Data-Driven Work Zone Process Reviews Case Study: Virginia Department of Transportation

October 2021

TECHNICAL REPORT DOCUMENTATION PAGE

<table>
<tr><td>1. Report No.
FHWA-HOP-21-053</td><td>2. Government Accession No.</td><td colspan="2">3. Recipient's Catalog No.</td></tr>
<tr><td colspan="2" rowspan="2">4. Title and Subtitle
Data-Driven Work Zone Process Reviews
Case Study: Virginia Department of Transportation</td><td colspan="2">5. Report Date
October 2021</td></tr>
<tr><td colspan="2">6. Performing Organization Code:</td></tr>
<tr><td colspan="2">7. Author(s)
Param Sankar, Ram Boyapati, Alan Pate</td><td colspan="2">8. Performing Organization Report No.</td></tr>
<tr><td colspan="2" rowspan="2">9. Performing Organization Name and Address
Battelle
505 King Avenue
Columbus, OH 43201</td><td colspan="2">10. Work Unit No.</td></tr>
<tr><td colspan="2">11. Contract or Grant No.
DTFH6116D00049 / 693JJ319F000284</td></tr>
<tr><td colspan="2" rowspan="2">12. Sponsoring Agency Name and Address
United States Department of Transportation
Federal Highway Administration
1200 New Jersey Ave. SE
Washington, DC 20590</td><td colspan="2">13. Type of Report and Period</td></tr>
<tr><td colspan="2">14. Sponsoring Agency Code
HOP</td></tr>
<tr><td colspan="4">15. Supplementary Notes
Jawad Paracha (FHWA – HOTO) was the FHWA Task Manager.
Assistance from the Virginia DOT team was provided by David Rush (Virginia DOT), Bruce Martin (Virginia DOT), Katie McCann (Virginia DOT), and Karen King (FHWA – Virginia Division)</td></tr>
<tr><td colspan="4">16. Abstract
Federal regulations in 23 CFR part 630 subpart J require State highway agencies to conduct a Work Zone Process Review (WZPR) every 2 years to evaluate work zone processes and procedures, as well as identify systematic improvements to current and future projects. The Federal Highway Administration now encourages agencies to use a data-driven approach to make WZPRs more outcome- and performance-driven, while bringing about a continuum mindset to WZPRs, as opposed to isolated point-in-time reviews. This type of approach uses quantitative data and analyses including exposure, safety, mobility, and inspection data, as well as qualitative information in WZPRs. This case study is one of a series of resources on data-driven WZPRs. It was developed in collaboration with the Virginia Department of Transportation (VDOT) and focuses on three major performance areas: safety, mobility, and field reviews. Anonymized data from crash reports, probe vehicles, work zone field reviews, and work zone project tracking were used to conduct the analyses, derive metrics and trends, and identify key issues. The case study used data from 2016 through 2020. This case study demonstrates how VDOT successfully uses crash, traffic, field review, and construction data to streamline its WZPRs and provide a repeatable quantitative basis for more systematic reviews that extend across multiple process review cycles.</td></tr>
<tr><td colspan="2">17. Key Words
Work zone process review, work zone management, exposure data, safety data, field review data, mobility data</td><td colspan="2">18. Distribution Statement
No restrictions.</td></tr>
<tr><td>19. Security Classif. (of this report)
Unclassified</td><td>20. Security Classif. (of this page)
Unclassified</td><td>21. No. of Pages
35</td><td>22. Price</td></tr>
</table>

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

Table of Contents

List of Figures

List of Tables

List of Abbreviations and Acronyms

CQIP	Construction Quality Improvement Program
DOT	Department of Transportation
FHWA	Federal Highway Administration
MUTCD	Manual on Uniform Traffic Control Devices
NPMRDS	National Performance Management Research Data Set
NOVA	Northern Virginia
RITIS	Regional Integrated Transportation Information System
SWZ	Smart work zone
TED IIM	Traffic Engineering Division Instructional and Informational Memoranda
TOC	Traffic operations center
TTC	Temporary traffic control
VaTraffic	Virginia Traffic Information Management System
VDOT	Virginia Department of Transportation
VHD	Vehicle hours of delay
VMT	Vehicle miles traveled
WZ	Work zone
WZM	Work zone management
WZPR	Work Zone Process Review

Introduction

Federal regulations in 23 CFR part 630 subpart J require State highway agencies to conduct a Work Zone Process Review (WZPR) every 2 years to evaluate work zone (WZ) processes and procedures, as well as identify systematic improvements to current and future projects.[1] WZPRs apply to all project development and implementation phases, including planning, preliminary engineering, impact assessment, design, implementation/construction, and performance monitoring and management. Recognizing the importance of data for effective WZPRs, the Federal Highway Administration (FHWA) incorporated another provision in Subpart J requiring States to use available data, observations, and information to manage WZ impacts of individual projects, as well as to continually pursue broader improvement of WZ processes and procedures through WZ data analysis (e.g., crash/safety data, mobility data, construction metrics, operational metrics).[2]

The FHWA published guidance in April 2015 to assist State highway agencies in conducting effective WZPRs.[3] That guidance document recommends a nine-step approach for performing a WZPR, as shown in figure 1. In the guidance document, FHWA also emphasizes the importance of using data and performance measures in WZPRs to make the process reviews more comprehensive, actionable, and effective.

Suggested Process Review Steps in FHWA's Guidance for Conducting Effective Work Zone Process Reviews (2015 Publication)

1. Assemble a multidisciplinary team.
2. Develop a review plan.
3. Conduct review.
4. Analyze and interpret results.
5. Develop inferences, recommendations, and lessons learned.
6. Prioritize recommendations and lessons learned.
7. Develop an action plan to implement the prioritized recommendations.
8. Present findings.
9. Initiate the action plan.

Source: FHWA

Figure 1. List. Suggested Process Review Steps in FHWA's Guidance for Conducting Effective Work Zone Process Reviews

However, State departments of transportation (DOTs) have found it challenging to include data consistently and effectively in their WZPRs due to a lack of awareness and access to data, as well as limited resources for conducting streamlined data-driven process reviews. A renewed focus on performance-based work zone management (WZM), new industry paradigms, and the emerging data sources from connected, autonomous, and probe vehicles present State DOTs with many new opportunities to leverage data in their WZPRs. A data-driven WZPR approach will help

[1] 23 CFR part 630 subpart J. https://www.ecfr.gov/current/title-23/part-630/subpart-J.
[2] 23 CFR part 630 subpart J § 630.1008. https://www.ecfr.gov/current/title-23/chapter-I/subchapter-G/part-630/subpart-J/section-630.1008.
[3] FHWA. Guidance for Conducting Effective Work Zone Process Reviews (2015). https://ops.fhwa.dot.gov/publications/fhwahop15013/index.htm.

agencies to make WZPRs more outcome- and performance-driven, while bringing about more of a continuum mindset to WZPRs, as opposed to isolated point-in-time reviews.

This Virginia Department of Transportation (VDOT) case study was developed by FHWA to demonstrate a data-driven, systematic, and comprehensive approach to conducting WZPRs. It provides examples of how State DOTs can leverage existing data sources and performance assessment findings to incorporate data into steps two to five of the nine-step WZPR approach (shown in figure 1). It does not represent FHWA guidance or an example WZPR report and is not intended to replace the WZPR report format that State DOTs follow. As presented in figure 2, the data integration approach comprises identifying data needs for each performance area, conducting data analyses, identifying trends for issues and best practices, collecting contextual information about trends identified, selecting action plans based on trends, developing metrics to assess action items, implementing continuous data collection, and analyzing the impacts of implemented action items on program outcomes.

VDOT conducted its previous WZPRs by focusing on select strategies implemented during the process review cycle. The discussions in those WZPRs were driven by qualitative observations with limited focus on quantitative data assessments of WZM outcomes. Although data were not included in prior WZPRs, VDOT has been routinely collecting WZ-related data as part of VDOT's internal performance management efforts. This presents a significant opportunity for VDOT to use these data resources to make its WZPRs more data-driven, with the goal of using quantifiable benchmarks for performance management.

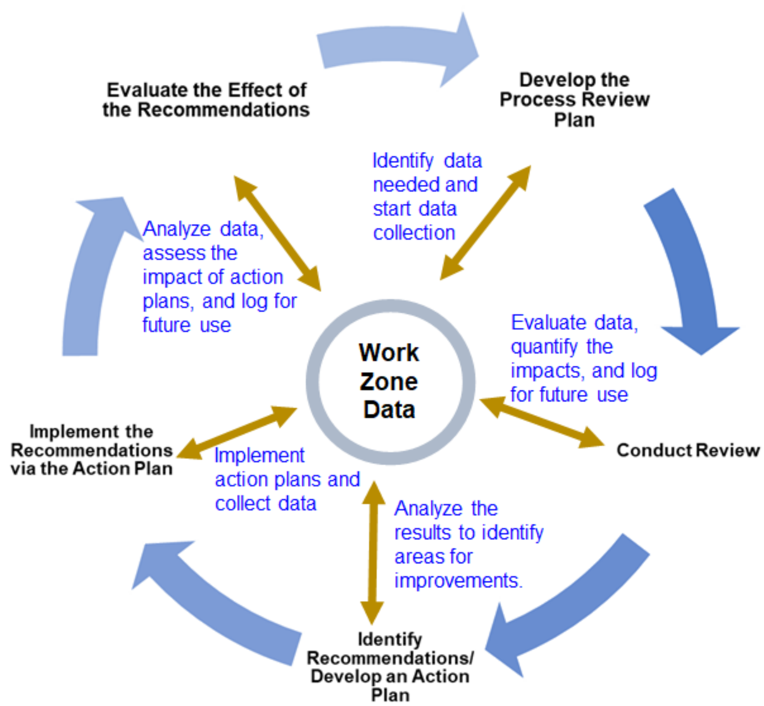

Figure 2. Diagram. An integrated approach for data-driven Work Zone Process Reviews
Source: FHWA

Performance Areas Selected for the Work Zone Process Review Case Study

The project team chose safety, mobility, and field reviews as the three main WZ performance areas for this WZPR case study. Anonymized data from crash reports, probe vehicles, WZ field reviews, and WZ project tracking are used to conduct the analyses, derive metrics and trends, and identify key issues. The safety and field review assessments cover all WZ projects implemented by VDOT, while the mobility assessment is limited to WZ projects implemented on interstates due to limited data availability. For the mobility and WZ field review performance areas, VDOT provided the project team with data from 2018, 2019, and 2020 to use in the case study. Similarly, for the WZ safety performance area, the team used data from 2016 through 2020. The project team selected different evaluation years for each performance area to accommodate the variabilities in data availability. The project team did not perform any statistical significance testing due to inconsistencies in data availability. Findings from the case study for each performance area are presented in the following sections. The discussion starts with an overview of the WZ exposure data that VDOT tracks, which provides a basis for assessing performance based on the volume of WZ activity.

