Work Zone Data Management Applications and Opportunities

Final Report
March 2021

SWZDI
Smart Work Zone Deployment Initiative

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Iowa State University
Institute for Transportation

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Smart Work Zone Deployment Initiative
(Part of TPF-5(295))
Federal Highway Administration
(InTrans Project 18-646)

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The preparation of this report was financed in part through funds provided by the Iowa Department of Transportation through its "Second Revised Agreement for the Management of Research Conducted by Iowa State University for the Iowa Department of Transportation" and its amendments.

The opinions, findings, and conclusions expressed in this publication are those of the authors and not necessarily those of the Iowa Department of Transportation or the U.S. Department of Transportation Federal Highway Administration.

Technical Report Documentation Page

1. Report No. InTrans Project 18-646	**2. Government Accession No.**	**3. Recipient's Catalog No.**
4. Title Work Zone Data Management Applications and Opportunities		**5. Report Date** March 2021
		6. Performing Organization Code
7. Author(s) John W. Shaw (orcid.org/0000-0001-5929-5120) and Archana Venkatachalapathy (orcid.org/0000-0003-3361-4538)		**8. Performing Organization Report No.** InTrans Project 18-646
9. Performing Organization Name and Address Center for Transportation Research and Education Iowa State University 2711 South Loop Drive, Suite 4700 Ames IA 50010		**10. Work Unit No. (TRAIS)**
		11. Contract or Grant No.
12. Sponsoring Organization Name and Address Smart Work Zone Deployment Initiative and Iowa Department of Transportation 800 Lincoln Way Ames, Iowa 50010	Federal Highway Administration U.S. Department of Transportation 1200 New Jersey Avenue SE Washington, DC 20590	**13. Type of Report and Period Covered** Final Report
		14. Sponsoring Agency Code Part of TPF-5(295)

15. Supplementary Notes

Visit https://swzdi.intrans.iastate.edu/ for color pdfs of this and other Smart Work Zone Deployment Initiative research reports.

16. Abstract

Highway work zones often have major safety and mobility impacts, which are made worse when travelers are unaware that they are approaching a work zone. To monitor and mitigate the mobility and safety impacts of road construction, transportation agencies, first responders, and the public require accurate information about the location, extent, and timing of construction-related closures.

This project reviewed various stakeholders' current needs for pre-construction, real-time, and post-construction work zone information and compared these needs to the available work zone data sources and standards. The analysis identified a substantial mismatch between the roadway and lane closure data currently available and the data required to manage work zone traffic impacts effectively. To address this gap, the project developed a conceptual prototype for a tool that would facilitate self-reporting of closure details by contractors and maintenance crews.

17. Key Words DATEX—lane closures—performance measures—TMDD—traffic management—traffic monitoring—work zone communications—work zone construction—work zone data—WZDI		**18. Distribution Statement** No restrictions.	
19. Security Classification (of this report) Unclassified.	**20. Security Classification (of this page)** Unclassified.	**21. No. of Pages** 113	**22. Price** NA

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

WORK ZONE DATA MANAGEMENT APPLICATIONS AND OPPORTUNITIES

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Sponsored by the Smart Work Zone Deployment Initiative and
the Federal Highway Administration (FHWA) Pooled Fund Study TPF-5(295):
Iowa (lead state), Kansas, Missouri, Nebraska, and Wisconsin

Preparation of this report was financed in part
through funds provided by the Iowa Department of Transportation
through its Research Management Agreement
with the Institute for Transportation
(InTrans Project 18-646)

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ACKNOWLEDGMENTS

This research was conducted under the Smart Work Zone Deployment Initiative (SWZDI) and Federal Highway Administration (FHWA) Pooled Fund Study TPF-5(081), involving the following state departments of transportation:

- Iowa (lead state)
- Kansas
- Missouri
- Nebraska
- Wisconsin

The project was guided by a technical advisory committee (TAC) comprised of the following individuals:

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The authors would like to thank the TAC members, the FHWA, the Iowa Department of Transportation (DOT), and the other pooled fund state partners for their financial support and technical assistance.

EXECUTIVE SUMMARY

Highway work zones often have major safety and mobility impacts, which are made worse when travelers are unaware that they are approaching a work zone. To monitor and mitigate these traffic impacts, transportation agencies, first responders, and the public require accurate information about the location, extent, and timing of construction-related closures.

This project reviewed various stakeholders' current needs for pre-construction, real-time, and post-construction work zone information and compared these needs to the available work zone data sources and standards. The analysis identified a substantial mismatch between the roadway and closure data currently available and the data required to manage work zone traffic impacts effectively. To address this gap, the project developed a conceptual prototype for a tool that would facilitate self-reporting of closure details by maintenance crews and contractors.

