs; 20 use field observations (all who responded); 10 use count stations; 9 use travel time data; and 4 utilize other sources such as public feedback or ITS. This is consistent with the Domestic Scan’s assertion that (manual) field observations are the most common (and, likely, the least expensive) source of work zone mobility data. Oregon DOT noted that they are just beginning to introduce “Smart Work Zone” traffic management systems to measure work zone traffic operations and report real-time information and warnings to motorists; these systems will be limited to large, long-term projects.

4.1.3 Work Zone Impacts Assessment

Nearly all states who responded utilize software tools to predict work zone impacts. Of the three states that do not, it could be that those agencies rely on lane closure/queue charts – or the respondent from that state simply may not have been familiar with software tools. Some software tools, such as *Highway Capacity Manual*-based software and spreadsheets, as well as Synchro, QuickZone, VISSIM, and CORSIM, were more popular than other tools, such as QUEWZ or Dynasim. The Domestic Scan suggested that spreadsheet tools based off of the HCM are very common; more complex simulation tools are generally used for larger, more complex projects. Most states said that the complexity of tools used depends on the complexity of the project; however, ten states said that the complexity of the project does not affect the type of impacts assessment tool used.

Similar to mobility performance measure responses, there was no overwhelming consensus among state agencies in regards to which software-produced measures were most important for assessing work zone impacts. Results were fairly evenly split over travel times/delays and average/maximum queue lengths.

The final question in this section asked states to rate how satisfied they are with their work zone impacts assessment tools. Figure 4 displays states' responses.



15. Rate the following statement: my agency is generally satisfied with traffic analysis software when it is used to predict work zone impacts.

	Response Percent	Response Count
Strongly Agree	14.3%	4
Agree	**35.7%**	**10**
Neutral	32.1%	9
Disagree	14.3%	4
Strongly disagree	3.6%	1
	Additional comments?	6
	answered question	**28**
	skipped question	**7**

Figure 4. Agency satisfaction with software tools for predicting work zone impacts.

Agencies were allowed to make comments in response to this question. One state noted that their "current software is inaccurate, difficult, and time-consuming to use…training seems to be unavailable." That state developed their own sketch planning spreadsheets. Some states noted that they were generally satisfied with results but have seen over-estimates of queues and road user costs, especially from QUEWZ. One state commented that their issue with software tools was "gaining consistency statewide with our designers using the software." Oregon DOT, who utilize their own web-based software known as the Work Zone Traffic Analysis (WZTA) Tool as opposed to the software tools we listed, was one of the few states who "strongly agreed" that they are satisfied with their traffic analysis software. They noted that a recent study of their software's benefit-cost ratio suggested a ratio of 9.31:1 over five years (dollars spent in development/maintenance/operation versus savings related to reduced delay).

4.1.4 Monitoring Work Zones

More than one-third of states surveyed stated that they check field conditions against software-predicted impacts; more than one-third of states surveyed said that they check field conditions against predefined performance thresholds. Four states (Michigan, Missouri, New Mexico, and Oregon) said that they do both. More than half of states that collect data said that the data are used to update and revise TMPs during construction. Slightly more than half of states said that data collected during construction is also used to update agency policies and procedures post-construction.

4.1.5 Work Zone Information Dissemination

In regards to tools used to disseminate information to motorists and agency personnel about work zone conditions, nearly all states mentioned 511 systems and/or changeable message signs. Many also mentioned press releases, social media such as Twitter, web sites, and media outlets such as TV and radio stations.

States were asked whether they assess the effectiveness of their public awareness/motorist information strategies; nearly two-thirds said that they do not. This could be due to a lack of methodology to assess PI strategies. Of states that said they do assess public information strategies, explanations included observing if the public adjusted driving routes or public outreach surveys. Texas DOT mentioned that districts are asked to review TTC, TO, and PI strategies annually in a post-project review and forward results to Traffic Operations Division. They noted that there are “no formal performance measures” but rather input on strengths and weaknesses of strategies used.

4.1.6 Additional Questions

States were asked what their biggest barriers to sound post-construction work zone impacts assessment were. A lack of personnel (manpower) was an overwhelming response from states as to why post-construction assessment of work zone strategies and impacts is not completed more thoroughly. Data and funding were also common responses. A few states noted an issue of consistency; that is, states have not established methods or performance measures for post-construction assessment.

Finally, states were asked if their agency currently has guidelines for assessing TMP performance. Nineteen states said they had some sort of guidelines for assessing TMP performance, while 11 said that they do not. The extent of these guidelines varies. Some mentioned that their guidelines are limited or in their infancy, such as a process review every 2 years. One state mentioned that they had a policy but extremely limited manpower to do the work. New York State has developed a work zone inspection program which has been modified and updated over the years. They stated that "the most successful method is having an extremely experienced design/review team that fulfills the function on ALL regional projects." NYSDOT has a fairly rigorous post-construction inspection report form which "grades" a project. NYSDOT, Wisconsin, and Illinois were kind enough to send us their TMP policies.

Wisconsin's TMP policy describes a process for assessing the "quality, performance, and effectiveness of the TMP in achieving project objectives," stressing that TMP strategies need to be linked to performance measures. Performance measures can vary for different projects, and new measures may need to be developed to evaluate the effectiveness of new strategies. Performance data should be documented in a post-construction report containing the following:

- an overall statement reflecting the usefulness of the TMP
- changes made to correct oversights in the TMP
- changes made to the original TMP and how successful those changes were
- public reaction to the TMP (i.e. using surveys)
- average delay time, queue length, etc., during construction
- frequency and nature of complaints as well as how these complaints were resolved
- crashes/incidents during construction and how they were resolved
- recommendations or suggestions for future projects
- highlights of the most successful areas of the TMP

This language is very similar to the language described in Chapter 1 from VDOT's TMP policy *(8)*. While these requirements are stipulated in department policy, the research team is unsure to what extent reports detailing these requirements are produced following significant projects. The most thorough post-construction report from another state was provided by the California DOT (Caltrans) for a project involving the closure of two lanes on a major freeway in Los Angeles County *(24)*. This report summarized TMP strategies used such as message signs and detours; the report goes on to evaluate the effectiveness of the TMP using travel time and volume data for both the mainline and detour routes. Caltrans provided a list of "lessons learned" at the end of the report for future TMP development.

4.1.7 Research Team's Assessment

The results of this survey correlate closely to the Domestic Scan findings, as expected. Some states are much further along in their TMP Policy efforts than others. Some states acknowledge a lack of manpower, resources, or funding to more efficiently predict, monitor, and assess work zone impacts; other states have developed innovative strategies to do so with which they are quite happy. Several states provided us with their TMP policies, including sample TMPs and TMP evaluation forms. These policies and reports, along with the overall survey findings, were taken into consideration to help develop the guidelines provided at the conclusion of this report.

4.2 VDOT REGIONAL WORK ZONE COORDINATOR SURVEY RESPONSES

Following the survey to state transportation agencies across the country, the research team developed a similar survey for VDOT work zone coordinators. The research team received four responses each from Northern Virginia (NOVA) and Northwest Region, two responses from Central Region, and one response each from Southeast Region and Southwest Region. The following sections summarize results from the survey to regional work zone coordinators.

4.2.1 Performance Measures

All respondents used number of crashes as a safety performance measure. Number of complaints, worker injuries, a subjective rating of safety, and SSP/police response time were also mentioned as safety performance measures. The most commonly cited mobility performance measures (in decreasing order) were travel times and maximum queue length, average queue length and average delay, and maximum delay and volume to capacity ratio. Other cited measures include a subjective rating of congestion, incident clearance time, and bicycle/pedestrian mobility during closures. As expected, the safety and mobility performance measures used by various VDOT districts are overwhelmingly “highly dependent” upon available data according to those surveyed.

4.2.2 Work Zone Impacts Assessment

VDOT personnel, including inspectors, traffic engineering, and work zone personnel, are all part of the responsible parties for work zone impacts assessment in all districts. Multiple regions also stated that the contractor has some responsibilities as well. To assess and/or predict work zone impacts prior to construction, multiple respondents utilize the VDOT Allowable

Work Hours Tool developed by VCTIR. Hourly traffic volumes (seasonal adjusted AADT or pre-construction counts), geometry and driving patterns, traffic mix, and accident data were also cited as data used to predict impacts.

Tools used to predict impacts varied among regions. Three respondents said that they have and use spreadsheet tools to predict impacts. Four respondents said that they have and use software tools to predict impacts. Figure 5 displays which software tools are most popular among the respondents.

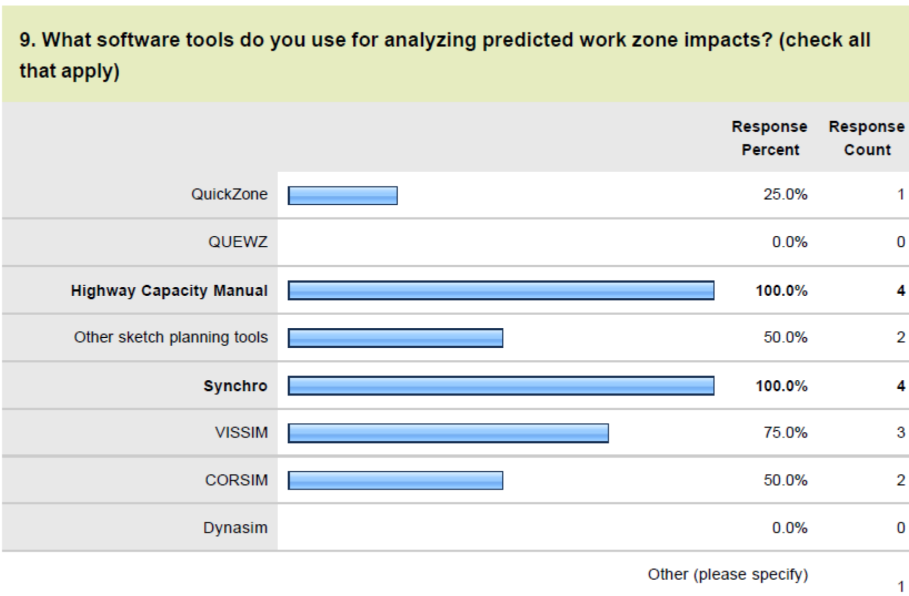


Figure 5. VDOT work zone coordinators' preferences for work zone software tools.

4.2.3 Other Pre-Construction Information

The research team also asked regions about various usages of Domestic Scan-recommended best practices prior to construction. Regions were asked whether they ever incorporated performance measures into contract language (i.e. using performance-based specifications as opposed to method-based specifications); four responded with "yes". Regions were also asked whether or not they incorporated Road User Cost (RUC) information into agency cost analyses; five respondents stated that they do. One respondent explained that RUC information is used to set incentives/disincentives when applicable and needed to complete a critical phase of work where traffic is most impacted.

Regions were asked about maintenance-of-traffic (MOT) alternatives analysis prior to construction. Five respondents said that they do compare traffic alternatives during project development. One respondent commented that for Megaprojects, a formal alternatives analysis occurs only on major short-term or long-term closures. Regions were also asked about another popular practice: lane closure charts. Five respondents said that they use a permitted lane closure chart.

The Domestic Scan also recommends that certain practices be avoided. One of these is lane rental provisions, in which a contractor can pay additional fees to close lanes during normally-non-permitted time periods even if adverse impacts to traffic are anticipated. Only one of seven respondents said that their region/district said that they allow for lane rental provisions.

4.2.4 Data Collection and Monitoring

Three regions stated that they require work zone performance monitoring in TMPs. When asked who was responsible for monitoring work zones, answers varied. One respondent stated that VDOT specifications require a designated work zone safety person on contractor staff. Another respondent stated that “contractors are expected to, but don’t do a very good job, so we end up doing it.” Multiple responses listed VDOT staff or inspectors, which could be an outside consultant.

For sources of safety data, all respondents stated that field observations were used. Police crash reports, customer surveys/complaints, crash reports from work zone personnel, and fire/rescue dispatch frequency were also cited. There was no overwhelming source of mobility data. TMCs were the most popular response, followed by travel time data and count stations; project logs were also used by two respondents. Five respondents said they monitor travel time or queue lengths in the field and compare them to predicted impacts; four respondents said they monitor travel time or queue lengths in the field and compare them to predefined performance thresholds.

In regards to best practices recommended by the *Domestic Scan*, five respondents said that they do have some access to real-time work zone data. This data comes from cameras and data accessed by the Traffic Operations Center. Three respondents stated that they utilize electronic data collection. This data includes traffic volumes (on some major projects) and speeds. Only two respondents (Central, NOVA) stated that they have an electronic system for entering crashes. Three regions stated that they have database management systems for lane closures and traffic performance ("511, Virginia Traffic and Traveler Information Database"). Two also stated that they have a crash analysis database. Three respondents said that they use customer surveys for assessing work zones. These can take the form of "customer awareness surveys." TMCs seem to play a major role in work zone monitoring. TMCs use cameras to monitor congestion (where they are available) and coordinate/report lane closures. TMCs also coordinate Highway Advisory Radio and Safety Service Patrol.

4.2.5 Updating/Revising TMPs and Agency Policies

Regions were asked whether they use monitoring/performance results to make changes to TMPs during construction. Four respondents said that they do. For example, based on traffic monitoring, a location adjustment was made to a merge taper and sign spacing for a project along I-295 southbound over I-64. In Northern Virginia, "constant changes to traffic operations" are made “to optimize traffic flow while maintaining safety for all modes of travel”; this occurs around the I-495 HOT Lanes, the Dulles Rail Metro project, BRAC, and the I-95 4th lane widening.

When asked if they use performance results to make changes to work zone policies, three respondents said “yes.” Changes could include hours of operation, acceptable configurations, and coordination between projects. When asked if they use performance results to make changes to design standards, only one respondent said “yes”; this referred to changing sign spacing due to roadway geometry. One respondent stated that this is not a district responsibility but rather a headquarters responsibility. When asked if they used performance results to make changes to values for capacity used in analysis, three respondents said “yes.” One example mentioned was multiple-lane ramp lane closure time. Another respondent referred to the I-495 HOT Lanes project, in which the highly congested and dynamic environment is constantly having data collected on it so that staff “has a better understanding of the capacity to move traffic.”

4.2.6 Additional Input

The final question to VDOT regions asked what their biggest barriers or constraints to doing more with work zone data were. A lack of personnel was mentioned by multiple respondents. One respondent mentioned limited real-time data or non-user-friendly data. Respondents from Northern Virginia mentioned that available right-of-way on an over-capacity system and finances also constrain the ability to collect more data.

4.2.7 Research Team's Assessment

While eleven respondents "started" the survey, only around six seem to have responded to most of the questions. This is a very small sample size of VDOT personnel, and it is unknown whether the responses of these personnel are reflecting the general practices of their entire district/region or simply their specific experiences. All five regions are accounted for in these six respondents. Table 1 summarizes best practices targeted in this survey and the number of respondents from within VDOT who stated that they had used or were familiar with each practice.

Table 1. VDOT usage of work zone "best practices" from survey results.

Practice	# Respondents
Performance-based specs for contracts	4
Incorporating Road User Costs (RUCs) into agency cost analyses	5
Comparing maintenance-of-traffic alternatives during project development	5
Permitted lane closure charts	5
Requiring work zone performance monitoring in TMPs	3
Comparing mobility data to predicted impacts	5
Comparing mobility data to predefined performance thresholds	4
Electronic data collection	3
Electronic crash entry database	2
Electronic lane closure database	3
Customer surveys for assessing work zones	3
Using monitoring/performance results to make changes to TMP during construction	4
Using performance results to make changes to work zone policies	3
Using performance results to make changes to design standards	1
Using performance results to make changes to values for capacity used in analysis	3

Many of the responses seemed to reflect the unique nature of each construction project – different constraints and resources exist for individual highway construction projects. Some projects are not impactful enough to require extensive procedures or manpower to develop and monitor the TMP; other projects require significant data collection efforts and technologies to soundly monitor the TMP.

It appears that VDOT utilizes many of the recommended "best practices" set forth in the Domestic Scan, at least for select projects. These practices include heavy TMC involvement, incorporation of Road User Costs (RUCs) into agency cost analyses, and use of database management systems including electronic crash entry. Multiple regions have also used data collected from projects to update TMPs, change design standards or agency policies, or update values used in capacity analysis to better understand traffic flow through work zones.

4.3 VDOT CENTRAL OFFICE WORK ZONE SELF-ASSESSMENT (WZ SA) RESPONSES

The 2010 Work Zone Self-Assessment (WZ SA) survey *(10)* contained 46 questions designed to assist those with work zone management responsibilities in assessing their programs, policies, and procedures against many of the best work zone practices in use today. Each question is rated on a scale of 0 to 15; a score of 7 or greater indicates that a state is implementing/executing the item in question. 52 agencies (divisions or states) were surveyed in 2010. Table 2 documents VDOT's responses over the course of 2007 to 2010 for questions deemed most relevant to this project by the research team. VDOT Central Office's comments relating to each question can be found in Appendix C3. By 2010, VDOT generally rated itself as performing higher than the national average in WZ SA questions relating to TMP development, monitoring, or performance assessment. While VDOT is performing many best practices suggested by the FHWA and rates itself as performing above average nationally, assistance is still needed to formalize a process for assessing individual project TMPs.

Table 2. VDOT Responses to Select WZ SA Questions, 2007-2010

Section	WZ SA Item #	Question	National Average Score (2010)	VDOT Self-Scores			
				2007	2008	2009	2010
Leadership and Policy	4.1.2	Has the agency established strategic goals specifically to reduce congestion and delays in work zones?	9.1	7	8	9	10
	4.1.3	Has the agency established strategic goals specifically to reduce crashes in work zones?	9.8	14	14	14	14
	4.1.4	Has the agency established measures (e.g. vehicle throughput or queue length) to track work zone congestion and delay?	7.9	9	9	9	10
	4.1.5	Has the agency established measures (e.g. crash rates) to track work zone crashes?	10.6	14	14	14	14
	4.1.6	Has the agency established a policy for the development of TMPs to reduce work zone congestion and crashes?	11.2	9	10	11	13
	4.1.7	Has the agency established work zone performance guidance that addresses maximum queue lengths, the number of open lanes, maximum travel delay, etc.?	10.1	9	9	9	11
Project Planning and Programming	4.2.1	Does the agency's planning process actively use analytical traffic modeling programs to determine the impact of future type I and II road construction and maintenance activities on network performance?	8.5	7	8	8	9
	4.2.2	Does the agency's planning process include developing alternative network options (e.g. frontage roads, increased capacity on parallel arterials, beltways, or strategically placed connectors) to maintain traffic volumes during future road construction and maintance?	8.4	11	11	11	11
Project Design	4.3.1	Does the agency have a process to estimate road user costs and use them to evaluate and select project strategies (full closure, night work, traffic management alternatives, detours, etc.) for type I and II projects?	10.7	5	6	7	10
	4.3.2	Does the agency develop a TMP that addresses all operational impacts focused on project congestion for type I and II projects?	10.9	8	10	11	12
	4.3.12	When developing the Traffic Control Plan for a project, does the agency use computer modeling to assess Traffic Control Plan impacts on traffic flow characteristics such as speed, delay, and capacity for type I and II projects?	9.6	8	9	10	12

Section	WZ SA Item #	Question	National Average Score (2010)	VDOT Self-Scores			
				2007	2008	2009	2010
Communications and Education	4.5.4	During type I, II, and III project construction, does the agency use a public information plan that provides specific and timely project information to the traveling public through a variety of outreach techniques (e.g. agency website, newsletters, public meetings, radio, and other media outlets)?	13.2	15	15	15	15
	4.5.5	During type I, II, and III projects, does the agency use ITS technologies to collect and disseminate information to motorists and agency personnel on work zone conditions?	10.9	8	8	8	9
Program Evaluation	4.6.1	Does the agency collect data to track work zone congestion and delay performance in accordance with agency-established measures? (see 4.1.4)	6.3	5	7	8	9
	4.6.2	Does the agency collect data to track work zone safety performance in accordance with agency-established measures? (see 4.1.5)	9.1	12	12	13	13
	4.6.3	Does the agency conduct customer surveys to evaluate work zone traffic management practices and policies on a statewide/area-wide basis?	6.3	12	13	13	13
	4.6.4	Does the agency develop strategies to improve work zone performance based on work zone performance data and customer surveys?	7.3	14	14	14	15

CHAPTER 5: CASE STUDY I – INTERSTATE 81 SOUTHBOUND PAVEMENT RECLAMATION PROJECT, AUGUSTA COUNTY

The research team thoroughly studied a Category II construction project on a rural interstate in western Virginia during the 2011 construction season. This report presents findings from this study relating to the development, monitoring, and assessment of the project's TMP.