Exposure Data

A comprehensive data-driven WZPR allows comparison of WZ performance across multiple years, as well as normalization of WZ performance by the volume of WZ activity (i.e., WZ exposure) in any given year. WZ exposure data include metrics such as the number of WZs, mileage of construction and maintenance activity, project duration, lane closure hours, and traffic volume affected by WZs.

> **Exposure Data Used in Case Study**
>
> **Data Source:** Virginia Traffic Information Management System
>
> **Metrics:** Number of WZs, WZ miles, WZ hours, and lane closure hours

VDOT tracks and digitizes WZ exposure information for all WZ projects using the Virginia Traffic Information Management System (VaTraffic) database. VDOT's VaTraffic is designed to improve VDOT operations by providing a more efficient and advanced integrated data management platform for managing a variety of activities that affect the quality of travel experienced by motorists in the Commonwealth of Virginia (Commonwealth). It is a network of applications that VDOT staff use to manage planned events (e.g., roadway maintenance) and unplanned events (e.g., traffic accidents), as well as to provide information for other VDOT systems. VaTraffic provides VDOT operations staff with an integrated tool to collect, monitor, update, and disseminate roadway information. This comprehensive database acts as a robust tool for VDOT's central office to collect granular WZ-related activity and mobility data on a regular basis.

The project team obtained WZ-related activity data from the VaTraffic database for 2016 through 2020 and analyzed them to assess statewide WZ exposure metrics. Metrics calculated using the WZ activity data include number of WZs, WZ miles, WZ hours, and lane closure hours.

Number of Work Zones

In the period 2016 to 2020, the average number of WZs implemented per year was 37,734. In 2020, VDOT implemented 40,143 WZs, which is a 6-percent increase compared to the 5-year average (figure 3). VDOT was able to accelerate activities on WZ projects by taking advantage of the reduced traffic demand during the COVID-19 pandemic, which led to the increased number of WZs implemented in 2020. Another broader driver of the increase in WZs beginning in 2017 is VDOT's conscious efforts to invest more in paving-related projects.

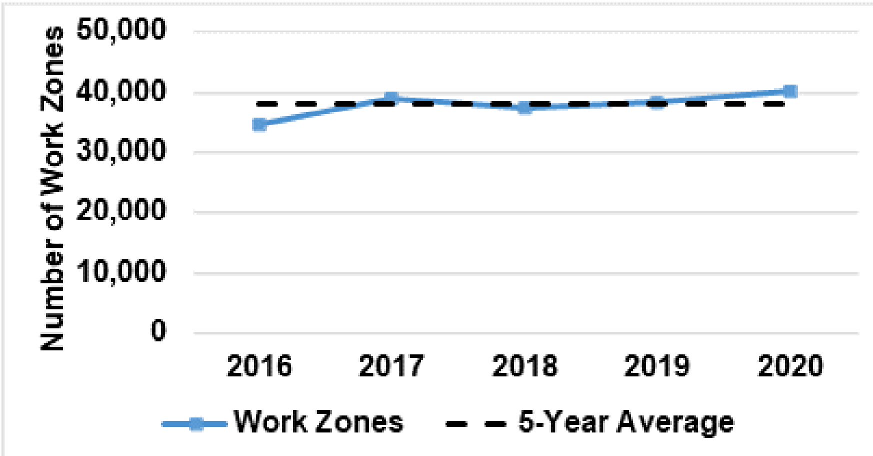

Figure 3. Chart. Number of work zones completed
Source: VDOT

Number of Work Zone Miles

This metric provides the number of WZ miles across all facilities, which is the sum of the length of each WZ. The number of lanes also factors into the calculation of the number of WZ miles (e.g., a 2-mile WZ segment with two lanes is 4 WZ miles). As mentioned previously, beginning in 2017, there was an increase in WZ activity due to VDOT investing in paving projects, with WZ miles hovering around the 5-year average of 266,208 miles in 2017, 2018, and 2019 (figure 4). In 2020, VDOT took advantage of the reduced travel caused by the COVID-19 pandemic to accelerate the implementation of WZ projects, resulting in 301,876 WZ-lane-miles, which was a 13-percent increase compared to the 5-year average.

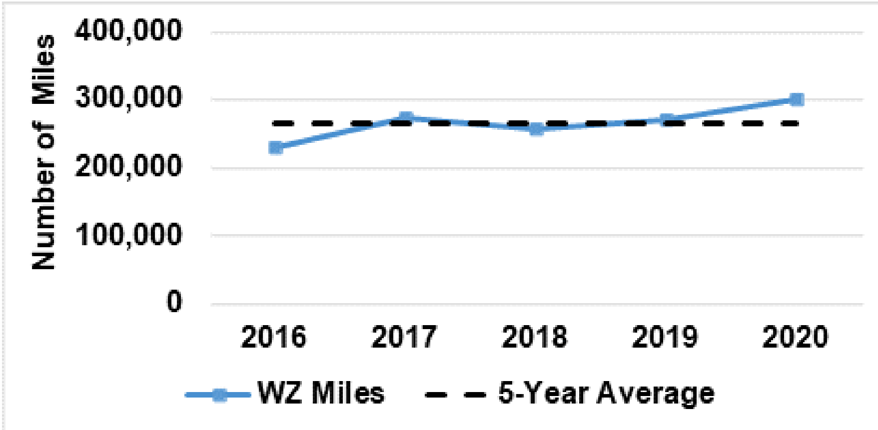

Figure 4. Chart. Number of work zone miles
Source: VDOT

Number of Work Zone Hours

This metric presents the total duration of hours spent performing VDOT's WZ activities. In 2017, 2018, and 2020, VDOT spent 2.19, 2.04, and 2.28 million WZ hours, respectively, which were 9, 1, and 13 percent higher, respectively, than the 5-year average of 2.02 million WZ miles (figure 5). In 2016 and 2019, VDOT spent 1.66 and 1.91 million WZ hours, respectively, which were 18 and 5 percent lower than the 5-year average. In all years except 2019, the trend in WZ hours spent by VDOT matched the trend in number of WZ miles implemented. In 2019, VDOT spent fewer WZ hours while implementing more WZ miles than the 5-year average—likely because VDOT focused more on paving and road-widening projects in 2019, which take less time than new construction projects.

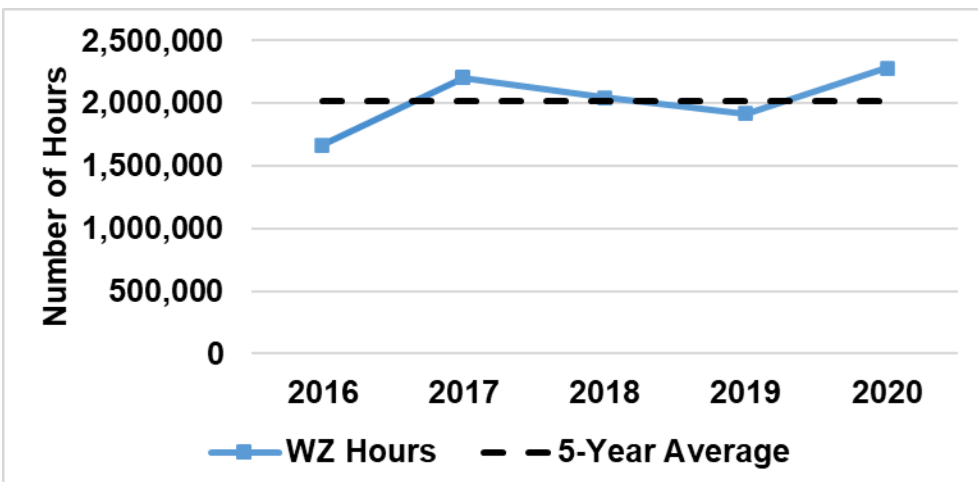

Figure 5. Chart. Number of work zone hours
Source: VDOT

Work Zone Hours per Work Zone Mile

To put WZ hours and WZ miles into perspective, the project team calculated a "WZ hours per WZ mile" rate for all WZ projects implemented each year. This metric refers to the number of WZ hours spent on intended work on each WZ mile. Ideally, when comparing individual WZ projects of the same activity type, complexity, and scope, this metric offers good insight into the implementation efficiency of WZ agencies. Due to limited data availability, the project team could not perform this analysis at a project level or by WZ activity type. For its upcoming WZPRs, VDOT should consider this project-level analysis to set performance benchmarks and measure and improve the timeliness of its WZ project implementation.

Overall, in comparison to the 5-year average (7.56), the number of WZ hours per WZ mile spent by VDOT marginally decreased in 2016 and 2019, marginally increased in 2017 and 2018, and remained on par in 2020 with the average (figure 6). Though there is some variation in the number of WZ hours per WZ mile across the years, it is not possible to compare trends and assess variation across the different WZ activity types due to lack of access to the granular exposure data. Discussions with VDOT indicated that VDOT implemented fewer new roadway construction projects and more paving and road-widening projects in 2019 compared to previous years. Because paving or road-widening projects complete sooner than new roadway construction projects, fewer WZ hours may have been spent per WZ mile in 2019 than the 5-year average.

