Work Zone Safety Data Collection and Analysis Guide

January 2013

This material is based upon work supported by the
Federal Highway Administration
under Grant Agreement No. DTFH61-06-G-00004

ATSSA
SAFER ROADS SAVE LIVES
American Traffic Safety Services Association

U.S. Department of Transportation
Federal Highway Administration

Form DOT F 1700.7 (8-72)

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle Work Zone Safety Data Collection and Analysis Guide		**5. Report Date** January 2013 **6. Performing Organization Code**
7. Authors Brian Chandler; Nicholas Kehoe; Cara O'Donnell; Tim Luttrell; Eric Perry		**8. Performing Organization Report No.**
9. Performing Organization Name and Address American Traffic Safety Services Association 15 Riverside Parkway, Suite 100 Fredericksburg, Virginia 22406-1022 Science Applications International Corporation (SAIC) 8301 Greensboro Drive, MS E-12-3 McLean, VA 22102		**10. Work Unit No. (TRAIS)** **11. Contract or Grant No.** DTFH61-06-G-00004
12. Sponsoring Agency Name and Address Federal Highway Administration U.S. Department of Transportation		**13. Type of Report and Period Covered** **14. Sponsoring Agency Code**
15. Supplementary Notes Mr. Jawad Paracha, FHWA COTM		

16. Abstract

This guide is designed to assist highway agencies in developing techniques and strategies to successfully collect and analyze work zone safety-related data for the purpose of making work zones safer for motorists and workers. This guidance shares work zone safety-related data analysis methods that are effective in identifying safety improvement strategies and developing work zone crash reduction programs and analysis techniques. Methods that are currently being implemented in the United States are included in the guide to empower work zone safety practitioners to effectively reduce crashes, injuries, and fatalities.

Material presented here is for informational purposes only. Users should check local standards and guidelines for additional information. Any opinions or recommendations expressed in this guidance document are those of the authors and do not necessarily reflect the views of the FHWA or ATSSA.

17. Key Words	18. Distribution Statement		
Work zone, data collection, analysis, safety, mobility, work zone Rule.	No restrictions.		
19. Security Classif. (of this report) Unclassified	**20. Security Classif. (of this page)** Unclassified	**21. No of Pages** 54	**22. Price** N/A

Table of Contents

Executive Summary

In order to reduce the number and severity of work zone crashes, it is important to know the size and scope of the problem. This can be determined through the collection and analysis of work zone safety-related data. This guide is designed to assist highway agencies in developing techniques and strategies to successfully collect and analyze work zone safety-related data for the purpose of making work zones safer for motorists and workers. This guidance shares work zone safety-related data analysis methods that are effective in identifying safety improvement strategies and developing work zone crash reduction programs and analysis techniques. Methods that are currently being implemented in the United States are included in the guide to empower work zone safety practitioners to effectively reduce crashes, injuries, and fatalities.

The guide is organized as follows:

Section 1: Introduction and Objectives of this Guide

This section of the guide provides readers with an introduction to work zone safety-related data collection and analysis, how it applies to the *Work Zone Safety and Mobility Rule*, and guide objectives.

Section 2: Work Zone Data Collection

This section introduces methods for work zone data collection and confronts barriers to collecting safety-related data. Using information gathered through an extensive literature review and stakeholder discussions, the guide presents examples of successful work zone safety-related data collection techniques that overcome these challenges.

Section 3: Data Analysis

This section focuses on data analysis techniques, tools, and best practices that can be implemented to increase work zone safety by identifying barriers to data analysis and solutions to overcome these barriers.

Section 4: Application

This section provides guidance on implementation strategies and next steps to use the results of work zone safety-related data collection and analysis to improve work zone safety. This section includes a template for identifying critical steps toward implementation.

Section 5: Conclusion

The conclusion summarizes the guide and relates the previous four sections back to the overall objectives of the guide.

1. Introduction and Objectives of the Guide

1.1 Overview

According to the Fatality Analysis Reporting System (FARS), 576 fatalities in motor vehicle traffic crashes were reported in work zones in 2010. This is a 13.6 percent reduction from 2009, and continues the trend of decreasing work zone fatalities that has been occurring since work zone fatalities peaked at 1,186 in 2002.

In 2004, the Federal Highway Administration (FHWA) published the *Work Zone Safety and Mobility Rule* to focus on work zone impacts as well as methods and strategies to limit these impacts on the traveling public. Since the introduction of these approaches in 2004 and subsequent implementation efforts from transportation agencies, work zone fatalities have decreased by nearly half – 45.8 percent (from 1,063 in 2004 to 576 in 2010). To help agencies implement these approaches in the most effective manner, Section 630.1008 of the Rule requires agencies to use work zone data at the project and program levels to enhance work zone safety and mobility.

Implementation challenges include resource limitations, inconsistent work zone definitions in State crash reports, and lack of available detail. It can be difficult for agencies to identify their real work zone safety problems or determine the most cost-effective way to address them. This leads to a lack of confidence in countermeasure selection, as safety professionals do not always know if their safety efforts are solving an actual or perceived problem. To address these issues, guidance is needed on the most effective ways to collect and analyze work zone safety-related data in order to identify problems and develop solutions.

1.2 Introduction

In order to reduce the number and severity of work zone crashes, it is important to know the size and scope of the problem. This can be determined through the collection and analysis of work zone safety-related data.

The *Work Zone Safety and Mobility Rule* addresses work zone data collection and analysis specifically in Section 630.1008(c): "States shall use field observations, available work zone crash data, and operational information to manage work zone impacts for specific projects during implementation. States shall continually pursue improvement of work zone safety and mobility by analyzing work zone crash and operational data from multiple projects to improve State processes and procedures." FHWA developed guidance documents to assist transportation agencies with implementation of the Rule. These include a Rule Implementation Guide, a Work Zone Impacts Assessment Guide, a technical guidance document on transportation management plans (TMPs) for work zones, and a technical guidance document on work zone public information and outreach strategies.

FHWA's *Implementing the Rule on Work Zone Safety and Mobility* provides general guidance on implementation of the Rule, including content on data collection and analysis. The implementation guide focuses on the following areas:

- Components of a work zone policy, including information on policy development and implementation.
- Overview of agency-level processes and procedures, including impacts assessment, use of work zone data, implementation of training, and work zone process reviews.
- The concept of significant projects and why, when, and how to identify them.
- The development of TMPs, including potential TMP components and work zone impact management strategies.
- Overview of Rule implementation, including variances from compliance requirements and implementation resources.

FHWA's *Work Zone Impacts Assessment: An Approach to Assess and Manage Work Zone Safety and Mobility Impacts on Road Projects* provides general guidance on the process of assessing and managing the safety and mobility impacts of a road construction, maintenance, or rehabilitation project. The impacts assessment guide focuses on the following areas:

- The overall structure of the impacts assessment process and key issues related to work zone impacts.
- The development and implementation of a work zone policy, including examples of policy provisions.
- Principles and processes that can be to assess impacts during the systems planning, preliminary engineering, design, and construction phases.

- How work zone performance assessment aids in the process of assessing and managing the impacts of work zones.
- Work zone impacts assessment for maintenance and operations.

Although the Rule requires the use of safety and operational data to improve work zone safety and mobility, it can be difficult for practitioners to implement data collection and analysis practices in the field due to resource or institutional limitations. This guide has been developed to provide practitioners examples of collecting, analyzing, and using work zone safety-related data to increase collection and analysis efficiency and therefore overcome some resource or institutional limitations.[1] For example, a strategy covered in this guide includes deployment of portable traffic monitoring devices (PTMDs), which can be more efficient for collecting mobility data and providing faster access than traditional methods, such as the use of tube counters. Improved data collection and analysis and the application of its results can lead to a reduction in the number and severity of work zone crashes.

1.3 Objectives

As illustrated in Figure 1, this guide has been designed to assist work zone practitioners with improving safety in work zones by walking through the following process:

1. **Identify Agency Objectives.** Objectives must be defined prior to the start of any data collection or analysis process. These objectives can be defined broadly (e.g., increase safety in work zones) or specifically (e.g., decrease work zone crashes in nighttime work zones by 10 percent).
2. **Identify Data Needs.** Practitioners must determine which data are required for relevant analysis.
3. **Develop Baseline.** Work zone practitioners need to identify and analyze the current level of work zone safety-related data collection and analysis in their home state.
4. **Identify Strategies.** Practitioners can learn strategies and techniques currently being implemented around the country and determine if similar strategies are feasible in their State.
5. **Take Next Steps.** Practitioners should identify and begin taking steps to improve work zone safety-related data collection, analysis, and implementation.

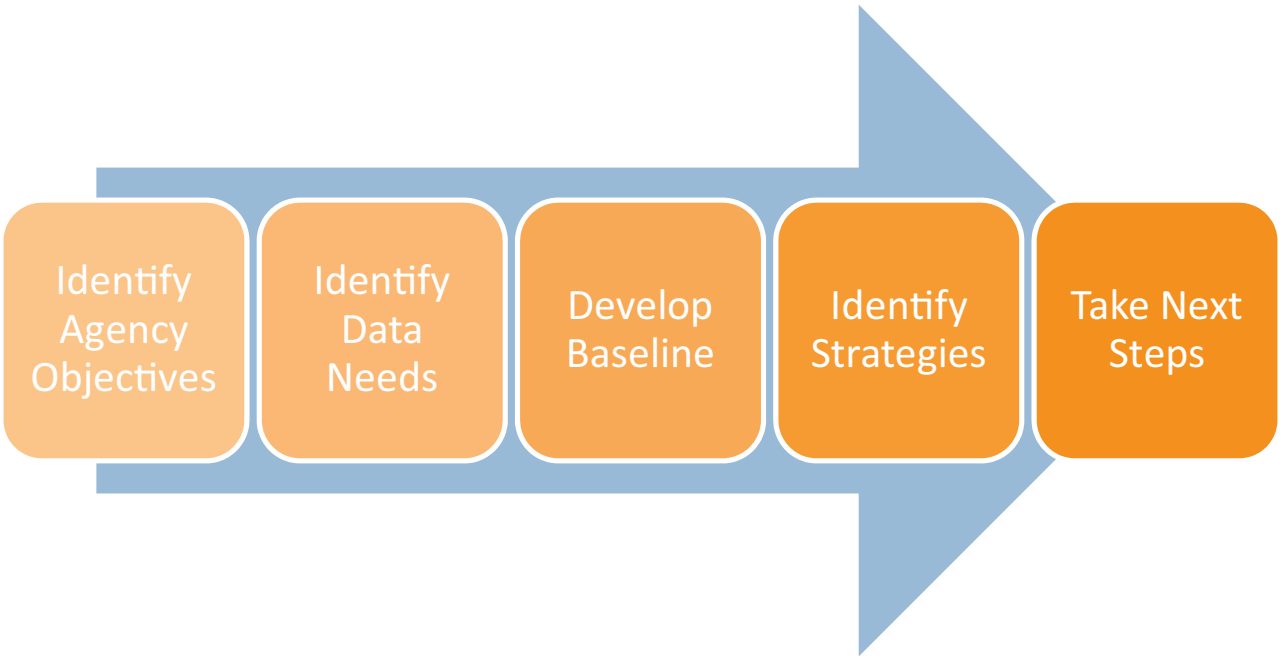


Figure 1. Process for Improving Work Zone Data Collection and Analysis

[1] Federal Highway Administration, *Practitioner-focused Online Collaborative Session*, August 31, 2011.

While many of the next steps discussed in this guide come in the form of direct work zone improvements or modifications, it is important to note that the application of work zone analysis does not only come in that form. Practitioners can find that collecting and analyzing work zone data does not lead to a direct improvement, but may show where more study is needed. For example, an analysis of work zone queue lengths may uncover instances of end of queue crashes that warrant an additional study to determine the most appropriate countermeasures. Regardless of the outcome, it is important to ensure that a set procedure, such as the one presented above, is established and followed throughout the collection, analysis, and application process.

1.4 Feedback Capture Tool

The Feedback Capture Tool included in this document is comprised of a series of questions that focus on practices and case studies likely to have the greatest impact on improving data collection and analysis.

By completing the questions in the feedback capture tool, readers will receive personalized feedback on next steps they can take to improve work zone safety-related data collection and analysis in their jurisdiction, ultimately leading to a reduction in the number and severity of work zone crashes.[2]

1.4.1 Using the Tool

The Feedback Capture Tool includes questions after each of the major categories and case studies presented in the guide. It is designed to be easily completed and to capture detailed information to help the reader identify the most useful and feasible strategies. Readers are encouraged to answer the questions while reading through the guide. The tool is presented in a matrix format that allows the user to input responses via radio buttons for various topics. In each matrix, functions are listed vertically on the left and questions are listed horizontally across the top. Figure 2 shows an example strategy and questions.

	Identified Practice/Practice in Question			
	Not at all	**Rarely**	**Often**	**Always**
How often do you currently use this practice?	○	○	○	○
Would this practice benefit your jurisdiction?	○	○	○	○
Is it feasible to implement this practice in your jurisdiction?	○	○	○	○

Figure 2. Example Feedback Capture Tool Question

[2] The Feedback Capture Tool is modeled after a similar tool in *Construction Peer Network, A Guide to Collecting and Sharing Information to Improve Highway Construction Practices*, November 2011.

The Feedback Capture Tool prompts the reader to provide a response following each case study presented in the guide. The questions asked are:

1. **How often does your agency use this practice?** This question corresponds to the orange shaded columns shown in the figure above. Select the radio button that appropriately describes how often the function is performed. The frequency of how often a function is performed may relate to time (e.g., how many times per year) or to the percent of overall projects.

2. **How much would this practice benefit your jurisdiction?** This question corresponds to the orange shaded columns in the figure above, with four possible selections for the level of implementation of a specific function. It is important to determine the most appropriate response to each question based on input from discussions with key stakeholders.

3. **How feasible is it to implement this practice in your jurisdiction?** This question will help practitioners identify the likelihood that a practice could be implemented in their jurisdiction, factoring in cost, institutional and political issues, and other considerations.

1.4.2 Feedback Tool Results

After reading through the guide, practitioners will have the opportunity to review their answers to all questions in a report format. This will provide users with an overview of the strategies and case studies they felt were most applicable to potentially try in their jurisdiction. Once a reader chooses the strategies they deem most useful and feasible to pursue, they can consider the steps identified in Appendix A: Example Next Steps as a guide for implementation of that specific strategy.

2. Work Zone Safety-related Data Collection

This section of the guide describes general types of work zone safety-related data, data collection methods, and barriers to data collection, and provides examples of strategies to improve data collection. Before starting a data collection process, practitioners should consider the previously-introduced process:

1. **Identify Agency Objectives.** What issue is our agency attempting to address, and how will data collection help achieve that objective?
2. **Identify Data Needs.** What is the most pertinent work zone safety-related data that should be collected?
3. **Develop Baseline.** What is our agency's current status regarding data collection?
4. **Identify Strategies.** What data collection strategies and techniques would be the most useful and feasible to implement at our agency?
5. **Take Next Steps.** Once identified, how do we take the next steps to improve work zone data collection?

2.1 Data Collection Background

While data can be generally categorized into safety- or mobility-related data, this guide divides mobility-related data into three categories (queue, speed, and mobility) to highlight the importance of speed and queue data in work zone analysis. Adding crash data to these three categories provides a list of four types of data to collect, as described by this guide: crash, queue, speed, and mobility data. Each type of data has a role in improving work zone safety.

2.1.1 Crash Data

Work zone crashes pose a significant risk not only to drivers involved in the crash, but to other motorists in the work zone as well as anyone actively working on the construction project in close proximity to the crash. Because work zones can involve lane reductions (both number of lanes and lane width), a single vehicle crash can be the cause of secondary crashes if other motorists are inattentive or have little room to navigate around the crash. Collecting crash data allows work zone practitioners to learn more about the causes of the crash and apply necessary modifications to the work zone, as well as future, similar work zones, to reduce future crashes.

Crash data can be further analyzed by incorporating exposure elements. Exposure-based analysis, if performed at all in a work zone setting, is often conducted after the construction project due to the time lag in receiving crash data. However, exposure data is essential to calculating crash rates, and practitioners may be unaware of how much data is needed and what to do with the large volume of data that is available. Some data may include average daily traffic, annual average daily traffic, hourly traffic volume counts, and data for shorter exposure durations.

Even when the crash database does not indicate a work zone safety problem, other sources can provide useful evidence. Basic field observations may include skid marks near a curve or transition point, damaged traffic control devices, or aggressive driving behavior.

2.1.2 Queue Data

Queues disrupt the flow of traffic and can result in significant speed differentials between approaching traffic and stopped traffic. As a result, queues are a contributing factor in many work zone crashes and can be severe in some cases.[3] In California, 26 percent of the State's work zone fatalities occur at the back of queues. Additionally, a queue stemming from the recovery of something as simple as a minor property-damage-only crash can lead to severe secondary crashes. Texas Transportation Institute conducted extensive research on identifying key work zone safety and mobility performance measures, and the researchers recommended that Texas DOT focus on the collection of queue length and travel time delay data for mobility-based measures.[4]

---

[3] Federal Highway Administration, *Practitioner-focused Online Collaborative Session*, August 31, 2011.

[4] Texas Transportation Institute, *Monitoring Work Zone Safety and Mobility Impacts in Texas*, May 2009.

2.1.3 Speed Data

According to the National Safety Council, speeding is a contributing factor in more than 25 percent of work zone fatal crashes.[5] The combination of inattention and other potential impairment increases the danger from drivers speeding through work zones. With an ever-changing traffic environment to navigate in a work zone and workers often near the roadway performing their construction and maintenance duties, speed is a significant factor in a driver's ability to react when necessary to avoid potential conflicts. Capturing speed data can help work zone practitioners identify the potential for future crashes and take action before they occur.

2.1.4 Mobility Data

In addition to direct crash data and measures like queue length, congestion metrics such as throughput, delay, and travel time can influence work zone safety and provide practitioners with another set of surrogate measures to determine the risk of work zone crashes. Delay and congestion can lead to queuing, which can increase the opportunity for high-speed back-of-queue crashes in work zones.