5.1 BACKGROUND

Interstate 81 is a vital U.S. freeway corridor connecting major destinations in the south to the northeast while circumventing major metropolitan areas. The highway is two lanes in each direction for much of its length and, being mostly rural, it is heavily used as a trucking corridor, often as a bypass of the busier Interstate 95. Like many rural interstates, I-81 was built parallel to previously existing U.S. and state highways. In the spring and summer of 2011, VDOT rehabilitated a 3.7 mile, two-lane section of I-81 southbound in Augusta County (just south of the City of Staunton) between Exits 217 and 213. At the project location, I-81 SB carries an average of 21,000 vehicles per day (vpd), of which approximately 30 percent are heavy trucks.

This section of pavement along I-81 SB had deteriorated due to age and heavy truck traffic to the point where the aggregate and soil base was no longer stable. While this issue could be temporarily rectified through milling and re-paving of the surface layer, the underlying conditions would remain. Therefore, VDOT chose to reconstruct this section of roadway to its foundation in the right lane (due to more extensive damage from truck usage) and to its secondary asphalt layer in the left lane. In order to efficiently complete these reconstruction efforts, a TMP was developed to complete a significant portion of the project over five continuous lane closure periods. VDOT and the contractor developed a unique traffic control plan in which one lane of I-81 southbound would be closed 24 hours a day, with the right lane of traffic being detoured to a parallel highway for approximately four miles.

5.2 PROJECT TMP

VDOT Northwestern Regional Operations (NWRO) developed a TMP for the project in conjunction with VDOT's IIM-241, the Virginia Work Area Protection Manual (WAPM) *(26)*, and the MUTCD *(6)*. The project involved the closure of one of two southbound lanes along I-81 between MM 217.66 and MM 214.00 and a subsequent detouring of some traffic onto parallel US 11. This work zone was essentially located between two exits – Exit 217 (SR 654) and Exit 213 (US 11). A map of the work zone area is displayed in Figure 6.

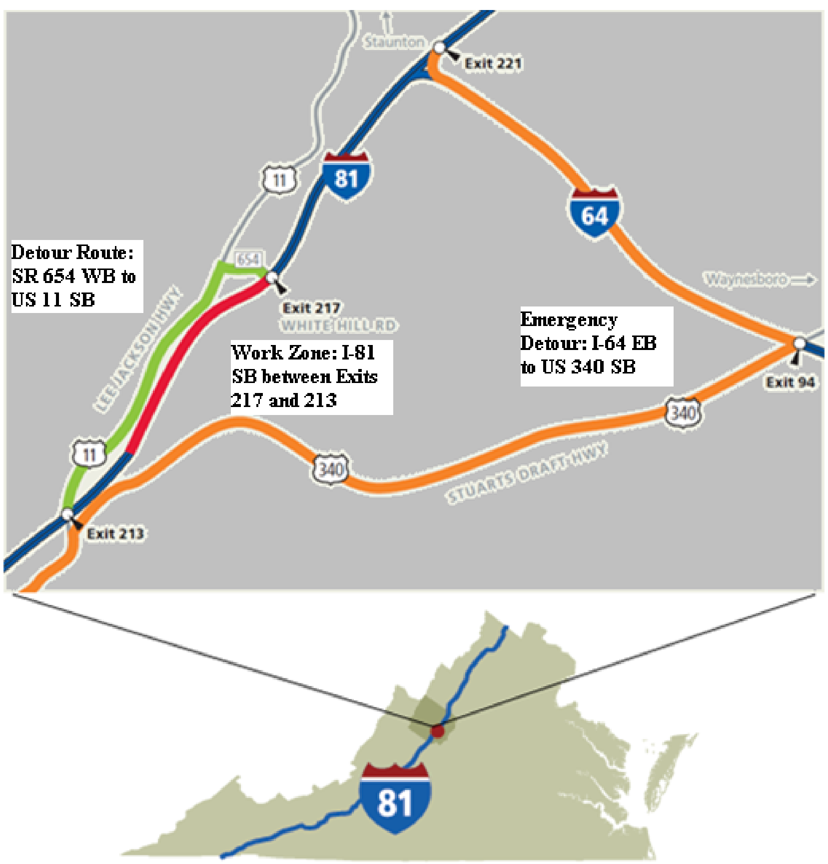


Figure 6. I-81 SB Pavement Reclamation work zone area.

5.2.1 Temporary Traffic Control Strategies

During construction, I-81 SB was reduced from two lanes to one lane between Exits 217 and 213; these closures occurred five times over a two-month period and were continuous from 9 P.M. on Friday to 7 A.M. the following Thursday. NWRO, in conjunction with the contractor, developed a unique traffic control plan to mitigate adverse impacts to travelers through the use of a forced detour onto US 11 SB, a parallel two-lane undivided primary route. US 11 SB carries an average of 3,300 vpd and is located approximately one-half mile west of the work zone. It connects to I-81 at Exit 217 via Virginia Secondary Route 654 and intersects with I-81 at the south end of the work zone at Exit 213. Along I-81 SB upstream of the work zone, vehicles in the right lane were diverted off of the interstate at Exit 217 and followed signage and flaggers first westbound along SR 654 and then southbound along US 11 before rejoining the traffic stream to I-81 SB at Exit 213. Vehicles in the left lane of I-81 SB upstream of the work zone stayed on I-81 SB along the one open lane through the work zone. Because there is no documented experience with this detour strategy, various improvisations used had to be carefully observed in case unexpected problems arose and modifications were necessary.

Upstream of the work zone, VDOT and the contractor provided limited warning of the right lane detour. This was done intentionally to alleviate late-merge conflicts at the start of the work zone. Upstream trucks were directed to utilize the left lane to stay on I-81 SB; during peak volume periods, cars were directed to utilize the right lane. As vehicles approached the work zone, Type II channelizing devices divided the highway, forcing vehicles in the right lane onto the off-ramp for Exit 217. The channelizing devices were placed far enough upstream of the exit that many motorists may not have realized right away that they were being detoured. Figure 7 shows the lane split at the start of the work zone. Flaggers and signs at the top of the ramp directed diverting vehicles to turn right onto SR 654. Figure 8 shows flaggers and signage directing vehicles at this turn. After approximately half a mile, flaggers and signs again directed diverting vehicles to turn left onto US 11 SB, which vehicles could follow for approximately four miles back to I-81 at Exit 213.

Figure 7. Lane split along I-81 at start of work zone (Exit 217).

Figure 8. Flaggers and signage directing traffic along I-81 detour route.

NWRO also developed an emergency detour route. This route was only recommended if queues extended at least 3 miles to Exit 220 (see Figure 6). I-81 SB traffic north of the I-64 interchange (Exit 221) would be directed to use I-64 east to Exit 94 and then proceed south along US 340 to meet with US 11 and I-81 at Exit 213. This detour was approximately 21 miles in length; in comparison to traveling along I-81 SB, it would add approximately 13 miles in distance.

5.2.2 Public Outreach Strategies

VDOT underwent an extensive public outreach effort to inform stakeholders, travelers, truckers, and the general public about the project. These efforts included:

- A project website featuring detour maps and traffic alerts

- Radio notices as far north as Harrisburg, PA, as far south as Roanoke, and as far east as Richmond
- Meetings and presentations at a local high school
- Meetings with emergency responders and law enforcement
- Weekly media briefings
- Letters to local citizens, General Assembly members, “the tourism community”, the Virginia Truckers Association, area chambers of commerce, local government officials, and the I-81 Corridor Coalition

5.2.3 Traffic Operations Strategies

Several tools and strategies to actively manage traffic were described in the TMP. These included changeable message signs, cameras, CB Wizards to inform truckers of the work zone, and an advance warning vehicle placed upstream of queues. The message signs would change based upon the level of queuing taking place in and around the work zone.

5.3 PRE-CONSTRUCTION IMPACTS ANALYSIS

VDOT Central Office Traffic Engineering Division (TED), at NWRO’s request, developed a microscopic simulation of the I-81 and US 11 corridors using the VISSIM traffic simulation software. The purpose of this effort was to identify the queues and extent of traffic congestion resulting from the closure of one of the two lanes along I-81 SB and subsequent forced detour of some vehicles onto US 11. The study area for the model included I-81 from north of Exit 225 to south of Exit 213 with all interchanges between those locations included. The study area also included US 11 from north of VA 262 to south of its interchange with I-81 at

Exit 213; it also modeled VA 262 between I-81 at Exit 220 and US 11. A map of the VISSIM study area is shown in Figure 9.

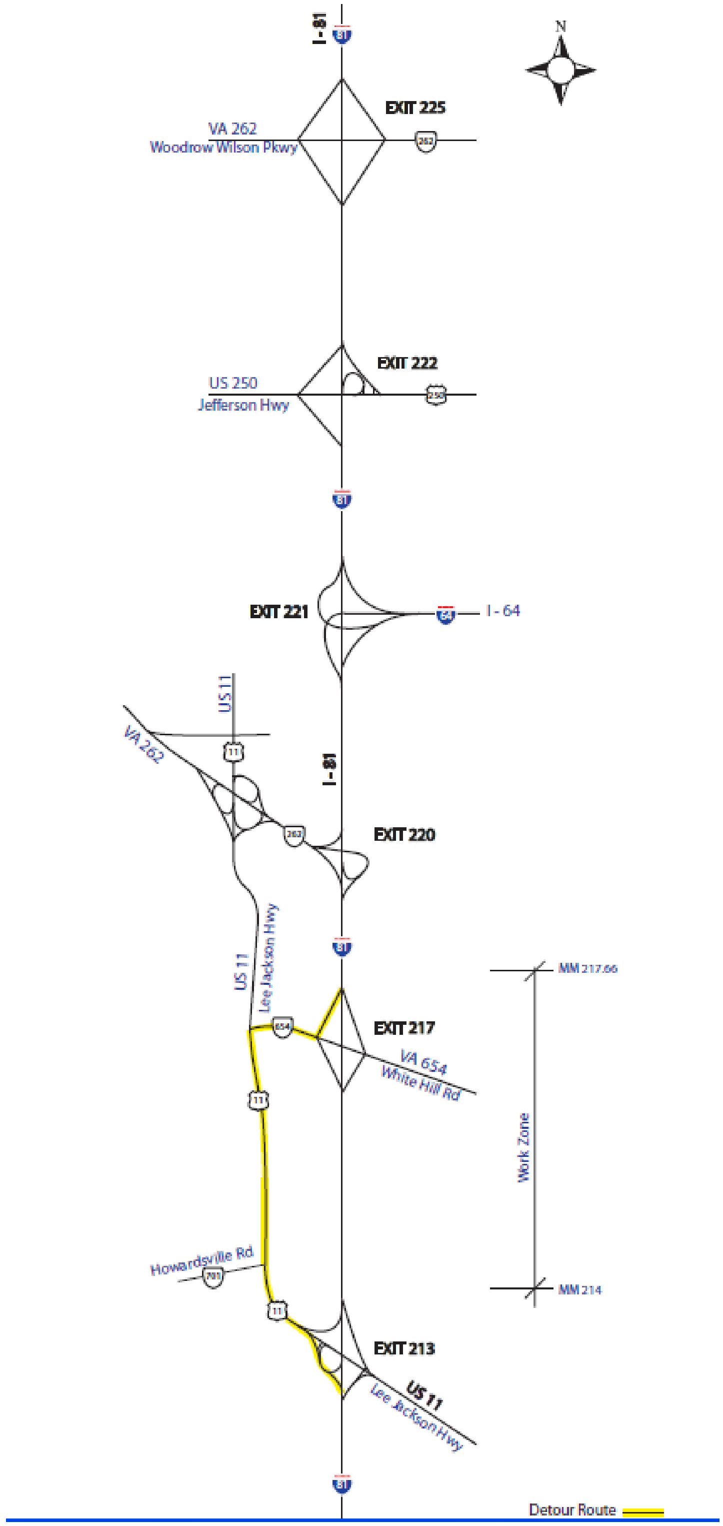


Figure 9. I-81 Pavement Reclamation VISSIM model study area.

5.3.1 Existing Conditions

From the analysis document provided by TED, "[e]xisting roadway conditions used in the model include speed limits, number of travel lanes, lane widths, ramp configuration, stop control and signal control locations, and stop bar locations." I-81 traffic characteristics were based off of traffic volume and speed data from permanent continuous count stations along I-81 and I-64. These continuous count stations also provided heavy vehicle percentages used in the model. Traffic volumes for interchange ramps and local arterials were determined from various sources, including historic 48-hour counts and turning movement counts at intersections during peak hours as well as a recent environmental impact statement for the I-81 corridor. The Existing Conditions model was verified by comparing existing count data with the model output volume data at certain locations between interchanges along I-81, averaged across five runs. The model output volumes were deemed acceptable as they were all within 10 percent of the input count volumes.

5.3.2 Predicted Work Zone Impacts

In modeling the work zone lane closure, TED built several assumptions into the VISSIM model. As Staunton District Public Affairs was to provide information to the local media in regards to the lane closure and a request for local traffic to avoid using I-81, TED assumed less traffic would travel along I-81 between 6 A.M. and midnight. This traffic was assumed to divert onto local roads such as US 250, VA 262, and US 11. Perhaps the model's most interesting assumption was that only 10 percent of I-81 southbound traffic would use the posted detour at Exit 217; this assumed that no trucks would divert and some passenger vehicles would choose to move to the left lane as well. Using a work zone speed limit of 55 mph through the work zone, the model assumed a desired speed of 50 mph for heavy vehicles in the work zone. The model also assumed a desired speed change for all vehicles from 65 mph to 60 mph between Exit 220 and Exit 217 in advance of the work zone.

TED simulated five runs of both the Existing Conditions and Work Zone models, averaging results for maximum queue length and average travel times for select locations on an hourly basis. Maximum queue lengths along I-81 were measured from a location approximately 2,700 feet north of Exit 217 where the double solid white line separating lanes begins. This assumed that queues were likely to begin forming here, as vehicles would merge into one lane to avoid exiting. Queue lengths were also estimated for the I-81 SB Exit 217 ramp and SR 654 approaching US 11 to make sure that both of these queues would not exceed 900 feet.

The maximum queue length along I-81 was predicted to be only 1,000 feet during the peak hour from 4 P.M. to 5 P.M. According to TED, "this queue is much shorter than what was originally expected…however, a closer look at the hourly volumes on I-81 SB in this area adds some validity to the model results." The peak hourly volumes, which range from 1,460 to 1,640 vph (both lanes), are not much greater than the 2010 *Highway Capacity Manual* volume of 1,300 pc/h/ln at which flow rate begins to affect average passenger car speeds *(25).* The HCM states that "the point at which an increase in flow rate begins to affect the average passenger car speed varies from 1,300 to 1,750 pc/h/ln" *(25)*. Along exit ramps, maximum queues did not exceed 900 feet, the value at which flaggers were instructed to not allow queues to reach.

Average travel times were compared along I-81 SB from north of Exit 225 to south of Exit 213 – a distance of 14.2 miles that includes the work area. The work zone was predicted to cause a maximum delay of 139 s, or just over 2 minutes, for a segment that, at base conditions, takes 796 s, or slightly more than 13 minutes, to traverse normally. This delay was attributed to the assigned drop in speed limit in the work zone area to 55 mph and the single lane of vehicles going through the work zone. If vehicles utilized the detour during the peak hour, they were delayed 215 s, or approximately 3 and a half minutes. This suggested that the detour would take longer than traversing through the entirety of the work zone. TED acknowledged that the beginning of the detour was at nearly the same location as where the bottleneck was predicted to end, and through traffic would experience the same decreases in speed and potential backups prior to the detour route. Thus, vehicles detouring from I-81 were predicted to be doing so after already passing the work zone bottleneck, simply forcing them to travel a greater distance at lower speed limits. This suggested that the detour may not even be necessary – or that vehicles should instead be directed to detour upstream of the work zone at Exit 220, where they could access US 11 via VA 262.

TED also acknowledged a potential concern that was not addressed in the VISSIM work zone model. The TMP does not state that motorists will be notified that the "right lane must exit" until reaching Exit 217. This lack of an advance warning of a lane change "could result in significantly longer queues than the model indicates," TED acknowledged. In the VISSIM model, vehicles begin to change lanes from the right lane to the left lane well in advance of the lane drop, resulting in less queuing from fewer vehicles slowing down.

TED ran a slightly revised analysis using VISSIM following concerns about some of the original model's assumptions. This new model adjusted the capacity of the work zone to 1,550 vphpl by adjusting both the link's speed and driving behavior. It also adjusted for seasonal AADT variations, which can range from 18,000 vpd in March to 22,000 vpd in July. Adjusting only for capacity, the maximum queue length increased from 1,000 to 1,330 feet. Adjusting for seasonal volumes, however, resulted in a maximum queue length of 14,127 feet – nearly 3 miles, which could prompt signage for the emergency detour route along I-64 and US 340. Travel times for the 14.2 mile stretch of I-81 increased to a maximum of 2144 s (using the detour), or nearly 36 minutes when seasonal AADT adjustments were made. These results suggested that work should not be scheduled for the summer months, when I-81 sees its highest volumes.

5.3.3 Summary of notable predictions and concerns from the pre-construction impacts analysis

- TED's during-construction model assumed less local traffic along I-81 during construction – some of which is diverted to US 11.
- The model assumed that only 10% of SB traffic along I-81 utilizes the detour (and only during the day).
- The original work zone model predicted a maximum queue length of only 1,000 feet, with queues ending at the start of the detour. The detour route was predicted to have longer travel times in comparison to vehicles which simply stay on I-81.
- The late notification of the lane change (according to the TMP) could potentially create much longer queues; this late notification was not modeled in VISSIM.
- The detour route may not even be necessary according to TED predictions.
- A revised version of the model suggests that seasonal AADT adjustments could significantly worsen queues.

5.4 NOTABLE ISSUES WITH THE TMP

The research team observed a few questions and concerns with the TMP. As mentioned, the TMP appeared to set up message signs in advance of the work zone that give no warning of vehicles from the right lane being forced off the interstate onto the detour route. There was also less than a mile of advance notice for trucks to move into the left lane; in addition, solid double-white lines began within 1,500 feet of this notice. There was concern that this advance notice, coupled with the TED prediction that not all vehicles in the right lane would be willing to utilize the detour, would lead to a significant amount of last-minute lane changing. This was hypothesized to potentially lead to more braking in advance of the work zone and longer queues, as well as perhaps causing potential safety issues.

The TMP mentioned a setup of traffic cameras along I-81 for incident management, monitoring of traffic queues, and verification of potential impacts. However, a noticeable gap existed in camera positioning between a camera at Exit 217 and a camera at Exit 221. This four-mile gap was the area in which queues would be expected to form, as the SB work zone begins at MM 217.66. If no additional cameras were positioned between these two, there was question as to whether detection of queues along this stretch would be compromised.

Overall, however, the project TMP and pre-construction impacts analysis were thorough, detailed, and complete, especially for a Type II project. The TMP was provided in a Word document providing project background and then detailing TTC, PI, and TO strategies. The TMP references the pre-construction impacts analysis, provided as a second Word document, which thoroughly details the methodology used to predict volumes and delays. These documents provided the research team, as well as VDOT and contractor, with a set of expectations for how traffic would flow through the work zone and a reference for comparison and TMP evaluation.