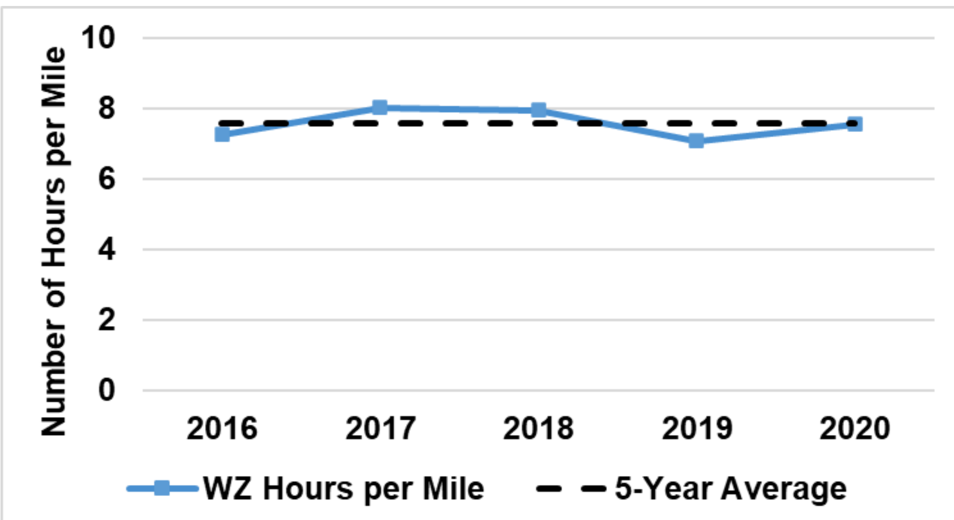

Figure 6. Chart. Work zone hours per work zone mile completed
Source: VDOT

Number of Lane Closure Hours

This metric presents the number of hours traffic lanes were closed for WZ activity. VDOT requires its construction staff to notify the traffic operations center (TOC) at the start and end of WZ lane closure activity. Information reported includes WZ location, lane closure hours of operation, and number of lanes closed. VDOT's TOC staff log this information daily in the VaTraffic database using its VaRoads[4] tool. In 2016, VDOT implemented 1.4 million lane closure hours, which was 20 percent lower than the 5-year average of 1.77 million. Starting in 2017, VDOT's efforts to invest more in paving projects led to an increase in overall WZ activity. In 2017, 2018, and 2019, VDOT implemented 1.85, 1.82, and 1.70 WZ lane closure hours, respectively, which were close to the 5-year average. In 2020, VDOT implemented 2.08 million

[4] VDOT's Open Data Portal, Virginia Roads, https://www.virginiaroads.org.

lane closure hours, which was 17 percent more than the 5-year average (figure 7). The increase in 2020 lane closure hours was because VDOT accelerated its road projects to take advantage of the reduced travel demand due to the COVID-19 pandemic. Additionally, by normalizing the lane closure hours with the WZ hours for projects that require lane closures, VDOT can assess the lane closure efficiency and compliance of WZ agencies. This metric can provide key insights, such as WZ exposure to traffic outside of the activity hours, leading to additional traffic disruptions and WZ costs.

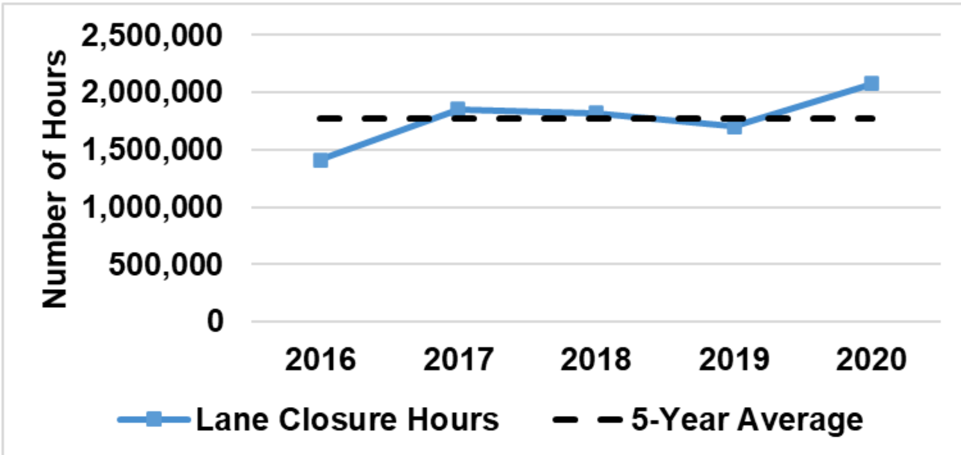

Figure 7. Chart. Number of lane closure hours
Source: VDOT

Key Findings and Observations for Data-Driven WZPRs

- VDOT requires its construction staff to notify the TOC at the start and end of WZ activity and lane closures. The information collected includes WZ name, location, hours of operation, and number of lanes closed. The TOC staff log this information into the VaTraffic database daily. VDOT's VaTraffic dashboard is a valuable tool for saving the project activity and mobility data and tracking patterns and trends over time, as well as for visual presentation and analysis of the data.
- WZ activity data collected by VDOT include number of WZs, WZ miles, WZ hours, and lane closure hours. Tracking these WZ activity data will enable VDOT to compare WZ performance across multiple years, as well as to normalize WZ performance by the volume of WZ activity (i.e., WZ exposure) in any given year. Incorporating the WZ activity data collection into its WZM business processes demonstrates VDOT's commitment to quantify, measure, and manage its WZ performance consistently. In addition to its current exposure data, VDOT should consider collecting WZ VMT, which provides a common frame of reference to measure WZ performance across projects and years, and provides a better basis for identifying trends and actions in WZPRs.
- Beginning in 2017, VDOT started investing in more road paving projects. Therefore, the overall WZ activity (WZs, WZ miles, WZ hours, and lane closure hours) in 2016 was below the 2016 through 2020 5-year average. In 2017, 2018, and 2019, the WZ activity was around the 5-year average. In 2020, VDOT took advantage of the reduced travel caused by the COVID-19 pandemic to accelerate the implementation of WZ projects, resulting in increased WZ activity.
- For upcoming WZPRs, VDOT should consider normalizing the lane closure hours with the WZ hours for projects that require lane closures to assess the lane closure efficiency and compliance of WZ agencies. This metric can provide key insights such as WZ exposure to traffic outside of the activity hours, leading to additional traffic disruptions and WZ costs.
- In 2016 through 2020, Virginia experienced marginal variations in WZ hours spent per WZ mile. Due to limited availability of granular exposure data, the project team could not compare trends and assess variation across the different WZ activity types. Ideally, when comparing individual WZ projects of the same activity type, complexity, and scope, this metric offers good insight into the implementation efficiency of WZ agencies. For its upcoming WZPRs, VDOT should consider this project-level analysis to set performance benchmarks and measure and improve the timeliness of its WZ project implementation.

Performance Area 1 – Work Zone Safety

Work Zone Crashes

Safety Data Used in Case Study

Source: Virginia Crash Reports

Metrics: Crashes per VMT, Number of WZ crashes, and Crash rates per thousand WZ miles

The project team analyzed WZ-related crash data to assess the safety performance of WZs implemented in Virginia from 2016 to 2020. The crashes included in the analysis are those coded on crash reports as being associated with a WZ. In addition to capturing crashes associated with WZs, Virginia police officers note the contributing factors (e.g., speeding, distracted driving) and vehicle types involved (e.g., large trucks) in their crash reports. Tracking and digitizing these additional factors enables VDOT to measure the efficiency of its WZ safety policies (e.g., adequate transition areas, frequent speed limit information).

In 2016, 2017, and 2018, Virginia experienced 2,432, 2,667, and 2,528 WZ crashes, respectively, which were 20, 13, and 17 percent fewer than the 5-year average of 3,051 crashes (Figure 8). However, VDOT experienced 3,869 and 3,757 WZ crashes in 2019 and 2020, respectively, which were 27 and 23 percent higher compared to the 5-year average. A crash distribution analysis conducted by the project team indicated similar trends for speeding-related (figure 9) and large truck (figure 10) crashes, which could have contributed to the dramatic increase in WZ crashes in 2019 and 2020. A further investigation of the crash-contributing factors and sequence of events from the crash reports may shed light on the root causes for the changes in safety performance. The dramatic increase in WZ crashes in 2019 and 2020 could also be attributable to actual WZ vehicle miles traveled (VMT), which, if available, would provide additional context.

VDOT does not collect and record VMT through WZs. To get a relative measure of VMT variation across the years, the project team compared total VMT across the years. The total VMT in Virginia for 2016 to 2019 was marginally higher than the 5-year average of 83.9 billion but dropped to 74.5 billion in 2020. The 9.4 billion drop in 2020 VMT is likely a result of reduced travel demand due to the COVID-19 pandemic conditions. A similar trend was observed for total crashes (both WZ and non-WZ crashes) and crash rate per million VMT. Though the overall VMT trends provide indicative information about the changing travel behaviors across the Commonwealth, it is essential to normalize the WZ performance data by WZ VMT to accurately benchmark and understand WZ performance across multiple projects and years.