To address the needs and opportunities related to work zone traffic data, this project included five main activities:

- Conduct surveys and interviews to gain a better understanding of the work zone data use cases and applications most relevant to near-term state transportation agency needs
- Gather information about the work zone data sources currently available to state transportation agencies
- Identify and summarize existing US and European protocols for the collection and electronic transmission of work zone data, including the work zone performance monitoring recommendations currently being developed on behalf of the Federal Highway Administration (FHWA)
- Identify and document the gaps between the data requirements for high-priority use cases and the data sources that are currently available
- Develop a set of conceptual sketches that lay out a vision for an easy-to-use mobile application (app) or website that could be used to fill these gaps by gathering closure data that are not currently available from other sources

Nomenclature

For the purposes of this report, a hierarchy was established to relate construction projects, work zones, and closures (Figure 1).

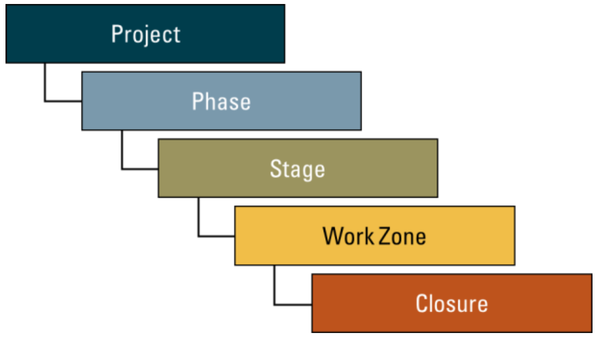

Figure 1. Hierarchy of terminology used in this report, where each highway construction project can involve multiple phases/stages, each phase/stage can involve multiple work zones, and each work zone can involve multiple closures

Although simple projects often require only a single work zone location with a single period of closure, larger projects often involve multiple locations and a series of closures. Thus, a project represents the overall effort of accomplishing the maintenance or improvement of a roadway facility, and that project could be divided into phases and/or stages (the nomenclature and number of levels varies by state). Each of these phases or stages typically includes one or more work zones, or areas where construction activities are taking place. Many work zones require closures, or locations where the use of a specific part of the road space is restricted for a period of time to provide space for work activities.

Closures have several important characteristics:

- Typically, each closure involves one or more lanes, ramps, shoulders, or sidewalks. On urban streets and undivided rural highways, a single closure could involve both travel directions. At intersections, a single closure could involve multiple approach directions or turning movements. Thus, in the most general case, reporting systems require flexibility sufficient to manage closures for both divided and undivided roadways and various types of intersections.

- For the purposes of this project, it is assumed that each closure is an event with distinct start and end times. Thus, two closures occur if a specific part of the road is closed to traffic, reopened, and then closed again. In addition, any change in the road space that is available to traffic constitutes a second closure (for example, reopening one lane at a site where two lanes were previously closed).

Use Cases

To address the need for better traveler information, state departments of transportation (DOTs) have invested heavily in disseminating pre-trip closure information through press releases, websites, and dial-up services such as the 511 telephone hotline. In addition, several agencies provide extensible markup language (XML) data feeds that are often picked up by radio traffic reports and commercial traffic information services such as Here Traffic, Google Maps, TomTom, and Waze. Although these information channels can help travelers adjust their travel plans to avoid construction areas, they are often based on incomplete or outdated information about construction-related closures and their impacts.

In the surveys, interviews, and technical advisory committee meetings conducted for this project, transportation agencies in the Smart Work Zone Depolyment Initiative (SWZDI) states and beyond expressed a strong need for better information about the location, extent, and timing of lane closures. More than a dozen use cases for lane closure data were discussed and prioritized. Some examples include helping police and other first responders avoid closures when responding to emergency calls, providing more accurate information about closure locations and timing for travelers and the general public, and improving the effectiveness of post-construction traffic management reviews. In the long term, this type of data may also be needed to support the safe operation of connected and automated vehicles.

Mismatch between Data Sources and Data Applications

Although numerous actual and potential applications of detailed work zone data were identified, the vast majority of state DOTs reported that they currently lack the ability to track lane closures at the level of temporal and spatial detail required for the uses they consider to be the most important. For example, agencies identified the following issues:

- The lack of detailed records for closure locations, extent, and timing can make it very difficult for agencies to evaluate the effectiveness of their work zone traffic control strategies, thwarting one of the goals of the federal Work Zone Safety and Mobility Rule adopted in 2004 (23 C.F.R. §630.1008).

- Agencies reported that lane closures involving county and municipal routes are hardly ever tracked, raising the possibility that concurrent closures on state highways and reliever routes could magnify work zone impacts.