5.5 DATA COLLECTION METHODOLOGY

Due to weather and other issues, construction did not begin until Sunday, April 17th. This initial construction was only for an approximately 2,000-foot section of the interstate just past Exit 217 and only lasted until Tuesday, April 19th. Construction did not occur during the week of

Easter and resumed April 29th. Each week of construction, the work zone was cleared by Wednesday night. Full lane closure periods took place during the following time periods:

- Sunday, April 17 – Tuesday, April 19: right lane 2,000-foot closure
- Friday, April 29 – Wednesday, May 4: right lane full closure
- Friday, May 6 – Wednesday, May 11: right lane full closure
- Friday, May 20 – Wednesday, May 26: right lane full closure followed by first 2000' of left lane
- Friday, June 3 – Wednesday, June 8: left lane full closure

The research team collected extensive traffic data at various locations along I-81 SB and US 11 SB before and during the five continuous construction periods. Volume and classification data were collected along I-81 SB using Wavetronix devices (radar-based traffic sensors) at four locations: upstream of the work zone (Mile Marker 220.1), at the start of the work zone past the beginning of Type II channelizing devices (MM 218.4), within the work zone (MM 214.2), and past the work zone and Exit 213 (MM 212.2). Volume and classification data were collected along US 11 SB via pneumatic tubes at five locations: upstream of SR 654, three locations between SR 654 and I-81 (the detour segment), and the ramp to I-81 SB at Exit 213. The Wavetronix devices were deployed on Friday afternoons prior to the start of construction and usually recorded data until the following Tuesday or Wednesday. Figure 10 displays the setup of Wavetronix devices along the side of the freeway. The pneumatic tubes recorded data continuously throughout the week.

Figure 10. Setup of Wavetronix device along side of I-81.

Baseline and during-construction travel time data were collected using the floating-car method. Travel times were collected for three different weekday peak-hour (4 P.M. – 6 P.M.) periods during construction and one baseline weekday peak-hour period. During data collection, two probe vehicles traveled along I-81 SB through the work zone, while one probe vehicle exited I-81 SB at Exit 217 to utilize the detour route. Travel times were measured between Exit 222 upstream of the work zone and Exit 213 at the end of the work zone (a 9.1 mile link).

5.6 PROJECT IMPACTS

This section documents observed impacts during construction. These impacts are compared to both pre-construction baseline data as well as TED's predicted impacts. In addition, VDOT's and the contractor's implementation of the TMP and changes made to the TMP are detailed.

5.6.1 Observed Impacts

The research team met with the project's two main traffic control coordinators, the contractor's work zone traffic control coordinator and VDOT's work zone safety coordinator. Discussed were concerns and questions with the TMP, most notably the "forced detour" strategy and monitoring/performance measurement practices.

The detour strategy and traffic control plan was developed by Forester Wright and Bruce Martin of VDOT based on their experience with a previous project along I-81 using US 11 as a detour route. The forced detour was intentional, as the coordinators both echoed concerns with giving vehicles an advance warning of the detour, which could cause excessive volumes and queues along I-81, as few motorists would actively choose to utilize the detour route. Rather, by design, trucks stayed on I-81 by being directed to the left lane, and during high-volume periods, cars were instructed to use the right lane, where they were forced onto the detour route.

During construction periods, the contractor's work zone traffic control coordinator and VDOT's work zone safety coordinator monitored queues and volumes approaching the work zone from the SR 654 bridge over I-81 and via an advance warning vehicle placed upstream of queues. Traffic control strategies such as message signs and flagging were altered based on the coordinators' judgment. Perhaps the most noticeable impact was that queues were minimal upstream of the work zone due to a very high percentage of car traffic utilizing the detour during peak volume periods. During the 24-hour construction periods, at no point did queues extend to the "emergency detour" threshold of Exit 220. Within the work zone, some delays were experienced both along I-81 within the single lane through the work zone, as heavy truck traffic often slowed in close proximity to construction vehicles, and along the detour, where flaggers could obviously not provide completely continuous flow to all detouring vehicles. These delays, which often occurred past the divide for the work zone, were measured in terms of travel times through the work zone. Figure 11 shows slow-moving traffic within the work zone adjacent to intense construction activity.

Figure 11. Slow-moving traffic through I-81 work zone adjacent to construction activity.

5.6.2 Changes to TMP During Construction

Both coordinators echoed the idea that a TMP is a living document and a constant work in progress. One can only account for so much in a TMP and traffic control plan; unforeseen issues arise that must be adjusted during the project. These issues and changes were not explicitly documented, however; rather, the contractor and traffic control coordinators relied on their judgment and knowledge. During the first week of construction, the coordinators estimated that there were “far more on-the-fly changes” to traffic control strategies in comparison to a typical construction project. For example, the project coordinators initially had not accounted for the fact that I-64 runs concurrent with I-81 along this stretch of interstate; to mitigate this and aid confused motorists, additional signage for I-64 was installed. The project coordinators also lowered the speed limit along SR 654 to 45 mph. Another change made to the TMP involved the wording of upstream message signs. For lighter volumes, a message of "Trucks use left lane / right lane exits" was used, alerting motorists of the detour and "allowing" cars to stay on I-81 SB. For heavier volumes, when it was necessary to move more traffic to the detour route, the message was changed to "Trucks use left lane / cars use right lane".

The coordinators aggressively managed traffic in the work zone to minimize delays and make best use of the available interstate and detour capacity. If the route through the work zone (left lane) became slow, perhaps due to an excessively slow-moving truck, the coordinators would instruct the TOC to change the upstream message signs to shift car traffic onto the detour route. If a truck failed to merge into the left lane along I-81 and instead was forced onto the detour route, the coordinators would instruct flaggers to not "stop" the truck at intersections, which could create a shock wave of slow vehicles behind it. There were no queue length or data "thresholds" for the decisions made by the coordinators – the work zone traffic coordinators "just used [their] gut[s]" *(27)*.

5.6.3 Measured Impacts

5.6.3.1 Crashes and Safety Performance

VDOT and its contractors set a goal of zero crashes for all projects. Crash data is collected by law enforcement and entered into a shared database maintained by the DMV. Both law enforcement and VDOT have access to this database, which uses standardized FR300 crash entry forms. These forms can make notes of the condition of a crash location, such as it being in a work zone. During the continuous closure periods, there were 5 crashes in the work zone, including 1 DUI. It does not appear that the number of crashes or crash rate in the work zone is being held to or compared with a standard or threshold. The only other safety performance measure of note for this project was complaints, which are directed to VDOT's call center. Substantive complaints are passed along the work zone safety coordinator; during the continuous closure period, there were less than five complaints in regards to traffic control.

5.6.3.2 Queue Lengths

As mentioned, at no point did queues extend to Exit 220 during 24 hour lane closures, even during the PM peak volume periods. Queues were monitored by the contractor work zone traffic control coordinator and VDOT's work zone safety coordinator via visual inspection and by using a roving "advance warning vehicle" placed upstream of queues. Changes in queue lengths resulted in changes to the traffic control at the coordinators' judgment. Queue lengths were not explicitly recorded for analysis.

5.6.3.3 Volumes and Heavy Vehicle Percentages

Traffic data collected from roadside sensors recorded 15-minute flow rates at locations both upstream of the work zone and within the work zone. Data suggests that equivalent hourly flow rates upstream of the work zone (in the advance warning area) during peak periods were often in excess of 1,500 vph and approached 2,000 vph. As some of this volume was forced to detour, within the transition area, the maximum 15-minute flow rates were less than 1,500 vph and usually less than 1,300 vph. Within the work zone (the activity area), the maximum 15-minute flow rate was 1,180 vph, and most flow rates were usually less than 1,100 vph or even 1,000 vph. This suggests that the capacity of the work zone is less than peak-hour volumes upstream on I-81 SB. Figure 12 shows fluctuations in daily flow rate within the work zone for two Saturdays during construction and for one Saturday prior to construction; peak flows outside of construction periods are more than double the peak flows during construction. Figure 13 shows weekday hourly volumes for select weekdays during construction and also shows low flow rates at the start of the work zone. Thus, a significant portion of upstream volume needed to be detoured, and VDOT and the contractor aggressively maintained this. These flow rates also suggest that the capacity of the work zone was much less than the capacity of a typical single lane of rural freeway.

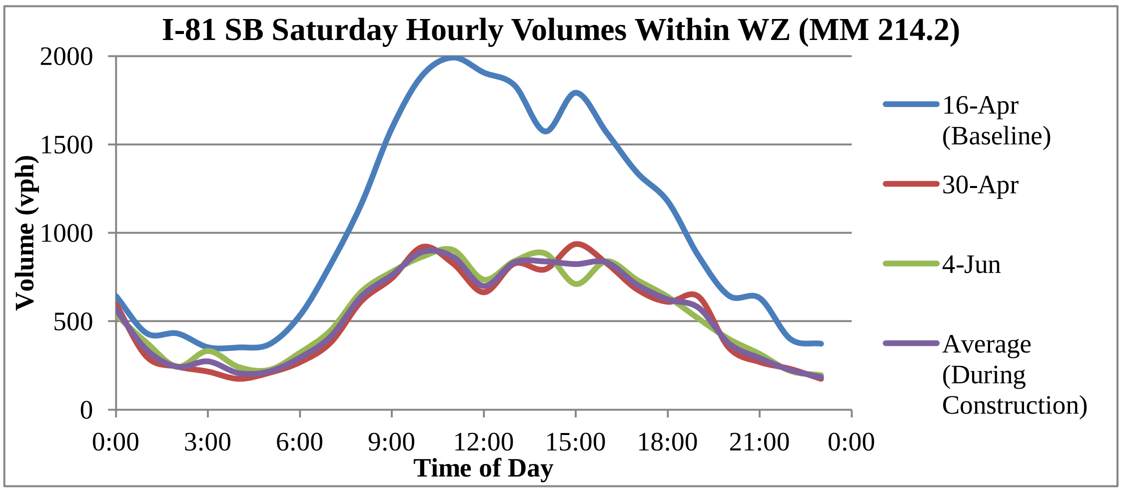


Figure 12. Hourly volumes along I-81 within work zone for select Saturdays during construction.

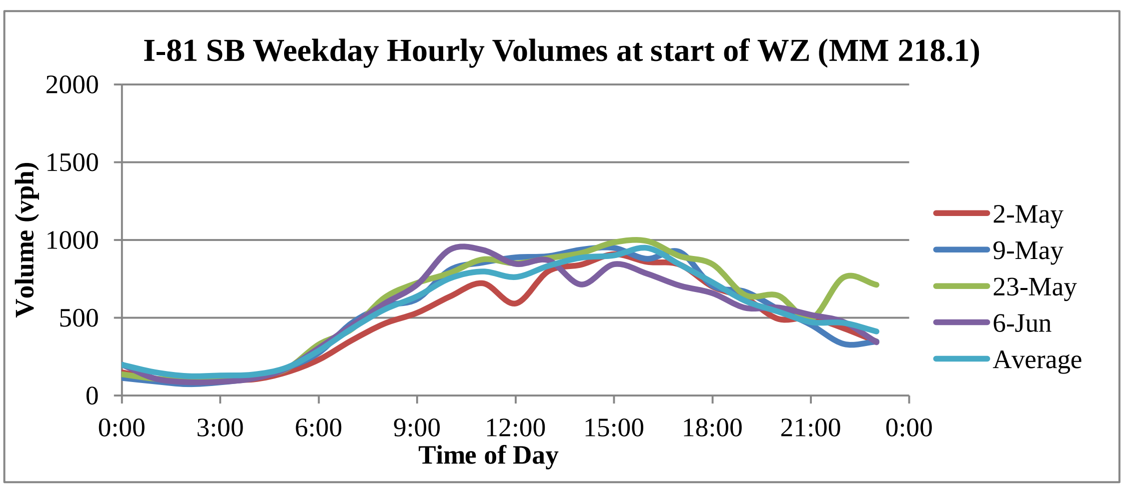


Figure 13. Hourly volumes along I-81 at start of work zone for select weekdays during construction.

TED was fairly accurate with predictions of daily volumes in the work zone area. Figure 14 compares actual average weekday daily volumes with TED predictions. The most noticeable difference is the daily volume within the work zone, as much more traffic utilized the detour route (and thus did not travel through the work zone) than expected.

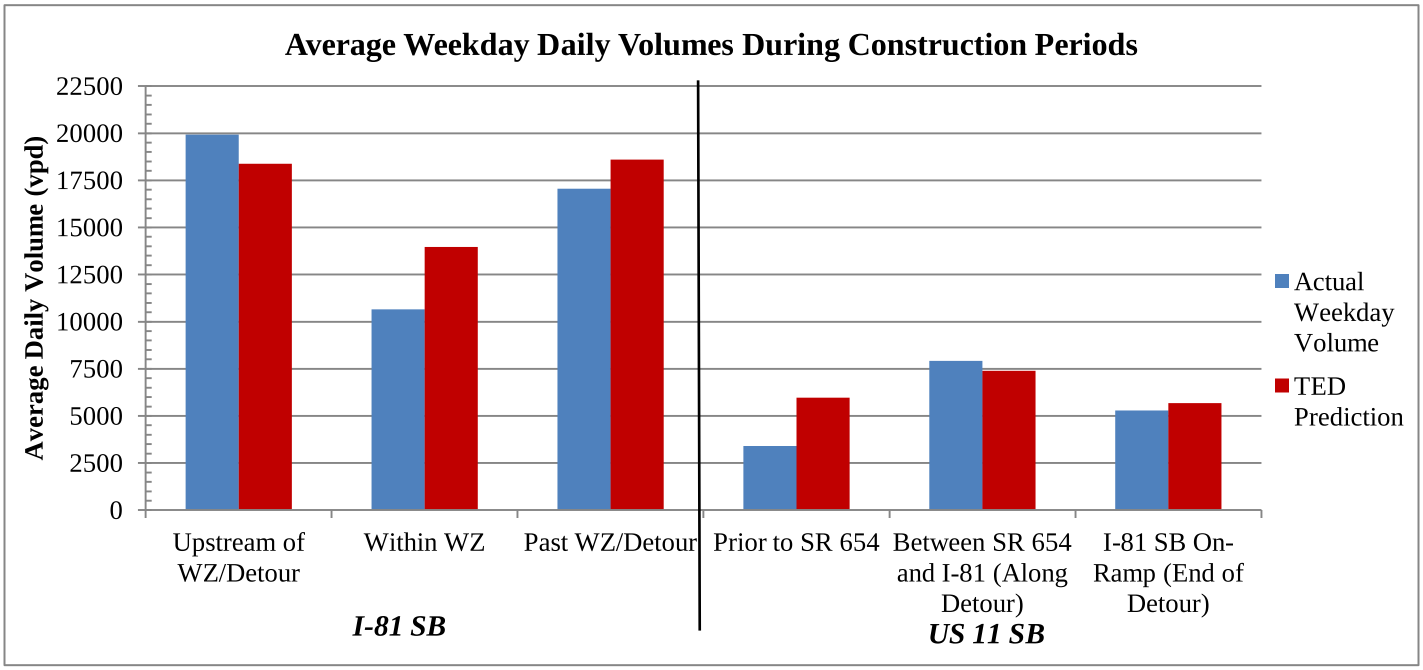


Figure 14. Average weekday daily volumes during I-81 construction periods.

I-81 SB is a notorious corridor for heavy truck volumes. Along I-81 SB in this region, data confirmed that an average of nearly 30% of vehicular traffic is truck traffic, with much higher percentages during overnight periods (often between 50% and 60% trucks). VDOT and the contractor were very successful in keeping truck traffic along I-81 SB while forcing cars to detour when necessary. While much of the truck traffic is typically confined to the right lane (the pavement damage to the right lane of I-81 SB due to truck volume provoked this construction project), data showed that during construction periods, truck volumes in the left lane were much higher upstream of the work zone, even at MM 220.1. Figure 15 displays average heavy vehicle percentages in each lane both in advance of and just approaching the work zone during construction and outside of construction hours. These figures suggest that many truckers were aware of the upcoming work zone and detour in advance of the work zone.

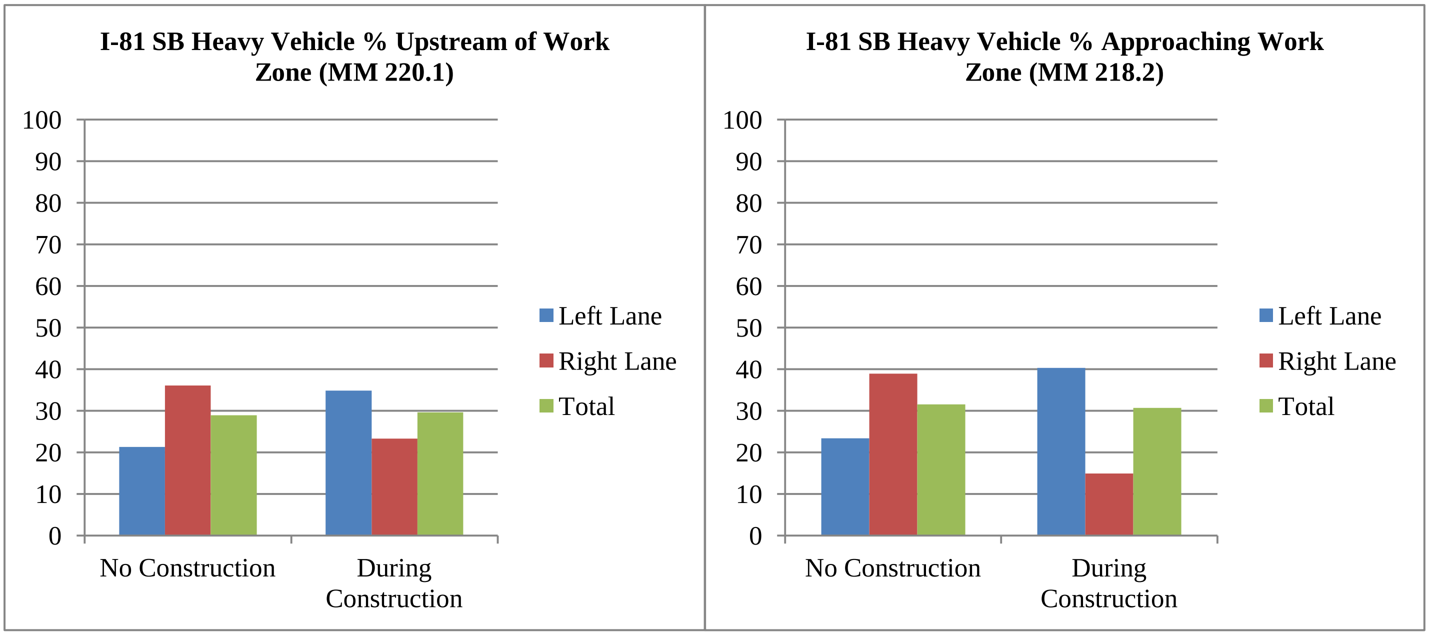


Figure 15. I-81 SB heavy vehicle percentages upstream and approaching the work zone.

Nearly 90 percent of heavy trucks, defined as vehicles measured to be longer than 50 feet, stayed on I-81 SB through the work zone. Within the work zone, the traffic stream had a much higher composition of heavy vehicles than typical I-81 traffic, as expected. On weekdays, the makeup of the traffic stream within the work zone was 40 percent heavy trucks. Out of the overall traffic stream, over 45 percent of all cars and nearly 40 percent of all vehicles traveling along I-81 SB upstream of the work zone exited at Exit 217, most of which were utilizing the detour. This was much higher than VDOT's conservative estimate that only an additional 10 percent of traffic would utilize the detour route (in addition to the 13 percent typical local traffic that exits at Exit 217).