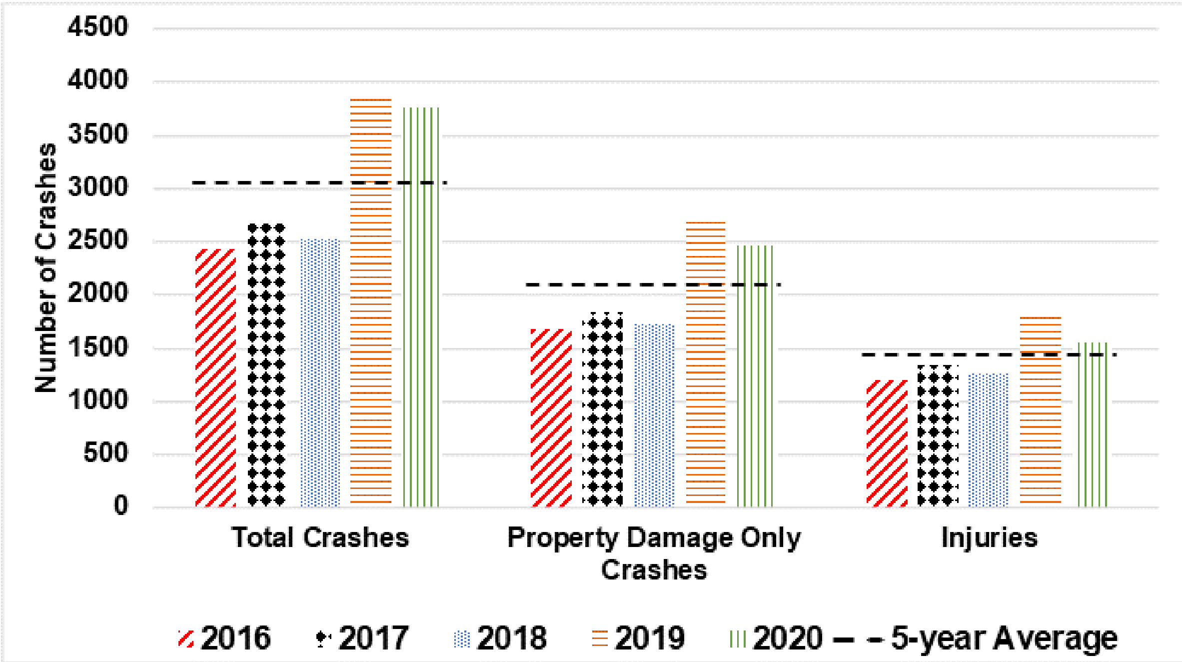

Figure 8. Chart. Number of crashes, property damage only crashes, and injuries in work zones

Source: VDOT

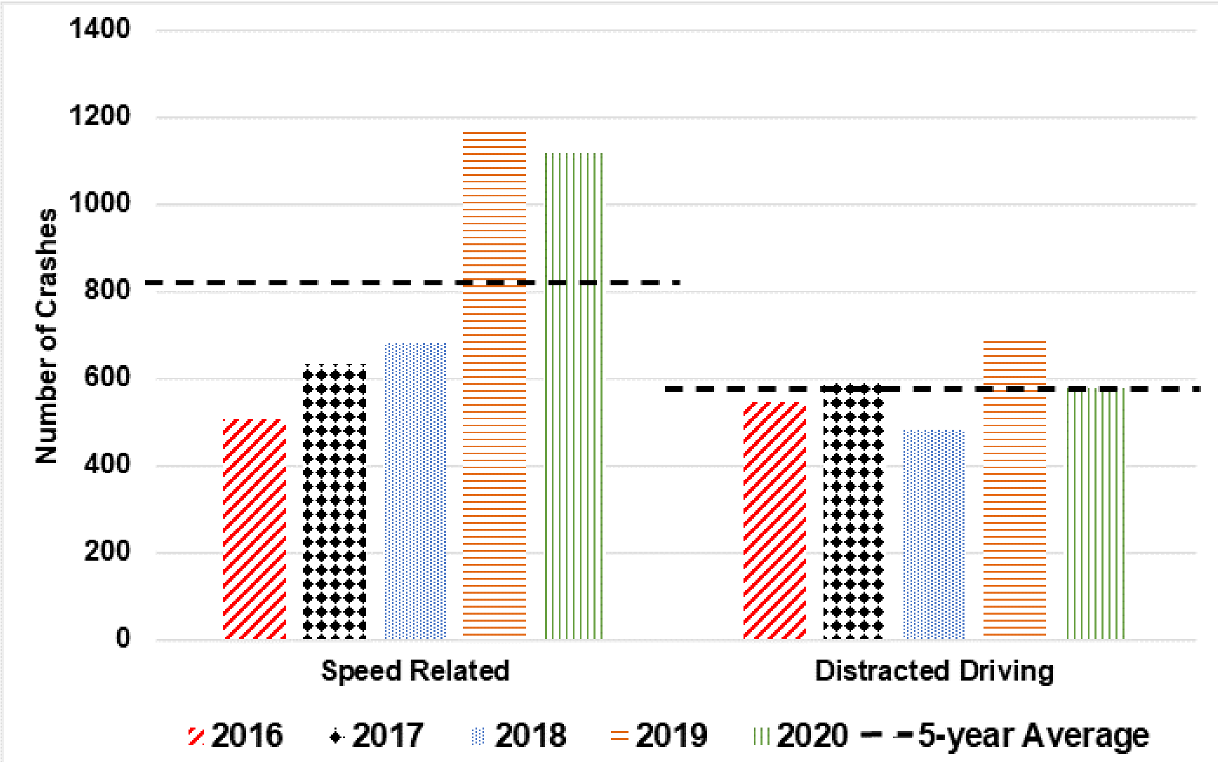

Figure 9. Chart. Number of work zone crashes caused by speeding and distracted driving

Source: VDOT

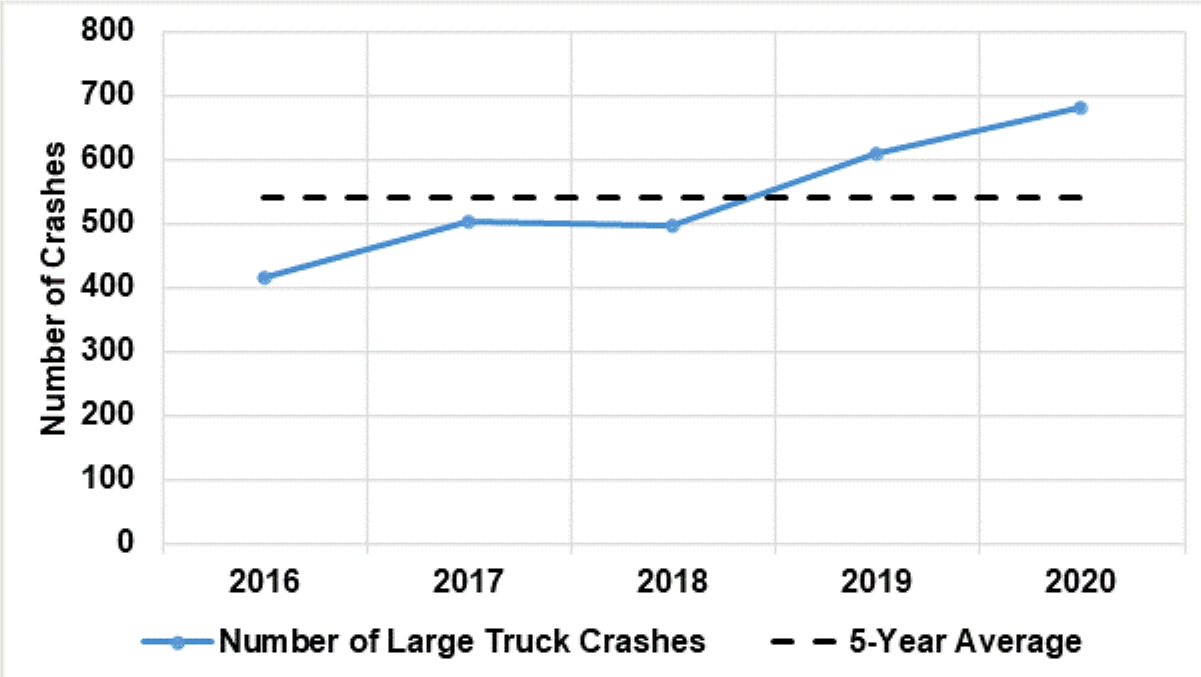

Figure 10. Chart. Number of work zone crashes involving large trucks
Source: VDOT

The project team also analyzed WZ fatalities across the 5-year period. VDOT experienced 10, 11, 9, and 11 fatalities in 2016, 2017, 2018, and 2020, respectively, which were close to the 5-year average of 12 fatalities (figure 11). In 2019, Virginia experienced 17 fatalities, which was 44 percent higher than the 5-year average. A further analysis conducted on the contributing factors suggests that increase in speeding-related and distracted driving crashes (figure 10) could have contributed to the increased crash severity in 2019. A secondary investigation into the fatal crash reports may shed light on any recurring causes (e.g., involving large trucks, secondary crashes, speeding), locations (transition areas, entrance ramps), and patterns in fatal crashes across the years. The project team did not have access to the necessary crash data to perform this assessment.

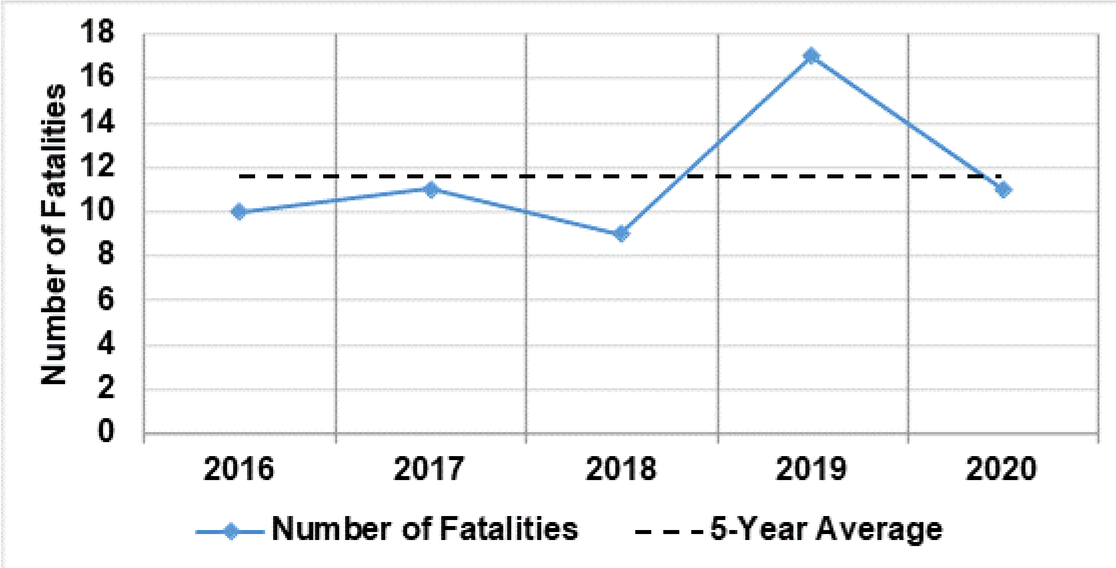

Figure 11. Chart. Number of fatalities from work zone crashes

Source: VDOT

Work Zone Crashes per Thousand Work Zone Miles

To account for the varying levels of traffic exposure to crash risks, the project team used the number of WZ miles as a surrogate metric for WZ VMT to normalize WZ crash data (figure 12). Per 1,000 WZ miles, Virginia experienced 11 crashes in 2016, 10 crashes each in 2017 and 2018, 14 crashes in 2019, and 12 crashes in 2020. Compared to the 5-year average, Virginia experienced marginal variations in WZ crash rates across the years. Similar crash rate trends were observed for normalized large truck crashes (figure 13). Even though the overall WZ crashes were considerably higher in 2019 and 2020 compared to the 5-year average (figure 8), the normalized crash rates indicated only a marginal increase in 2019 and 2020. Normalizing the WZ crashes using WZ VMT may shed more light on the actual crash trends and contributing factors across the years.