- Only a few agencies said they have a database for logging detailed lane closure information. Most of the systems that do exist currently track planned, expected, or allowed closure times, but these systems are not set up to record the actual times of closures and reopenings. In practice, contractors and agency crews are often given very wide time windows to complete their work but use only a small fraction of that time. As a result, retrospective determinations of closure timing can be extremely difficult. Similarly, the closure permits often span several miles of a highway corridor, with actual closures taking up only a fraction of that space at any given time, making it difficult to determine the geographical extent of the closure at a later date.

Nearly all of the work zone data currently being collected are a byproduct of some other data collection system. For example, underperforming work zones sometimes show up in traffic management center (TMC) traffic delay data, but it is difficult to distinguish work zone delays from those caused by crashes, special events, weather, and so forth. The TMC databases provide almost no information about well-performing work zones, making it extraordinarily difficult to pinpoint factors of success.

Although most agencies reported having speed data for major freeways, traffic volume data are often sparse. Performance data for rural highways and urban streets are also scarce. Most agencies can geospatially identify crashes that coincide with construction project limits but find it difficult to determine whether the crashes were in some way related to a closure. And while most agencies have electronic field logs for tracking construction activities, the field notes are often incomplete or difficult to understand. Moreover, several respondents noted shortages of construction oversight personnel.

Technical Standards

In addition to gathering information about existing work zone data sources and agency operational needs, this project reviewed several technical standards for work zone data exchange. Notable examples include DATEX II, the Traffic Management Data Dictionary, and the proposed FHWA Work Zone Data Exchange protocol. These standards provide a technical basis for combining work zone data from multiple sources, but each standard has its own data model. The resulting data elements are not very consistent from one standard to another. Selected data elements from four potentially applicable technical standards are listed in Appendix A.

In spite of the global nature of the automotive industry, there did not appear to have been much coordination between US and European efforts to develop new data interchange standards. For example, elements of the FHWA Work Zone Data Initiative appeared to overlap with standards being developed by European Committee for Standardization (CEN Technical Committee 278 2018, FHWA 2018, FHWA 2020). In addition, much of the relevant data is kept in legacy data management systems that predate current technical standards, such as TMC central system software, traffic count databases, and crash databases.

Data Collection Tool

To close the gap between existing data sources and the data required for high-priority work zone use cases, this project developed a series of sketches that lay out a vision for an easy-to-use mobile-friendly web-based lane closure data collection tool. Six example screens are shown in Figure 2, and a more complete example is presented in Appendix B.