Traffic management centers (TMCs) provide a rich source of data, especially for freeways in urban areas. However, the vast amount of data available can overwhelm practitioners. It is important for data collectors and analysts to understand the purpose of the data being collected.

[5] http://www.nsc.org/safety_road/DriverSafety/Pages/Speeding.aspx

2.2 Types of Data Elements to Collect

As work zone practitioners implement strategies to make their work zones safer for motorists and workers, information related to the following categories is often desired: crash, vehicle, person, and exposure.[6] Some data elements many may need to be derived through a review and analysis of the collected data, even across categories. For example, while a crash report form may have a checkbox indicating that the crash occurred in a work zone, the form may not indicate if workers were present at the time of the crash. At the same time, while the work zone inspector's diary may indicate when workers were present, it may not explicitly indicate that workers were present at the time of the crash. By compiling different data sources, practitioners can create a fuller picture of the work zone and improve work zone analysis results.

2.2.1 Crash Data Elements

Crash data elements include information related to a work zone crash as well as elements regarding the environment surrounding the crash. Examples of these elements can be seen below:

- Crash frequency;
- Crash severity (motorists and workers);
- Crash location, time of day/day of week;
- Crash narrative;
- Involvement of pedestrian(s) or bicyclist(s);
- Light condition (e.g., daylight, dark, street lights);
- Type of work operation;
- Type of traffic control and layout;
- Queue length (if present);
- Traffic speed;
- Roadway geometry and characteristics;
- Location of crash within work zone; and
- Weather conditions.

Organizing crashes by crash type can assist practitioners in determining trends, potential causes of crashes, and developing effective countermeasures. Common crash types in work zones may include:

- Rear-end;
- Run-off-road; and
- Pedestrian/worker-related.

2.2.2 Vehicle Data Elements

Vehicle data elements describe characteristics, actions, and results of the vehicle or vehicles in the crash. This information can be useful to practitioners as it will allow them to group crashes based on vehicle type (e.g., passenger vehicle, commercial vehicle, motorcycle, construction equipment, etc.). Analysis of crashes in groupings based on vehicle type can provide a basis for modifications to be made in a work zone to increase safety. Other vehicle-related data elements include total occupants in the vehicle, vehicle travel direction prior to crash, and sequence of events leading to the crash. Practitioners can use vehicle data elements to document the crash and identify the action or

[6] Khattak, A. J., Council, F.M. *Fatal and Injury Crash Characteristics in Highway Work Zones*, 2007. Available at http://www.workzonesafety.org/files/documents/database_documents/Publication9950.pdf

actions leading to the crash. For example, if it appears that there is a trend of rear-end crashes involving construction equipment around ingress or egress points, those areas may need to be modified to allow for construction equipment to more easily and safely leave the construction area and merge onto the roadway.

2.2.3 Person Data Elements

Person data elements describe the characteristics, actions, and results of those individuals involved in the crash. These elements include factors such as driver age and contributing factors to the crash, such as any driver impairment, inattention, or speeding, etc. Obtaining and interpreting person data elements can be useful to work zone practitioners as these data elements may help explain why a work zone crash occurred.

2.2.4 Exposure Information

In general, work zone exposure data are not captured at the present time. While historic traffic volumes as well as planned work zone duration and length are often readily available to work zone practitioners, changes in the field (e.g., to the project schedule or phasing) can occur which may affect exposure data elements but not be documented with sufficient quality to be used effectively in safety analyses. The actual duration and length of the work zone may be captured in contractor logs, but these logs are typically not stored in an electronic database available to practitioners and thus are not easily accessible for data analysis. Road authorities, such as State DOTs, keep records of project duration, but when a project "starts" and "stops" may be difficult to define (e.g., does the project start when the first work zone sign is installed?). Actual occupation of the work area may not occur for some time. Project duration can also be ambiguous (e.g., is the project complete when the majority of work is done, or when the final acceptance document is signed?).

Having a true picture of these exposure measures within work zones would allow practitioners to calculate and compare work zone crash rates more effectively.[7] Examples of this type of information include:

- Type of work operation (e.g., paving, bridge work);
- Type of traffic control layout (e.g., crossover, lane closure, lane shift);
- Presence of queuing and queue length;
- Roadway geometry and characteristics (e.g., lane width);
- Number of times incident response was called;
- Location of crash within work zone, which is further broken down into advanced warning area, transition area, buffer space, work space, and termination area; and
- Weather and environmental conditions (e.g., rain, fog, snow) to identify visibility concerns.

2.3 Data Sampling and Collection Methods

Sampling is critical to the topic of work zone data collection and analysis, and it can provide a benefit to analysts and practitioners. Some agencies may find the idea of collecting more than already-developed crash report data to be overwhelming. But it is important to note that completing a portion of the data collection and analysis in this guide on even a sample of work zones can be highly beneficial. The size of the sample needed will vary widely based on the safety issues, jurisdiction details, and traffic patterns in those work zones.

For the purpose of this guide, work zone data collection methods consist of two types: real-time and lagging.

[7] Qi, Y., Srinivasan, S., Teng, J., Baker, R., *Frequency of Work Zone Accidents on Construction Projects*, August 2005, Available at http://www.utrc2.org/publications/frequency-work-zone-accidents-construction-projects

2.3.1 Real-Time (and Near-Real-Time) Data Collection

Collection of real-time data allows practitioners to access work zone-related information while that work zone is active, providing an opportunity for observed safety and mobility issues to be addressed immediately in the field. Real-time data are typically collected and compiled through intelligent transportation systems (ITS) tools, electronic databases (e.g., law enforcement crash reports immediately available), or observations by field and project staff.

Though ITS tools and sensors have the ability to collect and present raw mobility data to practitioners showing conditions in the field at about the same time they are occurring, safety data such as crash reports still need to be filled out by law enforcement, submitted, and archived before they are accessible to practitioners, even when submitted electronically. For the purpose of this guide, this information is considered near-real-time data that can be used to improve safety at the same active work zone where the data were collected.

In general, although States find real-time information extremely helpful when assessing existing work zones, they do not collect as much real-time data as they would like to have available.[8] Identifying work zone traffic crashes as soon as possible after the crash – which can occur in near-real-time with electronic reporting – can provide practitioners with valuable information to address potential safety concerns at that work zone. The sooner a highway agency learns of a crash, the sooner practitioners can begin to analyze the data and suggest countermeasures to prevent future crashes.

A number of States have developed processes to collect crash report information electronically to allow for earlier access than paper crash reporting forms.[9] An agreement between the law enforcement agency and the State DOT, such as a Memorandum of Agreement (MOA) or Memorandum of Understanding (MOU) that allows for a real-time transfer of information, can help immediately prevent future crashes.

Project and field staff members often keep a project diary to track project-related items including work progress, site conditions, and labor and equipment usage. Information recorded in these diaries is useful to practitioners looking to improve work zone safety. Electronic crash databases may provide practitioners the information they need to build an understanding of why a crash occurred, but field or project staff members on-site have the ability to observe instances leading up to crashes in person, including evidence like skid marks or hit traffic control devices. This firsthand knowledge, coupled with the construction or engineering background of the field staff, provides work zone practitioners a detailed source of information to make changes to upcoming and similar work zones.

2.3.2 Lagging Data Collection

Lagging work zone data are not compiled until after the project has been completed. While lagging data are often not available to make immediate modifications to an active work zone, lagging data are a good source of information to make changes on future projects, measure performance against, and, where needed, help justify modifications to agency-wide policy. General examples of collecting lagging data involve collecting paper crash reports or compiling archived mobility or safety data. Specific data collection examples are included in Section 2.5 Data Collection Practices.

In some States, accessing crash data can be a lengthy process. This delay can eliminate the State DOT's ability to use crash data as a near-real-time measure, so this information can only be used after-the-fact as lagging data. States have reported that lagging data are both useful and readily available, but not always timely.

Each type of data has advantages and disadvantages, as shown in Table 1. For instance, while real-time and near-real-time data may allow practitioners to address work zone safety and mobility issues quickly, this information is often more expensive and difficult to collect than lagging data.

---

[8] Federal Highway Administration, *Practitioner-focused Online Collaborative Session*, August 31, 2011.

[9] DeLucia, B.H.; Scopatz, R.A. *E-Crash: The Model Electronic Crash Data Collection System*, 2010.

Table 1. Comparison of Real-time and Lagging Data Collection

Type of Collection	Advantages	Disadvantages	Barriers
Real-time	Information is quickly available to address needs in the work zone where data are collected. More detailed data (e.g., time-stamped speed and volume data from loop detectors as opposed to traffic counts from tube counters) may be available or collectable via site visits.	Accuracy can be a concern due to the focus on timeliness. Data from electronic methods, although available more quickly, may be too voluminous to use unless analysis and reports have been pre-programmed.	For crashes, need to clear the incident as soon as possible.
Lagging	Data may provide a larger sample size, more comprehensive picture, and connections can be made among various data sets.	The information is not quickly available on the work zones where collected. Any details missing from the data are likely unobtainable or would require significant resources to obtain (e.g., by having to comb through project logs).	Without obtaining the information when a work zone is active, adjustments are reserved for future work zones.

2.4 Barriers to Data Collection

While there are barriers related to the collection of specific types of data, there are also numerous overarching barriers related to the collection of both types of work zone safety-related data discussed in this guide. For the purpose of this guide, there are three main entities that collect work zone safety-related data: highway agencies, contractors, and law enforcement officers. Each of these entities has their own barriers, as described in the following sections.

2.4.1 Barriers at Highway Agencies

Due to the variety of work zone definitions and lack of key details in State crash reports, it is sometimes difficult for highway agencies to identify their real work zone safety problems. This leads to a lack of confidence in countermeasure selection, as safety professionals do not always know if their safety efforts are solving a real or perceived problem.

As the highway agency generally oversees the data analysis, it is one of the primary entities with data collection responsibility. However, specific highway agency staff may not be on-site at all times, and these staff typically have several other duties, such as inspections or quality testing. For crash data, the highway agency may rely on law enforcement officers and their crash reports. While completed crash reports can serve as both a useful and detailed account of a crash, highway agencies must wait until these forms are completed, reviewed, and submitted by law enforcement before they are able to access the information. Agreements can be negotiated between highway agencies and law enforcement agencies so that this data can be collected in a timely manner. Regarding real-time data, public agencies suffer from a lack of resources to deploy ITS equipment or staff to monitor work zones and collect this information in the field. In fact, State DOTs cite a lack of personnel and resource availability as an obstacle to collecting and analyzing data (either real-time or lagging) and making changes to work zones to improve safety. One solution to address this challenge could be to task data collection to the contractor or to a third-party vendor, which can have its own complications.

2.4.2 Contractor Related Barriers

Because contractors on work zones have firsthand knowledge of issues within their projects, they can be a good source of work zone safety-related data. Barriers to data collection by contractors can exist for several reasons, including the following:

1. **Liability.** Contractors may have a perception that collecting data increases their legal liability. In the event of a safety-related issue on a construction project, contractors may feel that collected data may serve as a source of information to indicate fault.

2. **Level of Effort.** Contractors and highway agency field staff are sometimes reluctant to add "one more duty" to their work in the field, especially one that is not directly tied to work completion or contractual duties.

3. **Misunderstanding of Purpose.** Because much of the work zone safety-related data that are useful in analysis are often obtained from a crash or near-miss within a work zone, contractors may feel that this data would be used in a disciplinary process rather than to improve safety and mobility of work zones.

To address these issues, a highway agency could include language and a pay item in its contract documentation requiring data collection and provision as part of the contract work. In this case the contractors will be required to collect data regardless of their perception of liability, and adding the pay item directly addresses any reluctance to add "one more duty." Finally, it is important to explain the purpose of the data collection in the contract documentation; this language can highlight the reason they are being asked to collect the information.

Finally, crashes may occur during times when no contractor or DOT staff are on-site (e.g., at night when project work hours are during the day). To collect data during these times, law enforcement officers become the primary documentation source.

2.4.3 Barriers with Law Enforcement Crash Reports

Work zone safety analysis is often conducted using data obtained through police crash reports. A barrier in this analysis is that crash report forms are not always populated accurately or completely by law enforcement for a number of reasons.

In some cases, the crash may have occurred regardless of the presence of the work zone, such as an impaired driver traveling above the speed limit or a crash during inclement weather conditions. However, it is also possible that the presence of the work zone and the way it altered roadway conditions may have contributed to the driver's difficulty in navigating the roadway. It can be difficult for law enforcement officers, work zone practitioners, and safety-related data analysts to determine if these incidents should be identified as work zone crashes.[10, 11]

Clearing the Scene. When a crash occurs, law enforcement officers follow a series of protocols, including, but not limited to, protection of the scene, tending to the injured, and expediting the free flow of traffic. In a work zone, there is an increased urgency to remove the vehicles and injured from the scene to minimize the chance of secondary crashes and to get traffic flowing. Law enforcement officers' on-scene responsibilities include collecting evidence, interviewing witnesses, and collecting data. In some cases, they may lack an understanding of the value of and need for additional in-depth real-time crash investigation information that is useful for work zone safety follow-up action.

Lack of Report Details. Work zone crash reports often lack the detail necessary to tell the story of a work zone's safety and mobility. These details are sometimes unavailable because the contributing circumstances may be difficult to determine or the report form does not ask for specific information. For example, some crash reports do not include data elements that help facilitate analysis (e.g., work zone location, work zone workers present, and work zone type) and rely solely on a checkbox indicating the crash took place in the work zone as well as any law enforcement officer narrative. Without these elements specified on the form, practitioners must derive the information from the crash report form, the officer's narrative, or other supporting work zone data, such as inspector diaries or service patrol and emergency medical service logs. This derivation can lead to inaccurate analysis if the practitioner's assumptions are not correct or can prevent analysis from being completed if the data elements specified above are not able to be derived at all. In some cases, even with work zone-specific data elements included on the work zone crash report form, varying data element definitions can hinder analysis.

---

[10] Daniel, J., Dixon, K., Jared, D., *Analysis of Fatal Crashes in Georgia Work Zones*, 2000.

[11] Pigman, J.G., Agent, K.R., *Highway Accidents in Construction and Maintenance Work Zones*, 1990.

Data Element Definitions. Within a State, there should be a consistent definition of each data element; however, the remaining challenge is to ensure each definition is consistently applied. In addition, responding officers sometimes do not provide necessary details in the sketch or narrative sections of the crash report form, and these details may not be captured in an electronic records database. For example, it has recently been discovered that a high proportion of work area intrusions are intentional, which necessitates a different set of countermeasures than those that would be used for unintentional intrusions.[12, 13]

Lack of Training. If law enforcement personnel writing crash reports are not properly trained in handling work zone crashes, the data may be flawed, and any analysis performed on the flawed crash data may hide or misdiagnose the actual problems within the work zone that contributed to the crash. One method to increase the chances of overcoming this barrier is additional training for law enforcement on the crash report itself and on the definitions of data elements related to work zone crashes.[14] Because law enforcement officers generally have limited time and resources to focus on work zone training, this additional training must be readily available (e.g., web-based) and an efficient use of their time.

Timeliness of Data Availability. Even when data are collected accurately and in a timely manner, information is often not available to practitioners for a period of time after the crash. Once reports are completed in the field, these reports are often reviewed and finally filed electronically prior to being accessible to the work zone practitioner. Recent improvements in crash reporting forms and documenting procedures by law enforcement, such as using a tablet computer or other device at the scene of the incident to record the report, have decreased the time between an incident occurring and the data becoming available to the work zone practitioner.

---

[12] Spainhour, L., Mtenga, P., *Analysis of Work Zone MOT Data Collection*, May 2002. Available at http://www.dot.state.fl.us/research-center/Completed_Proj/Summary_CN/FDOT_BC395_rpt.pdf.

[13] Washburn, S., Carrick, G., *Data Collection Needs for Work Zone Incidents,* August 2006. Available at http://stc.utk.edu/STCresearch/completed/PDFs/wzonefinal.

[14] Federal Highway Administration, *Practitioner-focused Online Collaborative Session*, August 31, 2011.

2.5 Data Collection Practices

This section of the guide provides examples of successful data collection practices currently being implemented by highway agencies around the country.

2.5.1 Real-Time Data Collection

Collecting Crash Data in Real-Time

Ohio DOT uses a real-time crash analysis tool to track work zone crashes on a subset of pre-selected work zones. The data are captured in near real-time by electronic queries and bi-weekly visits to law enforcement agencies. This allows traffic engineers to find problems in active work zones, investigate the issues, and apply necessary enforcement strategies while the work zones are still active.[15]

Kansas DOT (KDOT) has standard policies for collecting crash reports and other data from work zones. Kansas law enforcement agencies are required to notify authorized agency personnel of all crashes that occur in work zones and submit crash reports with all necessary information within a reasonable timeframe. The crash reports are reviewed for contributing factors and stored in a crash database. In addition, work zone supervisors are required to fill out a basic form whenever a crash occurs in a KDOT work zone.[16]

In addition to official crash reports, customer calls or agency/contractor field experiences of "near-misses" in work zones can provide important real-time information to practitioners. Although these events are typically not recorded or included in a database, they can be precursors to crashes, and as such can be helpful for finding potential upcoming safety problems. Learning the details of these events can prove valuable to improving safety in that work zone and on future projects.[17] Because "near-misses" are generally not recorded, the main source of these data would be from work zone inspectors on-site when the event occurred. Establishing communication with the work zone inspectors can allow for practitioners to learn about these events in a timely fashion.

Collecting Speed Data in Real-Time

Motorist speeds can also be captured using new technologies, such as portable traffic monitoring devices (PTMDs), portable ITS equipment such as sensors on trailers, or permanent ITS equipment available in some areas. These devices can automatically upload the information to a central location for immediate analysis. If a potential concern is identified (e.g., speeds much higher than the posted speed limit through a work zone), practitioners can address the speed concern through law enforcement, additional traffic control devices, or other means. The ability to collect, analyze, and respond to work zone speeding in real-time has the potential to prevent work zone crashes and associated injuries and fatalities.