A further analysis on the crash type distribution indicates that the rear-end crashes constitute more than 50 percent of overall WZ crashes for both 2019 and 2020. During its 2021 WZPR assessment meetings, VDOT combined the qualitative findings on safety from district staff with the quantitative findings from this case study to identify rear-end crashes as a key issue for its 2021 WZPR assessment.

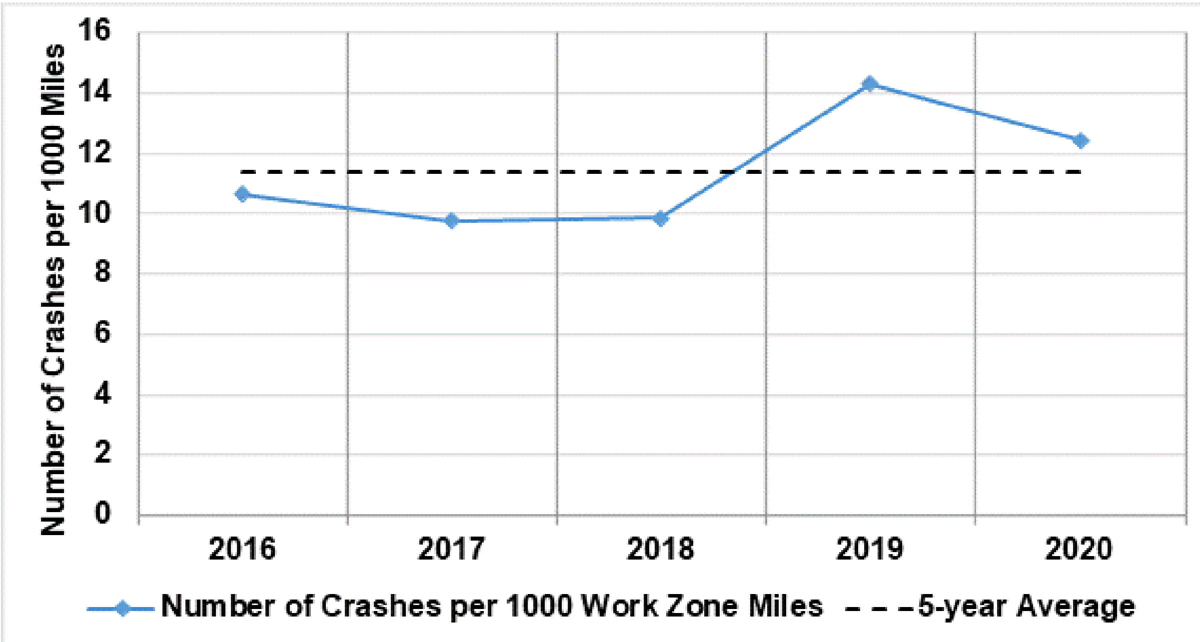

Figure 12. Chart. Number of work zone crashes per thousand work zone miles

Source: VDOT

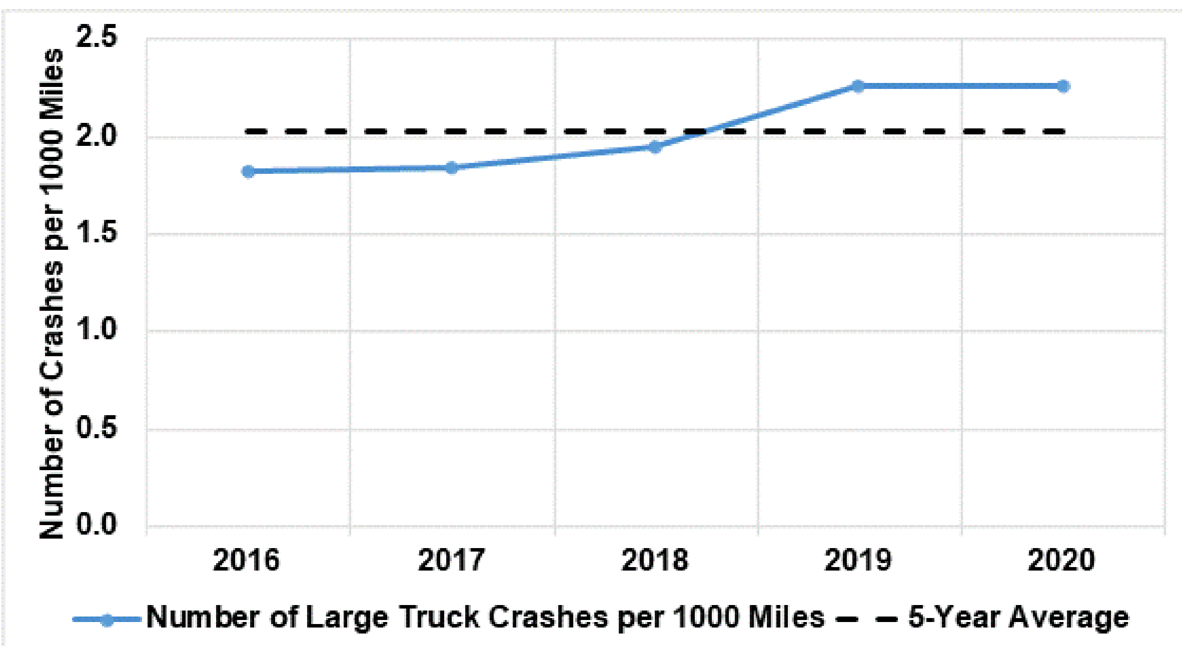

Figure 13. Chart. Number of large truck crashes per thousand work zone miles

Source: VDOT

Key Findings and Observations for Data-Driven WZPRs

- In addition to reporting crashes associated with WZs, Virginia police officers note the contributing factors (e.g., speeding, distracted driving) and vehicle types involved (e.g., large trucks) in their crash reports. Tracking and digitizing these additional factors enables VDOT to measure the efficiency of its WZ safety policies (e.g., adequate transition areas, frequent speed limit information).
- Virginia experienced fewer WZ crashes between 2016 to 2018 and considerably higher crashes in 2019 and 2020 compared to the 5-year average. The project team used the number of WZ miles as a surrogate metric for WZ VMT to normalize WZ crash data to account for the varying levels of traffic exposure to crash risks. The normalized crash rates minimized the differences in WZ crashes between the years and indicated only marginal variations across the years. Normalizing crash data against WZ VMT will shed more light on the actual crash trends and potentially explain the marginal increase in average crashes per thousand WZ miles in 2019 and 2020.
- VDOT tracks the number of WZs, WZ miles, WZ hours, and lane closure hours. These data offer a good foundation for comparing WZ performance across the years. Tracking additional exposure information such as WZ VMT, vehicle hours traveled, mileage, number of lanes closed, percent capacity reduced, etc., will further help provide a common frame of reference to measure WZ performance across years and incorporate those findings into WZPRs.
- The project team conducted an additional analysis on crash distribution and contribution factors and identified that the steep rise in speeding-related and large truck crashes in 2019 and 2020 could have contributed to the overall increase in crashes, as well as crash severity. VDOT should consider further investigation of granular crash reports and capture qualitative observations from law enforcement staff to identify the cause and effect of these changes in WZ safety performance.
- The project team further explored an extensive list of crash types and their distribution to understand the impact and recurrence of each crash type. These quantitative findings, when combined with the qualitative observations from the district staff, indicated that rear-end crashes constituted more than 50 percent of overall WZ crashes for both 2019 and 2020. During its 2021 WZPR assessment meetings, VDOT identified and ranked rear-end crashes as the top priority issue for its 2021 WZPR assessment. These correlations inferred from a combination of quantitative and qualitative data demonstrate the true value of WZPRs in measuring, identifying, and addressing issues associated with WZM.

Performance Area 2 – Work Zone Mobility

> **Mobility Data Used in Case Study**
>
> **Source:** RITIS, NPMRDS, and a private data collection and analytics software.
>
> **Metric:** Vehicle Hours of Delay

VDOT's mobility policy requires that all WZs conform to the allowable WZ Lane Closure Hours tool[5]. This tool sets volume thresholds for allowable lane closures by time of day. If the expected WZ traffic volume exceeds the allowable thresholds, the project team must perform a queuing analysis. The allowable WZ queue length is one mile. If the WZ project team estimates queues to be less than one mile, VDOT permits the closure. If the estimated queue is greater than one mile for any period, the WZ project team must submit an exception request to the VDOT Central Office, along with appropriate queue and delay mitigation strategies. Every year, VDOT Central Office and District personnel update the data in the Allowable WZ Lane Closure Hours tool. VDOT is continually making this tool more accurate by incorporating newly available data.

The policy-driven approach to WZ mobility management begins during project planning and extends into the construction phase of projects. During the construction phase, VDOT monitors WZ queues and speeds and takes appropriate informative or corrective action to improve mobility performance in WZs.

In 2021, VDOT conducted an "Estimated Causes of Congestion" study using data from 2018 to 2020.[6] In that study, VDOT used probe vehicle data from the Regional Integrated Transportation Information System (RITIS), the National Performance Management Research Data Set (NPMRDS), and private data collection and analytics software to identify delay events on interstates, where the speeds were 20 miles per hour (mph) below the free-flow speed. VDOT used the data from that study to estimate the vehicle hours of delay (VHD) experienced by travelers on Virginia interstates due to various events including WZs, recurring events, non-recurring incidents, weather, and other events. VDOT used the WZ project data (geographic boundaries, start and end dates, hours of operation) from the VaTraffic database to identify delay events at WZs. Due to limited staffing resources, VDOT limited its study to interstates. However, VDOT plans to extend this study to non-interstate limited-access highways for upcoming iterations. As part of this case study, the project team analyzed the VHD results from VDOT's study to understand the impact of WZs on the mobility performance of the interstates.