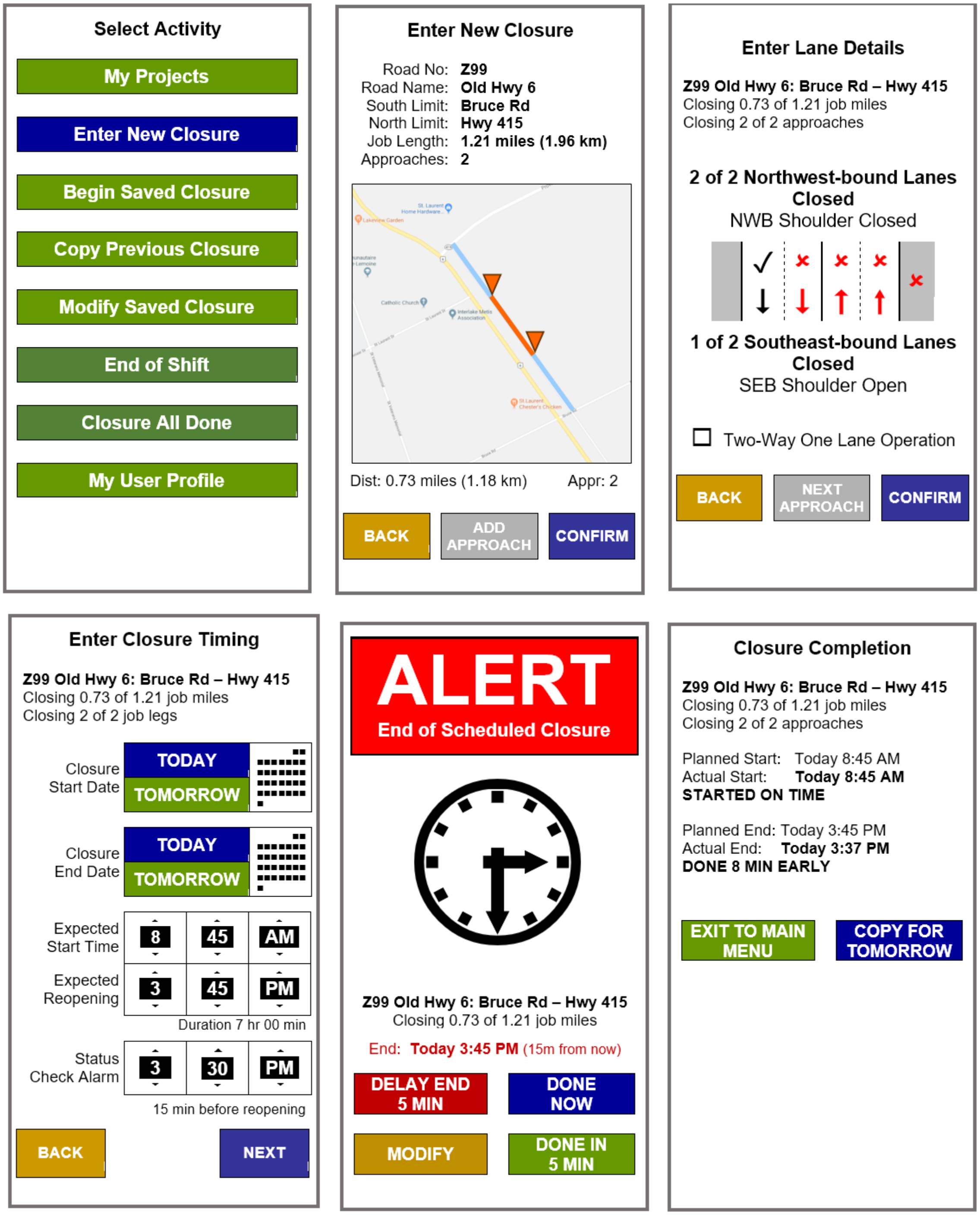

Figure 2. Lane closure tool data entry examples developed in the SWZDI Phase I project

Recognizing agency resource constraints, the sketches are built around the idea that most closures will need to be self-reported by contractors and maintenance crews. Thus, the proposed tool anticipates a carrot-and-stick business model that would require self-reporting of closures while also generating information that is useful to the managers of construction companies.

Further development of this tool is recommended. It is anticipated that the tool would be developed in several phases. Development could begin with proof-of-concept implementation of a system to collect the most essential work zone data. A modular approach could be adopted so that new functions and features can be added if additional software development funding becomes available in the future. For example, some of the states contacted for this project expressed interest in integrating the lane closure data collection tool with lane closure permitting systems, and these functions might be a future add-on. Similarly, states that make use of open-source TMC central system software (such as IRIS, the Intelligent Roadway Information System [IRIS Coalition 2020]) might want to move toward tight integration with their traffic monitoring systems.

INTRODUCTION

The National Highway Traffic Safety Administration (NHTSA) defines a highway work zone as "an area of a trafficway where construction, maintenance, or utility work activities are identified by warning signs/signals/indicators, [including] roadway sections where there is ongoing moving (mobile) work activity" (NHTSA 2017). Given the age of the roadway infrastructure in Smart Work Zone Deployment Initiative (SWZDI) states, effective management of these construction and maintenance areas is crucial for resolving pavement and bridge problems, improving roadway safety, and forestalling degradation of traffic conditions.

Highway work zones often have major safety and mobility impacts, which are made worse when travelers are unaware that they are approaching a work zone. To monitor and mitigate these traffic impacts, transportation agencies, first responders, and the public require accurate information about the location, extent, and timing of construction-related closures.

This project reviewed various stakeholders' current needs for pre-construction, real-time, and post-construction work zone information and compared these needs to the available work zone data sources and standards. The analysis identified a substantial mismatch between the roadway and lane closure data currently available and the data required to manage work zone traffic impacts effectively. To address this gap, this project developed a conceptual prototype for a tool that would facilitate self-reporting of closure details by contractors and maintenance crews.

Background

Most of the United States Interstate Highway System was initially constructed in the 1950s and 1960s. By the 1990s, major portions of the Interstate system began reaching the end of their service lives. The need for major reconstruction stimulated increased awareness of the effects of work zones on road user safety and mobility, culminating in the adoption of the federal Work Zone Safety and Mobility Rule (23 C.F.R. §630.1008) in 2004. By the late 2000s, state departments of transportation (DOTs) and other public agencies throughout the United States had begun to make substantial strides toward minimizing the adverse safety and mobility impacts of highway construction through data-driven transportation management plans (TMPs).

The Work Zone Safety and Mobility Rule encourages transportation agencies to develop ongoing processes that support continuous improvement in the efficiency and effectiveness of work zone management. Specifically, the rule requires that "States shall use…data…to manage work zone impacts [and] 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."