5.6.3.4 Travel Times

Table 3 displays a summary of average travel times through the work zone area from the test vehicle runs. Baseline travel times along the 9.1-mile link from Exit 222 to Exit 213 averaged 477 s (7 min 57 s). During construction, peak-hour travel times for vehicles remaining along I-81 averaged 673 s (11 min 13 s) while the detour travel time averaged 758 s (12 min 38 s). Thus, on average, the work zone delayed travelers staying on I-81 196 s (3 min 16 s) and delayed travelers using the detour 281 s (4 min 41 s). During construction, there was much variability in travel times along both routes, which can be attributed to the heavy truck traffic through the work zone. At the start of construction period and during incidents and rolling road blocks, travel times were longer as noted by the work zone coordinators.

Table 3. Average recorded travel times through I-81 work zone area.

	Baseline		**During Construction**		**Difference**	
	Travel Time (s)	Travel Time (min)	Travel Time (s)	Travel Time (min)	s	min
I-81 Work Zone	477	8.0	673	11.2	196	3.3
Detour Route	624	10.4	758	12.6	134	2.2

5.7 EFFECTIVENESS OF TMP AND LESSONS LEARNED

Forester Wright, VDOT’s work zone safety coordinator for this project, provided several “lessons learned” from the project that VDOT can utilize in the future *(28)*. By being proactive with traffic control, traffic can be actively managed, as the work zone coordinators realized through their forced detour strategy. Mr. Wright suggested that flaggers can be as good, if not better than signals at moving traffic, especially because they can assist motorists with questions. Mr. Wright stressed the need for having an incident manager and local wrecker available on site during critical times in case of a crash or incident. Cameras in the work zone area were essential for monitoring queues. Mr. Wright suggested that it would have been ideal to have more changeable message signs upstream of the work zone with additional spacing to allow increased lane changes. He praised the work of the TOC in this project, which had a dedicated operator for the project changing message signs based on camera-provided conditions and the coordinators' judgment. Overall, traffic management did not add significant costs to the project; installation and tear-down, work orders for additional signs, and flaggers were costs cited by Mr. Wright *(28)*.

The extensive PI campaign implemented for the project contributed to some benefits in work zone safety and mobility. As supported by data showing vehicle classifications upstream of the work zone, within the work zone, and along the detour route, truckers were generally quite aware of the work zone and VDOT's/the contractor's desire to have trucks remain on I-81. Trucks were moving into the left lane in advance of the work zone even with limited signage, suggesting that they may have been aware of the work zone through media outlets such as the CB Wizard or radio ads. Additionally, daily and hourly volumes upstream of the work zone and through the work zone were somewhat lower than baseline volumes (although not as low as predicted by TED).

TED conducted an extensive and thorough pre-construction impacts analysis, which allowed VDOT and the contractor to anticipate work zone impacts and actively manage traffic. The analysis did overestimate some work zone impacts, such as queue lengths, travel times, and the volume of vehicles within the work zone. The analysis also did not take into account the reduced capacity of the work zone, which slowed traffic moving through the work zone at the activity area. This reduced capacity necessitated use of the forced detour. The research team conducted a study using VISSIM simulations (based on TED's model) to assess the observed field impacts *(29)*. This study suggested that the forced detour traffic control scheme employed by VDOT and the contractor reduced travel times and queues in comparison to a traffic control strategy that employed no detour or suggested a detour (but kept one lane closed through the work zone). The study recommended that this strategy be documented by VDOT and utilized in similar work zone scenarios in the future.

VDOT and the contractor did not document changes made to the TMP and did not submit a written post-construction lessons learned report. Ultimately, however, this project provided an example of an innovative traffic monitoring and control strategy that could be utilized in future work zones. This project also provided a thorough, detailed example of a TMP and pre-construction impacts analysis report. These reports provide documentation that could be used for future work zone traffic control strategies. The research team asserts that a post-construction evaluation would be a valuable supplement to the TMP and impacts analysis by addressing oversights, changes, and lessons learned.

CHAPTER 6: CASE STUDY II – GILMERTON BRIDGE REPLACEMENT PROJECT, CITY OF CHESAPEAKE

The research team also studied a construction project on a busy principal arterial corridor in the Hampton Roads region during the 2011 construction season. This report presents findings relating to the development, monitoring, and assessment of the project's TMP. Unlike the I-81 Pavement Reclamation project, this project did not feature an extensive TMP, as project plans may have been developed prior to FHWA Final Rule implementation.

6.1 BACKGROUND

Military Highway (US 13 and US 460) is a 4-lane principal arterial corridor in the southeastern Hampton Roads region, connecting the cities of Suffolk, Portsmouth, Chesapeake, Norfolk, and Virginia Beach. In the area near Chesapeake, the highway runs east-west and parallels Interstate 64, and both facilities cross the south branch of the Elizabeth River, an important segment of the Intracoastal Waterway. Military Highway's crossing of the Elizabeth River is known as Gilmerton Bridge. The existing double-leaf bascule bridge was built in 1938 and has reached the end of its 70-year life span; in addition, the bridge currently provides very low clearance for waterborne vessels and thus requires frequent drawbridge openings, resulting in frequent delays to motorists. The bridge is currently being replaced by a new span that will provide a 35-foot closed clearance. Prior to construction, the bridge saw average daily volumes of approximately 35,000 vpd (both directions combined).

The research team studied the traffic control plan for the Phase One of the Gilmerton Bridge replacement. The bridge replacement project is occurring in three phases. First, the contractor is constructing the eastbound side of the new bridge, which began in November 2009 and is scheduled to be completed by summer 2012. Motorists are limited to one lane in each direction and shifted to the westbound lanes (north side) of the bridge during this Phase. During Phase Two, the bridge will be closed for 14 days to allow for the new drawbridge to be floated in via barge. Finally, during Phase Three, the contractor will construct the westbound lanes of the bridge, shifting motorists to the east (on the new bridge) for the final two years of construction. The replacement bridge will take approximately three years to build while remaining open to vehicular traffic, albeit with one lane in each direction. Although construction of the span will take a long period of time, the project team coordinated the construction schedule and traffic control to significantly lessen the impact on the motoring public.

6.2 PROJECT TMP

As opposed to the I-81 Pavement Reclamation project, the Gilmerton Bridge replacement project does not have an extensive TMP document describing TTC, PI, and TO strategies. This is likely due to the project being developed prior to the establishment of the Final Rule *(3)* and TMP requirements *(3, 8).* The TMP Task Force team noted that while project managers are supposed to be updating these “Pre-TMP” projects, many are not updated due to time, budget, or personnel constraints. The TMP for the Gilmerton Bridge replacement project consists of the maintenance-of-traffic CAD sheets in the project blueprints. These sheets display and describe the TTC setup according to the MUTCD. PI and TO strategies were not explicitly documented, although project personnel explained many of these to the research team.

Since the start of construction in November 2009, Military Highway has been reduced to one lane in each direction in the work zone area, which is between Canal Drive on the east side of the bridge and Interstate 464 on the west side of the bridge. On the west side of the bridge between I-464 and the bridge, US 460 enters and exits the highway via an interchange. Figure 16 displays a map of the work zone area. This map includes the suggested detour for vehicles in either direction, which requires use of I-464, I-64, and US 17 (George Washington Highway). All three of these detour facilities are two lanes in each direction, with I-64 and I-464 being freeways.

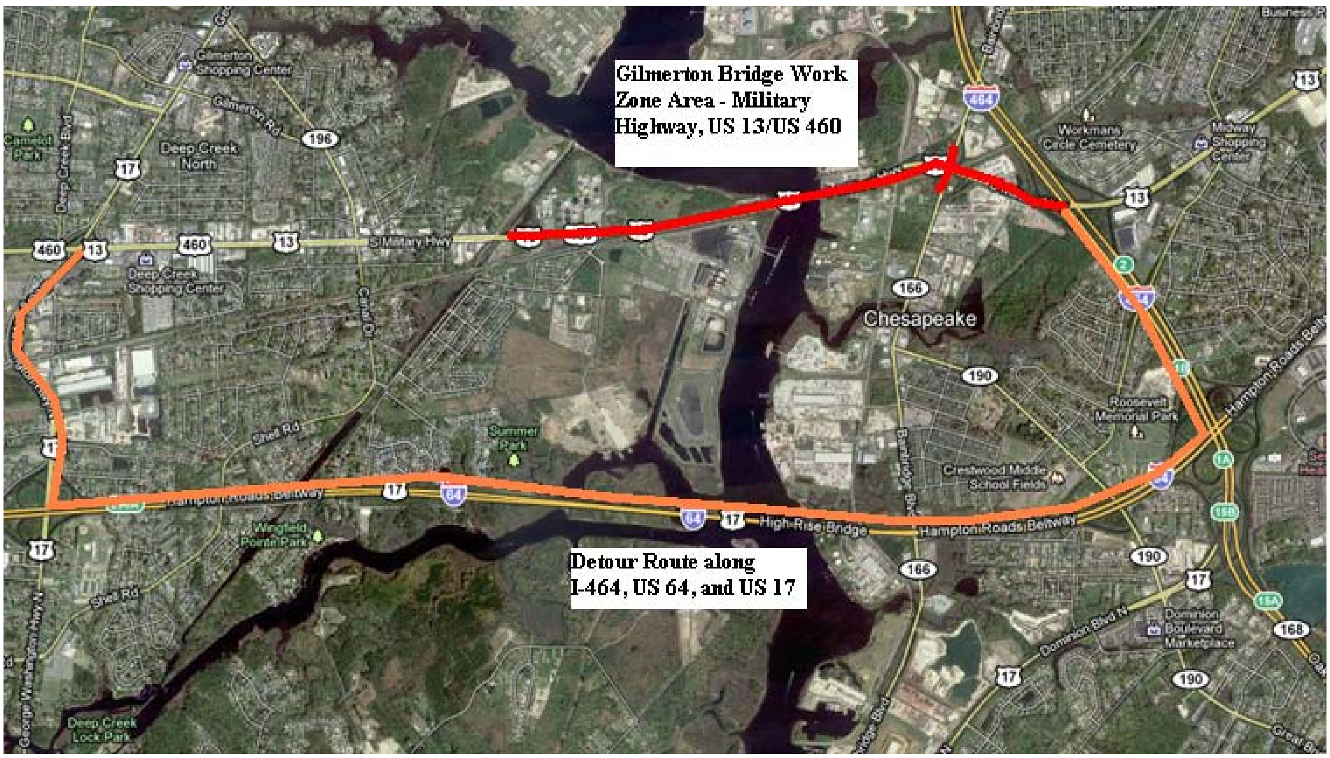


Figure 16. Gilmerton Bridge replacement work zone area.

VDOT Hampton Roads District Public Affairs underwent several initiatives to alert motorists of the work zone and alternate routes. These include news releases, emails to database subscribers, highlighted project closures in the District’s weekly lane closure forecast, and traffic “sponsorships” on local radio stations. Beginning in September 2011, the bridge has been completely closed to traffic on Sunday nights through Thursday nights from 8 P.M. to 5 A.M. to expedite construction; these closures will continue through Summer 2012 until Phase Two of the project is implemented. VDOT ran public service announcements on cable television to not only inform motorists of these closures but also explain the benefits of the project.

6.3 PRE-CONSTRUCTION IMPACTS ASSESSMENT

The Hampton Roads Planning District Commission (HRPDC) utilized the regional planning model to predict impacts resulting from the proposed lane closures on Gilmerton Bridge *(30)*. As mentioned, Gilmerton Bridge carried approximately 35,000 vehicles per day (both directions combined) prior to construction. With all four lanes open, the bridge has a V/C ratio of 0.94, which is approaching capacity. Although some traffic was predicted to divert during the lane closures, a reduction of 2 lanes to 1 lane in each direction yields a predicted V/C ratio of 1.58 during the closure. Therefore, a further evaluation of traffic impacts was required.

The HRPDC used QuickZone (recommended by the FHWA as the appropriate tool for a project of this scope) to analyze a single lane closure in each direction along the bridge. From their results, it was anticipated that the capacity of the single lane would not be able to accommodate the predicted demand, resulting in substantial delays during the peak hour periods.

- “Inbound” (eastbound) direction: during weekday peak periods, queues were expected to be less than 1,400 feet; during Friday peak periods, queues were predicted be greater than 3,000 feet. On weekdays, travel times across the bridge were predicted to increase from just over 2 minutes to between 10 and 15 minutes during the morning peak and between 20 and 25 minutes during the evening peak. During the Friday afternoon peak periods, travel times were expected to be greater than 50 minutes.

- “Outbound” (westbound) direction: during weekday peak periods, queues were expected to be between 1,400 and 1,800 feet; during Friday peak periods, queues were predicted be greater than 3,500 feet. On weekdays, travel times across the bridge were predicted to increase from just over 2 minutes to between 15 and 20 minutes during the morning peak and around 30 minutes during the evening peak. During the Friday afternoon peak periods, travel times were expected to be greater than 60 minutes.

The HRPDC study noted that “no consideration was given to account for traffic signal timing optimization on the city surface streets as they are maintained by others” *(30)*; coordination of these efforts could result in improvements to predicted performance.

In addition to impacts on Military Highway, the HRPDC notes that diversion of traffic could result in an increase of traffic on the I-64 High Rise Bridge. Existing traffic currently already results in “congestion of varying degrees” on the High Rise Bridge *(30),* which had a V/C ratio of 0.98 in 2006. Using HCS+ software, it was predicted that the volume along I-64 would increase by 3,500 vpd from 79,849 vpd to 83,349 vpd. This results in a V/C ratio above 1.0 and a reduction in LOS along I-64 from E to F.

Importantly, the HRPDC study does not take into account any volume changes along Military Highway that may result from public awareness of construction and alternate routes. The traffic impacts of this project could be dramatically different from predicted impacts if volumes over the bridge were to change.

6.4 NOTABLE ISSUES WITH TMP

The Gilmerton Bridge replacement project TMP is essentially a CAD sheet from the engineering plans displaying the traffic control setup with several notes. The TMP does not address or reference any pre-construction impacts analyses. Due to right-of-way and scheduling issues, VDOT and the contractor were forced to reduce right-of-way across the bridge to one lane in each direction. The suggested detour along US 17, I-64, and I-464 is signed throughout the project area. While project staff did suggest that the public was informed of the project both in advance and currently through the media, there is no physical documentation of PI or TO strategies implemented to lessen traffic impacts in the work zone.

6.5 DATA COLLECTION METHODOLOGY

The research team met with project staff and determined that mobility impacts were not to the magnitude predicted by the HRPDC study. Queues and delays on both approaches to the work zone were evident but not to the extent of the pre-construction impacts analysis. The research team chose to examine volumes through the work zone and travel times along both Military Highway and the detour route as measures of work zone traffic impacts.

VDOT has multiple sources of volume data for examining work zone data; the research team sought to determine which sources could provide volume data for this particular work zone. As opposed to setting up Wavetronix devices for this project, which were not available at the time, or hiring a contractor to collect data, the research team decided to explore VDOT’s archived volume data. TED has a continuous count station along Military Highway adjacent to the Gilmerton Bridge that could accurately provide volumes traveling in both directions through the work zone both prior to and during construction.

Travel time runs were conducted in both directions along Military Highway and the detour route, using GPS devices to track travel times. The links along Military Highway (and the detour route) between the Military Highway/US 17 intersection and the Military Highway/I-464 interchange were chosen as appropriate indicators of travel time through the work zone area. The travel time runs were conducted on Tuesday, October 11, 2011, and Wednesday, October 12, 2011. The research team used four probe vehicles (two in each direction) and conducted P.M. peak-hour travel time runs on both Tuesday and Wednesday; the research team conducted A.M. peak-hour and mid-day travel time runs on Wednesday as well.

To help verify travel time data, the research team explored VDOT's access to archived Inrix travel time data. For the Hampton Roads area, VDOT has access to travel time data from the past several years taken from fleet vehicles traveling on various links. Travel time data is available for many Interstates and arterials as well *(19)*. A challenge exists in processing this travel time data, however: archived data is provided as 5-minute average speeds for various traffic message channels (TMCs), or links. These links are often very short in nature – many less than a mile in length. In order to compute travel times along a desired stretch of highway, the desired TMCs comprising this stretch must first be identified using GIS or Google Earth, and the TMC lengths must also be obtained. Travel times along an individual TMC can be computed by dividing the link length by the average speed; average travel times along an overall link can be estimated by summing average travel times along individual TMCs for a given time period. For this project, the research team was able to identify a set of TMCs for an approximately 4.0 mile stretch of Military Highway around the Gilmerton Bridge work zone between US 17 and I-464 in which travel time data could be analyzed.

6.6 PROJECT IMPACTS

Figure 17 displays the setup of the work zone across Gilmerton Bridge. All traffic is shifted to the north (right) side of the bridge; one lane of traffic is permitted in each direction. Construction activities such as staging are conducted along the south (left) side of the bridge, as the new eastbound span is being constructed just south of the current span. As the project progresses, traffic will eventually be shifted to the new eastbound span while the westbound span is constructed in the area of the currently existing bridge.

Figure 17. Work zone setup across Gilmerton Bridge.

As mentioned, Military Highway was approaching capacity prior to construction with all four lanes open; due to space constraints for constructing a new bridge, VDOT and the contractor were forced to limit traffic to one lane in each direction. Starting in September 2011, the bridge has been completely closed to traffic from 8 P.M. to 5 A.M. Sunday through Thursday nights. The I-64 High Rise Bridge is the main detour route at all times, as mentioned, although tunnels in downtown Norfolk also provide a parallel crossing of the Elizabeth River.

VDOT, the contractor, and the research team all found that delays predicted by HRPDC were not occurring in the field. The research team also found that the major source of delays through the work zone can be mainly attributed to drawbridge openings, not work zone activities. During peak hours (6:30-9:30 A.M., 3:30-6:30 P.M.), the bridge does not need to open to recreational or commercial vessels. However, the bridge must open at any time for vessels carrying flammable gases/hazardous materials upon arrival. In addition, if a commercial cargo vessel (including tugs and tugs with tows) gives two hours notice, the bridge will open for it upon arrival. During off-peak hours, the drawbridge opens on signal on the half-hour every half hour. These bridge openings can last ten minutes or longer and significantly affect the flow of traffic, taking several minutes or even tens of minutes to clear the queue. Outside of drawbridge opening events, however, queues on both approaches to the work zone are short, and traffic proceeds through the work zone slowly but steadily.

6.6.1 Volume Impacts

The 2010 *Highway Capacity Manual* estimates the capacity of a two-lane highway as 3,200 passenger cars per hour (pc/h) in both directions, with a maximum of 1,700 pc/h in one direction *(25)*. This is under base conditions (lane width greater than or equal to 12 feet, clear shoulders wider than or equal to 6 feet, no no-passing zones, all passenger cars, level terrain, no impediments to through traffic). For the two-lane segment of the Gilmerton Bridge work zone, while adequate lane width is maintained, there are no shoulders and no passing is allowed. In addition, construction activities take place directly adjacent to traffic. Thus, it can be estimated that the peak flow rate through the work zone in one direction should be less than 1,700 pc/h.

Prior to construction, peak-hour volumes in both directions along Military Highway were much greater than the capacity of a single lane (as two lanes were provided in each direction). The research team examined volume data from July 2008 – the most recent archived data available prior to the start of construction in November 2009 – and averaged hourly volumes for weekdays (Tuesdays-Thursdays). In the northbound (eastbound) direction, volumes exceeded 2,100 vph during the A.M. peak and approached 1,700 vph during the P.M. peak; in the southbound (westbound) direction, volumes exceeded 1,700 vph during the P.M. peak.

The research team analyzed volume data from two-week periods in August 2010, February 2011, and August 2011, and compared this data with volume data prior to construction (July 2008) to gauge if volumes changed along Military Highway. Considering “weekdays” as Tuesdays through Thursdays, it was found that peak-hour and average daily volumes are much lower since the initiation of construction. Figure 18 displays average weekday hourly volumes in the northbound direction through the work zone; Figure 19 displays average weekday hourly volumes in the southbound direction. Figure 20 displays average weekday daily traffic in both directions along Military Highway for each 2-week period examined. The highest average peak-hour volumes occurred in the southbound direction in August 2010, in which approximately 1,400 vph were recorded on average across a two-week period from 4 P.M. to 5 P.M. In 2011, no peak-hour volumes in either direction averaged greater 1,300 vph for the selected time periods.