Vehicle Hours of Delay

From the data analysis findings using probe data, VDOT used VHD as the key metric to assess the mobility performance on interstates. VDOT calculated the annual VHD by subtracting the estimated free-flow vehicle-hours traveled from the actual vehicle-hours traveled when speeds fell 20 mph or more compared to the free-flow speed. The VHD findings suggest that WZ-related travel delays were highest on I-64, I-66, I-95, and I-395 when compared to other

[5] https://www.virginiadot.org/business/resources/OperationsDivision/Statewide_Lane_Closure_Final_IIM-OD-16-03.pdf

[6] https://www.virginiadot.org/vtrc/main/online_reports/pdf/22-r15.pdf

interstates (table 1). In comparison to 2018, the total annual VHD on interstates increased by 39 percent and 1 percent in 2019 and 2020, respectively. In comparison to 2018, VDOT's implementation of at least 15 percent more WZs on I-64, I-95, and I-395 interstates likely contributed to the dramatic increase in WZ VHD. Despite a considerable increase in total number of WZ miles (13 percent) and lane closure hours (16 percent) in 2020 when compared to the 5-year average, the 2020 VHD on interstates remained close to the 2018 VHD. This marginal variation in 2020 VHD is possibly due to the reduced travel demand during the COVID-19 pandemic conditions. Ideally, the VHD would be normalized by exposure metrics such as WZ VMT, WZ miles, or lane closure hours. VDOT collects and digitizes WZ exposure data for all WZ projects. However, the project team did not have access to these exposure data at a project or interstate highway level. VDOT should normalize the VHD by WZ miles or lane closure hours for each interstate to perform a comparable mobility analysis across the years.

Through its ongoing data collection efforts, VDOT began implementing intelligent drums with detection sensors at its WZs to improve mobility data collection. These devices can relay the location of the WZ to a cloud-based computer that meets the FHWA WZ Data Exchange guidelines.[7] The computer then supplies the WZ location to various mapping applications. When multiple intelligent drums are combined on a job site, they can provide queue measurements along with headway speed, basic traffic counts, and VMT. VDOT plans to use the speed and VMT data for determining delay per VMT at a WZ segment level. VDOT also could use these queuing metrics to assess the efficiency of its allowable work hours by comparing the estimated queue lengths to the actual queuing at WZs.

Table 1. Annual Vehicle Hours of Delay Related to Work Zones on Interstates

Route	2018	2019	2020
I-64	85,570	166,234	31,396
I-66	225,773	183,189	294,577
I-77	56,432	1,207	6,148
I-81	28,065	27,715	56,149
I-85	679	3,275	2,472
I-95	100,803	207,315	123,415
I-195	914	4,787	576
I-264	1,171	388	833
I-295	6,074	6,969	5,003
I-381	0	0	0
I-395	18,030	125,595	14,307
I-464	245	30	0
I-495	6,888	14,145	2,899
I-564	301	92	94
I-581	545	0	30
I-664	321	865	261
All Interstates	**531,811**	**741,806**	**538,160**

[7] https://github.com/usdot-jpo-ode/wzdx

To better understand the causation that resulted in the WZ VHD variations across the different interstate facilities, the project team gathered qualitative assessments from VDOT's WZPR team. Key findings from these qualitative assessments include:

- **A 6-year-long road-widening project on I-64 caused high VHD**. On I-64, the majority of WZs are located in the Hampton Roads area. These ongoing WZs focus on widening the interstate from a two-lane to three-lane route in each direction.
- **A 25-mile road-widening project on I-66 caused high VHD.** I-66 is the most heavily traveled route for drivers going to and coming from Washington D.C. (thus experiencing high VMT) and has a 25-mile road-widening project that is ongoing. The WZs associated with this project led to many of the recurring delays on this interstate.
- **Road-widening activity conducted beyond Virginia borders on I-77 led to a VHD spike in 2018.** In 2016 through 2018, there was a major road-widening project on I-77 just across the Virginia/North Carolina border. There would often be miles of delay in Virginia, especially if a crash occurred that temporarily shut down SB I-77.
- **Road-widening activity implemented in 2020 and heavy truck volume led to excessive delays on I-81.** In 2020, VDOT began widening work on a few areas on I-81 (in the Bristol, Salem, and Staunton districts). I-81 is a major truck route and experiences traffic backups during crash events at WZs.
- **Increased WZ activity in the heavily traveled corridors of I-95 created queues during peak hours**. I-95 stretches from north to south through Virginia and has construction projects in the Richmond, Fredericksburg, and Northern Virginia (NOVA) districts. More than 35 percent of Virginia's population (8.5 million) lives in the NOVA district. In 2019, VDOT implemented more WZ projects in the heavily traveled I-95 portion between Fredericksburg and NOVA, which resulted in excessive queuing during WZ incidents.
- **Continuous traffic demand and busy corridors on I-395 led to excessive delays**. I-395 passes through a short stretch of Springfield and Arlington urban areas but holds high year-round traffic demand. Even small incidents at WZ segments on this interstate can lead to large queuing events.

Key Findings and Observations for Data-Driven WZPRs

- VDOT's mobility policy requires that all WZs conform to the allowable WZ Lane Closure Hours tool. This tool sets volume thresholds for allowable lane closures by time of day. If the expected WZ traffic volume exceeds the allowable thresholds, the project team must perform a queuing analysis. The allowable WZ queue length is one mile. If the WZ project team estimates queues to be less than one mile, VDOT permits the closure. VDOT also approves the extended hours if the queuing on affected traffic corridors remains below one mile. VDOT developed this design and planning tool to accommodate the mobility needs of WZs with differing durations and lengths.
    - The policy-driven approach to WZ mobility management begins during project planning and extends into the construction phase of projects. During the construction phase, VDOT monitors WZ queues and speeds and takes appropriate informative or corrective action to improve mobility performance in WZs.
- In 2021, VDOT conducted an "Estimated Causes of Congestion" study for 2018 to 2020. In this study, VDOT used probe vehicle data from RITIS, a private data collection and analytics software, and NPMRDS to identify delay events on interstates, where the speeds were 20 miles below the free-flow speed. VDOT used the data from that study to estimate the VHD experienced by travelers on Virginia interstates due to various events including WZs, recurring events, non-recurring incidents, weather, etc. VDOT used the WZ project data (geographic boundaries, start and end dates, hours of operation) from the VaTraffic database to identify delay events associated with WZs.
    - Study findings indicated a 39-percent and 1-percent increase in VHD in 2019 and 2020, respectively, compared to 2018. Multi-year road-widening projects on heavily traveled interstate corridors resulted in high VHDs experienced in 2019. A marginal 2020 VHD increase despite higher number of WZs implemented is likely an effect of the reduced travel demand in 2020 due to the COVID-19 pandemic conditions.
    - VDOT intends to expand its VHD evaluation to non-interstate limited-access highways as part of its forthcoming WZ performance measurement.

Key Findings and Observations for Data-Driven WZPRs (continued)

- Through its ongoing data collection efforts, VDOT started implementing intelligent drums at its WZs to improve mobility data collection. These devices can relay the location of the WZ to a cloud-based computer that meets the FHWA WZ Data Exchange guidelines. The computer then supplies the WZ location to various mapping applications. When multiple intelligent drums are combined on a job site, they can provide queue measurements along with headway speed, basic traffic counts, and VMT. VDOT plans to use the speed and VMT data for determining delay per VMT at a WZ segment level. Further, VDOT could use these queuing metrics to assess the efficiency of its allowable work hours by comparing the estimated queue lengths to the actual queuing at WZs.
- VDOT collects WZ exposure metrics including the number of WZs, WZ miles, WZ hours, and lane closure hours. Although these are metrics that can provide a common frame of reference across the years, the project team did not have access to the exposure metrics at corridor- or project-level granularity. For its upcoming WZPR mobility analysis, VDOT should consider normalizing the WZ VHD at each interstate with appropriate exposure data to get a comparable WZ mobility metric across the years. VDOT's initiative to collect WZ VMT through intelligent drums to as a normalizing metric for its mobility analysis will set a good standard for a more accurate comparison of mobility performance across the years.

Performance Area 3 – Work Zone Field Reviews

Work Zone Field Reviews Data Used in Case Study

Source: VDOT Construction Quality Improvement Program

Metrics: Number of WZ projects inspected, Projects with acceptable or higher ratings, and Projects with unacceptable or lower ratings.

VDOT's Construction Quality Improvement Program (CQIP) provides field inspection and engineering oversight on VDOT's construction projects, with the aim to improve the future quality of VDOT's roads and bridges. Engineers from the CQIP team randomly select and review active construction projects across Virginia for compliance with applicable law, contract, plans, and department policy and procedures by focusing on the process and the product. The CQIP team reviews safety devices, pavement markings, signs, barriers, flagging, temporary traffic signals, traffic maintenance, stabilization of entry/exit points, traffic control supervisors, unsafe traffic condition corrections, and WZ area compliance with traffic control figures, the *Manual on Uniform Traffic Control Devices for Streets and Highways* (MUTCD)[8], and the *Virginia Work Area Protection Manual*[9].

[8] https://mutcd.fhwa.dot.gov/htm/2009r1r2/html_index.htm
[9] http://www.vdot.virginia.gov/business/resources/traffic_engineering/workzone/wapm/2011__REV_2_1.pdf

The CQIP team completes project reviews using a checklist of more than 120 questions. VDOT's Construction division analyzes and aggregates the CQIP scores annually and generates a report to provide transparency to the general public regarding the quality of work performed under VDOT contracts.[10] The CQIP team inspected 170, 150, and 148 projects in 2018, 2019, and 2020, respectively (figure 14).

CQIP has been a critical element of the VDOT construction program for more than 15 years. Over time, the data collected and analyzed from the reviews have been, and continue to be, instrumental in continuously improving VDOT's contracts, specifications, policies, procedures, and most of all the quality and safety of construction projects.

In addition to the CQIP inspections, WZM experts from FHWA and VDOT review a small percent of randomly selected projects for additional oversight on project compliance with VDOT's policies and procedures. The FHWA/VDOT team inspected 16, 15, and 7 WZ projects in 2018, 2019, and 2020, respectively. The COVID-19 pandemic conditions limited the number of in-person inspections conducted in 2020 (figure 15).