To accomplish this objective, it is necessary to monitor traffic conditions and relate them to the specific characteristics of the affected work zones, such as the location, extent, and timing of lane closures. Thus, this project focuses primarily on how to obtain the data required to relate construction closure characteristics to operational performance measures such as queuing and delay. The focus includes not only implementing methods for identifying poorly performing work zones but also developing the capability to determine factors of success for well-performing work zones. A second objective of the project is to improve the quality and extent of the lane closure information disseminated to first responders (police, fire, emergency medical services, and towing services) and the public.

Defining Closures

For the purposes of this report, distinctions are made between construction projects, work zones, and closures (Figure 1, page xi). Specifically, a project represents the overall effort of accomplishing the maintenance or improvement of a roadway facility, and large projects could be divided into phases and/or stages (the nomenclature and number of levels used varies by state). Each of these phases or stages typically includes one or more work zones, or areas where construction activities are taking place. Many work zones require closures, or locations where use of a specific part of the road space (one or more lanes, ramps, shoulders, or sidewalks) is restricted for a period of time to provide space for work activities. Some closures (such as those required for bridge re-decking) remain unchanged in extent and location for weeks, while others (such as those required for pothole patching) might last only a few minutes. Lateral shifts that affect roadway capacity, such as crossovers, are also considered closures for the purposes of this report.

In simple cases (for instance, a small guard rail repair), a project, work zone, and closure could all completely overlap in time and space. On the other hand, if one roadway segment is closed and reopened several times (for example, every night for a week), each of these events is considered a closure for the purposes of this report. In addition, some types of construction require a series of closures, perhaps affecting different portions of the roadway each day as work proceeds along a corridor. For example, for contractual purposes a repaving project could be treated as both directions of a five-mile freeway segment, while the area actually impacted by the roadwork might be limited to half a mile at any given time. In more complex cases, projects might be divided into phases and/or stages, and each phase or stage could include various work zones that are distinct in terms of work location, duration, or activity.

An example is illustrated in Figure 3, which presents a timeline for closures along a hypothetical freeway corridor.

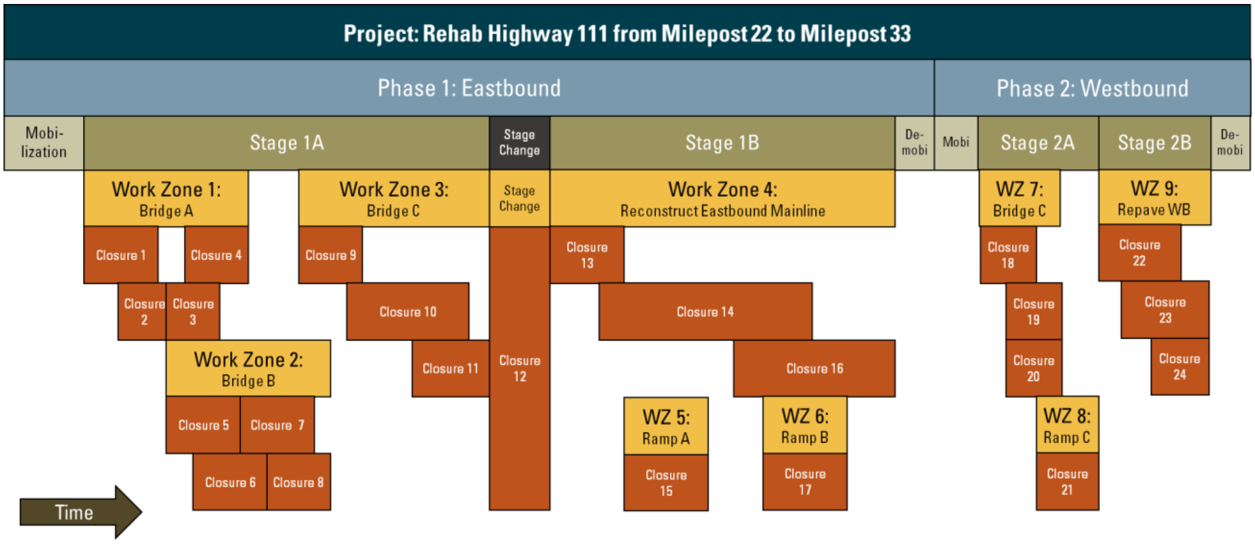

Figure 3. Relationships between work zones and closures in a complex project

In this case, the eastbound lanes are to be rehabilitated in the first year of the project (Phase 1) and the westbound lanes in the second year (Phase 2). Within Phase 1, Stage 1A involves reconstruction of three bridges (Work Zones 1 through 3); activities at Work Zone 2 begin before Work Zone 1 is completed, and activities at Work Zone 3 begin before Work Zone 2 is completed. Within each work zone is a series of closures; some occur concurrently, while others cannot begin until a previous closure has been completed. Similar overlaps and finish-to-start relationships can be seen in subsequent stages of the project. For example, in Stage 1B the rebuilding of the freeway mainline requires an extended time duration, and two ramps are completed while the mainline work is ongoing. In all, this hypothetical project includes 9 work zones and 24 closures.