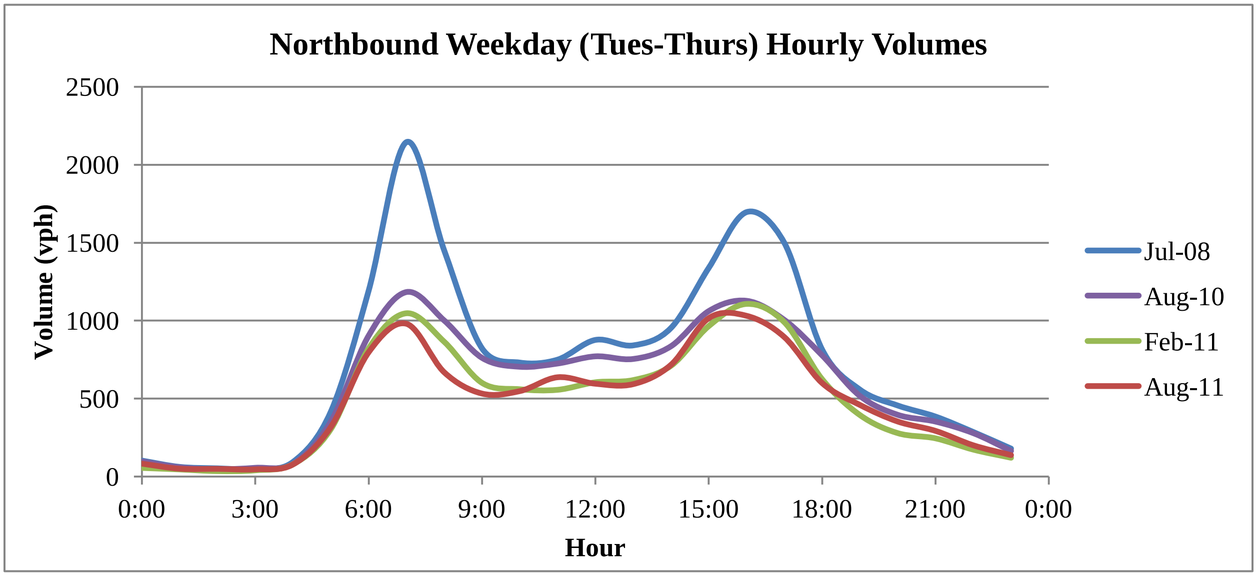


Figure 18. Average weekday hourly volumes along Military Highway NB at Gilmerton Bridge Work Zone.

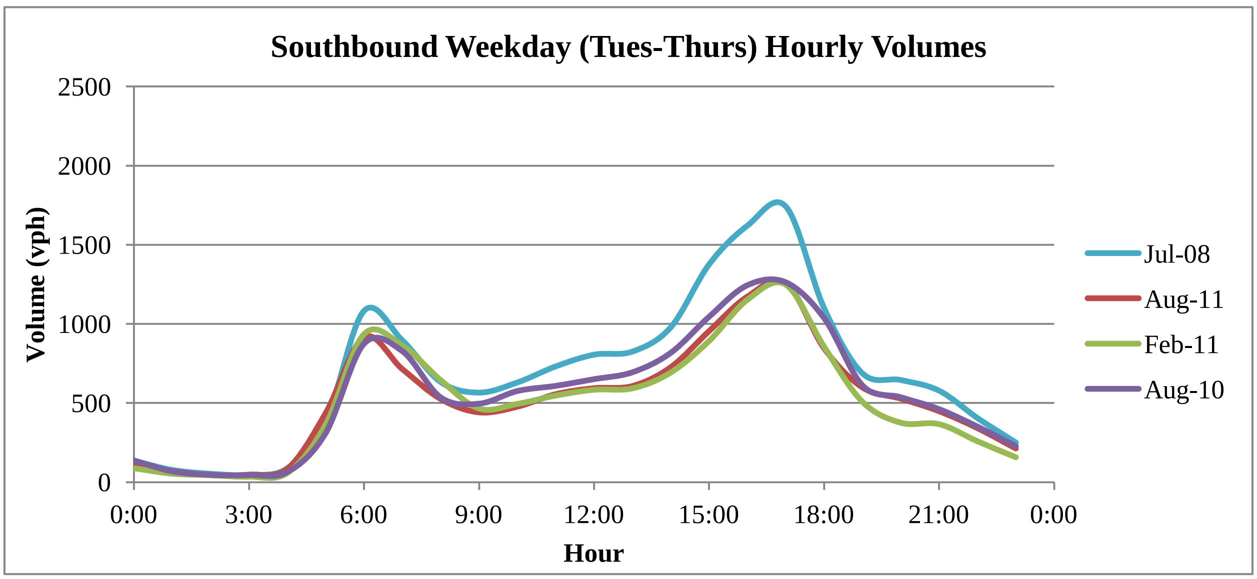


Figure 19. Average weekday hourly volumes along Military Highway SB at Gilmerton Bridge Work Zone.

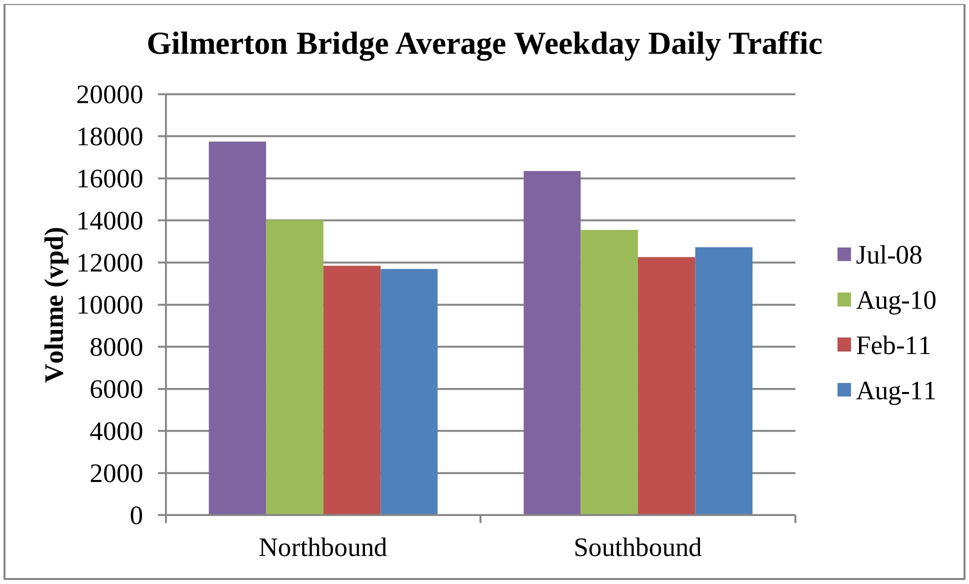


Figure 20. Average weekday daily traffic counts along Military Highway at Gilmerton Bridge.

In response to this long-term work zone, some motorists appear to be avoiding Military Highway through the work zone area. One lane through the work zone in each direction is not enough to handle the volume that existed along Military Highway prior to construction. Due to time and data constraints, the project team could not examine volume trends on I-64 or other parallel facilities such as the Downtown Tunnel. However, the project team was able to examine travel along both Military Highway and the I-64 High Rise Bridge detour through travel time runs.

6.6.2 Travel Time Impacts

Travel time runs through the work zone during Phase I of the project were conducted on October 11th and 12th, 2011. As the Gilmerton Bridge work zone has been in place since 2009, the project team was unable to firsthand conduct travel time runs through the work zone to gauge baseline times.

Table 4 summarizes the results of travel time runs through the work zone in 2011. By noting times of drawbridge openings, the researchers were able to separate out travel time runs during drawbridge openings from those not during drawbridge openings. In the northbound direction, average travel times through the work zone were less than travel times along the detour route, even with runs during drawbridge openings included. In the southbound direction, average travel times through the work zone were less than travel times along the detour route when only considering runs outside of drawbridge openings. If runs including drawbridge openings are included, average travel times during the October 11 P.M. peak hour were greater along Military Highway SB than along the detour route, and average travel times during the October 12 A.M. peak hour were approximately the same along Military Highway as along the detour route.

Table 4. Summary of travel times along Military Highway and detour route.

		10/11/2011	10/12/2011		
		PM Peak	AM Peak	Mid-day	PM Peak
Military Highway NB	Avg Travel Time	6:40	10:09	7:46	6:02
	Standard Deviation	2:26	5:56	3:18	0:46
	Avg Travel Time (No Drawbridge)	5:48	7:56	5:55	6:02
	Standard Deviation	0:48	3:20	1:20	0:46
Detour NB	Avg Travel Time	16:30	11:52	11:37	11:46
	Standard Deviation	2:31	0:33	0:34	0:54
Military Highway SB	Avg Travel Time	15:08	8:45	7:22	5:41
	Standard Deviation	6:30	4:28	3:34	0:33
	Avg Travel Time (No Drawbridge)	11:45	6:04	6:11	5:41
	Standard Deviation	1:57	0:55	2:09	0:33
Detour SB	Avg Travel Time	9:35	8:46	8:36	8:14
	Standard Deviation	1:23	1:28	1:49	0:31

The travel time data suggests that the drawbridge openings have a much greater impact on travel time through the work zone than the work zone setup itself. During the P.M. peak hour on October 11th, extensive delays were experienced that can be attributed to a drawbridge opening at 5 P.M. that lasted for ten minutes but took much longer for queues to clear. During the P.M. peak hour on October 12th, travel times were much quicker through the work zone as there were no drawbridge openings. Upon examining volumes from the continuous count station through the work zone for both days, hourly flows are very similar for both P.M. peak hours; however, there are multiple 15-munute flow rates that are much lower on October 11th – corresponding to drawbridge events.

Using the methodology previously described, Inrix data were examined to gauge differences in travel times along Military Highway before and during construction. By adding average travel times (derived from average speeds) across consecutive TMCs in one direction for a time period, average travel times for an entire link can be estimated. Average travel times were examined for A.M. and P.M. peak periods for a one-week period in September 2009 (prior to construction) and for one-week periods in Februrary 2010 and August 2010 (during construction). While travel times in all time periods were undoubtedly affected by drawbridge openings, the only noticeable differences in travel times before and during construction appear to be in the southbound direction during the P.M. peak hour. Travel times through the four-mile work zone link during this time period appear to be taking approximately two minutes longer than travel times along Military Highway prior to construction. Once again, travel time data suggests that drawbridge openings have a much greater impact on travel times than the work zone itself.

6.7 EFFECTIVENESS OF TMP AND LESSONS LEARNED

Although the HRPDC predicted extensive queues and delays through the Gilmerton Bridge work zone, the project team and contractor attested to minimal delays outside of drawbridge openings. The most noticeable queuing and travel time impacts are in the southbound direction during the P.M. peak hour (as verified by the contractor), but these delays are not more than a few minutes for travelers not encountering a drawbridge opening. A major reason for the reduction in queuing and delays appears to be a decrease in volume along Military Highway since the start of construction. Peak hourly flows and daily flows are much lower during construction in comparison to pre-construction counts. This could be attributed to increased motorist awareness of the work zone, whether by familiarity with the area or from public outreach employed by VDOT.

As this project is in an urban location, it provides a much greater opportunity than the I-81 project for VDOT to utilize existing data sources. VDOT has a continuous count station within the work zone area collecting volume and classification data in both directions. Additionally, VDOT has an archive of private-sector travel time data that, with some time and expertise committed, can provide reliable estimates of work zone mobility.

Discussions with the TMP Performance Assessment Task Group suggest that many current VDOT project plans were developed prior to Final Rule implementation. Although project staff are asked to update plans to comply with Final Rule requirements and include fully-developed TMPs, this does not appear to be happening currently and is exemplified by the lack of a formal TMP for this project. This could be due to a lack of manpower, funding, time, or expertise. Ultimately, VDOT needs a methodology to formalize and standardize “lessons learned” from work zones. The ability to tie project impacts to chosen strategies and pre-construction predictions is crucial to developing more efficient traffic control plans in the future. VDOT has the resources to enable such a process.

CHAPTER 7: DEVELOPMENT OF GUIDELINES TO ASSESS TMP PERFORMANCE

Based on the results of the literature review, surveys, and case studies, the research team developed an initial set of recommendations and presented them to the Task Group for review. The Task Group thoroughly reviewed these recommendations, and the research team took these revised recommendations to develop official Guidelines for TMP Performance Assessment. These Guidelines were submitted to the Task Group for further review, and the revised Guidelines are presented in Appendix B. These Guidelines are considered the primary product of this research project and are being submitted to VDOT for streamlined implementation. The VDOT TMP Performance Assessment Guidelines are divided into two main components: (1) guidelines for assessing the effectiveness of individual project TMPs and (2) guidelines for assessing TMPs at the agency level over a given time period.

7.1 SUMMARY OF FINDINGS

Upon completion of the literature review, surveys, and case studies, as well as upon meeting with the TMP Performance Assessment Task Group, the research team established the following major findings:

1. *Most VDOT and contractor personnel are not currently completing written post-construction assessments of TMPs*. Those who are completing these assessments may not be currently submitting these completed assessments to the State Traffic Engineer. As a result of this, the Task Group developed a standardized post-construction form based off of Rhode Island DOT's assessment methodology and reflecting VDOT's TMP Policy.

This form must be completed and delivered to the State Traffic Engineer following construction. It is recommended that this TMP Assessment be completed by the VDOT project manager. While the contractor will ideally provide input to VDOT personnel in this assessment, VDOT itself should collect data and monitor the work zone rather than include this in the project contract.

2. *Various options exist for conducting many of the tasks in the Guidelines.* These tasks range from pre-construction performance measure selection and impacts analysis, during-construction data collection and monitoring, and post-construction assessment. VDOT Central Office should specify the parties responsible for carrying out the required tasks in the Guidelines. In some cases, the contractor may be required to perform a task, while in other cases, a consultant may be needed. The project team again recommends, however, that VDOT complete the data collection and TMP assessment process in-house rather than contracting this out.

3. *VDOT does have a process in place to assess TMP performance at the agency level but needs to ensure that this process is completed on a consistent basis*. This process review involves surveying field personnel on their use of TMPs, a review of construction projects in select regions, a review and evaluation of work zone crash data, and a review of additional work zone data.

7.2 RECOMMENDATIONS WITHIN TMP PERFORMANCE ASSESSMENT GUIDELINES

The following recommendations are spelled out specifically for various TMP Types in the TMP Performance Assessment Guidelines provided in Appendix B.

- The research team and TMP Task Group recommend that VDOT standardize a set of procedures across TMP Types (A, B, and C). These include the level of pre-construction impacts analysis, monitoring, documentation, and performance assessment required.
- Performance measures must be established prior to construction for all projects. For safety performance, crash records must be obtained no matter how complex the project. For more complex projects, crash rate should be calculated and complaints should be recorded. Mobility performance measures also must be established. The research team asserts that the most relevant mobility performance measure to the public is travel time through a work zone – the measure of the delay incurred by motorists. Queue lengths are also essential to work zone personnel not just from a mobility perspective from a safety perspective as well; knowledge of queue lengths is essential to setting up advance warning to motorists upstream of the work zone. Supplemental data, such as volumes and diversion percentages, can also be useful in analyzing traffic patterns and impacts.
- During construction, safety and mobility data must be collected and tied to established performance measures. Crash and travel time data can be made available for analysis through a variety of methods, whether manual or electronic.
- The research team, while not suggesting these as a requirement, also supports the use of electronic data collection (especially for crashes), use of lane closure charts, and a lane closure database.

- Changes made to the TMP must be documented to adequately track lessons learned. Work zone personnel should be encouraged to update TMPs based on monitoring results.
- Following construction, a written TMP Performance Evaluation should be completed, and the analysis should reflect the complexity of the TMP. This evaluation should document quantitative safety and mobility impacts, changes made to the TMP, and lessons learned. The research team developed a template TMP Assessment Form based off of Rhode Island DOT's form to be completed post-construction and summarizing these results. The evaluations from individual projects will help steer an agency-level TMP process review that will help VDOT understand best practices and impacts management strategies.

CHAPTER 8: CONCLUSIONS, RECOMMENDATIONS AND SUGGESTIONS FOR FUTURE RESEARCH

8.1 CONCLUSIONS

- TMP performance assessment is a process that occurs over the life-cycle of a project and must include tasks that occur before and during construction as well as post-construction. Constant changes need to be made to a TMP during construction that cannot possibly be accounted for prior to construction.
- The research team identified many recommended "best practices" for the various stages of TMP performance assessment from the FHWA, other state agencies, and VDOT regions and districts. VDOT implements many of these identified best practices, such as electronic data collection and database usage. However, there exists a lack of consistency across VDOT regions for various practices. This situation results from the lack of a formalized process of practice for use throughout VDOT to assess TMPs, as well as a lack of manpower, funding, and resources in certain cases.
- VDOT and its contractors are using innovative traffic control strategies for managing work zones, in addition to extensive public information campaigns and transportation operations/demand management strategies. For example, the I-81 Pavement Reclamation project implemented an innovative forced detour traffic control strategy that, through data collection, analysis, and simulation, can be verified to be more effective than traditional detour strategies.
- Full-scale TMPs, while required for all construction projects since Final Rule implementation, are still not being produced or updated for some projects that were

developed prior to the Final Rule (but not yet funded at the time of Final Rule implementation).

- VDOT contractors and personnel make changes to TMPs and traffic control plans in response to observed impacts; however, documentation of these changes and effectiveness of strategies is still minimal.
- VDOT personnel and contractors are not currently conducting post-construction TMP performance assessments as required by FHWA and VDOT. VDOT's current post-construction performance assessment is inadequate and not allowing full benefits/lessons learned from projects to be achieved.
- VDOT has in-house expertise and data collection resources that could allow TMP performance assessment to be conducted by VDOT personnel rather than the contractor. The case study projects suggested to the research team that contractor personnel are not required or motivated to collect data from monitoring work zones.
- Ultimately, the TMP Performance Assessment Guidelines provided from this research are a starting point for VDOT to explicitly document traffic impacts from work zones and use these findings to further improve work zone safety and mobility.

8.2 RECOMMENDATIONS

- VDOT should implement the proposed TMP Performance Assessment Guidelines for all roadway construction projects. VDOT will benefit from implementing these Guidelines by more reliably measuring safety and mobility impacts of work zones. By having a formalized process to assess TMP strategies, VDOT will foster innovation in traffic control strategies, such as the unique traffic control strategy used in the Interstate 81 Pavement Reclamation project. The processes established in these Guidelines should allow for continuous improvement in traffic impacts mitigation strategies, reduced safety and mobility impacts, and cost savings to contractors, VDOT, and roadway users.

- TMP performance assessment must take into account performance measures which are established prior to construction and can be tied to data available to be collected during construction. The extent of performance assessment should correlate with the complexity of the TMP. The performance assessment should analyze collected data from the project in relation to the established performance measures and pre-constructions impacts analysis.
- From the case studies and surveys, the project team recommends that the TMP performance assessment process be completed in-house by VDOT. Data collection and monitoring requirements should not be added to contract specifications, although the contractor will ideally provide input to VDOT personnel to assist in the TMP performance assessment. VDOT has expertise and resources available, such as VCTIR.
- After a time period of either one or two years, VDOT should review completed assessments and use these analyses to update or tweak the TMP Performance Assessment form questions or requirements.
- The state-level TMP process review proposed by these Guidelines should also assess the effectiveness of the Guidelines. This process review should take place every two years and examine a selection of projects from at least half the regions of the Commonwealth. Ideally, this process review will be able to combine the results of many completed TMP Performance Assessments, providing VDOT with a list of lessons learned and successful strategies to employ in future work zones. This process review could also assess whether the requirements in the Guidelines have resulted in safety and mobility benefits across the Commonwealth.