Speed data can also be collected by conventional means (e.g., manual radar studies, tube counters) and analyzed at the office. Reports often include average speed, 85th percentile speed, 10-mph pace, and speed differential metrics. Collecting and analyzing this "near-real-time" information can provide practitioners with valuable information to determine if speed is a concern in their work zones.

Collecting Queue Information in Real-Time

One method to collecting queue information in real-time is through the use of ITS queue detection tools. ITS queue detection tools can monitor travel speed in the work zone, and when low travel speeds are detected they signal that a queue may be forming. This queue information can be sent back to the TMC for collection and analysis. In addition, these detectors can be linked to other warning systems, such as a changeable message sign, to warn approaching drivers that a queue may exist.[18] By disseminating the data in real-time, this type of system can reduce rear-end and secondary crashes while collecting data for future use by work zone practitioners. In addition to motorist notification and data collection, these systems can be used to initiate an immediate response to work zone issues causing the

---

[15] Stargell, R., *Best Practices in Work Zone Assessment, Data Collection and Performance Measurement.*

[16] Kansas Department of Transportation, *Kansas DOT Reporting Accidents in Construction and Maintenance Work Zones*, December 2005, Available at http://www.ops.fhwa.dot.gov/wz/resources/final_rule/ks_acct_const_wz.htm.

[17] Federal Highway Administration, *Practitioner-focused Online Collaborative Session*, August 31, 2011.

[18] America Traffic Safety Services Association. *ITS Safety and Mobility Solutions, Improving Travel Through America's Work Zones.* July 2008. Available at: http://www.atssa.com/galleries/default-file/2008July21_ITS_Safety_and_Mobility.pdf

queue. For example, Missouri DOT has used queue detection systems to identify issues at the work zone, and when the TMC receives a notification of an active queue, project staff members are directed to review and, if possible, remedy the origin of the queue.[19]

It is likely that not every work zone can or needs to be equipped with ITS equipment for collecting real-time queue data, so it is important to identify other methods for capturing and collecting this information in "near-real-time." The congestion and queuing that result from temporary lane closures is the simplest to isolate and can be collected by field crews and work zone inspectors.[20] Inspectors can document traffic characteristics such as the presence of a queue and can even estimate the average queue, maximum queue, and/or the duration of the queue.

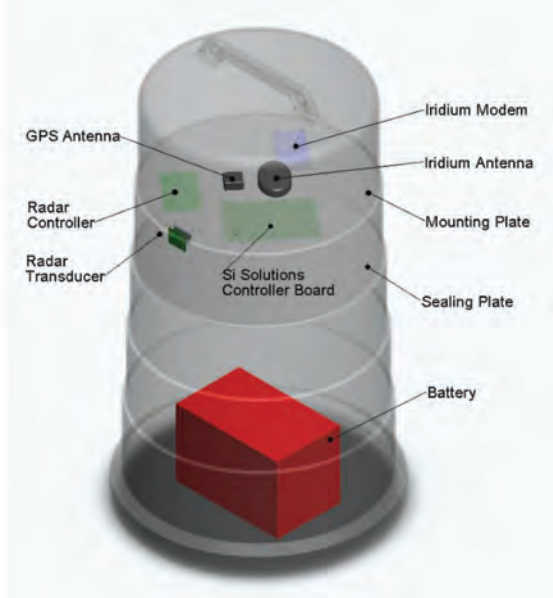


Figure 3. Diagram of a PTMD

Case Study: Caltrans Portable Traffic Monitoring Devices[21]

Due to recent advances in traffic-monitoring technologies, battery power, and communications, vehicle speeds and traffic volumes can now be collected more readily in work zones using PTMDs. This facilitates the identification and management of queues in real-time. Caltrans recently tested the use of PTMDs in work zones in a variety of locations.

How a PTMD works. *The PTMDs are battery-powered, thus they do not require an external power source, but they do require battery charging approximately every two weeks. Each PTMD uses a single K-band radar unit that can be used to collect either vehicle speeds or traffic volumes. The range of each device is approximately 300 feet for speed detection and 100 feet for traffic volume. The devices are housed inside a National Cooperative Highway Research Program (NCHRP) 350-compliant traffic channelizer with a built-in Global Positioning System (GPS) (Figure 3).*

The Caltrans Test. *Caltrans District 4 in the San Francisco Bay Area was the primary location for the data collection (Figure 4). The test site locations were chosen based on two main criteria: first, where large queues were expected and traffic would be significantly impacted, specifically work zones requiring lane closures; and second, where there was potential to expand work windows, such as locations with steep grades or limited sight distances with high traffic volumes. The six test sites in District 4 were as follows: Interstate 680, Bay Bridge Closure on Labor Day weekend, Highway 101 at the Golden Gate Bridge, Bay Bridge reverse curve, Interstate 880, and event management in Pasadena for the Rose Bowl Parade.*

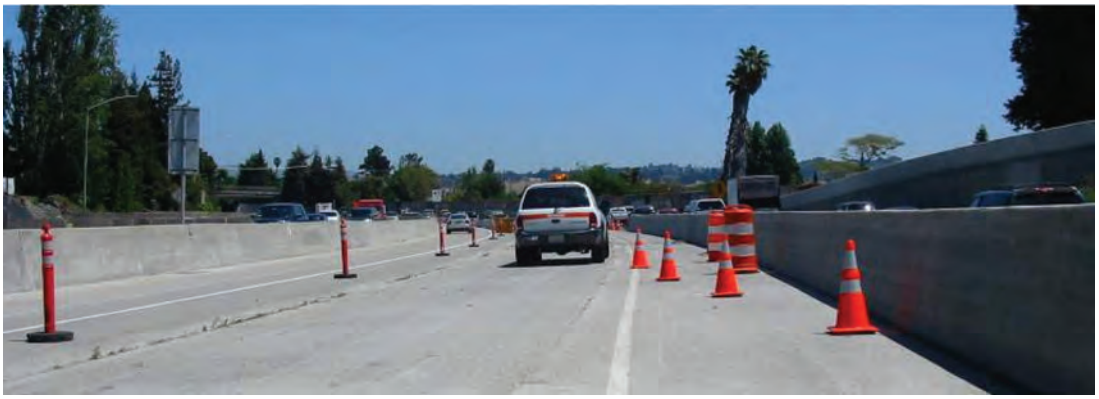


Figure 4. PTMD Deployment in California, one collecting speeds and one collecting traffic volumes

PTMDs used during the Interstate 680 project ensured that the mid-day reduction of one of the three-lane connector ramps that connects the interstate to other major routes in the region did not cause queues over Caltrans' thresholds for delay. During the Bay Bridge closure over Labor Day weekend, PTMDs detected and managed queues on the

---

[19] FHWA. *Work Zone Operations Best Practices Guidebook*. October 2007. Available at: http://ops.fhwa.dot.gov/wz/practices/best/documents/bpguidebook.pdf

[20] Texas Transportation Institute, *Monitoring Work Zone Safety and Mobility Impacts in Texas*, May 2009.

[21] Chandler, B.; Beasley, K.; Rephlo, J. *California Deployment of Portable Traffic-Monitoring Devices*, 2010.

San Mateo Bridge and on Southbound Highway 101 near the Golden Gate Bridge. Caltrans used a PTMD at a reverse curve on the Bay Bridge following a fatal crash to determine if speeding was a significant problem. Because the length and duration of queues were greater than normal during a bridge rehabilitation project on Interstate 880 in Oakland, practitioners used PTMDs to monitor traffic flow and coordinate with the TMC. Finally, PTMDs were used to monitor traffic before and after the BCS National Championship football game in Pasadena.

Results

Overall, the data gathered during the test helped Caltrans personnel better understand the queuing activity in and around work zones and will help them plan future work zone activities more efficiently and effectively. Based on the findings from users interviewed about PTMDs, the devices appear to be a cost-effective and flexible means for an agency to monitor traffic conditions remotely.

Responses to the interactive table below can be selected and saved by choosing the appropriate response and left-clicking with the mouse. Use the table below to evaluate the potential benefits and feasibility of implementing a similar PTMD practice in your jurisdiction:

	Identified Practice/Practice in Question			
	Not at all	**Rarely**	**Often**	**Always**
How often do you currently use this practice?				
Would this practice benefit your jurisdiction?				
Is it feasible to implement this practice in your jurisdiction?				

Figure 5. Feedback Capture Tool: Portable Traffic Monitoring Devices

Collecting Mobility Data in Real-Time

Tools to collect mobility data in work zones are useful as a means to leverage both work zone safety- and mobility-related efforts. Information collected through these tools can be used to monitor traffic in a work zone to identify both safety and mobility concerns while the project is active and to conduct analysis during or after the project has completed. Highway agencies and researchers have used a number of ITS and other common devices and technologies to collect data in work zones. An example of this is the use of Bluetooth technology to collect travel times from probe data to evaluate work zone mobility performance. Additionally, real-time volumes can be obtained from existing TMC traffic sensors, if available, portable ITS equipment such as sensors on trailers, video analysis from TMC images, or manual methods such as travel time runs by project personnel or other agency staff.

Case Study: Obtaining Travel Times with Bluetooth Technology

Travel time data can be collected using probe vehicles under control of the data collectors. This technique is relatively reliable; however, it takes considerable time and effort to gather large amounts of travel time and delay data. The saturation of Bluetooth devices in vehicles on the road has reached a level that provides an emerging opportunity for agencies and researchers to gather large sets of real-time data in a short period of time.

Researchers from Purdue University, in cooperation with the Indiana DOT (IDOT), used Bluetooth technology to study the real-time measurement of travel time and delay in work zones. Each Bluetooth device emits a unique electronic identifier known as a media access control (MAC) address. By capturing these MAC addresses at different locations on a roadway, researchers can determine the travel times between the two locations. Using MAC address data captured from Bluetooth devices, the researchers analyzed 1.4 million travel time records collected during the 12-week study along a 10-mile section of I-65 in northwestern Indiana in 2009. The researchers used portable battery-powered suitcase units and semi-permanent solar-powered portable dynamic message signs (PDMS) retrofitted with Bluetooth antennas to complete their study.[22]

[22] Haseman, R.; Wasson, J.; Bullock, D. *Time Measurement of Travel Time Delay in Work Zones and Evaluation Metrics Using Bluetooth Probe Tracking*, 2009.

The study defined metrics such as travel time and delay in terms of providing real-time information to drivers and other applications associated with agency operations and vehicle mobility. The researchers also indicated that the collection of work zone travel time can provide agencies with the ability to evaluate and monitor the relationship between crashes and work zone queuing. By collecting real-time travel time data via Bluetooth, agencies can monitor when travel times are increasing, which is a strong indicator that a queue may be building. Agencies are thus able to identify potential queues more accurately than was possible in the past. Crash rates have been reported to increase due to queuing resulting from capacity constraint. With the use of Bluetooth technology, agencies now have the ability to monitor travel times in real-time to proactively prevent queue-related crashes before they occur.

Use the interactive table below to evaluate the benefits and feasibility of implementing Bluetooth or similar technologies to track travel times in your jurisdiction:

	Identified Practice/Practice in Question			
	Not at all	Rarely	Often	Always
How often do you currently use this practice?				
Would this practice benefit your jurisdiction?				
Is it feasible to implement this practice in your jurisdiction?				

Figure 6: Feedback Capture Tool: Collecting Travel Times with Bluetooth Technology

2.5.2 Lagging Data Collection

Collecting Lagging Crash Data

Crash reports are filled out by law enforcement officers at the scene of a crash and represent a useful source of crash information. Crash reports are often consistent on a system-wide basis and may be more likely to include infrastructure deficiencies than reports from work zone practitioners.

In most States, work zone crashes are handled in the same manner as all other crashes: on the uniform crash report. There is a checkbox on the crash report indicating that the crash occurred in a work zone, but there is not a separate review process for analyzing or developing countermeasures by location.[23]

Virginia has identified this problem and taken action to address it by recently adding numerous fields for work zone-related information to its crash reporting form, shown in Figure 7.

The Model Minimum Uniform Crash Criteria Guide (MMUCC) provides guidance to assist States in collecting consistent information on their crash report forms.[24] The MMUCC defines work zone crashes as crashes that occur in or are related to a work zone, including crashes that occur prior to the first work zone warning sign. The guidance presented in the MMUCC is similar to that implemented in Virginia; the MMUCC recommends collecting, at minimum, the following work zone related information for work zone crashes: location of the crash, type of work zone (e.g. utility, construction, or maintenance), worker presence, and law enforcement presence.

Work Zone C13
- 1. Yes
- 2. No

Work Zone Workers Present C14
- 1. With Law Enforcement
- 2. With No Law Enforcement
- 3. No Workers Present

Work Zone Location C15
- 1. Advance Warning Area
- 2. Transition Area
- 3. Activity Area
- 4. Termination Area

Work Zone Type C16
- 1. Lane Closure
- 2. Lane Shift/Crossover
- 3. Work on Shoulder or Median
- 4. Intermittent or Moving Work
- 5. Other

Figure 7: Work Zone Section of Virginia Crash Report Form

[23] Dissanayake, S., Akepati S.R., *Characteristics of Work Zone Crashes in the SWZDI Region: Differences and Similarities*, August 2009, Available at http://www.intrans.iastate.edu/pubs/midcon2009/DissanayakeZone.pdf.

[24] Available at http://www.mmucc.us/sites/default/files/2008MMUCCGuideline.pdf

Law Enforcement Crash Reporting

Work zone safety-related data analysis can provide a mechanism to help shape future standards, programs, and policies. One way this can be accomplished is to help ensure that law enforcement officers operating within work zones have a shared understanding of the work zone.

Because a wealth of work zone safety-related data can be obtained through law enforcement crash reports, much of the work zone analysis depends on whether this data is easily available, useful, and accurate. One strategy for improving the information obtained from crash reports is to meet with the involved enforcement agency (or agencies) to discuss the crash reporting forms and training. It is useful for both the highway agencies and the law enforcement officers to know what data are being collected and how the data are being used. As mentioned in Section 2.5.1 Real-Time Data Collection, an MOA or MOU between law enforcement agencies and State DOTs are helpful in coordinating the timely transfer of data. This understanding can encourage law enforcement to more accurately collect the data, which could result in improved analysis. It may also serve to motivate agencies to use data-focused enforcement strategies, where higher crash locations are being emphasized for targeted activities.

Additionally, if it is discovered in such meetings that the crash reporting forms being used are inadequate for the analysis that the highway agency would like to conduct, though it is difficult, the agency can identify and request that changes be made to the crash data reporting form. The MMUCC provides guidance on recommended elements of State uniform crash report forms, including information related to work zones, and can be referenced as a recommended minimum to build upon. An example of a comprehensive crash report form is included in Appendix B.

Finally, highway agencies could discuss work zone training with law enforcement to provide law enforcement officers with a better understanding of how the highway agency designs and operates a work zone. This transparency and equal understanding can help law enforcement officers more accurately fill out crash report forms and be more motivated to do so.

Beyond just reported crashes, law enforcement citation data, incident response information, or data from motorist assist patrols can provide additional useful information to practitioners.

TMC Coordination

Coordination with TMC managers can help determine the appropriate sampling technique and ensure that the plan is appropriate to produce the right data for analysis of crash rates. Section 3.2.1 Crash Rate Calculation outlines how to appropriately use exposure data to calculate crash rates and how having an associated plan that covers who will collect the data, which data will be collected, and data access considerations will maximize the accuracy of the results and the potential for meaningful results.

Improvements can be made to increase work zone safety using work zone inspector diaries. These inspector diaries are a commonly available source of crash, incident, and queuing information, and this information can be used after a project is completed to determine levels of safety and identify potential areas for improvement.

Collecting Lagging Mobility Data

If ITS or other real-time sources are not available, traffic volume data may be obtained through historical automatic traffic recorder counts or through highway agency average daily traffic counts or estimations. However, collecting mobility data during construction may prove to be challenging as lane shifts and other construction phasing changes may reduce automatic detector accuracy.

Many highway agencies conduct field inspections or reviews of their work zones, and the results of those reviews should be collected and viewed in conjunction with other safety-related data to determine if any correlation exists. In addition to individual project reviews by field inspectors, annual temporary traffic control review inspections conducted by highway agencies at the program level can serve as a source of obtaining lagging mobility data, as well as safety data such as the condition of work zone traffic control setups.

Using mobility data as a source can help practitioners to better understand the impacts of a project and help identify the risk of work zone crashes. Necessary changes to temporary traffic control setup or a project staging transition can become apparent through analysis of construction inspector diary data. It is important to set up the expectations and requirements for the construction inspection information beforehand so that the requirements can be met and inspectors can include the appropriate level of detail in the diaries.

3. Work Zone Safety-Related Data Analysis

Once viable data sources have been identified and information is being collected, the next step is to begin analyzing the data. States have various methods for analyzing work zone safety-related data and different ideas about the importance that work zone crash elements have in determining which strategies to employ. How and which work zones to analyze will depend on the desired outcome. In some studies, researchers analyzed crashes in work zones during active work, when no work was occurring (but a work zone was in place), and when no work zone was in place.[25,26] In addition, work zone safety studies have analyzed different aspects of crashes. The focus of these studies varied; some studied the locations, others studied severity, and others focused on various causal factors. This section of the guide presents available safety data analysis tools and techniques, and examples of data analysis challenges and successful practices that overcome these challenges. As with data collection, the agency should answer questions related to the following process as it relates to data analysis:

1. **Identify Agency Objectives.** What issue is our agency attempting to address, and how will data analysis help achieve that objective?
2. **Identify Data Needs.** What is the most pertinent work zone safety-related data that should be analyzed?
3. **Develop Baseline.** What is our agency's current status regarding data analysis? Where can we improve?
4. **Identify Strategies.** What data analysis strategies and techniques would be the most useful and feasible to implement at our agency?
5. **Take Next Steps.** Once identified, how do we take the next steps to improve work zone data analysis in our jurisdiction?