It is important to acknowledge that the working definitions provided above could differ from the way organizations define a project for financial administration and contract bidding. For instance, the reconstruction of a major urban freeway might be a single project spanning numerous contracts (possibly awarded to different firms), including some that overlap in time or location.

Work Zone Data Stakeholders and Use Cases

Table 1 lists several of the main stakeholders in the work zone data collection and dissemination process.

Table 1. Work zone data stakeholders

<table>
<tr>
<td>Internal to Transportation Agencies
• Traffic management center personnel
• Work zone engineers
• Roadway designers
• Construction coordinators
• Maintenance personnel
• Utility coordinators
• Oversize/overweight (OSOW) permit coordinators
• Law enforcement coordinators/liaisons</td>
<td>External to Transportation Agencies
• Road users (motorists, trucking, transit, bicyclist, pedestrians)
• First responders (police, fire, emergency medical services, towing)
• Contractors
• Utilities
• Other roadway agencies (adjoining jurisdictions, other levels of government)
• Regional/metropolitan planning agencies
• FHWA and other oversight agencies</td>
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</tr>
<tr>
<td>Primarily Data Creators
• Construction coordinators
• Contractors
• Utilities
• Maintenance personnel</td>
</tr>
</table>

The unshaded top half of the table separates the groups that reside within state DOTs (internal stakeholders) from those associated with other organizations (external stakeholders). The shaded bottom half of the table lists the same groups again, organizing them into entities that are primarily end users of work zone data, those that are primarily data creators, and those that are both creators and users of the data.

The questions posed by data users are multifaceted, leading to numerous data use cases, as described in a subsequent section (for example, see Table 2):

- External data users are often interested in real-time information about when and where roadways are closed. These users include first responders, motorists, trucking company personnel, bus operators, bicyclists, and pedestrians. The timeliness of closure information can be particularly important for first responders. For example, to ensure a timely response to a patient in cardiac arrest, an emergency medical services dispatcher might wish to know whether work at a recurring intermittent lane closure has wrapped up for the day. If that information is readily available, the dispatcher could potentially avoid unnecessarily detouring an ambulance along a slower second-best route, or unnecessarily sending a costly air ambulance to a patient who could be reached just as quickly by road.

- As discussed in the use case example below, analyzing TMP effectiveness is a very different use case, since it affects a combination of internal and external stakeholders.

Use Case Example: Work Zone Performance Assessment

Construction closures on lanes, shoulders, ramps, and sidewalks affect the safety and mobility of road users, which include motorists, heavy truck drivers, bus operators and passengers, bicyclists, and pedestrians. Closures can also adversely impact road user and worker safety. Effects on safety are not easily separated from effects on mobility. For example, freeway lane closures can hasten the onset of traffic congestion, potentially resulting in high-speed back-of-queue crashes.

To satisfy national reporting requirements and the internal business needs of DOTs, work zone performance monitoring and management has become increasingly important in recent years. Examples of questions of interest to internal DOT stakeholders include the following:

- How often do queues and delays occur in our work zones? How severe are they?
- Is the crash rate in our work zones excessive?
- Are the crashes/delays caused by things we can control?
- We tried a new traffic management method. Did it help?
- Did our investment in alternate route improvements pay off?
- Are we making valid assumptions in TMPs?
- Is the agency doing as well as it can to manage work zone traffic impacts?

Information about traffic speeds, queueing, and delay is increasingly available from agency-owned traffic sensors and commercially produced data derived from in-vehicle global positioning systems (GPS). When these data are combined with detailed information about actual work zone closure conditions and timing, the results can be insightful. For example, by combining both data sources, analysists are likely to be able to determine whether slow traffic in a work zone was caused by a lane closure, a crash downstream of the work zone, or a crash in an area where roadwork was authorized but not underway. Similarly, when there are two or more closures in close proximity, details about the location and timing can help analysts determine which closure was the primary cause of the slowdown.

Current Practice

Many state DOTs have implemented automated real-time traffic monitoring systems, which can be used to derive information about traffic speeds, queuing, and delay. In addition, the increasing availability of speed data from in-vehicle GPS devices has made it possible for a handful of private companies to provide real-time traffic data for most high-volume roadways. Some of this information is gradually finding its way into the work zone design/planning process to help guide pre-construction traffic management decisions, such as the allowable hours for lane closures.