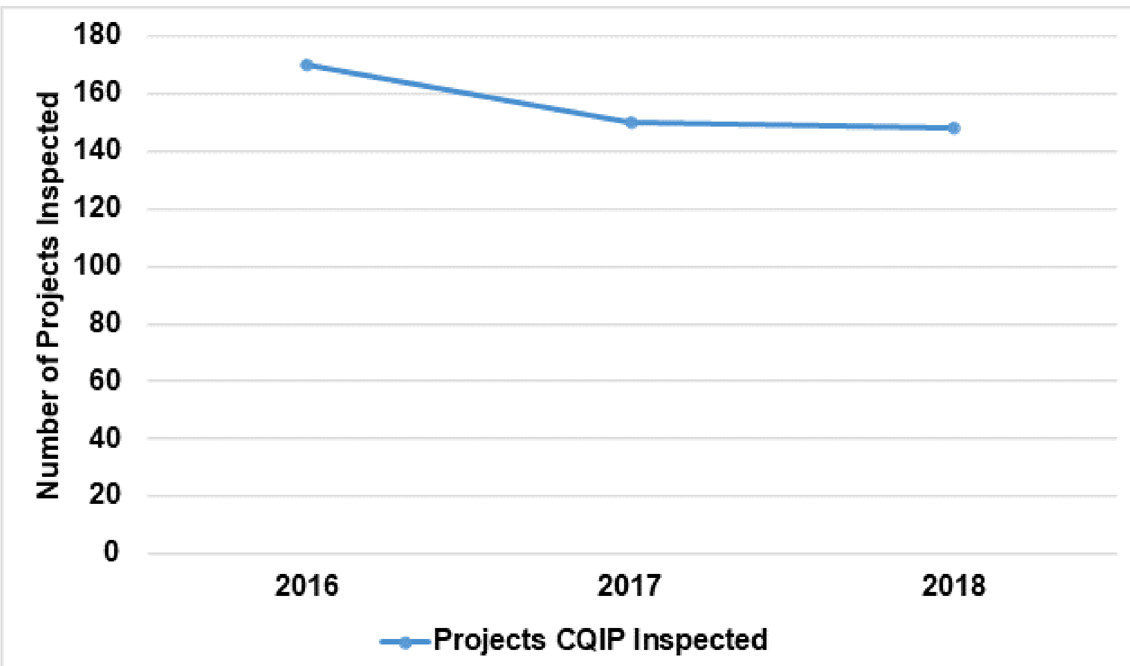

Figure 14. Chart. Number of projects inspected under the Construction Quality Improvement Program
Source: VDOT

[10] http://publicreports.dpb.virginia.gov/rdPage.aspx?rdReport=vp_OneMeasure&MeasureID=50160315.002.001

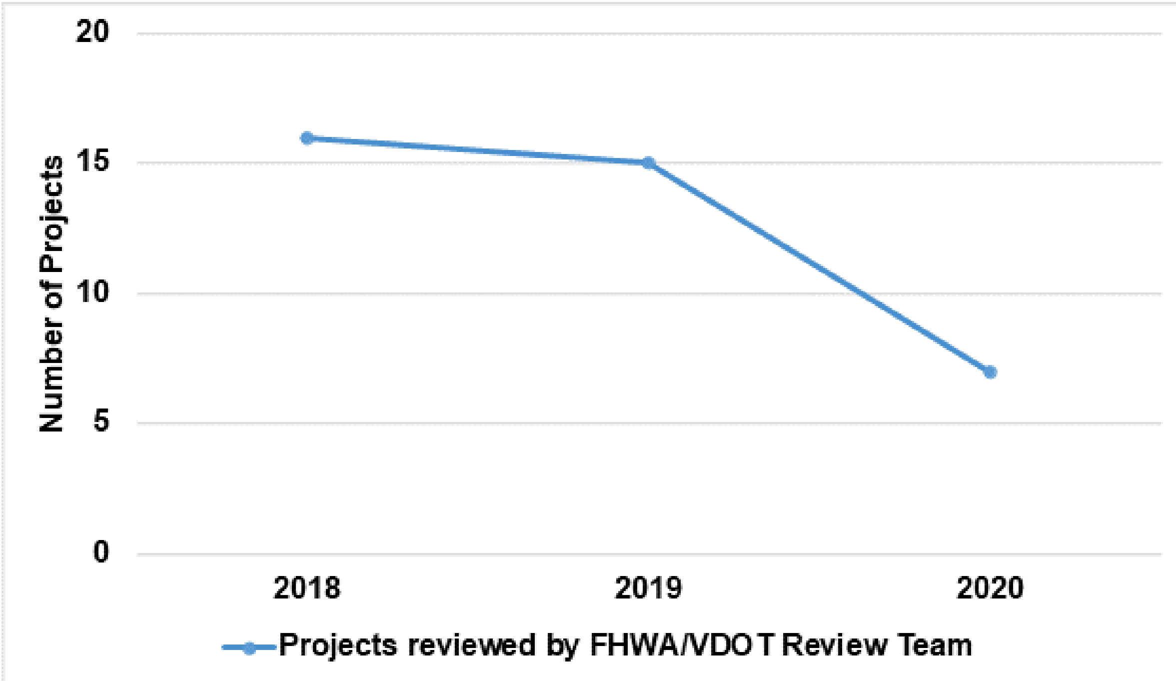

Figure 15. Chart. Number of Construction Quality Improvement Program projects reviewed by FHWA/VDOT team
Source: VDOT

The project team aggregated and categorized the CQIP inspection ratings into two groups: 1) projects with acceptable or higher ratings and 2) projects with unacceptable or lower ratings. Projects that meet or exceed VDOT’s WZ compliance requirements are rated acceptable or higher. Projects that do not meet VDOT’s policy and compliance requirements are rated unacceptable or lower.

An increasing trend was observed in the number of WZ projects that received acceptable or higher ratings, with 85 percent, 93 percent, and 95 percent in 2018, 2019, and 2020, respectively (figure 16). In correlation, a decreasing trend was observed in the number of WZ projects that received unacceptable or lower ratings, with 15 percent, 7 percent, and 5 percent in 2018, 2019, and 2020, respectively (figure 16).

As previously mentioned, VDOT reviews, rates, and digitizes an extensive list of WZ strategies (i.e., safety devices, pavement markings, signs, barriers, flagging, temporary traffic signals, traffic maintenance, stabilization of entry/exit points, traffic control supervisors, unsafe traffic condition corrections, and WZ area compliance with traffic control figures, the MUTCD, and the *Virginia Work Area Protection Manual*). VDOT aggregates the individual ratings assigned for all strategies associated with a WZ project to provide an overall project score. These aggregated ratings provide a high-level context of the overall WZ performance. However, to gain an extensive understanding of the excelling and underperforming WZM processes (e.g., planning, design, traffic management), VDOT should make use of the granular WZ field review data to conduct an in-depth evaluation of individual traffic control strategies (e.g., lane closures, signs, arrow boards, traffic management, detours, mobile WZs, transition areas, worker safety). This information will enable VDOT to identify recurring and non-recurring WZM issues (e.g., shorter transition areas, inaccurate signs, lack of flagger training) at the project and program levels.

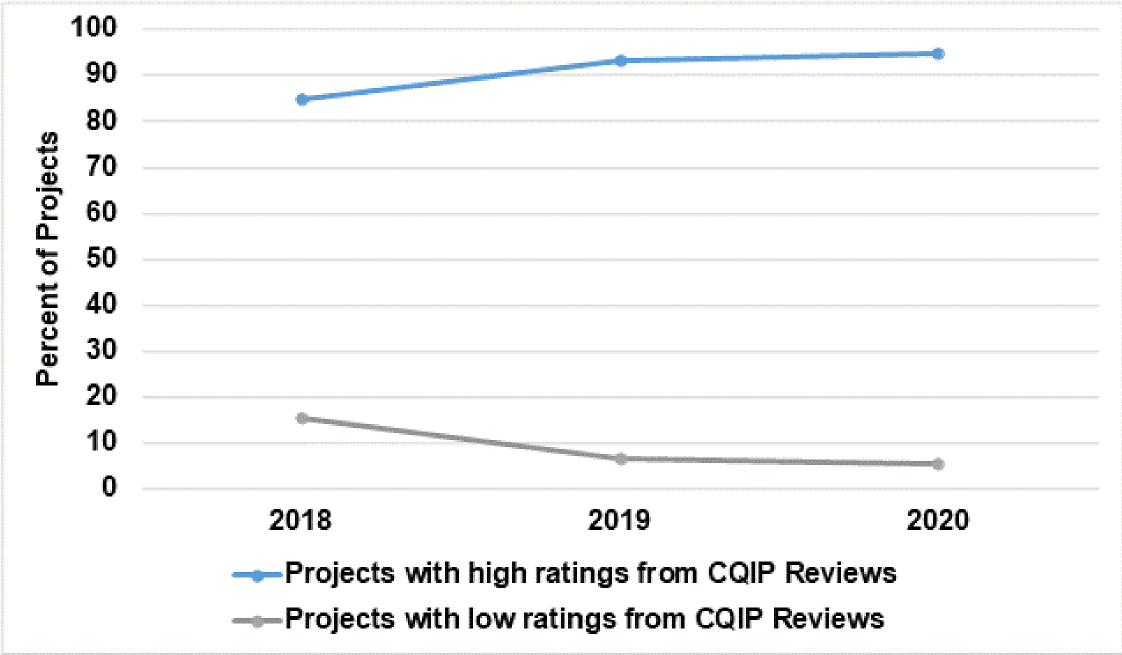

Figure 16. Chart. Percent of projects with acceptable or higher ratings

Source: VDOT

Key Findings and Observations for Data-Driven WZPRs

- Field reviews, traffic control safety reviews, and WZ safety and mobility audits are good information sources that provide both qualitative and quantitative assessments of WZ performance. VDOT's CQIP team collects and digitizes quantitative and qualitative feedback from field reviews of randomly selected WZ projects. The CQIP team reviews safety devices, pavement markings, signs, barriers, flagging, temporary traffic signals, traffic maintenance, stabilization of entry/exit points, traffic control supervisors, unsafe traffic condition corrections, and WZ area compliance with traffic control figures, the MUTCD, and the *Virginia Work Area Protection Manual*. In addition to the CQIP inspections, WZM experts from FHWA and VDOT review a small percentage of randomly selected projects for additional oversight on project compliance with VDOT's policies and procedures.
- VDOT's Construction division analyzes and aggregates the CQIP scores assigned for all strategies associated with a WZ project to provide an overall project score. The project team used these aggregated scores to compare the WZ performance across 2018, 2019, and 2020.
    - The study findings indicated that the number of WZ projects that met or exceeded VDOT's policy and compliance requirements increased from 2018 to 2020. Correspondingly, the number of projects that did not meet VDOT's policy and compliance requirements decreased between 2018 and 2020.
- Although the aggregated project ratings provide a high-level context of the overall WZ performance, they do not provide additional context on the best practices and key issues associated with the WZM practices. To gain an extensive understanding of the excelling and underperforming WZM processes (e.g., planning, design, traffic management), VDOT should make use of the granular WZ field review data to conduct an in-depth evaluation of individual traffic control strategies (e.g., lane closures, signs, arrow boards, traffic management, detours, mobile WZs, transition areas, worker safety). This information will enable VDOT to identify recurring and non-recurring WZM issues (e.g., shorter transition areas, inaccurate signs, lack of flagger training) at the project and program levels.