Preparing Data for Analysis

Once data are collected, these data must be processed in a way that will facilitate the analysis. For example, while collecting crash report forms (either electronic or paper) provides information to determine crash frequencies and crash trends in an area, effort must be spent to extract this information from the reports and to store it in a format for analysis.

Practitioners may find that a data collection task is unnecessary as relevant historical data have already been collected and are available at their agency. In this case, it is likely that the currently-available data will need to be prepared for analysis, as it is possible the format this information is stored in may not be the same format needed for analysis. For example, if practitioners were developing a model to estimate potential work zone safety concerns, they may find that many of the necessary model inputs are currently available, but have not been coded in a way that corresponds directly to modeling. To develop the model, practitioners may need to extract necessary parameters from sources such as historic traffic volumes, the work zone's maintenance of traffic plans, or mobility data from the TMC. After developing and simulating the model, practitioners can then compare outputs to similar work zones in the area and draw conclusions. This can occur without conducting a formal data collection effort.

3.1 Challenges to Work Zone Safety-Related Data Analysis

3.1.1 Lack of Data and Limitations in the Data Sets

Due to the relatively short duration of construction projects (vs. 3-5 years of "after" data in a typical before/after study at a permanent location) and a relatively low number of crashes, there may not be enough data to make statistically significant conclusions from work zone crash data. Lack of detail about some of the data elements may make it difficult or impossible to properly code some of the data into the correct categories. Poor quality data in the data set can result in misleading or incorrect conclusions.

---

[25] Daniel, J., Dixon, K., Jared, D., *Analysis of Fatal Crashes in Georgia Work Zones*, Transportation Research Record, Issue Number 1715, Transportation Research Board, 2000.

[26] Pigman, J.G., Agent, K.R., *Highway Accidents in Construction and Maintenance Work Zones*, Transportation Research Record, Issue Number 1270, Transportation Research Board, 1990.

3.1.2 Confounding Factors

The number of variables that can impact the analysis of crashes within work zones can make the isolation of a single variable difficult. Confounding factors related to analyzing safety-related data in work zones include:

- **Frequent changes to the configuration of a work zone.** Many work zone construction projects are conducted in stages consisting of different activities and traffic control devices. Because these activities can change often throughout a single project's duration, it can be difficult to determine the exact work zone setup at the time the data was collected if layout and work zone activity information were not thoroughly recorded.
- **There are often a relatively small number of work zone crashes in a jurisdiction each year.** Compared to other types of crashes, most jurisdictions suffer a very small number of work zone crashes – especially severe crashes. Further, in some cases work zone fatalities are the main focus because the information is readily available, but this data set is so small that it does not provide an accurate or complete picture of a jurisdiction's work zone safety issues. To address this issue, practitioners should analyze all work zone crashes (not just those that resulted in injuries and fatalities) and look at other surrogate measures affecting safety (e.g., queue length, speed, inspection reports).
- **Traffic volume pre-work vs. during-work**. Practitioners may obtain pre-construction traffic volumes for analysis because traffic volumes during construction are not available. If the work zone is causing any significant diversion of traffic and the volumes during construction are significantly different than those pre-construction, the analysis may provide misleading conclusions.
- **Questions related to causation**. Because of the number of activities occurring in a work zone, it can be difficult to pinpoint a single cause of a work zone crash. Additionally, some work zone crashes may have been caused by non-work zone characteristics. In these cases, one must determine if the crash should be included in the work zone analysis. For example, if the driver was impaired, the work zone may not have been a contributing factor.

3.1.3 Lack of Resources for Analysis

Work zone practitioners cite a lack of personnel and resource availability as an obstacle to analyzing data and making changes to work zone safety. Many work zone practitioners do not have safety-related data analysis experience or staff with data analysis capabilities. Due to this knowledge gap, the benefits of post-construction safety-related data may be unknown. There is a limited number of staff dedicated to data analysis. Project staff members are often immediately tasked with another project and move on quickly from the completed project, leaving little time for post-project evaluation.

In addition, there is a limited number of successful crash modification factors (CMFs) identified through the research related to work zone safety countermeasures (see Section 3.2.2 Crash Modification Factors for a discussion of CMFs related to work zones).

3.2 Data Analysis Tools and Techniques

Highway agencies have developed and used agency-specific tools to overcome the analysis challenges presented in the prior section and to evaluate the safety of their work zones. This section discusses examples of practitioner success and serves as an introduction to analysis tools and techniques that can improve work zone data analysis.

3.2.1 Crash Rate Calculation

Crash rate calculation is a technique that can be applied to work zones to monitor trends in work zone crashes using either real-time or lagging data. Crash rate analysis of the relative safety of a work zone takes into account exposure data to determine relative safety compared to other similar roadways, segments, or intersections. Crash rate analysis typically uses exposure data in the form of traffic volumes or roadway mileage. Crash rates are calculated by dividing the number of crashes by a normalizing factor, examples of which can be found in Table 2. Such rates can be compared to pre-construction values to determine if potential safety hazards exist and if modifications to the work zone should be considered.

Table 2. Examples of crash rate normalizing factors

Normalizing Factor	Example(s)
Time	• Crashes per month
Exposure	• Crashes per 1,000 vehicles traveling through the work zone • Crashes per vehicle-hours of travel time through the work zone • Crashes per 100 million vehicle-miles traveled (VMT) through the work zone
Distance	• Crashes per mile

Typically, traffic volumes are expressed in the form of Annual Daily Traffic (ADT). For the pre-project ADT, information is typically available at the agency level. If it is expected that the traffic volumes and patterns may change from the pre-project situation during construction, practitioners are recommended to collect work zone traffic volume data. If the project is still in the planning stage and there is no work zone currently active, an estimate of traffic volumes may be obtained from historical data of a similar work zone. Techniques and tools for this data collection (e.g., PTMDs, temporary sensors, and tube counters) are discussed in Section 2.5.2 Lagging Data Collection.

The benefit of crash rate analysis is that it provides a more effective comparison of similar locations with safety issues than analyzing crash frequency alone. In a situation where the traffic volumes have changed significantly during the work zone, the crash rate calculation below allows practitioners to take this into account.

One way to calculate the crash rate for **road segments** is:

$$R = \frac{100{,}000{,}000 \times C}{365 \times N \times V \times L}$$

Where:

R = Crash rate for the road segment expressed as crashes per 100 million vehicle-miles of travel (VMT);

C = Total number of crashes in the study period;

N = Number of years of data (or fraction of a year);

V = Number of vehicles per day (both directions); and

L = Length of the roadway segment in miles.

For example, if a particular work zone is being assessed with the following values:

C = 70 crashes over the past 1 year within this work zone;

N = 1 year of data;

V = 20,000 vehicles per day; and

L = 10 miles.

The resulting segment crash rate would be:

$$R = \frac{100{,}000{,}000 \times 70}{365 \times 1 \times 20{,}000 \times 10} = 95.9 \text{ crashes per 100 million vehicle miles of travel (VMT)}$$

Depending on the details of crash reporting methods and crash history in a particular jurisdiction, a value of 95.9 crashes per 100 million VMT may or may not be cause for additional study. The most appropriate use of this crash rate is to determine the relative safety of the work zone in comparison to (1) the pre-work zone condition and (2) other work zones with similar characteristics.

If an agency has access to near real-time crash reports, they can improve safety in their work zones even further by modifying active work zones based on reported work zone crashes very quickly after a crash occurs. An example of an agency that has implemented such a practice is provided in the Ohio DOT case study below.

Case Study: Ohio DOT Near-Real-Time Crash Report Analysis [27]

One obstacle for many agencies regarding work zone safety analysis is the fact that the duration of most work zones combined with the time lag between the crash and the State receiving crash data prevents practitioners from accurately using this information to address safety and mobility issues in a current work zone. This case study illustrates a method employed by the Ohio DOT that addresses safety and mobility issues in active work zones and, in some cases, addresses potential issues before they occur.

In the early 2000s Ohio DOT was embarking on the largest construction program in their history and was concerned about the link between safety and congestion stemming from work zones. To understand if work zones were causing more crashes, Ohio DOT began an investigation on historical work zone crashes. During the course of this investigation, Ohio DOT found that there were clusters of crashes on their Interstate system and that these areas of crash clusters coincided with frequently congested locations. With this information, Ohio DOT made the assumption that congestion causes crashes and crashes cause congestion. Ohio DOT went on to identify proactive ways to limit crashes and therefore limit congestion and further crashes. One way was real-time crash data analysis.

What does this have to do with work zones? *The first action that Ohio DOT took to reduce crashes and congestion was a historic crash analysis. This analysis showed Ohio DOT that in the past, work zones had higher crash rates than non-work zones, and thus Ohio DOT turned their focus to work zones.*

Near-real-time crash data analysis consists of two main activities: data collection and data analysis.

Data Collection. *One of the biggest challenges of successfully implementing this type of analysis is timely data collection. The method that has proven successful in Ohio is a combination of utilizing an electronic crash database and cooperating with law enforcement to arrange Ohio DOT pickup of paper crash reports. While Ohio DOT was able to complete crash analysis through the use of paper crash reports, access to an electronic database of crash reports further improved Ohio DOT's method of analysis; electronic crash databases allow Ohio DOT staff to access crash records shortly after they are filed by law enforcement.*

Data Analysis. *The second activity is analysis of the crash data. To begin analyzing crash data, Ohio DOT constructed a system to routinely run queries on the crash data to draw attention to high crash areas. While such a system requires an initial programming and set-up effort, after the system is complete, the analysis, graphs, and summary data are produced instantly by the push of a button. An example of this type of evaluation is shown in Figure 8.*

[27] Stargell, R. *Best Practices in Work Zone Assessment, Data Collection and Performance Measurement.*

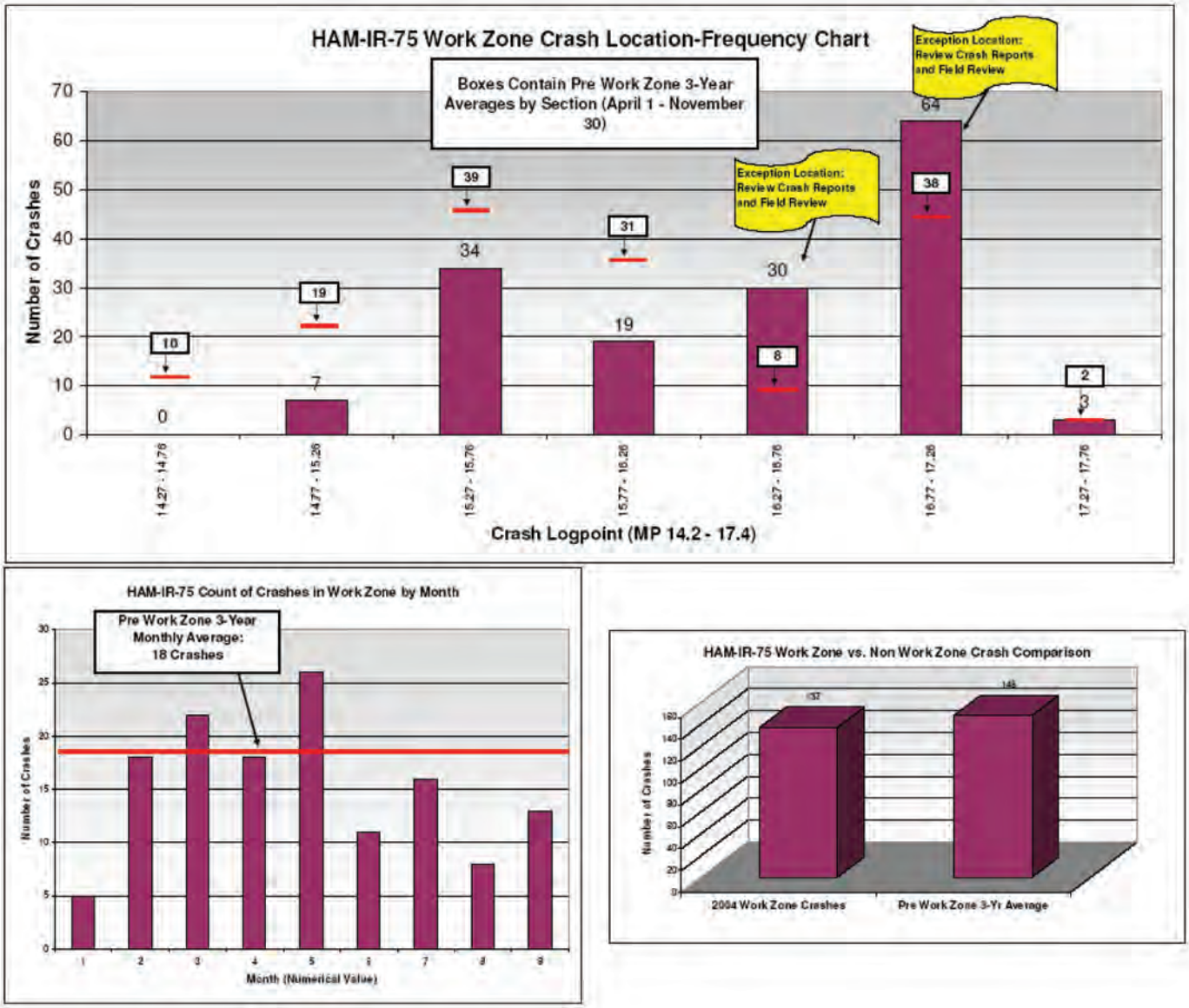


Figure 8. Example of Near Real-time Work Zone Safety Performance Measurement in Ohio

How is this analysis used? *With the collection of historic and near-real-time crash data, Ohio DOT monitors crash frequencies at select work zones to ensure they stay at or below the crash frequency at the same location prior to the establishment of the work zone. Additionally, by running analysis on real-time crash data, Ohio DOT can observe crash trends at their work zones. If Ohio DOT finds that the crash frequency is greater during a work zone than it was at the same location prior to the start of construction, or if Ohio DOT observes a developing trend, changes can be made to the work zone in an attempt to prevent potential crashes.*

Use the table below to evaluate the benefits and feasibility of implementing a near-real-time crash report analysis practice in your jurisdiction:

	Identified Practice/Practice in Question			
	Not at all	**Rarely**	**Often**	**Always**
How often do you currently use this practice?				
Would this practice benefit your jurisdiction?				
Is it feasible to implement this practice in your jurisdiction?				

Figure 9. Feedback Capture Tool: Near-real-time Crash Report Analysis

3.2.2 Crash Modification Factors

The Highway Safety Manual (HSM) provides some limited information on CMFs for practitioners to use in work zones. CMFs represent the relative change in crash frequency due to a change in one specific condition (when all other conditions and site characteristics remain constant). CMFs are the ratio of the crash frequency of a site under two different conditions. Therefore, a CMF may serve as an estimate of the effect of a particular feature, treatment, or condition. In the case of work zones, elements addressed in the HSM include the duration (number of days) and length (miles) of freeway work zones.

Duration. The following formula provides an expected average crash frequency for increasing work zone duration above the base condition (CMF = 1.00) of 16 days.

$$CMF_{all} = \frac{1.0 + (\%\ increase\ in\ duration \times 1.11)}{100}$$

Where:

CMF_{all} = crash modification factor for all crash types and all severities in the work zone; and

% increase in duration = the percentage change in duration (days) of the work zone.

Length. The following formula provides an expected average crash frequency for increasing the work zone length above the base condition (CMF = 1.00) of 0.51 miles.

$$CMF_{all} = \frac{1.0 + (\%\ increase\ in\ length \times 0.67)}{100}$$

Where:

CMF_{all} = crash modification factor for all crash types and all severities in the work zone; and

% increase in length = the percentage change in length (miles) of the work zone.[28]

[28] AASHTO, *Highway Safety Manual*, 1st Edition, 2010.

The United States Department of Transportation CMF Clearinghouse[29] currently lists 77 CMFs under the category of work zones. Of those 77 CMFs, only two have been identified as strategies that significantly decrease crashes in work zones:

1. **Implement mobile automated speed enforcement system.** This strategy consists of mobile unit vans with noticeable markings parked close to the work zone with law enforcement monitoring and enforcing the work zone speed limit. Additional signage and media campaigns inform the public of this enforcement activity. The CMF Clearinghouse has assigned this strategy a crash reduction factor (CRF) of 13.7, meaning that it is estimated this strategy will reduce 13.7 percent of fatal and injury crashes. This strategy earned a three (out of a maximum of five) Star Quality Rating, indicating a moderate level of quality or confidence in the results of the study documenting this strategy.

2. **Implement left-hand merge and downstream lane shift.** This strategy is illustrated in Figure 10 and consists of a lane closure that instructs drivers approaching the closed lane to merge left. Drivers are able to return to their original lane after the work zone. This strategy was found to decrease crashes when compared to a conventional right-lane work zone lane closure. The CMF Clearinghouse has assigned this strategy a CRF of 46, meaning that it is estimated this strategy will reduce 46 percent of fatal and injury crashes. The CMF Clearinghouse gives this CRF its lowest Star Quality Rating and has identified that the study design score, sample size score, and standard error score are poor.