In addition to using data from traffic monitoring systems to identify traffic flow disruptions, some agencies are using traffic crash data to support work zone design and management. In order to conduct an effective real-time or retrospective analysis of delays or crashes in designated work areas, it is necessary to match these types of data with information about the location, timing, and extent of lane closures. In other words, for most purposes, analysists need to know when the work zone was active. They can then explore the effects of work activity type, closure type, closure location, and closure duration. This allows the effects of the closure to be compared with the expected or observed temporal traffic demand, taking into consideration factors such as incidents that occurred in the work zone. This process of linking traffic monitoring data with on-the-ground work activities is currently challenging from both a technical and organizational perspective, particularly if the relevant data must be fused from two or more separate database systems (for example, a traffic speed database, a crash database, a field management database, and a contract administration database).

While this project was underway, the Federal Highway Administration (FHWA) announced a Work Zone Data Initiative (WZDI) aimed at integrating and harmonizing various data sources to support a wide range of work zone data use cases. The FHWA also began the process of establishing a new set of standards for exchanging work zone data elements and related traffic data. Concurrently, Technical Committee 278 of the European Committee for Standardization (CEN) was tasked with developing a set of standards for electronically communicating the location and timing of lane restrictions (including temporary closures) to connected and autonomous vehicles (CAVs) (CEN Technical Committee 278 2018).

To avoid duplication of the FHWA and CEN projects, the work completed under this SWZDI project focused on reviewing relevant technical standards, identifying the work zone data use cases that are of greatest interest to state DOTs, and evaluating the availability of the data required for those use cases. In addition, a survey and follow-up interviews were conducted to understand the current state of work zone data collection and management across various state DOTs in the US.

Major gaps in the available data were identified, crucially the lack of sufficiently detailed information about closure location and timing. To provide a clear path toward collecting the missing data efficiently, this project responed by developing a series of conceptual sketches for an easy-to-use mobile-friendly lane closure data collection tool.

LITERATURE REVIEW

Work Zone Data Stakeholders and Use Cases

To encourage uniformity and interoperability in work zone data management systems, the FHWA in 2018 began working on a set of guidance documents collectively known as the Work Zone Data Initiative (FHWA 2018, FHWA 2020). One of the challenges that this process intends to address is that some state DOTs currently have very few systems in place for managing lane closures and collecting work zone performance data, while others have advanced traffic management systems that collect extensive roadway performance information, at least for portions of their roadway networks.

The surveys and interviews conducted for the present project affirmed that currently most TMCs focus mainly on managing traffic on high-volume freeway corridors. Many are not set up to monitor arterial streets or two-lane rural highways, in part because these roadways are often under county or municipal jurisdiction.

A major complication is that among the states and regions that have implemented traffic management systems, a wide range of data collection techniques and TMC central system software packages are in use. These central system software packages are often proprietary and often have very limited capabilities to store performance data for analysis at a later date. Typically they are not integrated with other DOT data resources, such as traffic volume coverage counts or law enforcement crash data, especially if count and crash data (or similar resources) reside in legacy data management systems.

Deliverables available from the WZDI at the time the present project was conducted included a framework document and data dictionary. The framework is a guidance document aimed at helping agencies systemize the collection and exchange of work zone data. It describes the comprehensive structure of a work zone data model with components such as stakeholders, their needs (described as use cases), work zone data requirements, and examples for implementation.

The WZDI categorized the use cases based on broad categories of stakeholder needs (Table 2).

Table 2. FHWA work zone activity data use case categories

Category of Use Case	Description
Planning and Project Coordination	Coordination to minimize impact on traffic when different agencies or groups have projects affecting the same roadway, corridor, or area
Impact Analysis	Study of prior work zone projects to help improve traffic conditions during future projects
Construction and Maintenance Contract Monitoring	Compliance check for contractors and setting up of incentives for performance in work zones
Real-Time System Management/ Traveler Information Provision	Distribution of work zone information to the public, travelers, and third-party apps regarding warnings and notifications
Safety and Mobility Performance Measurement	Assessment and setting up of performance thresholds for work zones in terms of mobility and safety impacts
Law Enforcement and Emergency Service Providers	Distribution of work zone information to law enforcement agencies and emergency service providers for better route planning
Connected and Automated Vehicle Hardware Needs and System Readiness	Communication of work zone information to aid decision making in connected and automated vehicle environments

Seven categories of use cases are described in the framework. The framework describes these use cases in detail, with examples, stakeholder information, and data content. Four of the seven categories of work zone activity data use cases align with the priorities identified by the technical advisory committee (TAC) for the present study: construction and maintenance contract monitoring, work zone impact analysis, real-time system management/traveler information provision, and mobility performance measurement. These priorities can be described as follows:

- **Construction and maintenance contract monitoring** focuses on monitoring the contractor's on-site activities and evaluating contractor compliance with documented specifications.