8.3 SUGGESTIONS FOR FUTURE RESEARCH

- Future research should examine more individual TMPs and VDOT/contractor practices relating to those TMPs. This research should examine whether VDOT improves in updating "Pre-TMP" projects to include fully-developed TMPs as well as VDOT's monitoring and documentation processes.
- Upon implementation of the proposed TMP Performance Assessment Guidelines, research could examine the effectiveness of these Guidelines, verifying that all requirements are being fulfilled or perhaps requiring further research into best practices (for example, collecting travel time or queue length data in work zones). Research could also examine VDOT's utilization of completed TMP performance assessments.

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APPENDIX A: TMP PERFORMANCE ASSESSMENT TASK FORCE

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APPENDIX B: PROPOSED TMP PERFORMANCE ASSESSMENT GUIDELINES

APPENDIX B1:
GUIDELINES FOR ASSESSING TRANSPORTATION MANAGEMENT PLANS

INTRODUCTION AND BACKGROUND

In 2004, the FHWA published the *Final Rule on Work Zone Safety and Mobility*, which applies to all state and local government projects that receive federal-aid highway funding. The Rule required that states develop a policy to address work zone impacts through the various stages of a project's development and construction and required Transportation Management Plans (TMPs) for all federally-funded projects. States were required to be in compliance with the Rule by October 12, 2007 *(1)*. The Virginia Department of Transportation (VDOT) has established a TMP policy with a set of guidelines for TMP development *(2).*

A TMP should detail existing and future conditions of a work zone and assess predicted work zone impacts. In conjunction with these predicted impacts, work zone impacts management strategies should be selected. Monitoring of the work zone is necessary; part of VDOT's monitoring requirements *(2)* is an evaluation report for the TMP, which, upon completion of construction, should document lessons learned and provide recommendations on how to improve the TMP process. The guidelines in this report will detail strategies to measure work zone traffic performance, predict traffic impacts, monitor and collect data during construction, and use the data and performance measures to evaluate the effectiveness of TMPs.

By performing the tasks specified in these guidelines, VDOT and its contractors will be fulfilling a federal and state requirement for managing work zones. Safety and mobility benefits from better managed work zones are made possible due to improved traffic flow and road user cost savings. In addition, VDOT will be able to develop more realistic budgets and better customer acceptance and public relations. Finally, TMP assessment facilitates innovation and continuous improvement in mitigation strategy implementation and reducing work zone impacts. At the same time, some of these strategies will add to project costs in terms of time, manpower, funding, and data collection.

GENERAL GUIDANCE

A TMP is a living document that changes over the life-cycle of a project. Prior to construction, impacts can be predicted and used to develop appropriate traffic mitigation strategies. However, changes will need to be made during construction that cannot possibly be accounted for prior to construction. These changes are dependent upon the monitoring and data collection effort taking place. Documentation of these changes is essential for lessons learned to be applied to future TMPs.

The scope, detail, and content of a TMP vary with project complexity; likewise, the level of assessment necessary for a TMP should vary with project complexity. Engineering judgment should be used in all phases of project development. While every project is unique, VDOT should aim for consistency across various complexities of projects. VDOT has three types (or levels) of TMPs and five categories for its construction projects *(2)*.

TMP Types and Categories

The following TMP Types are defined in VDOT's TMP Requirements (IIM-LD-241.4) *(2)*:

Type A

- Typical Projects: No-Plan, Minimum Plan, Single Phase Construction, Maintenance Projects, Utility and Permitted Work
- Project Type: Simple project – widening of pavement or adding turn lanes or entrances. Sequence consists of temporary lane closures and flagging operations with no shifting of traffic onto temporary pavement and with two-way traffic operation maintained at all times or at new construction locations with no existing traffic.

Type B

- Typical Projects: Moderate level of construction activity with the primary traffic impact limited to the roadway containing the work zone.
- Project Type: Moderately complex project – pavement widening or bridges for additional through lanes and pavement rehabilitation. Sequence consists of lane closures to one or both directions with shifting traffic that may include temporary pavement or detours for the duration of the work. If detour routes are used they typically will remain in place 24 hours per day for the duration of the work. Project will be constructed over several phases and may include bridge replacements or new bridges, new interchanges, modifying existing interchanges or a new construction location with existing traffic crossing the construction area.

Type C

- These types of projects are anticipated to cause sustained and substantial work zone impacts greater than what is considered tolerable based on policy or engineering judgment. They should be identified early in the design process in cooperation with the FHWA.
- Typical Projects: Long duration construction or maintenance projects on Interstate and freeway projects that occupy a location for more than three days with intermittent or continuous lane closures within the following Transportation Management Areas; Northern Virginia (including the counties of Arlington, Fairfax, Loudoun, Prince William, Spotsylvania and Stafford), Richmond (including the City of Richmond, Chesterfield and Henrico Counties), and Hampton Roads (including the Cities of Chesapeake, Hampton, Newport News, Norfolk, Portsmouth and Virginia Beach as well as James City and York Counties). Also includes Interstate and Principle Arterial Roadways with complex multi-phase construction, high accident rates, full closures, or multiple work zones (two or more) within two miles of each other.
- Project Type: Complex project – adding additional thru lanes, bridge rehabilitation, interchange construction and reconstruction. Sequence consists of lane closures with several traffic shifts that may include temporary pavement or detours for the duration of the work. Impact of work zone on traffic operations extends beyond the work zone and affects alternate

and/or detour routes. Multi phase construction – bridge replacements or new bridges. Rebuilding interchanges with additional ramps or extensive modification to existing ramps.

Each project category is defined as follows:

- Category I – No-plan projects, small, simple and short-duration projects
- Category II – Minimum-plan projects, relatively simple, single-season construction projects
- Category III – Multi-season construction projects of medium complexity
- Category IV – Very large, complex, multi-season projects (generally >$100M)
- Category V – Major projects and multi-contract projects where seamless interaction among contractors is necessary.

Type A TMPs are required for Category I and II projects; Type B TMPs are required for Category III and IV projects; and Type C TMPs are required for Category V projects. The guidelines set forth herein for assessing individual project TMPs include matrices for various aspects of project development relating to TMP assessment. These matrices will show tasks that are required, recommended "when applicable" (based on engineering judgment), or not required based on the TMP Type (A, B, or C).

GUIDELINES FOR ASSESSING INDIVIDUAL PROJECT TMPs

These guidelines are divided into stages of project development that have a direct relation to TMP performance assessment. Pre-construction guidelines focus on tasks relating to performance measure selection and work zone impacts assessment. During-construction guidelines provide recommendations for monitoring and data collection techniques. The post-construction guidelines include a post-construction assessment report that documents lessons learned based on established performance measures and collected data.

Pre-Construction

1. Performance Measure Selection

Performance measures are essential to work zone assessments and are used as a quantitative way to evaluate successes and failures. Performance measures must be specific, measureable, and achievable; performance measures for TMP assessment should focus on safety and mobility impacts. These measures must be tied to available data. VDOT and work zone personnel must be aware during project planning and contracting as to what data they will have access to.

Safety Performance Measure Requirements:

- For all projects, number of crashes and complaints should be used to assess the relative safety of the work zone.

- For more complex, long-term projects, crashes can be converted to a crash rate and used as a performance measure and means of comparison to roadway characteristics prior to work zone implementation.

Mobility Performance Measure Requirements:

- Queue lengths are an important performance measure not just from a mobility standpoint but also from a safety perspective; queue lengths alert work zone personnel for placement of warning signs in advance of the work zone (and queue). Queue lengths may also determine the need for travel time measurement. Queue lengths are a required performance measure for Type B and C projects. Additionally, queue lengths are listed as recommended when applicable for Type A projects. Based on the pre-construction impacts assessment (see next section), if the proposed work for a Type A project cannot be completed within the Regional Operation's allowable lane closure time periods (and thus sketch-planning-level modeling is required), queue lengths must be included as a performance measure.
- Travel times are a relevant performance measure, especially to motorists. Travel times provide an easily-understood measure that can inform the public of delays. Travel time measurement is recommended when applicable for Type B projects and required for Type C projects.
- Volume and diversion percentage are useful performance measures when a detour is involved as part of the TMP so that VDOT and the contractor can gauge the effectiveness of a detour. These measures are not required but recommended when applicable for more complex projects.

Table A1 displays recommendations for performance measure requirements. Note that additional safety and mobility performance measures, such as incident clearance time or volume/capacity ratio, may be used when of interest.

Table A1. Performance measure requirements for projects.

Performance Measure Selection	**Performance Measure**	**TMP Type**		
		A	**B**	**C**
Safety	Crashes (#)	R	R	R
	Crash Rate	N	WA	R
	Complaints	R	R	R
Mobility	Queue Lengths	WA*	R	R
	Travel Times	N	WA	R
	Volumes	N	WA	WA
	Diversion %	N	WA	WA

R = Required
WA = Recommended When Applicable (based on engineering judgment)
N = Not Required

***Queue lengths required for Type A projects when proposed work cannot be completed within the Regional Operation's allowable lane closure periods.**

2. Impacts Assessment

TMPs are developed from work zone impacts assessments, so it is imperative that VDOT accurately predict project impacts in order to (a) develop an appropriate TMP and (b) properly evaluate the TMP to learn for the future. VDOT's requirements for pre-construction impacts assessment have been established in response to the Final Rule and are included in VDOT IIM-LD-241.4 (Transportation Management Plan Requirements) *(2).* These requirements specify the complexity of analysis to be done based on project significance, including types of simulation software to use:

- Type A: "If the proposed work cannot be completed within the Regional Operation's allowable lane closure time periods an assessment of the Work Zone Traffic Impact will be completed using a sketch planning traffic analysis tool such as Quick Zone, QUEWZ and/or an operational-level traffic analysis software program as appropriate."

- Type B: "An assessment of the Work Zone Traffic Impact will be completed using sketch planning traffic analysis tool such as Quick Zone, QUEWZ and/or an operational-level traffic analysis software simulation program such as CORSIM, Synchro or other applicable programs. Lane closures and detour routes will be implemented based on this evaluation."

- Type C: "An assessment of the Work Zone Traffic Impact shall be completed using an operational-level traffic analysis software simulation program such as CORSIM, Synchro or other applicable programs."

VDOT must ensure that results from the impacts analysis, whether done by VDOT personnel or a consultant, are published and given to those responsible for developing and implementing the TMP. This should be stipulated in the project contract. The measures used in the impacts analysis should also reflect the performance measures and data collection requirements for the project TMP Type.

During Construction

3. Monitoring

The performance of a TMP cannot be assessed without monitoring of traffic conditions and collection of data. VDOT has monitoring requirements and assignments for various work zone personnel described in IIM-LD-241.4 (Transportation Management Plan Requirements) *(2)*. Specifically, changes to the TMP should be documented as an essential aspect of "lessons learned" from a project. The TMP Task Group recommends that all adjustments or changes be documented and included as part of the post-construction evaluation report discussed in the

"Post-Construction" section. Changes, defined as any traffic control modification requiring a seal from a licensed Professional Engineer, are required to be documented. Adjustments, defined as a traffic control modification that is still within the standards or guidance of an applicable manual, are not required to be documented but are recommended.

Table A2 displays requirements and recommendations for documenting changes to the TMP.

Table A2. Monitoring requirements for projects.

TMP Monitoring Requirements	**Documentation**	**TMP Type**		
		A	**B**	**C**
Documenting TMP Changes	Adjustments	N	WA	WA
	Changes	WA	R	R

R = Required
WA = Recommended When Applicable (based on engineering judgment)
N = Not Required

4. Data Collection

Data that is collected should be tied to performance measures. There are several sources of both safety and mobility data that can be utilized by VDOT personnel to obtain data in a quick, cost-efficient manner.

Sources of safety data include:

- VDOT's *Roadway Network System* (RNS) and the statewide *Traffic Records Electronic Data System* (TREDS) are electronic databases containing crash information from all jurisdictions within the Commonwealth, including independent cities and counties. TREDS, housed by the Virginia Department of Motor Vehicles (DMV), is a multi-agency system that VDOT, DMV, and Virginia State Police and local law enforcement can access. Law enforcement officers submit Virginia's standardized FR-300 crash reports into TREDS. The DMV has reported that currently approximately 70 percent of crash data is now entered electronically and is hoping that this percentage approach 100 by the end of the year. By Fall 2012, all databases should be current to within a week of an incident, and TREDS data should be integrated with RNS, including georeferencing for crash locations. VDOT work zone personnel will be able to access crash data from RNS and identify work zone crashes (as well as causes of crashes) for a better understanding of safety of individual work zones.
- The *Virginia Traffic Database* contains crash, work zone, and lane closure data. Crash data can be matched up to work zone data to quickly determine crashes taking place in work zone areas, even those crashes taking place outside of work hours. Usage of this database requires prerequisite training as well as a log-in account.
- TOCs can provide information on crashes during work zone hours and complaints from citizens.

Sources of mobility data include:

- Queue lengths
    - Queue lengths can be monitored by work zone personnel by using landmarks, mileposts, exits, etc., or an advance warning vehicle. The TMP Task Group recommends that the queue management vehicle focus on monitoring and collecting queue data and that separate personnel be assigned to collect travel time data.
    - Queue lengths can also be estimated from speed/volume profiles of spot sensors set up in succession. The FHWA provides guidance for this methodology in its *Primer on Work Zone Safety and Mobility Performance Measurement* (September 2011) *(3)*.
- Travel times
    - Floating car travel time runs. These can be conducted by VDOT or contractor personnel (or interns) or be contracted to an outside consultant. Travel times runs should cover primary routes in all directions and any detour routes as well. The runs should start upstream of the work zone and any queues and conclude past the work zone limits. Travel times can be calculated via a stopwatch or using GPS devices that record a vehicle's location every second.
    - Intelligent Transportation System (ITS) deployments such as Bluetooth readers or automatic vehicle identification (AVI) technology. These tools provide time stamps for vehicles passing points on a network; two or more of these placed in succession along a roadway can allow one to calculate a vehicle's travel time based on the time stamps. These tools can collect data for multiple days and provide a range of travel times, including trends outside of peak hours or during incidents.
    - Third-party travel time data such as Inrix. VDOT pays for and has access to a host of third-party travel time data. The I-95 Corridor Inrix data, which also includes Hampton Roads, contains a historic archive of link travel times from vehicles deployed or monitored by these companies. Analysis of this data does require expertise and significant time to process and combine link data *(4)*. However, as VDOT already pays for this data, this analysis can be done without having to go into the field if data is available for a given roadway during the work zone time period.
- Volumes and diversion percentages
    - VDOT has numerous continuous count stations on freeways throughout the Commonwealth that may be in close proximity to the work area.
    - Pneumatic tubes to collect volume and classification data can be installed along roadways, although contractors may be unwilling to install these on high-speed or high-volume roadways.
    - Wavetronix side-fire radar devices or similar devices that detect vehicle classification and speed can be set up along the side of a highway. These devices can often detect vehicles across several lanes and even opposing lanes.
    - ITS "Smart Barrels" can also be used; these barrels resemble work zone traffic control barrels and thus do not grab a driver's attention. These barrels are highly durable and can collect volume and speed data as well as help estimate queue lengths *(5)*.

Safety Data Collection Requirements:

- A visual safety performance evaluation using the Work Zone Safety Checklist should be completed by an inspector for all projects.
- Crash data should be collected and analyzed for all projects. This analysis will typically occur post-construction and be included with the post-construction TMP assessment. However, for long, multi-phase (Type C) projects, a safety assessment should take place at least every few months or each phase. The TMP Task Force recommends that VDOT follow the example provided by Ohio DOT *(6)*, which collects crash data for large-scale projects and compares crash rates for that segment of roadway during construction to the historic 3-year crash rate on that roadway prior to construction.
- All complaints related to safety should be addressed in the post-construction assessment.

Mobility Data Collection Requirements:

- For Type B and C projects, queue lengths should be monitored and recorded by work zone personnel. Queue lengths should also be monitored and recorded for Type A projects that cannot be completed within the allowable work hours and required pre-construction modeling. Peak hours and incidents should be documented to explain fluctuations in queue lengths.
- For Type C projects, pre-construction (baseline) and during-construction travel time runs should be conducted during peak hours for each phase. Travel time runs are also recommended when applicable for Type B projects. Travel times runs should cover primary routes in all directions and any detour routes as well. The runs should start upstream of the work zone and any queues and conclude past the work zone limits.
- For Type B and C projects, the TMP Task Group recommends collecting volume and diversion data if applicable; however, this task is not required.
- Additional data collection and analysis, such as heavy vehicle composition or safety service patrol (SSP) responses to incidents, is encouraged but not required.

Table A3 displays safety and mobility data collection requirements. Note that these correspond to performance measure development requirements.

Table A3. Data collection requirements for projects.

Data Collection Requirements	**Data Type**	**TMP Type**		
		A	**B**	**C**
Safety	Crashes (#)	R	R	R
	Crash Rate	N	WA	R
	Complaints	R	R	R
Mobility	Queue Lengths	WA	R	R
	Travel Times	N	WA	R
	Volumes	N	WA	WA
	Diversion %	N	WA	WA

R = Required
WA = Recommended When Applicable (based on engineering judgment)

N = Not Required

Post-Construction

Following construction, it is imperative that VDOT and work zone personnel use the collected data and performance measures to evaluate the TMP through a post-construction assessment. VDOT's TMP Development Guidelines (and other states' guidelines including Wisconsin and Illinois) suggested the following should be included in the post-construction assessment:

- An overall statement reflecting the usefulness of the TMP
- Changes necessary to correct oversights in the TMP
- Changes made to the original plan and their level of success
- Public reaction to the TMP
- The maximum and average delay time encountered (e.g., average queues, slowdowns) during peak and off-peak periods, and delay history over the duration of the project
- Identification of the peak traffic periods
- Frequency of legitimate complaints and the nature of the complaints
- Types and numbers of crashes that occurred during construction
- Types and numbers of safety service patrols incidents
- Level of success and performance log for each strategy of the TMP implemented
- Suggested improvements or changes for similar future projects

Appendix B2 provides a copy of VDOT's TMP Assessment Form. This form was derived from a similar form developed by the Rhode Island Department of Transportation. This form should be completed following the completion of a project and should incorporate work zone data and lessons learned. The TMP Assessment form shall be completed by the Work Zone Safety Coordinator with assistance from VDOT and contractor work zone personnel. The Project Manager shall sign off on the form and submit the form to the State Traffic Engineer no later than one month following completion of a project.

Overall TMP Performance Assessment Process

As mentioned, TMP Performance Assessment is a process that proceeds throughout the life cycle of a project. It begins by establishing performance measures and predicting impacts before construction. These measures should be tied to data that will be collected in the field. Changes to the TMP should also be documented, and lessons learned should be evaluated upon completion of construction. Figure 1 displays a flow chart of how the VDOT TMP evaluation process should proceed through a construction project depending on the TMP Type.