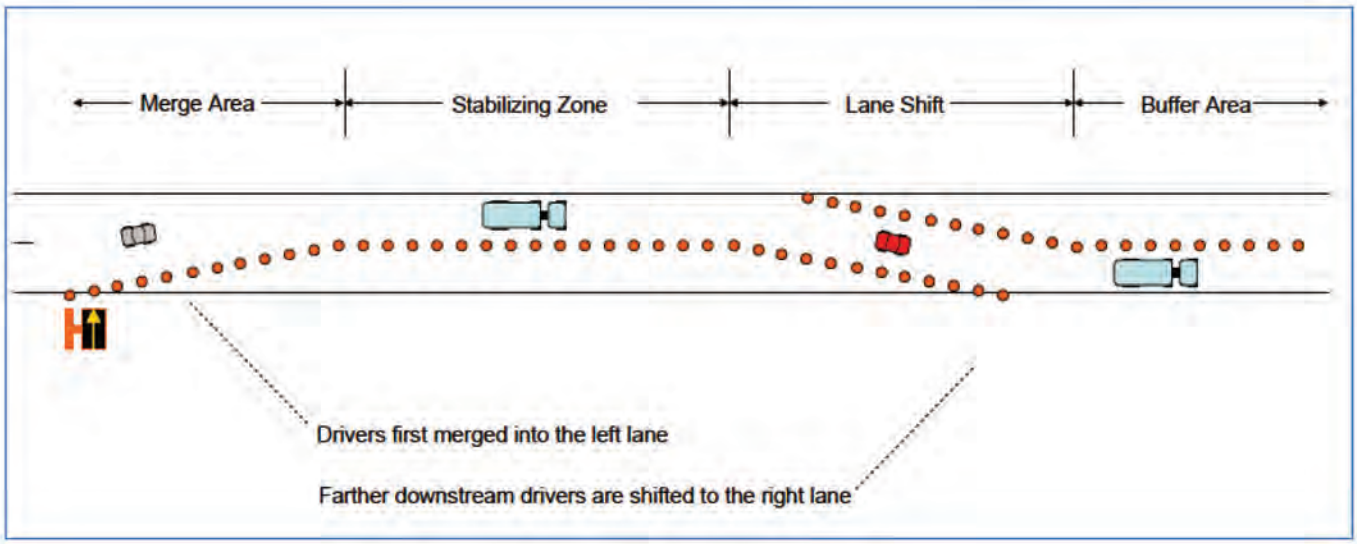


Figure 10: Example of an Iowa Weave Traffic Control Pattern[30]

Some researchers have suggested that additional research should be conducted on CMFs for work zone strategies because they are highly dependent on the types of traffic control used, project staging, and whether or not work is actually being performed at a given time within a work zone. The HSM could be modified to include the work zone data that States need for analysis. CMFs could be modified to fit the criteria highway agencies need to analyze their work zones. Significant research would be needed to determine which traffic control strategies work the most effectively in specific situations.

[29] Available at: http://www.cmfclearinghouse.org.

[30] Schrock, Fei See, Becker, and Mulinazzi. "Evaluation of Early Merge Static Work Zone Signing In Oklahoma," 2008. Available at: http://www.intrans.iastate.edu/smartwz/documents/project_reports/2008-schrock-static-sign.pdf

3.2.3 Road User Costs

In an effort to reduce work zone impacts through the consideration of road user costs (RUCs), FHWA has produced a guidance document entitled *Work Zone Road User Costs - Concepts and Applications.*[31] RUCs provide work zone practitioners a procedure to quantify work zone impacts in economic terms to allow for use in work zone management. As defined by FHWA in the *Work Zone Road User Costs - Concepts and Applications* guide, road user costs are "the additional costs borne by motorists and the community at-large as a result of work zone activity." These costs can be summarized into user delay costs, vehicle operating costs, crash costs, and emission costs.

While RUCs are fundamental to the maintenance of traffic (MOT) alternative selection or contract administration, much of the data required are similar to the work zone data discussed in this guide. For example, typical RUC inputs include: field observations including travel times (before and during the work zone), crash rates and frequencies, mobility data (e.g., traffic demand, composition, and travel speed), and work zone characteristics (e.g., capacity, configuration). Because of these similarities, data collected using procedures followed in this guide could also be applied to the calculation of RUCs on future work zones.

The advantage of using RUCs in work zone analysis is that this analysis method will produce recommendations of MOT alternatives or contract administration strategies that will have the least negative impact on the motorists and surrounding area. For example, RUC analysis can assist practitioners in deciding between work zone strategies (e.g., lane closures or nighttime construction) or contract administration strategies (e.g., the use of incentive/disincentives or lane rental). By decreasing negative impacts on the motorists, it is likely that safety and mobility will be improved as well.

For more information on RUCs and step-by-step instructions on how to apply such analysis, please review the *Work Zone Road User Costs - Concepts and Applications.*[32]

3.2.4 Using Crash Curves to Monitor Work Zone Safety

Crash curves are another procedure that can be used to monitor and assess safety in work zones. The intention of crash curves is to be used by district or project engineers to determine how frequently work zone accident data should be compiled and analyzed. In order to develop crash curves, three inputs are needed. These inputs are the work zone segment length, the average daily traffic expected through the work zone, and an estimate of the pre-work zone crash rate per 100 million-vehicle miles (MVM) on the work zone segment. The segment length can be either the entire work zone or a smaller segment within the work zone; however, smaller segments with homogeneous characteristics are ideal so that geometric changes are accounted for.

An example of how crash curves can be developed and used to analyze work zone safety data can be seen in the case study below on the research conducted by the Texas Transportation Institute (TTI).

---

[31] FHWA, *Work Zone Road User Costs Concepts and Applications*, 2011. Report FHWA-HOP-12-005. Available at: http://ops.fhwa.dot.gov/wz/resources/publications/fhwahop12005/fhwahop12005.pdf

[32] Mallela, J., Sadasivam, S. *Work Zone Road User Costs Concepts and Applications*, Report FHWA-HOP-12-005, December 2011. Available at: http://ops.fhwa.dot.gov/wz/resources/publications/fhwahop12005/fhwahop12005.pdf

Case Study: TTI Work Zone Safety and Mobility Monitoring [33]

As a part of a study completed on identifying key work zone safety and mobility performance measures to recommend to Texas DOT (TxDOT), TTI did extensive research on work zone mobility and safety monitoring analysis methodologies and computational procedures. The safety monitoring procedure that TTI developed can be used to estimate the practicality and frequency of real-time work zone safety monitoring and determine which projects are most suitable for safety monitoring.

In order to accomplish this, TTI developed crash curves using combinations of work zone segment length, average daily traffic through the work zone segment, and an estimate of the accident rate per MVM for the segment under normal operating conditions. Six crash curves were developed for pre-work zone accident rates ranging from 0.5 to 4 accidents per MVM.

The crash curves can be used by districts to provide recommendations on how frequently work zones should be monitored and which ones should be monitored in real-time. If the recommended monitoring period is about the same length as the work zone duration, then the work zone does not need to be monitored in real-time; however, if the monitoring period is much shorter than the work zone duration, then the work zone should be monitored in real-time. An example of one of the crash curves is shown below.

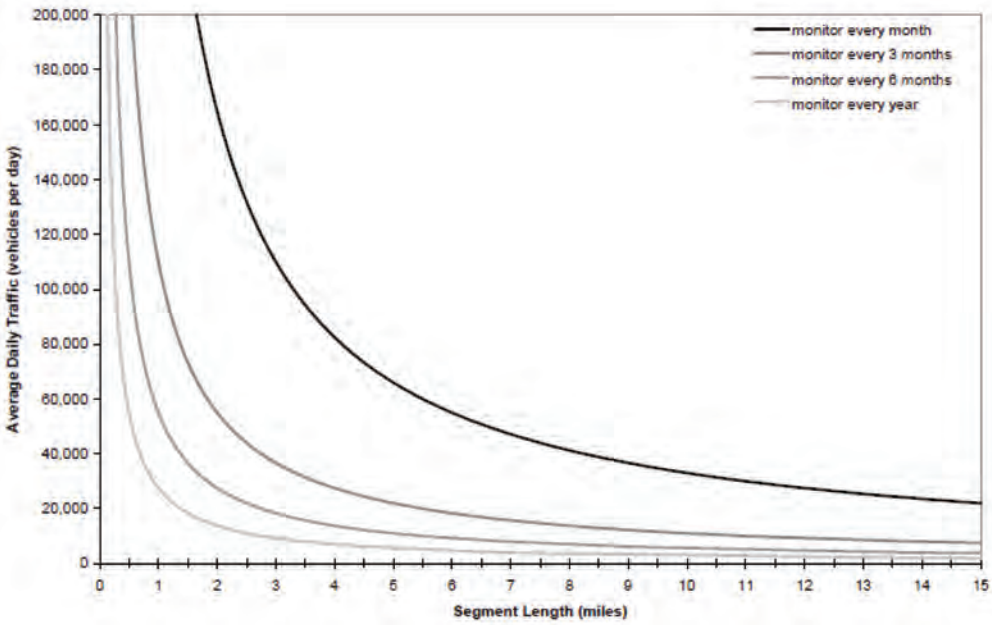


Figure 11. ADT and Project Length Combinations that Allow Detection of Significant Increases in Crashes during the Project (Pre-Work Zone Rate of 1.0 Accidents/MVM)

[33] Texas Transportation Institute, *Monitoring Work Zone Safety and Mobility Impacts in Texas*, May 2009.

Use the table below to evaluate the benefits and feasibility of implementing similar crash curves in your jurisdiction:

	Identified Practice/Practice in Question			
	Not at all	**Rarely**	**Often**	**Always**
How often do you currently use this practice?				
Would this practice benefit your jurisdiction?				
Is it feasible to implement this practice in your jurisdiction?				

Figure 12. Feedback Capture Tool: Developing Crash Curves for Safety Analysis

3.2.5 Modeling

Work zone modeling is used in many States, although usually to a limited degree, and it is often focused more on traffic operations and mobility impacts than potential safety concerns. These mobility-focused measures of effectiveness can provide information on the relative safety of a work zone setup, as mobility can act as an indicator of or surrogate for safety in some cases. For example, modeling can provide estimates of when and to what extent stop-and-go traffic or queues may form as a result of congestion in a work zone. Stop-and-go traffic and queues are both indicators of disruptions to traffic flow that can lead to speed differentials and greater potential for crashes.

There are many low-cost models available that can be used depending on available agency expertise and resources as well as level of effort warranted on the project. A collection of these models is described in more detail in the case study below.

Case Study: Using Simulation Models for Work Zone Assessment [34]

Agencies and contractors responsible for the planning, design, and operation of work zones are constantly under pressure to reduce the negative impacts that work zones can have on the traveling public. Modeling techniques can be used to assess the possible negative impacts of a specific work zone prior to it going operational.

Researchers at the University of Massachusetts compared estimates obtained from four work zone simulation models (QuickZone, CA4PRS, CORSIM, and QUEWZ) against actual work zone conditions at eight locations in New England. The researchers found that the QuickZone and QUEWZ models provided a low-risk, low-cost environment to test various work zone alternatives by providing reasonable order of magnitude estimates of queue lengths when compared to observational data in the field. QuickZone estimates work zone delays and can be used in the policy, planning, design, and operation phases of project development. CA4PRS estimates the length of pavement that can be rehabilitated or reconstructed within various project constraints and the amount of construction cost and road user costs that will arise from various alternatives. CORSIM is a well-known microscopic traffic simulation model that can be used to simulate traffic operation around a work zone. QUEWZ simulates queue lengths and additional road user costs as a result of work zone lane closures. These modeling programs were evaluated for their data requirements, ease of use, and ability to simulate work zone strategies.

How are simulation models related to work zone safety? *These models can be used in the planning and design process by both agencies and contractors to estimate variations in traffic flow. By estimating traffic flow under various work zone configurations, work zone strategies that focus on reducing queues, lowering speed differentials, and improving traffic flow can be developed to reduce the potential for crashes prior to the design and implementation stages of a work zone. The models can also be used during construction to analyze proposed changes to plans.*

[34] Collura, J.; Heaslip, K.; Moriarty, K.; Wu, F.; Khanta, R.; Berthaume, A. *Simulation Models for Assessment of the Impacts of Strategies for Highway Work Zones*, 2010.

Use the table below to evaluate the benefits and feasibility of implementing modeling in your jurisdiction:

	Identified Practice/Practice in Question			
	Not at all	**Rarely**	**Often**	**Always**
How often do you currently use this practice?				
Would this practice benefit your jurisdiction?				
Is it feasible to implement this practice in your jurisdiction?				

Figure 13. Feedback Capture Tool: Work Zone Modeling for Safety

4. Application

Once data are collected and analyzed by an agency, it is important that the results are used to address issues in current and future work zones. The results should also be used to make adjustments and improvements to an agency's goals and objectives; policies, practices, and standards; sources for future data; and analysis capabilities. Application of the data collected and analyzed is vital to improving safety in work zones.

4.1 Project-Level Changes

There is significant value in having real-time data and analysis available to make project-level changes at a work zone. One challenge regarding work zones is that because they are relatively short-term in nature, information obtained from the analysis of work zone data is often not applied to the work zone from which the data are obtained. With the support of real-time data collection practices, changes can be made in the field shortly after data are collected and analyzed. In general, highway agencies are not readily supplied with real-time data but find it useful when assessing potential changes to existing work zones.[35] Field observations by project staff such as the appearance of skid marks on the pavement or swipe marks on barriers, or finding certain traffic control devices repeatedly knocked down or out of place, can be helpful in identifying safety issues.

The Montana DOT is an example of an agency that has policy and practices to implement project-level changes. Real-time and archived data can be used to manage impacts during the implementation of the work zone. These data can be used to identify trends in safety and mobility issues and determine appropriate mitigation techniques. Also, the Montana DOT's Work Zone Safety and Mobility Guidelines state that a "Construction Zone Crash Assistance Team" will be created to review any fatal crashes that occur in a work zone. Among other goals, this Team will provide assistance to the work zone project crew, provide crash documentation, determine if any immediate improvements can be made to the work zone, and follow up with any possible lessons learned.

4.2 Changes to Standards, Programs, and Policies

The collection and analysis of both real-time and lagging work zone safety-related data allow highway agencies to make changes to upcoming projects that have similar characteristics to past projects.

After an agency walks through the process of defining objectives and identifying data needs, they will have the information needed to determine the most relevant data desired for analysis. Considering their current status of collection and analysis capabilities will drive the identification of strategies that they can take to the next step. Once an agency identifies strategies that are feasible and cost effective, they can begin taking steps toward implementing modifications to current work zone policy, design standards, or practices. These can vary widely, as the needs of the State and the current policies vary.

In Ohio, the DOT focused on three specific crash types identified from an analysis of work zone crashes.

Case Study: Ohio DOT Changes to Future Projects [36]

Viewing work zone crash data and addressing project-level issues is a first step in using crash data to address work zone safety and mobility issues. Additionally, gathering and viewing work zone crash data on an aggregate level can uncover findings that may enable the agency to make changes that can prevent future crashes on a larger scale. The Ohio DOT has used work zone crash data to make numerous changes to their work zone standards. Recently, reviewing historic crash data in work zone and non-work zone conditions led Ohio DOT to select three emphasis areas for work zone crashes: construction vehicle-related crashes, motorcycle-related crashes, and nighttime crashes.

Construction Vehicle-related Crashes. *When reviewing work zone crash records, Ohio DOT officials observed that there were numerous rear-end collisions occurring in the left-hand lane on some work zones in the State. Further investigation of these crashes determined that many of the crashes were taking place upstream of construction access points. In 2009, after determining these rear-end collisions were caused due to issues with slow-moving construction equipment merging onto the road, Ohio DOT officials drafted a Plan Insert Sheet to establish guidelines for construction access points to limit rear-end collisions due to construction equipment ingress and egress.*

---

[35] Federal Highway Administration, *Practitioner-focused Online Collaborative Session*, August 31, 2011.

[36] Stargell, R. *Best Practices in Work Zone Assessment, Data Collection and Performance Measurement.*

Motorcycle-related Crashes. *Analyzing historical work zone crash data obtained through law enforcement crash reports allowed Ohio DOT to determine that there was a rising trend of fatal motorcycle-related crashes occurring in work zones throughout the State. To address motorcycle-related crashes, officials reviewed their standards for pavement marking and marking removal. Concerns were raised that blackout tape typically used in Ohio work zones to conceal pavement markings as part of the temporary traffic control setup were causing motorcycle-related crashes because it reduced traction, particularly in wet conditions. Ohio DOT had multiple tests performed on different types of blackout tape, which resulted in the development of a qualified product list of blackout tape to be used in work zones. Additionally, Ohio DOT officials limited the use of blackout tape to a maximum of 45 days. After limiting the usage of blackout tape, Ohio DOT officials also modified specifications for removing pavement markings, which specified a maximum removal depth of 1/8 inch in the pavement to provide a safer ride for motorcyclists.*

Nighttime Crashes. *Analyzing historical work zone crash data obtained through law enforcement crash reports allowed Ohio DOT to determine that 50 percent of Ohio's work zone fatalities over a 10-year period occurred during nighttime hours. To address nighttime crashes, Ohio DOT officials adjusted their construction vehicle and work zone delineation policies. To improve visibility of work vehicles during nighttime work zones, officials modified Ohio DOT's specifications to require strobe or rotating lights on all work vehicles and to add reflective sheeting to all vehicles with a gross vehicle weight of 10,000 pounds or greater. To improve work zone delineation, Ohio DOT added to their work zone standards that the usage of raised pavement markers and barrier reflectors are required on temporary construction projects.*

This case study presented how Ohio DOT has used work zone crash data to address work zone crashes by modifying their work zone standards. By conducting similar work zone crash data reviews to identify trends or areas of emphasis on a regular basis, agencies can ensure that they are aware of any developing work zone crash trends in their jurisdiction.

Use the interactive table below to evaluate the benefits and feasibility of implementing a practice of incorporating results of work zone analysis, similar to the Ohio DOT case study presented above, in your jurisdiction:

	Identified Practice/Practice in Question			
	Not at all	**Rarely**	**Often**	**Always**
How often do you currently use this practice?				
Would this practice benefit your jurisdiction?				
Is it feasible to implement this practice in your jurisdiction?				

Figure 14. Feedback Capture Tool: Modifying Work Zone Policy Based on Crash Data Analysis

Another example of changes to policy can be provided through research projects, as shown in the case study below. In this study, researchers investigated nighttime work zone crashes and determined possible management strategies to help mitigate these crashes.

Case Study: Nighttime Work Zone [37]

NCHRP 17-30 conducted research to identify how daytime and nighttime work zones affect traffic safety, and whether nighttime work is more or less safe than daytime work. Project work activity and crash data from 64 projects in California, North Carolina, Ohio, and Washington were analyzed to determine similarities and differences in crash risks experienced during nighttime and daytime operations.