Application of Case Study Results to Future Work Zone Process Reviews

Results of the quantitative analyses conducted for the three performance areas provide VDOT with a basis to make decisions on how to focus efforts for future work zone process reviews. The project team worked with VDOT to identify how qualitative data can supplement the quantitative results to identify a key issue for the 2021 WZPR, as well as additional follow-up activities.

Qualitative Data

VDOT conducts regular meetings with its Work Zone Advisory Committee, which is composed of members from all areas of WZM including construction, project delivery, land use, maintenance, operations, traffic engineering, district staff, and the Virginia Transportation Research Council. VDOT leverages these committee meetings as an avenue to collect qualitative feedback on key issues experienced at Virginia WZs, as well as to vote and prioritize a list of key issues to be targeted for each review cycle.

Key Issue Selected for 2021 Work Zone Process Review Assessment

Based on the qualitative inputs from the WZ advisory committee and quantitative crash data findings, VDOT identified rear-end crashes at WZs as a key focus area for its 2021 WZPR assessment.

Based on the qualitative inputs from the WZ advisory committee and quantitative crash data findings, VDOT identified rear-end crashes at WZs as a key focus area for its 2021 WZPR assessment.

Virginia's WZPR team is conducting a series of meetings to examine innovative new technologies and equipment to help reduce WZ rear-end crashes and develop a plan to integrate those technologies into Virginia's WZ safety policies. During the first round of meetings, the Virginia WZPR team identified queue warning systems and speed limit trailers as smart work zone (SWZ) technologies of interest for further exploration. The Virginia WZPR team will conduct a series of meetings with State DOTs who have implemented the selected SWZ technologies and will collect key information including implementation costs, technical specifications, evaluation studies, and any required policy changes.

The Virginia WZPR team will leverage the findings from these series of meetings to:

- Identify the most suitable technology/equipment for reducing rear-end crashes in WZs.
- Develop and implement policy changes.
- Procure and implement technologies.
- Identify metrics and continue collecting safety data to assess the impact of the recommended technologies.

Follow-up Work Zone Process Review Activities

VDOT will leverage the findings from this case study to conduct follow-up WZPR activities including:

- Establishing processes to calculate the metrics selected for data-driven process reviews and identifying thresholds.
- Identifying undesirable trends in each performance area and projects contributing to those trends.
- Conducting WZ committee and District meetings to collect contextual information (e.g., root cause identification, correlating factors, issue identification) behind the trends.
- Selecting and prioritizing additional issues to be addressed during the next WZPR cycle.
- Identifying action items for addressing the prioritized issues.

These activities are not an extensive or exhaustive list, nor are required under any FHWA regulation. VDOT will tailor and conduct the activities to suit their WZPR goals and objectives.

Lessons Learned

Lessons learned from the VDOT case study include:

- **State DOTs have access to data resources for different performance areas through their intra-agency data collection efforts.** A comprehensive data inventory of all data resources will enable State DOTs to select their internal performance measures for various WZ strategies and performance assessments based on available data sources.
- **Developing quantifiable metrics will enable continuous performance tracking of WZ processes and procedures.** Developing and implementing metrics for different WZM outcome areas will enable States to quantify the impact of identified issues through qualitative data assessments. Depending on the level of impact, States can prioritize addressing the most pressing issues. Further, these metrics will help States to assess the impact of implemented action items in resolving the targeted issues.
- **Combining quantitative data trends with qualitative contextual information will lead to better root cause identification for WZ performance trends.** Neither quantitative trends nor qualitative contextual information alone depict a complete picture of WZ issues. When synthesized together, these two classes of data provide stronger and more precise identification of root causes and potential solutions to issues.
    - VDOT's proactive approach in combining quantitative safety findings with qualitative feedback from district staff to identify key issues (e.g., rear-end crashes) for WZPR assessment demonstrates its commitment to incorporating data into its WZPRs. Expanding this approach to mobility and field reviews will enable VDOT to draw a comprehensive picture of key issues across its WZM practices and correlations between different performance areas.
- **VDOT's mobility performance assessment is limited to WZs implemented on interstates.** Expanding these data collection and evaluation efforts to non-interstate facilities will enable VDOT to draw a comprehensive picture of WZ mobility performance across all facility types.

- **Comprehensive exposure data will be very valuable in normalizing WZ-performance data across years, projects, and other analysis dimensions.** These data will also aid in establishing correlations between performance areas (e.g., how does mobility performance affect safety and vice-versa). At the very least, tracking WZ VMT and lane closure hours will provide a strong foundation for WZ exposure data. VDOT requires its construction staff to notify the TOC at the start and end of the WZ activity and lane closures. The information collected includes WZ name, location, hours of operation, and number of lanes closed. The TOC staff logs this information into the VaTraffic database on a daily basis. VDOT's VaTraffic dashboard is a valuable tool for saving the project activity and mobility data and tracking patterns and trends over time, as well as for visual presentation and analysis of the data.
  - Although these are good metrics that can provide a common frame of reference across the years, the project team did not have access to the exposure metrics at corridor- or project-level granularity. For its upcoming WZPR mobility analysis, VDOT should consider normalizing the WZ VHD at each interstate with appropriate exposure data to get a comparable WZ mobility metric across the years. VDOT's initiative to collect WZ VMT through intelligent drums to use as a normalizing metric for its mobility analysis will set a good standard for a more accurate comparison of mobility performance across the years.
- **Field reviews, traffic control safety reviews, and WZ safety and mobility audits are valuable information sources that provide both qualitative and quantitative assessments of WZ performance.** VDOT's data aggregation process for field inspections was focused on a project level. Although this information lays a good foundation for continuous assessment of implemented WZ projects, it offers limited insights into the performance of individual traffic control strategies. VDOT should make use of the granular WZ field review data to conduct an in-depth evaluation of individual traffic control strategies (e.g., lane closures, signs, arrow boards, traffic management, detours, mobile WZs, transition areas, worker safety) and identify key issues, as well as best practices, for various aspects of WZ planning and implementation. This information will enable VDOT to identify recurring and non-recurring WZM issues (e.g., shorter transition areas, inaccurate signs, lack of flagger training) at the project and program levels.
- **In addition to tracking crashes associated with WZs, VDOT's safety data collection includes capturing the contributing factors (e.g., speeding, distracted driving) and vehicle types involved (e.g., large trucks) in its crash reports.** Tracking and digitizing these additional factors enables VDOT to measure the efficiency of its WZ safety policies (e.g., adequate transition areas, frequent speed limit information). The findings from this granular data analysis helped VDOT to identify the key safety issues associated with the WZs and their contributing factors.

Appendix A: Case Study Team and Follow-Up Activities

Work Zone Process Review Team

VDOT brings together a team of experts from multiple WZM disciplines to conduct its WZPRs, which ensures that all aspects of WZM are covered in the WZPRs. The WZPR team also collects qualitative feedback from District-level staff and field personnel on their experiences and issues during the design, planning, and implementation of WZs.

Follow-up from 2019 Work Zone Process Review

During its 2019 WZPR, VDOT identified action items to:

- Define very-short-duration maintenance operations and identify VDOT operations that fall under this definition.
- Develop an acceptable procedure to assist VDOT staff determine whether a WZ activity qualifies for very-short-duration operation.
- Include the temporary traffic control (TTC) requirements for very-short duration activities into the Traffic Engineering Division Instructional and Informational Memoranda (TED IIM).
- Prepare an online training session to train all WZ staff on the updated requirement.

As of May 2022, the TTC requirements for very-short duration activities were under review by VDOT's WZ Maintenance Division. VDOT's WZPR team will update the TED IIM once the TTC requirements are approved. VDOT has begun to create the online training session, which will be incorporated as a new section in the *Virginia Work Area Protection Manual*[11] covering TTC requirements for very-short-duration maintenance activities. Due to the current lack of data, the impact of this updated definition on WZ implementation cannot be evaluated until the 2021 to 2023 WZPR cycle.

[11] http://www.vdot.virginia.gov/business/resources/traffic_engineering/workzone/wapm/2011_wapm_rev_2_1.pdf

For more information on FHWA's Work Zone Management Program, please visit: https://ops.fhwa.dot.gov/wz and https://workzonesafety.org/topics-of-interest/smart-work-zones/

The FHWA is engaging with State DOTs and conducting research to incorporate data-driven practices into work zone process reviews. The information will be used to increase awareness on data, tools, and methods for State DOTs to use to prepare effective work zone process reviews. Topics of interest include analysis and use of quantitative data including exposure, safety, mobility, and inspection data, as well as analysis and use of qualitative data for inclusion in work zone process reviews. This case study is one of a series of resources on work zone process reviews.

U.S. Department of Transportation

Federal Highway Administration

Office of Operations

1200 New Jersey Avenue, SE

Washington, DC 20590

Office of Operations Website

https://ops.fhwa.dot.gov

October 2021

FHWA-HOP-21-053