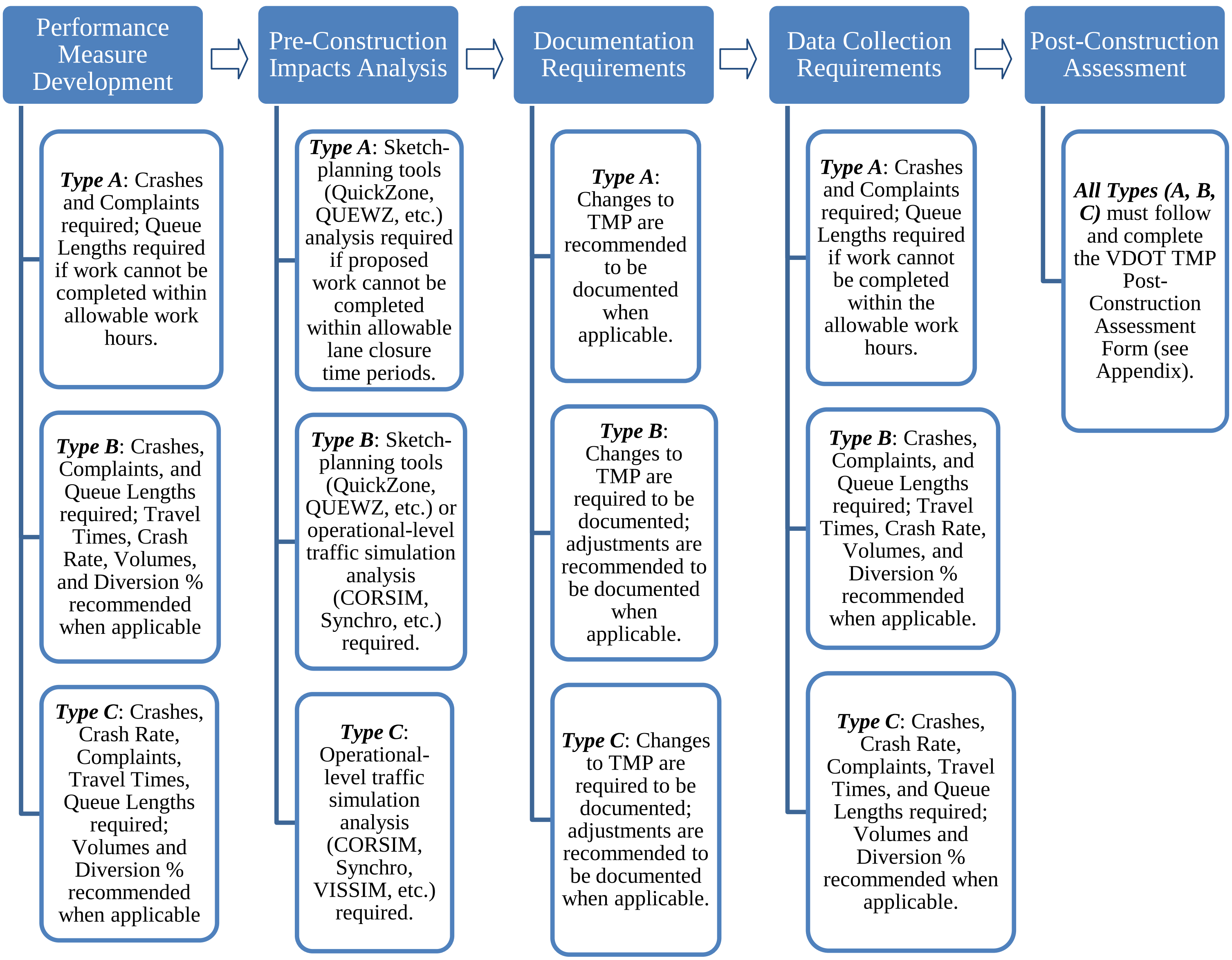

Figure A1. TMP Performance Assessment flow chart.

GUIDELINES FOR AGENCY-LEVEL TMP PROCESS ASSESSMENT

Section 630.1008(e) of the Rule requires agencies to perform a *process* review of TMPs at least every 2 years. This review "may include the evaluation of work zone data statewide and/or randomly selected projects". An overall review of TMP processes should address the following questions:

- Which management strategies have proven to be either more or less effective in improving the safety and mobility of work zones?
- Are there combinations of strategies that seem to work well?
- Should TMP policies, processes, procedures, standards, and/or costs be adjusted based on what has been observed or measured?
- Are the best decisions in planning, designing, implementing, monitoring and assessing work zones being made?

In 2009, VDOT Central Office personnel conducted a Work Zone Safety Program Process Review as required by the Final Rule *(7)*. This process review was led by the Work Zone Safety Team of the Traffic Engineering Office and included the review by others from the Location and Design, Scheduling and Contract, and Operations divisions of VDOT, Regional Traffic Engineering personnel, and FHWA Virginia Division personnel. The Process Review consisted of the following elements:

- *Survey of field personnel* on the use of Transportation Management Plans
- *Work Zone Team review of select construction projects* in the Eastern, Central, and Northwestern Regions and interviews with project and district personnel
- *Review and evaluation of work zone crash data* from the previous two years.
- Review of other activities of the Work Zone Safety Team.

Following the results of this Process Review, the TMP Task Group recommends that a similar Process Review take place at least every two years. The regions of the Commonwealth should vary for each process review so that within four years, all regions of the state have been examined. The Process Review should incorporate the results of previously assessed TMPs that have been evaluated using the methodology described in these Guidelines. These already-completed assessments should serve as a supplement to the Work Zone Team review of select construction projects in a region.

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APPENDIX B2: VDOT TMP PERFORMANCE ASSESSMENT FORM

VIRGINIA DEPARTMENT OF TRANSPORTATION

POST-CONSTRUCTION TRANSPORTATION MANAGEMENT PLAN (TMP) PERFORMANCE ASSESSMENT

This Assessment shall be completed by the Project's designated Work Zone Safety Coordinator upon completion of the work and approved by the Project Manager to document lessons learned and provide recommendations on how to improve the TMP process and/or modify guidelines. The responses should allow the reviewer of this completed Assessment to understand the successes/failures of the project TMP itself and its requirements. Please attach any relevant documents, project logs, etc. as well as any responses which cannot fit within the provided space.

WORK ZONE INFORMATION:

Project Title:	
Work Zone Safety Coordinator:	
Location:	
District/Region:	
UPC #:	

Provide an overall statement reflecting the usefulness of the TMP:

Summarize/describe all changes necessary to correct oversights in the TMP:

Summarize/desribe all changes made to the original plan and their level of success:

Summarize/describe public reaction to the TMP, including frequency of legitimate complaints and the nature of the complaints:

Summarize travel times encountered during peak periods, if required, using the table and questions below:

Starting Location: ____

Ending Location: ____

Date	Method used (i.e. floating car, Bluetooth, etc.)	Average Travel Time

Baseline (pre-construction) average travel time: ____

During-construction average travel time: ____

During-construction maximum travel time: ____

Predicted average/maximum travel time from impacts analysis: ______________________________________

Summarize queues encountered during peak periods, if required, using the table and questions below:

Date	Method used (i.e. advance warning vehicle, ITS barrel, etc.)	Queue Length

During-construction average queue length: ____

During-construction maximum queue length: ____

Predicted average/maximum queue length from impacts analysis: ____

Summarize/identify the peak traffic periods and any discrepancies in these periods from pre-construction impacts assesment:

Summarize types and number of crashes that occurred during construction:

	Property Damage Only	Injuries	Fatalities	Total
Rear-End				
Angle				
Side-Swipe				
Fixed-Object				
Off-Road				
Other				
Total				

Summarize types and number of safety service patrol responses (when applicable):

Summarize/describe the most successful and least successful strategies from the TMP:

Summarize/describe any suggested TMP improvements or changes for future similar projects:

This completed assessment shall be forwarded to the State Traffic Engineer following approval below.

Project Manager Approval	
Name:	
Title:	
Unit:	
Signature:	
Date:	

APPENDIX C: SURVEY RESPONSES

APPENDIX C1: STATE AGENCY SURVEY RESPONSES

Safety Impacts

1. *Does your agency ESTABLISH work zone safety performance measures at (a) the agency program level and/or (b) the individual project level?*

19 states said that they established safety performance measures at the agency/program level, while 12 states said that they establish safety performance measures at the individual project level. The *Domestic Scan* suggested that agency/program level safety performance measurement is much more common than agency/program level mobility performance measurement, as safety performance lends itself to an agency's overall policies and practices, not just one specific project. Note that only 6 states said that they evaluate safety performance on both the agency and individual project level; this could possibly be due to the wording of the survey question.

2. *Does your agency EVALUATE work zone safety performance measures at the program and/or individual project level?*

20 states said that they do evaluate safety performance measures, while 12 said that they do not.

3. *What types of performance measures does your agency use with respect to safety impacts of a TMP? (number of crashes, worker injuries, number of complaints, subjective rating of safety, or other – please specify)*

12 states said that they were using number of crashes as a safety performance measure; 7 states use worker injuries; 5 states use number of complaints; 9 utilize a subjective rating of safety; and 10 states gave other measures, including number of fatalities and crash *rate* (although some states may already be incorporating number of crashes into a crash rate). Other states suggested more mobility-related measures such as queues and delays. It is somewhat surprising that only 12 states claimed to use crashes as a safety performance measure. Note that only states that answered "yes" to the previous question could answer this question; hence, fewer responses.

4. *What safety data and information sources are available in your agency for projects that could be utilized for work zone performance assessment? (project logs, field observations, crash records, operational data, other – please specify)*

11 states use project logs; 17 use field observations; 20 (all who responded) utilize crash records; 11 utilize operational data; and 4 use other sources such as technical inspectors' reports. This supports the Domestic Scan's assertion that crash records are the most common source of safety (crash) information. Again, only states that answered "yes" to Question 2 could respond to this.

Mobility Impacts

5. *Does your agency ESTABLISH work zone mobility performance measures at (a) the agency/program level and/or (b) the individual project level?*

16 states said that they establish mobility performance measures at the agency level, while 15 said that they establish mobility performance measures at the individual project level. This somewhat agrees with the Domestic Scan's assertion that fewer states establish mobility performance measures at the agency level, and more establish mobility performance measures at the individual project level, which lends itself better to selected measures. Like Question 1, 6 states said that they establish mobility performance measures on both levels, although only 3 of the states were states who said they do both for safety.

6. *Does your agency EVALUATE work zone mobility performance measures at the program and/or individual project level?*

Similar to Question 2, 20 states said that they do evaluate mobility performance measures, while 11 said that they do not.

7. *What types of performance measures does your agency use with regards to operational impacts of TMPs? (average queue length, maximum queue length, volume to capacity ratio, average delay, maximum delay, travel time, subjective rating of delay/congestion, other – please specify)*

8 states use average queue length; 10 use maximum queue length; 9 use V/C ratio; 10 use average delay; 14 use maximum delay; 9 use travel time; 8 use a subjective rating of delay/congestion; and 3 used other measures such as level of service. This suggests that "maximums" may be more popular than "averages", but also suggests that there is no agreed-upon "best" mobility performance measure. Note that only states that answered "yes" to Question 6 could answer this question.

8. *What mobility data and information sources are available in your agency for projects that could be utilized for work zone performance assessment? (project logs, field observations, count stations, travel time data, other – please specify)*

11 states utilize project logs; 20 use field observations (all who responded); 10 use count stations; 9 use travel time data; and 4 utilize other sources such as public feedback or ITS. This is consistent with the Domestic Scan's assertion that (manual) field observations are the most common (and, most likely, the most inexpensive) source of work zone mobility data. Oregon DOT noted that they are just beginning to introduce "Smart Work Zone" traffic management systems to measure work zone traffic operations and report real-time information and warnings to motorists; these systems will be limited to large, long-term projects. Again, note that only states who answered "yes" to Question 6 could answer this question.

9. *Does your agency have a process to estimate road user costs and use this process to select work zone strategies (full closures, detours, night work, etc.)?*

13 states said that they do have a process to estimate road user costs (RUCs), while 8 said that they do not.

Impacts Assessment

10. *Does your agency utilize software tools to predict the impacts of work zones on traffic operations?*

28 states said that they do utilize software tools to predict work zone impacts prior to construction; 3 states said that they do not. Of the states who said that they do not utilize software tools, it could be that those agencies rely on lane closure/queue charts.

11. *What software tools does your DOT use for analyzing anticipated work zone impacts? (QuickZone, QUEWZ, Highway Capacity Manual, other sketch planning tools, Synchro, VISSIM, CORSIM, Dynasim, other – please specify)*

11 states said they use QuickZone; 5 said they use QUEWZ; 16 use some sort of HCM software; 5 use other sketch planning tools; 11 use Synchro; 7 said they use VISSIM; 7 said they use CORSIM; 1 said they use Dynasim, and 11 states mentioned other tools such as in-house-developed lane closure spreadsheets. The Domestic Scan suggested that spreadsheet tools based off of the Highway Capacity Manual, which some states may have encompassed under "Highway Capacity Manual" are very common; more complex simulation tools are used for larger, more intense projects. Note that only states who answered "yes" to Question 10 could respond to this question.

12. *Do the types of software tools to predict work zone impacts vary based upon project intensity/complexity?*

17 states responded "yes" while 10 responded "no" – not sure what to make out of this?

13. *With regard to software output, how important are the following when analyzing the operational impacts of a TMP? (rate "not important" to "very important": average queue length, maximum queue length, V/C ratio, average delay, maximum delay, travel time)*

	Not important	Somewhat important	Very important
Average queue length	7.1% (2)	**53.6% (15)**	39.3% (11)
Maximum queue length	3.6% (1)	32.1% (9)	**64.3% (18)**
Volume to capacity (V/C) ratio	14.3% (4)	**46.4% (13)**	39.3% (11)
Average delay	3.6% (1)	46.4% (13)	**50.0% (14)**
Maximum delay	14.3% (4)	21.4% (6)	**64.3% (18)**
Travel time	7.4% (2)	**59.3% (16)**	33.3% (9)

14. Rate the following statement: my agency is generally satisfied with traffic analysis software when it is used to predict work zone impacts (from "strongly disagree" to "strongly agree").

While 4 states strongly agree and 10 agree, 9 were neutral, 4 disagreed, and one state strongly disagreed! Agencies were allowed to make comments. One state noted that their "current software is inaccurate, difficult, and time-consuming to use…training seems to be unavailable." That state developed their own sketch planning spreadsheets. Some states noted that they were generally satisfied with results but have seen over-estimates of queues and road user costs, especially from QUEWZ. One state commented that their issue with software tools was "gaining consistency statewide with our designers using the software." Oregon DOT, who utilize their own web-based software known as the Work Zone Traffic Analysis (WZTA) Tool as opposed to the software tools we listed, was one of the few states who "strongly agreed" that they are satisfied with their traffic analysis software. They noted that a recent study of their software's benefit-cost ratio suggested a ratio of 9.31:1 over five years (dollars spent in development/maintenance/operation versus savings related to reduced delay).

Monitoring

15. Does your agency check field conditions (i.e. queue length, delay, capacity, etc.) during the project against (a) the anticipated impacts of a work zone predicted by software tools and/or (b) predefined performance thresholds?

12 states said that they check field conditions against software-predicted impacts, while 12 also said that they check against predefined performance thresholds. 4 states said that they do both.

16. Are the data collected used to update and revise TMPs during construction?

17 states said "yes", while 12 said "no".

17. Are the data collected used to update and revise agency policies and procedures (post-construction)?

16 states said "yes", while 14 said "no".

Information Dissemination

18. What types of tools does your agency use to disseminate information to motorists and agency personnel in regards to work zone conditions? (open-ended)

Nearly all states mentioned 511 systems and/or changeable message signs. Many also mentioned press releases, social media such as Twitter, web sites, and media outlets such as TV and radio stations.

19. Does your agency assess the effectiveness of its public awareness/motorist information strategies? If yes, how are they assessed?

10 states said “yes” while 19 said “no”. Of states that said they do assess public information strategies, explanations included observing if the public adjusted driving routes or public outreach surveys. Texas DOT mentioned that districts are asked to review TTC, TO, and PI strategies annually in a post-project review and forward results to Traffic Operations Division. They noted that there are “no formal performance measures” but rather input on strengths and weaknesses of strategies used.

Additional Questions

20. What are your agency’s biggest “barriers” to sound POST-construction work zone impacts assessment (i.e. manpower, data, funding, etc.)?

A lack of personnel (manpower) was an overwhelming response from states as to why post-construction assessment of work zone strategies and impacts is not completed more thoroughly. Data and funding were also common responses. A few states noted an issue of consistency; that is, states have not established methods or performance measures for post-construction assessment.

21. Does your agency currently have guidelines for assessing TMP performance?

19 states said they had some sort of guidelines for assessing TMP performance, while 11 said that they do not. The extent of these guidelines varies. Some mentioned that their guidelines are limited or in their infancy, such as a process review every 2 years. One state mentioned that they had a policy but extremely limited manpower to do the work. New York state has developed a work zone inspection program which has been modified and updated over the years. They stated that “the most successful method is having an extremely experienced design/review team that fulfills the function on ALL regional projects.” NYSDOT has a fairly rigorous post-construction inspection report form which “grades” a project. NYSDOT, Wisconsin, and Illinois were kind enough to send us their TMP policies.

APPENDIX C2: VDOT SURVEY RESPONSES

1. *What region/district are you associated with?*

   We received four responses each from Northern Virginia (NOVA) and Northwest Region, two responses from Central Region, and one response each from Southeast Region and Southwest Region.

Performance Measures

2. *What types of performance measures do you use with regards to SAFETY impacts of a TMP? (check all that apply)*

   All respondents used number of crashes as a safety performance measure. Number of complaints, worker injuries, a subjective rating of safety, and SSP/police response time were also mentioned as safety performance measures.

3. *What types of performance measures do you use with regards to MOBILITY impacts of a TMP? (check all that apply)*

   While there was no 100 percent-universal response to this question, the most commonly cited mobility performance measures (in decreasing order) were travel times and maximum queue length, average queue length and average delay, and maximum delay and volume to capacity ratio. Other cited measures include a subjective rating of congestion, incident clearance time, and bicycle/pedestrian mobility during closures.

4. *To what extent are these performance measures dependent upon available data?*

   As expected, the safety and mobility performance measures used by various VDOT districts are overwhelmingly “highly dependent” upon available data. One district noted that these performance measures are only “somewhat dependent” upon available data.

Work Zone Impacts Assessment

5. *Who is the responsible party for work zone impacts assessment during project development in your district/region (i.e. contractor, VDOT traffic engineering personnel, VDOT work zone personnel)?*

   All responses included some sort of VDOT personnel, including inspectors, traffic engineering and work zone personnel. Multiple respondents also stated that the contractor has some responsibilities as well.

6. *What DATA do you use to assess and/or predict work zone impacts during project development/prior to construction?*

Multiple respondents cited the VDOT Allowable Work Hours Tool developed by VCTIR. Hourly traffic volumes (seasonal adjusted AADT or pre-construction counts), geometry and driving patterns, traffic mix, and accident data were also cited.

7. *Do you have a spreadsheet tool developed to estimate project impacts (prior to construction)?*

   Of those who responded, four said "yes," while four said "no." This inconsistency is somewhat confusing.

8. *Do you use software tools to predict the traffic impacts of a work zone?*

   Of those who responded, five said "yes," while three said "no". This is again confusing; it could be that the specific respondents are not familiar with software tools to predict work zone impacts (as opposed to entire districts/regions not using software tools).

9. *What software tools do you use for analyzing predicted work zone impacts? (check all that apply)*

   Of those who responded, 100 percent (four responses) used the *Highway Capacity Manual* and VISSIM; 75 percent use Synchro. QUEWZ, QuickZone, CORSIM, GIS, and "other sketch planning tools" were also used. No respondents used Dynasim.

Other Pre-Construction Information

10. *Do you ever incorporate performance measures into contract language (i.e. using performance-based specifications as opposed to method-based specifications)?*

    Four responded with "yes," while three responded with "no." One respondent explained that Road User Cost (RUC) information is used to set incentives/disincentives when applicable and needed to complete a critical phases of work where traffic is most impacted.

11. *Do you incorporate Road User Costs (RUCs) into agency cost analyses?*

    Five respondents (71%) said that they do incorporate RUCs into agency cost analyses.

12. *Do you undertake a formal maintenance of traffic (MOT) alternatives analysis during project development?*

    Five respondents (71%) said that they do compare traffic alternatives during project development. One respondent commented that for Megaprojects, a formal alternatives analysis occurs only on major short-term or long-term closures.

13. *Do you have and/or use a permitted lane closure chart?*

    Five respondents (71%) said that they use a permitted lane closure chart. One respondent stated that they believe that this question refers to the LCAMS database used by NOVA.

14. *Do you have "lane rental provisions" (i.e. a contractor can pay a fee to close additional lanes even if adverse impacts are expected from these closures)?*

    Only one of seven respondents (Southwest region) said that their region/district does allow for lane rental provisions.