The researchers used project daily diaries and project construction management databases to extract basic data from each project, such as working hours, hours and locations of setup and removal of temporary lane closures, and number of travel lanes closed during each work period. The researchers also collected information on traffic control plans and construction phasing for each project, as well as crash and roadway inventory data for each project segment length, both while the project was active and during the years preceding it.

The researchers grouped the crashes into six categories: daytime and nighttime periods when the project was inactive; daytime and nighttime periods when work activity was occurring but no lane closures were in place; and daytime and nighttime periods when work activity was occurring and temporary lane closures were in place.

Under this project, researchers developed crash rates for nighttime and daytime work zones; determined the nature of and identified similarities and differences between traffic-related crashes in nighttime and daytime work zones; identified and evaluated management practices that promote work zone safety and mobility; and developed work zone crash reporting recommendations to further improve the data collected on work zone crashes. The theorized relationships between increased traffic crash risk and roadway traffic demand at nighttime and daytime work operations that require temporary lane closures is shown in Figure 15 below. This relationship is not linear, as it is expected that traffic volume increases significantly impact crash risks and the costs associated with them.

Some of the management strategies that the researchers found to have the most potential to lower crash rates are as follows: reduce the overall number of work zones necessary; use time-constrained contracts to reduce work zone duration; use medians or detours for full directional roadway closures; move work activities that include lane closures to nighttime; use enhanced traffic law enforcement; incorporate future work zone capacity into highway designs (e.g., design for a wider sub-base than needed on initial construction projects so that if future roadway expansion is needed, construction duration can be reduced); and use ITS to reduce congestion and increase safety. The researchers also acknowledged the necessity for crash report forms to have all of the recommended work zone crash analysis elements. Most of the study recommendations for data to collect via crash report forms were consistent with the nationally-developed MMUCC, with some additions, including exposure data and post-hoc analysis.

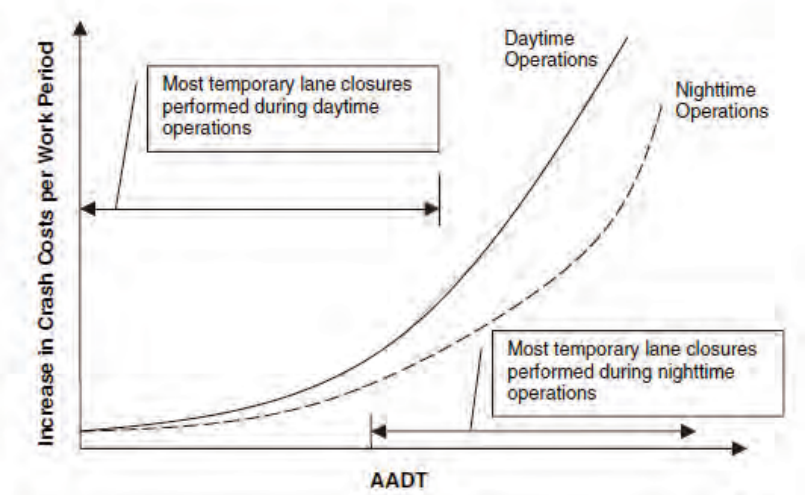


Figure 15. Theorized relationships between increased traffic crash risk and roadway traffic demand at nighttime and daytime work operations that require temporary lane closures

[37] Ullman, G., et al. NCHRP 17-30: *Traffic Safety Evaluation of Nighttime and Daytime Work Zones - Report 627*, 2008.

Use the table below to evaluate the benefits and feasibility of implementing a research study to assist in reviewing and modifying management strategies in your jurisdiction:

	Identified Practice/Practice in Question			
	Not at all	**Rarely**	**Often**	**Always**
How often do you currently use this practice?				
Would this practice benefit your jurisdiction?				
Is it feasible to implement this practice in your jurisdiction?				

Figure 16. Feedback Capture Tool: Research Study to Review Work Zone Strategies

System-level performance measurement is a key task in maintaining a safe work zone. Data monitoring and performance measurement can help highway agencies maintain a feedback loop to improve work zone safety. The level to which a State highway agency can effectively measure performance is tied directly to available data. An example of system-level performance measurement can be seen in the form of Montana DOT's biannual review of work zones within the State. The State has a variety of data collection procedures at the project and program levels. At the program level, statewide evaluations and analyses are conducted on every two years of crash reports to determine recommendations for future improvement.[38]

Case Study: Montana DOT Biannual Review[39]

Montana DOT (MDT) uses a variety of management strategies to manage construction zone impacts. As a part of their Work Zone Safety and Mobility Goal and Objectives, Procedures, and Guidelines, they developed a variety of data collection procedures and guidelines at both the project and program levels. The future goals for the use of crash data are to recognize where MDT's data need to be improved and to make those improvements. The Work Zone Safety and Mobility Guidelines state that MDT will set up procedures to collect traffic delay and traffic volume data for significant construction zone projects. The following procedures are some of the steps that the MDT has taken to improve safety and mobility in work zones.

At the program level, MDT continuously pursues improvements in safety and mobility of work zones. The data collected at the project level are analyzed for trends that can be useful at the program level. Additionally, MDT evaluates the safety of work zones every two years by performing a statewide construction zone safety engineering analysis of crash records produced by Montana Highway Patrol. Changes in work zone crash trends are noted and presented to the Work Zone Safety and Mobility Core Team to assist in determining recommendations for enhancing safety and mobility on current and future projects. These recommendations present corrective actions or program improvements to curb noted work zone crash trends. The Core Team also assesses work zone crashes annually to see if any immediate changes need to be made and to determine the topics for the biannual program review.

[38] Montana Department of Transportation, *Montana Department of Transportation Work Zone Safety and Mobility*, September 2007, Available at http://www.mdt.mt.gov/other/const/external/manuals_guidelines/workzone_safety_mobility.pdf.

[39] Montana Department of Transportation. *Work Zone Safety and Mobility Goal and Objectives, Procedures, Guidelines*, 2009. http://www.mdt.mt.gov/other/const/external/manuals_guidelines/workzone_safety_mobility.pdf

Use the table below to evaluate the benefits and feasibility of implementing a similar biannual review in your jurisdiction:

	Identified Practice/Practice in Question			
	Not at all	Rarely	Often	Always
How often do you currently use this practice?				
Would this practice benefit your jurisdiction?				
Is it feasible to implement this practice in your jurisdiction?				

Figure 17. Feedback Capture Tool: Develop a Bi-annual Work Zone Review

4.3 Next Steps

For the purposes of moving forward and improving work zone safety, potential next steps a practitioner can take are listed below.

4.3.1 Establish a Baseline: Identify Current Data Sources and Analysis Capabilities

Every highway agency has different capabilities for collecting and analyzing work zone safety-related data. After reading through this guide, practitioners can compare their current state of readiness and identify steps to take to meet their objectives and reach their desired state.

Data Collection. Before any analysis can be conducted, it is important to identify which data sources are available. Identify and compile a list of sources, potentially indicating to which of the major corridors these sources apply. As discussed previously, data collection is not necessary in some cases, as the data exists and only needs to be acquired and formatted for analysis. Once the quantity and quality of data elements are identified, the agency can develop a baseline from which to measure future progress.

Data Analysis. Each highway agency has a set of resources, expertise, and available tools. They should make note of what resources and tools are available and currently being used. Tools and resources readily available are those that are easiest to implement in work zone data analysis. For each available tool or resource, make note of what data sources are required, which may necessitate revisiting data collection needs.

4.3.2 Determine Applicability of Strategies from the Guide

Once an agency has established a baseline, practitioners should determine the applicability of the different case study examples and other recommendations of this guide. Throughout the guide, the reader has been given the opportunity to provide feedback on how that topic may benefit their safety-related data collection and analysis processes and approaches and how feasible it may be to implement. Readers are encouraged to review their answers in each Feedback Capture Tool in the previous sections to identify strategies deemed beneficial and feasible. After completing the Tool, the reader can reference the strategies introduced in this guide and begin taking steps to implement.

4.3.3 Identify Next Steps

Once an agency has determined how each example in this guide may be applicable to their situation, they can begin identifying the necessary steps to implement the strategy or strategies most likely to provide a benefit.

1. Identify the most beneficial and feasible strategies from information presented in Chapter 3 and the various case studies throughout this guide.

2. Determine the steps needed to implement each strategy by completing Table 3, and identify the other elements as follows:

   1. ***Critical Step.*** What is the first/next step in the process to move this strategy from concept to implementation?

   2. ***Responsible Party.*** Who will be responsible for the completion of this step? Assigning a lead for each step increases the likelihood of completion.

   3. ***Key Decision(s) Associated with Step.*** What must be decided before moving to the next step?

   4. ***Decision-maker.*** Who must make the key decision? Senior management? A work zone safety partner?

   5. ***Required Preparation.*** What are the activities that must be completed to ensure this critical step occurs?

   6. ***Estimated Timeframe to Complete Step.*** By when must this step be completed to ensure timely implementation?

   7. ***Date Completed.*** On what date did the responsible party complete this critical step?

Table 3. Critical Steps to Implementation Template

Critical Step	Responsible Party	Key Decision(s) Associated with Step	Decision-maker	Required Preparation	Estimated Timeframe to Complete Step (time from when activity begins)	Date Completed

Examples of strategy-specific next step processes are available in Appendix A.

4.3.4 Evaluation

After analyzing work zone data and making safety-related work zone improvements, it is important to evaluate these improvements to determine their effectiveness. This evaluation is critical in guiding future decisions stemming from work zone safety-related analysis.

To conduct such an evaluation, it is important to maintain a list of work zone improvements that have been implemented, the location and time of these improvements, and the reasoning behind these changes. For example, if revisions to standard work zone layouts were made due to an observation of an increasing trend of work zone crashes throughout a region, officials should make note of this change as well as the number of observed crashes before and after the change. Periodic assessments of crash reports from work zones in this region will allow for the determination of any changes to the trend and an assessment of the effect on work zone safety.

5. Conclusion

In order to reduce the number and severity of work zone crashes, it is important to know the size and scope of the problem. This can be determined through the collection and analysis of work zone safety-related data.

This guide is designed to assist highway agencies with improving their work zone data collection and analysis for the purpose of making work zones safer. It shared work zone safety-related data collection and analysis challenges, along with methods that are most effective in addressing those challenges. Further resources to assist in improving work zone safety can be found in Appendix C: Additional Resources.

This guide assists work zone practitioners with improving safety in work zones by walking them through the following process:

1. Identify Agency Objectives. Objectives must be defined prior to the start of any data collection or analysis process. These objectives can be defined broadly (e.g., increase safety in work zones) or specifically (e.g., decrease work zone crashes in nighttime work zones by 10 percent).

2. Identify Data Needs. Data needs present practitioners with information to determine which data are required for relevant analysis.

3. Develop Baseline. Developing a baseline will assist work zone practitioners in understanding the current level of work zone safety-related data collection and analysis in their home state.

4. Identify Strategies. Introduce practitioners to strategies and techniques currently being implemented around the country so practitioners may determine if similar strategies are feasible in their State.

5. Take Next Steps. Provide practitioners with next steps to improve work zone safety-related data collection, analysis, and implementation.

By taking these steps, work zone practitioners can improve their data collection and analysis efforts, ultimately resulting in a reduction in the number and severity of work zone crashes.

Appendix A: Example Next Steps

Example: Collecting Work Zone (WZ) Crash Report Data from Law Enforcement Agencies					
Critical Step	**Responsible Party**	**Key Decision(s) Associated with Step**	**Decision-maker**	**Required Preparation**	**Estimated Timeframe to Complete Step (time from when activity begins)**
1. Identify objective of collecting this information.	Work Zone Engineer, State DOT	How will we use these data?	Work Zone Engineer, State DOT	Meet with group to discuss.	1 month
2. Choose a pilot work zone and law enforcement (LE) agency.	Work Zone Engineer, District Resident Engineers	Choose sites and LE agencies for deployment.	Resident Engineers, Work Zone Engineer	Contact LE agencies to request their cooperation.	3 months
3. Visit pilot LE agency weekly to collect WZ crash reports.	District Resident Engineers, District WZ Engineers, Inspectors	Who will visit the LE agency to collect the reports?	District Resident Engineer, LE agency	Call ahead weekly before collecting reports.	6 months
4. Analyze reports to determine if real-time changes are necessary.	Traffic/Safety Engineer, Work Zone Engineer, Resident Engineers, Construction Inspectors	Who will analyze data?	Work Zone Engineer, District Resident Engineers	Get reports from the previous step to the analyst(s).	6-9 months
5. Evaluate the usefulness and benefits of collecting this data.	Work Zone Engineer, Traffic Engineer, District Resident Engineers	Determine benefits of having the data available. Has it been used to make WZs safer?	Work Zone Engineer	Understand data analysis reports. Log changes made based on crash data.	9-12 months
6. If successful, expand beyond the pilot work zone to additional projects and LE agencies.	Work Zone Engineer, Resident Engineers	Choose sites for additional deployment.	Resident Engineers, Work Zone Engineer	Contact LE agencies to ask for their cooperation.	12-18 months
7. Institutionalize crash report collection on appropriate projects.	Work Zone Engineer, Resident Engineers	Identify criteria for choosing when data is collected regularly from LE agencies.	Work Zone Engineer, Resident Engineers	Report on use to date.	18+ months
8. Identify desired data that are missing from crash reports and explore ways of addressing gaps.	Work Zone Engineer, State Safety Engineer, Traffic Records Coordinating Committee	When can the crash report form be amended?	Keeper of the State crash report form (varies)	Develop proposal to add/modify crash report form content.	Varies based on crash report form renewal cycle.

Example: Implement Portable Traffic Monitoring Devices (PTMDs) for Speed and Queue Data Collection

Critical Step	Responsible Party	Key Decision(s) Associated with Step	Decision-maker	Required Preparation	Estimated Timeframe to Complete Step (time from when activity begins)
1. Further evaluate current deployments of PTMDs in your State and other States.	Work Zone Engineer, State DOT	Should we deploy this strategy on our work zones?	Work Zone Engineer, State DOT	Prepare literature review report on current applications.	3 months
2. Determine most applicable sites/ project types in our jurisdiction for deployment.	Work Zone Engineer, District Resident Engineers	Choose sites for deployment.	Resident Engineers, Work Zone Engineer	Review temporary traffic control (TTC) plans.	6 months
3. Secure funding source and purchase PTMDs.	Work Zone Engineer, Management	Determine funding source and authorize purchase.	DOT Management	Analyze purchase options (e.g., lease vs. buy) and other costs.	9 months
4. Deploy PTMDs and collect data.	Resident Engineers, Construction Inspectors	Identify responsible party for data collection.	Resident Engineers	Identify process for data collection and archival.	10-12 months
5. Examine effects of the treatment where implemented.	Resident Engineers, Construction Inspectors, Work Zone Engineer	Determine what effect this treatment has on the safety and mobility of the work zone.	Work Zone Engineer, Resident Engineers	Identify objectives and performance measures.	12-15 months
6. Analyze data and evaluate effectiveness.	Work Zone Engineer, Traffic Engineer	Determine performance measures and desired metrics.	Work Zone Engineer	Understand data output.	12-15 months
7. If evaluation supports additional deployment, identify applicable sites.	Work Zone Engineer, Resident Engineers, Construction Inspectors	Choose sites for additional deployment.	Resident Engineers, Work Zone Engineer	Review TTC plans and TMP.	12-24 months
8. Institutionalize PTMD use in appropriate work zones based on most important criteria.	Work Zone Engineer, Resident Engineers	Identify criteria for choosing deployments. Develop special provisions for use of PTMDs on projects.	Work Zone Engineer, Resident Engineers	Determine most appropriate type of document (e.g., standard plan/drawing, special provision, specification).	24+ months

Example: Implement Bluetooth Technology to Obtain Travel Times					
Critical Step	**Responsible Party**	**Key Decision(s) Associated with Step**	**Decision-maker**	**Required Preparation**	**Estimated Timeframe to Complete Step (time from when activity begins)**
1. Further evaluate current deployments of Bluetooth technology in your State and other States.	Work Zone Engineer, State DOT	Should we deploy this strategy on our work zones?	Work Zone Engineer, State DOT	Prepare literature review report on current applications.	3 months
2. Determine most applicable sites/project types in our jurisdiction for deployment.	Work Zone Engineer, District Resident Engineers	Choose sites for deployment.	Resident Engineers, Work Zone Engineer	Review temporary traffic control (TTC) plans.	6 months
3. Secure funding source and purchase devices.	Work Zone Engineer, Management	Determine funding source and authorize purchase.	DOT Management	Analyze purchase options (e.g., lease vs. buy) and other costs.	9 months
4. Deploy Bluetooth reading devices and collect data.	Resident Engineers, Construction Inspectors	Identify responsible party for data collection.	Resident Engineers	Identify process for data collection and archival.	10-12 months
5. Examine effects of the treatment where implemented.	Resident Engineers, Construction Inspectors, Work Zone Engineer	Determine what effect this treatment has on the safety and mobility of the work zone.	Work Zone Engineer, Resident Engineers	Identify objectives and performance measures.	12-15 months
6. Analyze data, evaluate effectiveness, and identify benefits.	Work Zone Engineer, Traffic Engineer	Determine performance and benefits of having the data available.	Work Zone Engineer	Understand data output.	12-15 months
7. If evaluation supports additional deployment, identify applicable sites.	Work Zone Engineer, Resident Engineers, Construction Inspectors	Choose sites for additional deployment.	Resident Engineers, Work Zone Engineer	Review TTC) plans and TMP.	12-24 months
8. Institutionalize Bluetooth reading device use in appropriate work zones based on most important criteria.	Work Zone Engineer, Resident Engineers	Identify criteria for choosing deployments. Develop special provisions for use of Bluetooth data collection on projects.	Work Zone Engineer, Resident Engineers	Determine most appropriate type of document (e.g., standard plan/drawing, special provision, specification).	24+ months

Example: Use Simulation Models for Work Zone Assessments in Planning/Design Phase					
Critical Step	**Responsible Party**	**Key Decision(s) Associated with Step**	**Decision-maker**	**Required Preparation**	**Estimated Timeframe to Complete Step (time from when activity begins)**
1. Examine and identify the current work zone modeling capacity of the agency.	Work Zone Engineer	Determine if the entire agency will be examined, or only those directly involved with work zones.	Work Zone Engineer	Identify objectives and performance measures.	3 months
2. Fill gaps identified in Step 1 by purchasing modeling software and receiving training.	Work Zone Engineer, Traffic Engineer	Choose most applicable modeling software for the majority of agency needs.	Work Zone Engineer, IT staff	Determine options and examine costs and benefits.	6 months
3. Determine project goals for safety and mobility aspects of the work zone.	Work Zone Engineer, State DOT	What goals are feasible for type and location of project?	Work Zone Engineer, State DOT	Review DOT policies and goals.	8 months
4. Determine which simulation model best suits the needs of the project.	Work Zone Engineer, District Design Engineers	Match project type with relevant simulation tool.	District Design Engineers	Understand available simulation models and what level of information they provide.	10 months
5. Based on the simulation model's required inputs, collect relevant data.	Work Zone Engineer, Traffic Engineer	Identify responsible party for data collection and define data to be collected.	Traffic Engineer	Identify process for data collection and archival.	14 months
6. Iteratively model work zone characteristics until desired safety and mobility goals are met.	Design Engineer, Traffic Engineer	Determine the desired outcomes of the simulation.	Work Zone Engineer, State DOT	Understand the simulation output.	16 months
7. Select strategies, temporary traffic control (TTC) devices, and construction methods to incorporate in the design plans, TTC Plan, and TMP that adhere to goals for the work zone.	Work Zone Engineer, Traffic Engineer, Design Engineer	Identify potential strategies that meet project goals for safety and mobility.	Work Zone Engineer, Traffic Engineer	Research and discuss applicable mitigation strategies and TTC devices.	18 months

Example: Work Zone Safety and Mobility Monitoring using Crash Curves					
Critical Step	**Responsible Party**	**Key Decision(s) Associated with Step**	**Decision-maker**	**Required Preparation**	**Estimated Timeframe to Complete Step (time from when activity begins)**
1. Determine work zone segment length, AADT, and crash rate under normal operation conditions.	Work Zone Engineer, Traffic Engineer	How many years of data should be used to determine AADT and crash rate? How should segment lengths be determined?	Work Zone Engineer, Traffic Engineer	Review data and determine logical segment breakpoints.	2 months
2. Apply to appropriate crash curve and determine the recommended frequency of crash data collection.	Work Zone Engineer, Traffic Engineer	Which crash curve is most applicable?	Traffic Engineer	Conduct analysis of crash rate under normal circumstances.	3 months
3. Collect crash data.	Work Zone Engineer, Traffic Engineer	How will data be collected?	Work Zone Engineer, Traffic Engineer	Determine data elements to be collected.	5 months
4. Analyze data to determine effectiveness as related to work zone safety and mobility goals.	Traffic Engineer	Identify responsible party for data collection and analysis.	Traffic Engineer	Identify process for data collection and archival and select appropriate evaluation means.	7 months

Example: Review of Historic Work Zone Traffic Crash Data					
Critical Step	**Responsible Party**	**Key Decision(s) Associated with Step**	**Decision-maker**	**Required Preparation**	**Estimated Timeframe to Complete Step (time from when activity begins)**
1. Determine if work zone crash data is available.	State DOT Data Manager	Is work zone data housed at Statewide or Regional level?	State DOT and District level Data Manager	Seek understanding about the types of data available and the limitations of the data.	2 months
2. Assess the level of detail the crash data exhibits (i.e., crash reports vs. general summaries. Statewide vs. work zone specific).	State DOT Data Manager	Determine the combinations in which data could be segregated to drill down to the appropriate level of detail.	State DOT Data Manager, Traffic Engineer, Work Zone Engineer	Determine what level of data is relevant for analysis.	4 months
3. Organize data into like categories (i.e., urban/rural, AADT, etc.). Data can also be left organized at a Statewide level.	State DOT Data Manager	How should data be organized in order to make comparisons that are meaningful?	Traffic Engineer, Work Zone Engineer	Decide under which categories the data should reside.	6 months
4. Compare work zone crash data and crash data under normal circumstances to find similarities and disparities.	State DOT Data Manager	What threshold should serve as a basis for determining likeness?	State DOT Data Manager, Traffic Engineer, Work Zone Engineer	Compile database to easily cross reference and compare data across multiple categories.	10-12 months
5. Review comparison data to establish trends or potential improvement areas within identified categories.	State DOT Data Manager	Define what constitutes a trend and the threshold for when a work zone characteristic could be improved.	Work Zone Engineer, Traffic Engineer	Identify safety and mobility goals for work zones. Compare with trends and potential improvement areas.	16- 18 months

Example: Analyze Crash Risks Associated with Nighttime and Daytime Work Zone Operations					
Critical Step	**Responsible Party**	**Key Decision(s) Associated with Step**	**Decision-maker**	**Required Preparation**	**Estimated Timeframe to Complete Step (time from when activity begins)**
1. Define the types of data to collect with respect to daytime and nighttime work zone operations (e.g., project type, temporary traffic control devices used, presence of adjacent equipment or barrier, etc.). Define a segment length for each work zone.	Work Zone Engineer, State DOT	Determine work zone features that may play a role in increased crash frequency and severity.	Work Zone Engineer	Identify performance measures.	2 months
2. Collect data as determined in Step 1.	Traffic Engineers, Resident Engineers, Construction Inspectors	Who will collect this data? Define the methods used to collect data (i.e., construction journals, crash forms, etc.).	Traffic Engineers, Resident Engineers	Define data collection and documentation methods.	6 months
3. Retrieve comparative historic crash data for identified segment.	Data Manager	Determine the log points of the beginning and end of the work zone.	Work Zone Engineer, Data Manager	Submit detailed request to the Data Manager.	9 months
4. Analyze data and identify crash disparities with respect to type, frequency and severity.	State DOT Data Manager, Traffic Engineer	Ensure accurate data analysis and effective reporting mechanisms.	Work Zone Engineer	Previous steps.	12 months

Example: Periodic Crash Data Review					
Critical Step	**Responsible Party**	**Key Decision(s) Associated with Step**	**Decision-maker**	**Required Preparation**	**Estimated Timeframe to Complete Step (time from when activity begins)**
1. Determine the value of the Periodic Crash Data Review; decide on frequency and scope for the review; gain acceptance of the process.	Work Zone Engineer Traffic Engineer	What benefit will this review provide our State?	Senior Management	Develop presentation materials to share with managers.	3 months
2. Develop agenda and invitees.	Work Zone Engineer	Ensure key players can attend.	Work Zone Engineer	Begin thinking about performance measures to drive the agenda.	4 months
3. Schedule event (consider scheduling with biannual Work Zone Process Review).	Work Zone Engineer District Traffic Engineers FHWA	Ensure key players can attend.	Work Zone Engineer	Set up meeting space and logistics. Send pre-meeting read-ahead materials.	5 months
4. Compile crash data and other supporting information for review.	Work Zone Engineer, Traffic Engineer	What are the objectives and performance measures for discussion?	Work Zone Engineer	Determine which information is the most applicable for review.	6 months
5. Conduct Event: Identify performance measures.	Work Zone Engineer	What is the outcome we're looking for?	Work Zone Engineer Senior Management	Use the initial performance measure discussed from the previous task.	7 months
6. Conduct Event: Review crash data.	Data Manager	Define work zone crashes. Identify when the work zone was a contributing factor.	Data Manager	Become knowledgeable on work zone crash definitions.	7 months
7. Conduct Event: Identify strategies to improve data collection and analysis.	Work Zone Engineer Data Manager	Ensure strategies are feasible.	Data Manager Work Zone Engineer	Determine relative cost of various strategies.	7 months
8. Post-event: Develop strategy-specific action plans to improve data collection and analysis.	Work Zone Engineer Data Manager	Develop a step-by-step process.	Work Zone Engineer	Use these tables to develop a critical step process for each strategy.	10 months
9. Schedule follow-up to assess progress on completing the action plan.	Work Zone Engineer	Identify objectives and performance measures.	Work Zone Engineer Senior Management	Populate strategy-specific action plan tables to track progress	18-24 months

Appendix B: State Crash Report Example

MISSOURI UNIFORM CRASH REPORT PAGE _____ OF _____

1 - GENERAL CRASH INFORMATION

SPACE USED FOR BARCODE

AGENCY NAME AND ORI

LEFT THE SCENE ☐ Yes ☐ No | DRIVER NO. | CLEARED ☐ Yes ☐ No | CRASH CLASSIFICATION | PROPERTY DAMAGE ONLY ☐ | NO. INJURED | NO. KILLED | REPORT / CASE / INCIDENT NUMBER

NO. VEH. INV. | CRASH DATE | CRASH TIME (MIL.) | NOTIFIED DATE | TIME NOTIFIED (MIL.) | INVESTIGATION DATE | TIME ARRIVED (MIL.) | INVEST. AT SCENE ☐ Yes ☐ No

CRASH TYPE

ROADWAY: ☐ On Roadway ☐ Off Roadway

NON-COLLISION: ☐ Overturning ☐ Fire / Explosion ☐ Immersion ☐ Jackknife ☐ Fell/Jumped From MV ☐ Cargo / Equip Loss / Shift ☐ Other Non-Collision

COLLISION INVOLVING: ☐ Animal ☐ Pedalcycle ☐ Fixed Object ☐ Other Object ☐ Pedestrian ☐ Railway Vehicle ☐ Animal Drawn Veh / Animal Ridden Trans. ☐ Motor Vehicle in Transport → ☐ Parked Motor Vehicle → ☐ Working Motor Vehicle →

DIRECTIONAL ANALYSIS FOR IMPACT WITH MOTOR VEHICLE: ☐ Front to Front ☐ Front to Rear ☐ Rear to Rear ☐ Rear to Side ☐ Angle ☐ Sideswipe (Same Dir.) ☐ Sideswipe (Opp. Dir.) ☐ Failing / Shifting Cargo (Set in motion by MV) ☐ Other (Explain) ☐ Unknown (Explain)

COMMERCIAL MOTOR VEHICLE INVOLVEMENT CRITERIA - Answer the following to determine if the "Commercial Vehicle" fields in Section 7G must be completed.

1. Does this crash involve any of the following?
   1a. A person fatally injured; OR
   1b. A person transported for medical attention; OR
   1c. A vehicle towed due to disabling damage.
   ☐ No - No commercial vehicle fields need completion.
   ☐ Yes - Go to number 2. →

2. Examine each vehicle to determine if it is a commercial vehicle based upon the following:
   2a. A truck / cargo van with GVWR / GCVWR of more than 10,000 lbs; OR
   2b. A motor vehicle with seating for 9 or more including driver; OR
   2c. A vehicle with a hazardous materials placard.
   ☐ No - No commercial vehicle fields need completion.
   ☐ Yes - Complete Section 7G for appropriate vehicle.

EVIDENTIARY PHOTOS TAKEN ☐ Yes ☐ No | BY WHOM | AVAILABLE FROM ☐ Investigating Agency

RECONSTRUCTION ☐ Yes ☐ No | BY WHOM | AVAILABLE FROM ☐ Investigating Agency

2 - LOCATION

COUNTY | MUNICIPALITY | BEAT / ZONE | TRP/DIST/PCT | GPS COORDINATES (DD MM SS.S FORMAT) LAT: N LONG: W

ON | RDWY. DIR. | DISTANCE FROM ☐ NA _____ Feet _____ Miles | LOCATION ☐ After ☐ Before ☐ At ☐ NA | INTERSECTING

SPEED LIMIT | ROAD MAINTAINED BY ☐ State ☐ County ☐ Municipal ☐ Private Property ☐ Other ☐ Unknown | SPEED LIMIT | INT. DIR. | GEO - CODE

TRAFFICWAY: ☐ One-Way ☐ Two-Way; Not Divided ☐ Two-Way; Divided; Unprotected Median ☐ Other ☐ Two-Way; Not Divided, Continuous Center Turn Lane ☐ Two-Way; Divided; Positive Median Barrier ☐ Unknown

ROAD ALIGNMENT: ☐ Straight ☐ Curve ☐ Unknown (Explain)

ROAD PROFILE: ☐ Level ☐ Downhill ☐ Dip ☐ Uphill ☐ Hillcrest ☐ Unknown (Explain)

INTERSECTION TYPE ☐ NA: ☐ 4-way Intersection ☐ Y-Intersection ☐ 5-way / More ☐ Unknown (Explain) ☐ T-Intersection ☐ Roundabout ☐ Other (Explain)

ROAD CONDITION: ☐ Dry ☐ Snow ☐ Slush ☐ Standing Water ☐ Sand / Gravel ☐ Unknown (Explain) ☐ Wet ☐ Ice / Frost ☐ Mud / Dirt ☐ Moving Water ☐ Other (Explain)

ROAD SURFACE: ☐ Concrete ☐ Brick ☐ Dirt / Sand ☐ Cobblestone ☐ Asphalt ☐ Gravel ☐ Multi-Surface ☐ Unknown (Explain)

WEATHER CONDITION: ☐ Clear ☐ Rain ☐ Sleet / Hail ☐ Fog / Mist ☐ Other (Explain) ☐ Cloudy ☐ Snow ☐ Freezing (Temp) ☐ Severe Crosswind ☐ Unknown (Explain)

LIGHT CONDITION: ☐ Daylight ☐ Dark-Lighted ☐ Dark-Unlighted ☐ Dark-Unknown Lighting ☐ Other (Explain) ☐ Unknown (Explain)

3 - DAMAGE TO PROPERTY OTHER THAN VEHICLES ☐ None

LIST OWNER'S NAME & ADDRESS, DESCRIPTION OF PROPERTY, AND DAMAGE. ☐ MoDOT ☐ County ☐ Municipality

4 - WITNESS ☐ None Identified ☐ Additional Witnesses in Narrative

NAME	ADDRESS (Street, City, State, Zip)	PHONE NUMBER

5 - PEDESTRIAN ☐ NA ☐ Law Enforcement Officer ☐ Other Emergency Services Personnel ☐ MoDOT Worker ☐ Other Trafficway Worker ☐ Other Pedestrian

NO. | NAME (Last, First, MI) & ADDRESS (Street, City, State, Zip) | PHONE NUMBER

DATE OF BIRTH | SEX | STRUCK BY VEH #: | INJ | TRANS-PORT | SAFETY DEVICES | LOCATION ☐ On Roadway ☐ On Sidewalk ☐ In Driveway Access ☐ Off Roadway ☐ On Median / Crossing Island ☐ Unknown

CROSSING ROAD ☐ NA: ☐ With Signal ☐ Against Signal ☐ No Signal ☐ Unknown | ☐ Not At Crosswalk ☐ In Marked Crosswalk ☐ In Unmarked Crosswalk ☐ Unknown

OTHER ACTIONS ☐ NA / None: ☐ Getting On / Off Vehicle ☐ Standing / Lying / Sitting In Trafficway ☐ Pushing / Working On Vehicle ☐ Behind / In Front of Parked / Stopped Veh. ☐ Working In Trafficway ☐ Playing In Trafficway ☐ Walking / Running In Trafficway ☐ With Traffic ☐ Against Traffic ☐ Unknown ☐ Other (Explain)

SCHOOL INFO. ☐ NA: ☐ Going To / From School ☐ Getting On / Off School Bus ☐ Both Of The Above ☐ Unknown (Explain)

PROBABLE CONTRIBUTING CIRCUMSTANCES ☐ None: ☐ Failed To Yield ☐ Distracted / Inattentive ☐ Alcohol ☐ Drugs ☐ Vision Obstructed (Explain) ☐ Physical Impairment (Explain) ☐ Other (Explain) ☐ Unknown (Explain)

DISTRACTED / INATTENTIVE CODE(S) ☐ NA

ALCOHOL USE ☐ Yes ☐ No ☐ Unknown

DISTRIBUTION: COPY - AGENCY FILE: ORIGINAL - MISSOURI STATE HIGHWAY PATROL - TRAFFIC RECORDS DIVISION - P.O. BOX 568 - JEFFERSON CITY, MO 65102 SHP-2Q 01/12

REPORT #_____ PAGE _____ OF_____

7 - DRIVERS, VEHICLES, OWNERS, & OCCUPANTS

NO. | 7A. DRIVER - NAME (Last, First, MI) & ADDRESS (Street, City, State, Zip) | PHONE NUMBER

DRIVER LICENSE / ID NUMBER | STATE | LIC STATUS ☐ Valid ☐ Susp / Rev / Denied ☐ Canceled / Oth Invalid ☐ Expired ☐ Disqual CDL ☐ Unknown ☐ NA | LIC TYPE ☐ Operator Class ____ ☐ CDL Class ____ ☐ Interm / Grad ☐ Permit ☐ MC Only ☐ Unlicensed ☐ Unknown (Explain) ☐ NA | MC ENDORSEMENT ☐ Yes ☐ No ☐ NA ☐ Unknown (Explain)

DATE OF BIRTH | SEX | SEAT LOC | INJ | TRANSPORT | EJECTION | AIR BAG | SAFETY DEVICES | VISION OBSTRUCTED ☐ Not Obstructed ☐ Windshield ☐ Load on Veh ☐ Trees / Brush ☐ Building ☐ Embankment ☐ Sign ☐ Hillcrest ☐ Parked Veh ☐ Moving Veh ☐ Stopped Veh ☐ Glare ☐ Other (Explain) ☐ Unknown (Explain) ☐ NA

PROOF OF INSURANCE ☐ Yes ☐ No ☐ Not Required | INSURANCE COMPANY ☐ Expired | PHONE NO. (Optional) | POLICY NUMBER ☐ NA | ☐ Driver ☐ Vehicle

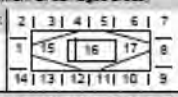
7B. VEHICLE - OWNER NAME (Last, First, MI) & ADDRESS (Street, City, State, Zip) ☐ SAO | PHONE NUMBER ☐ SAO

YEAR | MAKE | MODEL | COLOR | VEH. TYPE | TOTAL NO. OF OCC.