Data Collection and Monitoring

15. *Do you REQUIRE work zone performance monitoring in TMPs?*

    Three out of six respondents said "yes".

16. *Are contractors expected to monitor work zones or do you use agency staff (i.e. project engineers, inspectors) for monitoring?*

    Reponses were quite varied for this question. One respondent stated that VDOT specifications require a designated work zone safety person on contractor staff. Another respondent stated that "contractors are expected to, but don't do a very good job, so we end up doing it." Multiple responses listed VDOT staff or inspectors, which could be an outside consultant.

17. *What are your main sources of work zone SAFETY data? (check all that apply)*

    Of those who responded, all six used field observations. Police crash reports, customer surveys/complaints, crash reports from work zone personnel, and fire/rescue dispatch frequency were also cited.

18. *What are your main sources of work zone MOBILITY data? (check all that apply)*

    Six respondents replied to this question, and there was no overwhelming response. TMCs were the most popular response, followed by travel time data and count stations; project logs were also used by two respondents.

19. *Do you have access to real-time work zone data (crashes, queue lengths, travel time, etc.)?*

    Five out of six respondents said that they do have some access to real-time work zone data. This data comes from cameras and data accessed by the Traffic Operations Center.

20. *Do you employ any types of electronic data collection during work zones?*

Three out of six respondents stated that they do employ electronic data collection. This data includes traffic volumes (on some major projects) and speeds.

21. *Do you have an electronic system for entering crashes?*

Only two out of six respondents (Central, NOVA) stated that they have an electronic system for entering crashes.

22. *Do you have a database management system for any of the following: lane closures, crash analysis, traffic performance? (check all that apply)*

Only three respondents answered this question, but all three stated that they have database management systems for lane closures and traffic performance (“511, Virginia Traffic and Traveler Information Database”). Two also stated that they have a crash analysis database.

23. *Do you use any customer surveys for work zone performance assessment?*

Three out of six respondents said that they do use customer surveys. These can take the form of “customer awareness surveys.” One respondent stated that surveys are done via VDOT’s communications staff (“CRM system”).

24. *What role, if any, do Traffic Management Centers (TMCs) play in work zone monitoring in your district/region?*

TMCs seem to play a major role in work zone monitoring. TMCs use cameras to monitor congestion (where they are available) and coordinate/report lane closures. TMCs also coordinate Highway Advisory Radio and Safety Service Patrol.

25. *Do you monitor travel times/queue lengths that occur in the field and compare them to estimates from impacts analysis?*

Five out of six respondents said “yes.”

26. *Do you monitor travel times/queue lengths experienced in the field and compare them to predefined performance thresholds?*

Four out of six respondents said “yes.”

Updating/Revising TMPs and Agency Policies

27. *Do you ever use monitoring/performance results to make changes to TMPs during construction?*

Four out of six respondents said “yes.” For example, based on traffic monitoring, a location adjustment was made to a merge taper and sign spacing for a project along I-295 southbound over I-64. In Northern Virginia, “constant changes to traffic operations” are made “to optimize traffic flow while maintaining safety for all modes of travel”; this occurs around the I-495 HOT Lanes, the Dulles Rail Metro project, BRAC, and the I-95 4th lane widening.

28. *Do you ever use performance results to make changes to work zone policies?*

Three out of six respondents said “yes.” Changes could include hours of operation, acceptable configurations, and coordination between projects.

29. *Do you ever use performance results to make changes to design standards?*

Only one out of six respondents said “yes”; this referred to changing sign spacing due to roadway geometry. One respondent stated that this is not a district responsibility but rather a headquarters responsibility.

30. *Do you ever use performance results to make changes to capacity values used in traffic impacts analyses?*

Three out of six respondents said “yes.” One example mentioned was multiple-lane ramp lane closure time. Another respondent referred to the I-495 HOT Lanes project, in which the highly congested and dynamic environment is constantly having data collected on it so that staff “has a better understanding of the capacity to move traffic.”

Final Thoughts

31. *What are your district’s/region’s biggest barriers/constraints to doing more with work zone data (i.e. personnel, time, etc.)?*

A lack of personnel was mentioned by multiple respondents. One respondent mentioned limited real-time data or non-user-friendly data. Respondents from Northern Virginia mentioned that available right-of-way on an over-capacity system and finances also constrain the ability to collect more data.

APPENDIX C3: VDOT WORK ZONE SELF ASSESSMENT RESPONSES

Each year, the FHWA conducts a Work Zone Mobility and Safety Self-Assessment (WZ SA), a survey designed to assist agency work zone coordinators in assessing policies, programs, and procedures "against many of the good work zone practices in use today". The best practices featured in the WZ SA have been identified by the FHWA and are available in the *Work Zone Best Practices Guidebook*. The WZ SA facilitates communication and sharing of best practices among transportation professionals. It allows states/divisions to track their progress in work zone management and identify areas of need or improvement as well as areas of success.

The 2010 WZ SA Report contains 46 questions designed to assist those with work zone management responsibilities in assessing their programs, policies, and procedures against many of the best work zone practices in use today. There are 6 primary assessment areas:

1) Leadership and policy
2) Project planning and programming
3) Project design
4) Project construction and operation
5) Communications and education
6) Program evaluation

Each question was rated on a scale of 0 to 15; a score of 7 or more indicated that a state is implementing/executing the item in question. 52 agencies (divisions or states) were surveyed.

WZ SA questions of concern to this project are:

4.1.2. Has the agency established strategic goals specifically to reduce congestion and delays in work zones? Almost three-fourths (71%) of the responding agencies indicated that they have strategic goals to reduce work zone congestion and delays. Some agencies have goals, while some are in the process of developing strategic goals. Several agencies commented on performance measures in response to this question. One agency noted that they expect to develop performance measures prior to goal development, which may not be as effective since metrics should be tied to strategic goals. Another agency noted use of a permitted lane closure chart for freeway applications, focusing on minimizing delay and congestion without citing a specific goal. In a reference to performance measures, one agency noted using a threshold of 30 minutes of delay to determine when additional mitigation strategies are needed including modified windows within which to perform work.
National Average: 9.1
VDOT Self-Score: 10
VDOT comments: "VDOT has developed a SHSP which addresses strategies to reduce congestion and delay in work zones as well as in the TMP memorandum. Allowable work hour times have been developed for all five Regions, which reduces congestion and delay."

4.1.3. Has the agency established strategic goals specifically to reduce crashes in work zones? Three-fourths of reporting agencies (75%) have strategic goals specifically to reduce crashes in work zones. Similar to question 4.1.2, several agencies cited specific performance

measures considered in relation to a strategic goal. One agency noted a goal of reducing worker injury rates but had not established goals for motorist safety. Another agency noted use of contract specifications to improve safety, such as for portable changeable message signs, lettering on signs, and impact attenuator use. The same agency cited a goal to reduce work zone fatalities by 10% from 2004 to 2010. One agency cited a more general goal of reducing roadway crashes in work zones. Several agencies referred to their policy on work zone safety and mobility that addresses reducing crashes in work zones. Guidance on goal setting and performance measure development may be helpful to some agencies in the future.
National Average: 9.8
VDOT Self-Score: 14
VDOT comments: "A yearly performance measure for District Admininstrators is a 10% reduction in WZ crashes. The SHSP target of reducing WZ crashes and fatalities by 100 in 2010 and all roadway crashes by 4000 has not only been met but greatly surpassed."

4.1.4 Has the agency established measures (e.g., vehicle throughput or queue length) to track work zone congestion and delay? Over half (58%) of the agencies are implementing measures to track work zone congestion and delay. The average score for this item increased from 3 percent between 2009 and 2010. While a smaller percentage compared with previous years, the increase continues a trend from previous years. One agency develops measures for congestion and delay for individual projects. Another agency noted that they are reviewing available data sources to determine if performance measures can be established. The same agency cited public interest in displaying delay messages for work zones in the field. Another agency did not cite specific performance measures in use, but referenced a specific mitigation policy of moving warning signs upstream of queues. This policy may more directly relate to mitigating safety impacts of work zones. One agency noted use of performance measures such as delay, while the thresholds of what is considered reasonable are still under development.
National Average: 7.9
VDOT Self-Score: 10
VDOT comments: "The TMP IIM/TED Memorandum has elements of tracking queue lengths on projects including a TMP evaluation form."

4.1.5 Has the agency established measures (e.g., crash rates) to track work zone crashes? Forty-three agencies (83%) have established measures to track work zone crashes. The responses to this question indicate that the main focus is on improving reporting for work zone crashes compared with analysis or measurement of crash rates. For example, a few agencies noted the addition of a "location" parameter to crash reporting forms that assist with capturing the location of the crash (advance warning area, transition area, etc.). One agency noted that while work zone crashes are tracked, better analysis procedures are needed to generate results that can help with measuring performance. One agency cited the use of a tool to evaluate work zone crash data that was developed as part of Strategic Highway Safety Plan activities. Another agency focuses on analyzing fatal crashes to determine improvements, while another agency cited analysis of crash data based on issues that are discovered on a project by project basis.
National Average: 10.6
VDOT Self-Score: 14

VDOT comments: "WZ crashes, injuries, and fatalities are tracked on a yearly basis by Region, District, and roadway type."

4.1.6 Has the agency established a policy for the development of Transportation Management Plans to reduce work zone congestion and crashes? Forty-eight agencies (94%) are implementing a policy for the development of Transportation Management Plans (TMPs) to reduce work zone congestion and crashes. Since TMPs are required for all Federal-aid highway projects, 100% of agencies should be implementing TMPs. Of the agencies that provided comments, a majority of them have a policy that includes development of TMPs for projects. Some agencies noted use of guidelines that structure the development of the TMP. One agency referred to their project cost threshold for significant projects, as TMPs are required for those projects. A few agencies are assessing their guidelines for TMPs and are providing training on the implementation of the guidelines and TMP development. One agency cited the use of demand management and other traffic operations strategies for an Interstate widening project. The 8% increase for this item is due to increased ratings from 21 agencies, and one agency crossed the implementation threshold (7 or higher) from 2008 to 2009.
National Average: 11.2
VDOT Self-Score: 13
VDOT comments: "TMP Memorandum/IIM has been implemented and revised twice, and the agency has integrated this into its project execution process and culture."

4.1.7 Has the agency established work zone performance guidance that addresses maximum queue lengths, the number of open lanes, maximum traveler delay, etc.? Standards for work zone performance guidance have been established in 44 agencies (85%). Several agencies referred to use of a time period based permitted lane closure tool to display time periods to avoid due to the potential for unacceptable queues and delays. One agency noted that queuing and lane closure analysis is performed on a project level when incentive/disincentive contracts are used. Another agency sets a maximum queue length based on anticipated traffic volumes for project types I and II. The same agency cited temporary suspension of work activity as the primary result of unacceptable queues (4 miles or greater). Several agencies cited maximum delay as a primary metric used; 10 minutes, 12 minutes, and 30 minutes of delay are examples of maximum delay thresholds noted.
National Average: 10.1
VDOT Self-Score: 11
VDOT comments: "Maximum queue rates will vary in different regions of the state due to traffic volumes and available alternate routes. Lane closure restrictions have been developed to minimize queue lengths in each VDOT region."

4.2.1 Does the agency's planning process actively use analytical traffic modeling programs to determine the impact of future type I and II road construction and maintenance activities on network performance? Over two-thirds (69%) of the agencies actively use analytical traffic modeling programs to determine the impact of future type I and II

project activities. The average rating for this question increased by 5% from 2008. One agency uses a performance measurement system to assess freeway performance and identify operational weaknesses. The system utilizes data from detectors and helps decision makers estimate the effects of operational improvements. Agencies cited use of a fairly broad range of proprietary software applications, including PeMS, HCS, QuickZone, Paramics, VISSIM, NETSIM, WZCAT, and Synchro, for modeling construction impacts. Several agencies noted that use of analytical tools was fairly common on more complex projects.
National Average: 8.5
VDOT Self-Score: 9
VDOT comments: "Has been performed in the past on selected Category 1 (Types I and II) projects and is becoming a standard process."

4.2.2 Does the agency's planning process include developing alternative network options (e.g., frontage roads, increased capacity on parallel arterials, beltways, or strategically placed connectors) to maintain traffic volumes during future road construction and maintenance? Sixty-five percent (33) of the agencies reported using tools to determine alternate network options for traffic volumes that could be delayed due to road construction. One agency uses a process to upgrade alternate routes when higher volumes are expected to use these routes during major construction on adjacent facilities. Another agency makes an effort to maintain appropriate capacity through the construction area.
National Average: 8.4
VDOT Self-Score: 11
VDOT comments: "Looked at and has been implemented during bridge deck replacement or road widening projects, but cost limitations and available funding are still hurdles from being performed more."

4.3.1 Does the agency have a process to estimate road user costs and use them to evaluate and select project strategies (full closure, night work, traffic management alternatives, detours, etc.) for type I and II projects?
Forty-four agencies (85%) have a process to estimate road user costs. One agency cited use of the QUEWZ software to assist with the determination. The same agency noted that the results are combined with experience and historical knowledge to make decisions about the most appropriate strategies such as detours and nighttime construction. Some agencies noted that they have a process in place for estimating road user costs but either it is not used to determine types of project strategies or that some Districts choose not to use it (some use A+B bidding without a justification based on road user costs). One agency cited difficulties in comparing road user costs with other actual costs to justify decisions and investments based on benefits.
National Average: 10.7
VDOT Self-Score: 10
VDOT comments: "This has become a part of the overall project planning process to ensure limited funds are spent in the most efficient way; has been performed in the past on several projects."

4.3.2 Does the agency develop a Transportation Management Plan that addresses all operational impacts focused on project congestion for type I and II projects? Forty-nine agencies (94%) develop a TMP that addresses all operational impacts focused on project congestion for type I and II projects. The Rule requires TMPs and it was anticipated that all 51 responding agencies would have achieved the implementation level. In 2008, 46 agencies (88 percent) had reached the implementation level, with 48 of 51 agencies reporting having reached this threshold in 2009. One of the agencies that assigned a rating less than 7 (the implementation threshold) cited that components of the TMP are addressed for projects.
National Average: 10.9
VDOT Self-Score: 12
VDOT comments: “VDOT has integrated this item into its project development process.”

4.3.12 When developing the Traffic Control Plan for a project, does the agency use computer modeling to assess Traffic Control Plan impacts on traffic flow characteristics such as speed, delay, and capacity for type I and II projects? Forty-three agencies (83%) implement computer modeling in the development of traffic control plans. Some agencies use this computer modeling on a project-by-project basis (potentially for larger projects when higher impacts are anticipated) or on occasion to evaluate the potential impacts. Agencies reported using software such as QuickZone, Corsim, Synchro, VISSIM, TREX, COSMIX, CA4PRS, and WZCAT for analyzing impacts. Several agencies noted use of data on demand relative to capacity to help determine allowable hours for lane closures.
National Average: 9.6
VDOT Self-Score: 12
VDOT comments: “VDOT L&D and TED have implemented a policy which contains a process for determining project impacts to traffic.”

4.5.4 During type I, II, and III project construction, does the agency use a public information plan that provides specific and timely project information to the traveling public through a variety of outreach techniques (e.g., agency website, newsletters, public meetings, radio, and other media outlets)? This practice is being implemented by all 52 reporting agencies, giving it the highest implementation rate in the WZ SA. All agencies use a public information plan to provide specific and timely project information to the traveling public through a variety of outreach techniques. Some of these techniques include publishing information on the agency’s web site and providing information to media outlets. Other techniques include highway advisory radio messages, public relations managers, radio, TV, newspaper ads, telephone hotlines, and public information centers. This question remains the second highest scoring question on the WZ SA, indicating that the use of public information plans is widespread and is a well-established practice.
National Average: 13.2
VDOT Self-Score: 15
VDOT comments: “VDOT performs all of the strategies listed.”

4.5.5 During type I, II, and III projects, does the agency use ITS technologies to collect and disseminate information to motorists and agency personnel on work zone conditions? Forty-eight agencies (92%) use ITS technologies to collect and disseminate work zone information. This question had a decrease in the number of agencies implementing this practice (4 fewer agencies in 2009 compared with 2008), while the average rating did not change from 2008 to 2009. Many agencies use more basic systems, including portable changeable message signs to give the traveling public specific and timely project information and Highway Advisory Radio (HAR). Of the agencies who use ITS, several noted that use is on a project by project basis depending on need. One agency noted that use of ITS is currently being expanded to projects in rural areas as well

National Average: 10.9

VDOT Self-Score: 9

VDOT comments: "Smart traffic centers provide real time work zone traveler information, and traveler information is also entered into the 511 system. A travel time display ITS system was utilized on bridge repair work performed on I-81, and a VSL system has been deployed on the WWB project."

4.6.1 Does the agency collect data to track work zone congestion and delay performance in accordance with agency-established measures? (See Section 1, item 4.1.4) Less than half of responding agencies collect data to track work zone congestion and delay performance against agency measures. Although this question had the second lowest average score in the WZ SA, it had the second largest percent increase (13%) in the WZ SA and had the highest percent increase for this section. Thus it appears that more agencies are moving toward using data to track work zone congestion and delay. One agency stated that they have developed a policy and identified the need, but that performance measures still need to be established. Another agency noted that they will begin collecting congestion and delay information this year. One agency noted that they collect speed, volume, and occupancy data (the three common sources provided by wireless sensors), and they are determining how to use the data to calculate delay and queue length.

National Average: 6.3

VDOT Self-Score: 9

VDOT comments: "See TMP memo comments for this element."

4.6.2 Does the agency collect data to track work zone safety performance in accordance with agency-established measures? (See Section 1, item 4.1.5) Thirty-nine agencies (75%) are collecting data to track work zone safety performance. This question had a relatively large percentage increase (9%) over 2008. One agency noted that they plan to track work zone fatalities on a three year average statewide. Another agency cited a similar process, but noted that the data is not tied to performance measures due to some issues with accuracy and determining whether the fatality occurred within the work zone or downstream and outside the

work zone. One agency collects work zone crash data and senior managers track the statistics. Several agencies noted that they need to establish measures for tracking purposes.
National Average: 9.1
VDOT Self-Score: 13
VDOT comments: "WZ crashes, injuries, and fatalities are tracked on a yearly basis by Region, District, and roadway type and used for the development of district and statewide changes to WZS policy and SHSP strategies. In addition, WZ crashes is one of the items listed on VDOT's external dashboard program in the safety display."

4.6.3 Does the agency conduct customer surveys to evaluate work zone traffic management practices and policies on a statewide/area-wide basis?
Twenty-four agencies (47%) are using customer surveys to evaluate work zone performance. Agencies provide various opportunities for feedback on ways to improve work zones. Customer surveys are used in most cases. Customer surveys are often part of Context Sensitive Solutions practices in planning for and designing projects. One agency noted that the comments section of their website is available and used to solicit open public input on practices. Another agency is considering using customer satisfaction surveys as a tool to improve performance and to solicit input on programs and strategies. One agency asks the public to rate work zone practices on an "A to F" grading scale.
National Average: 6.3
VDOT Self-Score: 13
VDOT comments: "Have conducted surveys, have a statewide public hotline, and an information office for the WWB project located in the Springfield Mall in Northern Virginia."

4.6.4 Does the agency develop strategies to improve work zone performance based on work zone performance data and customer surveys? Over half of agencies (54%) develop strategies to improve work zone performance based on work zone data and customer surveys. One agency is developing a process for collecting, tracking, and monitoring work zone site information along with responses to customer surveys in order to develop a set of performance measures. The same agency noted that additional research into performance measures for work zone strategies is needed. One agency noted an informal review process occurs, where a team visits project sites with known issues and, after discussion, provides recommendations to the project team.
National Average: 7.3
VDOT Self-Score: 15
VDOT comments: "Based on motorist and worker feedback, VODT's WZ safety strategies have been developed with safety for workers and motorists in mind."