LICENSE - PLATE NO. | STATE | YEAR | VIN | TOWED FROM SCENE ☐ Yes ☐ No | TOWED DUE TO DIS. DAMAGE ☐ Yes ☐ No

VEHICLE DAMAGE (Mark all damaged areas) ☐ None / No Damage

INITIAL IMPACT NO: ☐ NA



18 - Undercarriage
19 - Windshield
20 - Burned
21 - Towed Unit
22 - Cargo
23 - Unknown
24 - Other (Explain)

TOWED BY ☐ Unknown ☐ NA

VEHICLE BODY TYPES - Automobiles / Specialty Vehicles ☐ Vehicle Used As Public Conveyance

- ☐ Passenger Car
- ☐ Van (< 9 W/Driver)
- ☐ Passenger Van (9+ W/Driver)
- ☐ Sport Utility Vehicle
- ☐ Limousine (7-8 W/Driver)
- ☐ Limousine (9-15 W/Driver)
- ☐ Motorized Bicycle
- ☐ Pedalcycle → ☐ To / From School
- ☐ Small Bus (9-15 W/Driver)
- ☐ Large Bus (16+ W/Driver) → ☐ School Bus ☐ Intercity ☐ Transit / Commuter ☐ Charter / Tour ☐ Other
- ☐ Motorcycle
- ☐ ATV → ☐ 2 Wh ☐ 3 Wh ☐ 4 Wh ☐ 5 Wh / More ☐ Unknown
- ☐ Motor Home
- ☐ Farm Implements
- ☐ Construction Equip. Heavy Mach.
- ☐ Other Vehicle (Code) _____
- ☐ Cargo Van
- ☐ Pickup
- ☐ Other Heavy Truck
- ☐ Unknown (Explain)
- ☐ Single-unit Truck; 2 axles, 6 tires
- ☐ Single-unit Truck; 3 or more axles
- ☐ Veh. Pulling Another Unit(s) (Does not apply to Truck Tractors)
- ☐ Truck Tractor With No Units
- ☐ Truck Tractor With One Unit
- ☐ Truck Tractor With Two Units
- ☐ Truck Tractor With Three Units

GVW / GCVW RATING (Not Licensed Weight) (Pickups, Cargo Vans, All Trucks, Truck Tractors, or Haz Mat Placard Veh. Only)
- ☐ Less than or equal to 10,000 lbs.
- ☐ 10,001 - 26,000 lbs.
- ☐ Greater than 26,000 lbs.
- ☐ Unknown

EMERGENCY VEHICLE INVOLVEMENT ☐ NA
- ☐ Police ☐ Ambulance
- ☐ Fire ☐ Other (Must check "A" / "B") →
- ☐ A. Emergency Vehicle on Emergency Run
- ☐ B. Stationary With Emergency Equip. Activated

CONTRIBUTING TRAFFIC CONDITIONS ☐ NA
- ☐ Congestion Ahead ☐ Other Incident Ahead
- ☐ Crash Ahead ☐ Unknown (Explain)

7C. VEHICLE ACTION / SEQUENCE OF EVENTS CODES ☐ Additional Codes Listed In Narrative (See Codes in Section 8)

SEQUENCE OF EVENTS CODES ☐ Unknown | ANIMAL CODE(S) | FIXED OBJECT CODE(S) | ALCOHOL USE ☐ Yes ☐ No ☐ Unk ☐ NA

7D. PROBABLE CONTRIBUTING CIRCUMSTANCES ☐ None

- ☐ Vehicle Defects (Explain)
- ☐ Speed - Exceeded Limit
- ☐ Too Fast For Conditions
- ☐ Violation Signal / Sign
- ☐ Failed To Yield
- ☐ Alcohol
- ☐ Drugs
- ☐ Vision Obstructed
- ☐ Driver Fatigue / Asleep
- ☐ Improper Signal
- ☐ Improper Backing
- ☐ Improper Turn
- ☐ Improper Passing
- ☐ Improperly Parked
- ☐ Failed To Dim Headlights
- ☐ Failed To Use Lights
- ☐ Following Too Close
- ☐ Wrong Side (Not Passing)
- ☐ Wrong Side (One-Way)
- ☐ Physical Impairment (Explain)
- ☐ Improper Start From Park
- ☐ Improper Towing / Pushing
- ☐ Improperly Stopped On Roadway
- ☐ Improper Lane Usage / Change
- ☐ Overcorrected
- ☐ Improper Riding / Clinging To Veh. Exterior
- ☐ Failed To Secure Load / Improper Loading
- ☐ Animal(s) In Roadway
- ☐ Object / Obstruction In Roadway
- ☐ Distracted / Inattentive (Designate Type)
- ☐ Unknown (Explain)
- ☐ Other (Explain)

DISTRACTED / INATTENTIVE CODE(S) ☐ NA (See Codes in Section 8)

7E. WORK ZONE ☐ Yes ☐ No ☐ Unknown

Workers Present ☐ Yes ☐ No ☐ Unknown

TRAFFIC CONTROL ☐ None ☐ Unknown

Electric: ☐ Green/Yellow/Red ☐ Flashing Red ☐ Flashing Yellow ☐ Ramp Meter ☐ Other (Explain)

Other Controls: ☐ Stop Sign ☐ No Passing Zone ☐ Turn Restricted ☐ Officer / Flagman ☐ Signal On School Bus ☐ Warning Sign / Device ☐ Railway Crossing Sign / Device ☐ School Zone ☐ Yield Sign ☐ Other (Explain)

CONTROL MALFUNCTIONING / INOPERATIVE / MISSING ☐ Yes (Explain) ☐ No ☐ Unknown ☐ NA

7F. OCCUPANTS - NAME (Last, First, MI) ADDRESS (Street, City, State, Zip)	DATE OF BIRTH MM-DD-YYYY	SEX	SEAT LOC	INJ	TRANSPORT	EJECTION	AIR BAG	SAFETY DEVICES	PHONE NUMBER

7G. COMMERCIAL MOTOR VEHICLE ☐ NA | Required on vehicle if "Yes" was answered to questions in parts 1 and 2 in CMV involvement criteria and vehicle meets one of the three criteria in part 2.

MOTOR CARRIER IDENTIFICATION (Lessee, etc.) - NAME & ADDRESS (Street, City, State, Zip) ☐ SAO | PHONE NUMBER ☐ SAO

COMMERCIAL / NON-COMMERCIAL ☐ Interstate Carrier ☐ Intrastate Carrier ☐ Not In Commerce - Government Vehicle ☐ Not In Commerce - Rental Vehicle ☐ Not In Commerce - Other Vehicle | MC / MX / ICC NO. | USDOT NO.

CARGO BODY TYPE ☐ Enclosed Box ☐ Cargo Tank ☐ Flatbed ☐ Dump ☐ Concrete Mixer ☐ Auto Transporter ☐ Garbage / Refuse ☐ Grain / Chip / Gravel ☐ Pole Trailer ☐ Log ☐ Vehicle Towing Another Veh. ☐ Intermodal Container Chassis ☐ NA (No Cargo Body) ☐ Other ☐ Unknown

HAZARDOUS MATERIALS | PLACARD DISPLAYED ☐ Yes ☐ No ☐ Unknown | 4-DIGIT NO. | CLASS | HM CARGO PRESENT ☐ Yes ☐ No ☐ Unknown | HM CARGO RELEASED ☐ Yes ☐ No ☐ Unknown | HAZARDOUS MATERIAL NAME

REPORT #_____ PAGE _____ OF_____

S - CODES

SEAT LOCATION
XX - Not Known
B - Pedalcycle
M - Motorcycle
FR SR TR / FC SC TC / FL SL TL
CP - Commercial Passenger
OE - Occupant - Enclosed Load Area
OU - Occupant - Unenclosed Load Area
RC - Rail Crew
SV - Other (Explain in Narrative)
NA - Not Applicable

INJURY
1. Fatal
2. Disabling
3. Evident - Not Disabling
4. Probable - Not Apparent
5. None Apparent
U. Unknown
N. NA

TRANSPORTED (For Medical Treatment)
1. No
2. EMS
3. Other
U. Unknown
N. NA

EJECTION
1. NA
2. No
3. Partially
4. Totally
U. Unknown

AIR BAG
1. None / NA
3. Not Deployed
4. Removed
5. Deployed - Front
6. Deployed - Side
7. Deployed - Curtain
8. Deployed - Other (Knee, Air Bell, etc.)
9. Deployed - Combination
10. Deployment Unknown
U. Air Bag Presence Unknown

SAFETY DEVICES
1. None
2. Not Used
3. Shoulder Belt Only
4. Lap Belt Only
5. Shoulder and Lap Belt
7. DOT Compliant MC Helmet
8. No Helmet
10. Booster Seat
11. Child Restraint - Forward Facing
12. Child Restraint - Rear Facing
13. Other Helmet
14. Reflective Clothing
15. Other
U. Use Unknown
N. Not Applicable

VEHICLE ACTION / SEQUENCE OF EVENTS (Items with double-asterisk ["*] require additional coding)
1. Going Straight
2. Overtaking
3. Making Right Turn
4. Right Turn on Red
5. Making Left Turn
6. Making U-Turn
7. Skidding / Sliding
8. Slowing / Stopping
9. Start in Traffic
10. Start From Parked
11. Backing
12. Stopped in Traffic
13. Parked
14. Changing Lanes
15. Avoiding
16. Cross Median
17. Cross Center Of Road
18. Cross Road
19. Airborne
20. Ran Off Roadway - Right
21. Ran Off Roadway - Left
22. Overturn / Rollover
23. Fire / Explosion
24. Immersion
25. Jackknife
26. Cargo Loss / Shift
27. Equipment Failure
28. Separation Of Units
29. Returned To Roadway
30. Collision Inv. Pedestrian
31. Collision Inv. Bicycle/Pedalcycle
32. Collision Inv. Railway Veh.
33. Collision Inv. Animal (**)
34. Collision Inv. MV in Transport
35. Collision Inv. Parked MV
36. Collision Inv. Fixed Object (**)
37. Collision Inv. Other Object (Explain)
38. Other Non-collision
39. Collision Inv. Bicycle/Pedalcycle In Bicycle Lane
40. Collision Inv. Animal Drawn Vehicle / Animal Ridden For Transportation
41. Collision Inv. Working MV
42. Downhill Runaway
43. Fell/Jumped From MV
44. Thrown/Falling Object
45. Struck By Falling, Shifting Cargo, Object Set In Motion By Own MV
46. Ran Off Roadway - Other (Explain)
47. Cross Separator

ANIMAL CODES FOR VEHICLE ACTION / SEQUENCE OF EVENTS
60. Deer
61. Farm Animal
62. Dog
63. Other Animal
U. Unknown

FIXED OBJECT CODES FOR VEHICLE ACTION / SEQUENCE OF EVENTS
20. Tree / Stump (Standing)
21. Embankment / Driveway / Ground / Rock Bluff
22. Guardrail Face
23. Utility Pole
24. Fence
25. Street Light Support
26. Culvert
27. Highway Traffic Sign Post / Support
28. Bridge Pier / Abutment / Support
29. Curb
30. Mail Box
31. Concrete Traffic Barrier
32. Building
33. Traffic Signal Support
34. Impact Attenuator / Crash Cushion
35. Fire Hydrant
36. Other (Explain)
37. Bridge Parapet End
38. Bridge Rail
39. Guardrail End
40. Other Traffic Barrier
41. Overhead Sign Support
42. Ditch
43. Other Post / Pole / Support
44. Wall
45. Cable Barrier
46. Bridge Overhead Structure
47. Overhead Line / Cable
U. Unknown

DISTRACTED / INATTENTIVE CODES
1. External Distraction
2. Passengers
3. Stereo / Audio / Video Equipment
4. Navigation Device
5. Communication Device - Hand-held
6. Communication Device - Hands Free
7. Communication Device - Texting / E-mailing
8. Communication Device - Web Browsing
9. Eating / Drinking
10. Reading
11. Tobacco Use
12. Grooming
13. Computer Equipment / Electronic Games / etc.
14. Adjusting Vehicle Controls
15. Other (Explain)

VEHICLE TYPE CODES
1. Motor Vehicle In Transport
2. Parked Motor Vehicle
3. Working Motor Vehicle
4. Pedalcycle
5. Animal Drawn Vehicle / Animal Ridden For Transport Purposes
U. Unknown

OTHER VEHICLE CODES
1. Riding Mower / Garden Tractor
2. Golf Cart
3. Snowmobile
4. Forklift
5. Animal Drawn Vehicle / Animal Ridden For Transportation
6. Low Speed Vehicle
7. Other (Explain)

9. NARRATIVE / STATEMENTS (If additional room is necessary, use Section 11 - Narrative / Statements Continuation)

10. REPORTING AND REVIEWING OFFICER INFORMATION

REPORTING OFFICER NAME	DSN / BADGE NO.	BEAT / ZONE	TROOP / DISTRICT / PRECINCT

REVIEWING OFFICER NAME	DSN / BADGE NO.	REVIEWING OFFICER 2 NAME	DSN / BADGE NO.

Appendix C: Additional Resources

For additional information on safety-related data collection and analysis, see the following resources:

NCHRP Report 500 Series: Guide for Implementation of the AASHTO Strategic Highway Safety Plan, Volume 19: A Guide for Collecting and Analyzing Safety Highway Safety-related data.

This guide was produced to assist State and local users in locating and analyzing pertinent safety-related data for use in their planning effort for any of the 22 emphasis areas of the AASHTO Strategic Highway Safety Plan. It provides analytical methods that can assist safety analysts in choosing and targeting safety improvement strategies and it provides guidance on sources of safety-related data, the procedures for choosing the best strategies and countermeasures within a given emphasis area, and targeting those strategies to either roadway locations or road-user subgroups.

Available at http://safety.transportation.org/guides.aspx?cid=40

Model Minimum Uniform Crash Criteria (MMUCC) Guideline

The Model Minimum Uniform Crash Criteria Guideline (MMUCC) is a minimum, standardized data set for describing motor vehicle crashes and the vehicles, persons and environment involved. The Guideline is designed to generate the information necessary to improve highway safety within each State and nationally.

Available at http://www.mmucc.us/sites/default/files/2008MMUCCGuideline.pdf

FHWA Crash Data Improvement Program (CDIP)

The CDIP is intended to provide States with a means to measure the quality of the information within their crash database. It is intended to provide the States with metrics that can be used to establish measures of where their crash data stands in terms of its timeliness, the accuracy and completeness of the data, the consistency of all reporting agencies reporting the information in the same way, the ability to integrate crash data with other safety-related databases, and how the State makes the crash data accessible to users. Additionally, the CDIP was established to help familiarize the collectors, processors, maintainers and users with the concepts of data quality and how quality data helps to improve safety decisions.

Available at http://safety.fhwa.dot.gov/cdip/

FHWA Highway Safety Facts and Statistics

Links to facts, statistics and data on a variety of highway safety-related topics are provided at this FHWA website. Information on a variety of searchable databases is also available to assist users in finding other sources of facts, statistics and data.

Available at http://safety.fhwa.dot.gov/facts_stats/

FHWA Work Zone Traffic Analysis

Links to reports, guidelines, examples, tools, articles, and webinars on analyzing and understanding various work zone impacts are available at this FHWA website. This information is intended to assist practitioners with determining appropriate mitigation strategies to use during project planning and design, and to include in their transportation management plans.

Available at http://www.ops.fhwa.dot.gov/wz/traffic_analysis/index.htm

FHWA Work Zone Performance Measurement

Links to useful resources to assist practitioners at the National, State, and local levels with tracking and analyzing performance measures are available at this FHWA website. These resources include the following: Work Zone Self-Assessment tool, Process Review Toolbox, Performance Measurement Development, Performance Measurement Examples, and I-95 Corridor Coalition Performance Measures Course.

Available at http://www.ops.fhwa.dot.gov/wz/decision_support/perf_measurement.htm

AASHTO Highway Safety Manual

The American Association of State Highway Transportation Officials (AASHTO) Highway Safety Manual (HSM) provides practitioners with information to facilitate roadway planning, design, operations, and maintenance decisions. AASHTO's webpage provides links to HSM-related tools as well as recorded training events that can be viewed free of charged providing individuals with an introduction to the HSM and how it can be used.

Available at http://www.highwaysafetymanual.org/Pages/default.aspx

Crash Modifications Factors (CMF) Clearinghouse

Crash Modification Factors (CMFs) provide practitioners a method to quickly estimate the expected number of crashes after implementation of a crash countermeasure. The USDOT's CMF Clearinghouse contains a wealth of information CMFs, searchable by countermeasure category, crash type, crash severity, and roadway type. In addition, the clearinghouse provides practitioners the ability to submit and share CMFs documented through studies in their State.

Available at: http://www.cmfclearinghouse.org/

FHWA Work Zone Data Examples Page

FHWA maintains a webpage on relevant work zone data examples to assist agencies in developing their own methods of data collection and analysis. In addition to the State examples, this webpage includes guidance and technical resources on work zone data collection and analysis, including webinar recordings, reports, and training information.

Available at: http://www.ops.fhwa.dot.gov/wz/resources/final_rule/data_examples.htm

AASHTO/FHWA Domestic Scan on Work Zone Data Collection, Assessment, and Performance Monitoring

This report highlights a domestic scan held by AASHTO and FHWA in March 2010 that investigated how 14 State agencies are planning for, monitoring, and managing work zone performance. Also included in this report are key recommendations to develop and improve work zone data collection and analysis.

Available at: http://onlinepubs.trb.org/onlinepubs/nchrp/docs/NCHRP20-68A_08-04.pdf

SAFER ROADS SAVE LIVES

Developed by:

The American Traffic Safety Services Association

15 Riverside Parkway Suite 100

Fredericksburg, VA 22406-1022

800-272-8772

U.S. Department of Transportation

Federal Highway Administration