- **Work zone impact analysis** can help agencies compare estimated and actual mobility impacts such as traffic flow rates, delays, and queuing, contributing to implementation of optimal traffic management practices in the future.

- **Real-time system management/traveler information provision** involves information regarding work zone locations, closure locations, and closure times that can help travelers plan their routes effectively. In addition, WZDI envisions improved dissemination of lane closure location and timing to public safety agencies, which could help police, fire, and emergency medical dispatchers make better decisions about how to position and route emergency vehicles.

- **Mobility performance measurement** is conducted to identify relationships between temporary traffic control and traffic conditions. This process allows agencies to identify well-performing and underperforming work zones, potentially leading to adjustments in the hours of work, the extent of the closure, or the staging of construction. Performance-based incentives can also be developed based on the safety and mobility impacts of the work zone, a practice mentioned by the Utah DOT in an interview for this project.

In many cases, traffic information is disseminated through third-parties such as mapping and navigation websites, in-dash navigation system vendors, and AM/FM radio broadcasts. In the United States, the electronic transmission of closure information to in-vehicle devices has been commercialized, while in Europe it usually occurs in collaboration with public broadcasters to avoid paywalls that limit access to the data.

As shown in Table 3, it is typical for the applicable work zone data use cases to evolve as a project moves from pre-construction planning into design, construction, and post-construction performance analysis.

Table 3. Typical work zone data use cases

Pre-Construction	Construction	Post-Construction
• Work zone traffic impact analysis • Determination of contractual parameters (hours of work, types of allowed closures, etc.) • Project sequencing and program coordination • Incident management pre-planning	• Lane closure permitting • Internal real-time traffic monitoring • Public-facing traffic info • First responder routing • Incident management • Adjustments to traffic control setup • Contract compliance monitoring • Optimizing employee and equipment utilization	• Biennial TMP process review • Evaluation of alternate route utilization • Internal work zone safety studies • Ad hoc inquiries • Work zone traffic management research

Thus, it is perhaps not surprising that the WZDI has found that industry stakeholders such as commercial real-time traffic data services have very different views of the work zone information that is useful (and the desirable formats for this information), as compared to the information state DOTs anticipate using internally.

Transportation agencies currently conduct several types of internal work zone performance analyses. For example, work zone data elements have been compiled to analyze traffic delays, and to evaluate work zone crash frequency and severity. This information has been useful for impact assessments designed to mitigate traffic congestion during construction and for research evaluating the effectiveness of a wide range of traffic mitigation practices. Based on the findings of such research, many policy-driven practices have been adopted for collecting and utilizing work zone data to support work zone design decisions.

Limitations of Existing Data

Work zone traffic mitigation research and the preparation of traffic mitigation plans are both currently limited by the content and structure of the available work zone data. For example, in an analysis of pedestrian and bicyclist crashes attributed to Wisconsin work zones, only 28% of the available crash reports contained enough information to determine whether work operations somehow contributed to the crash (Shaw et al. 2016).

Many agencies currently collect data elements such as traffic speeds through the work zone, posted speed limit, traffic volume, and the number of incidents or crashes (Figure 4).

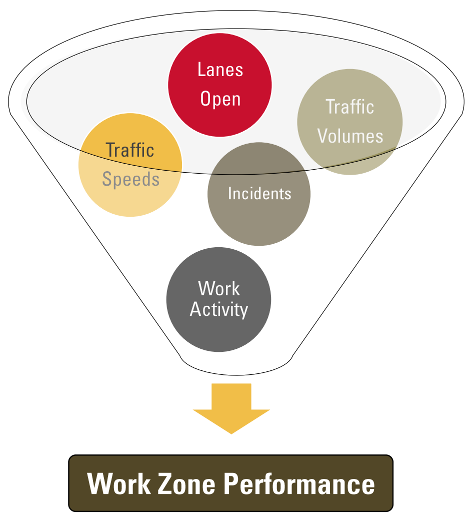


Figure 4. Elements of work zone performance

Additional data elements can be valuable to researchers, designers, and traffic analysts. For instance, one notable difficulty in post hoc analysis is determining whether a traffic slowdown was caused by a lane closure, an incident within the work zone, or a downstream incident that caused traffic to back up into the work zone. This could be clarified if data were available for items such as lane closure time and status, construction phasing/staging, activity type, and the presence of construction/maintenance vehicles at the site.

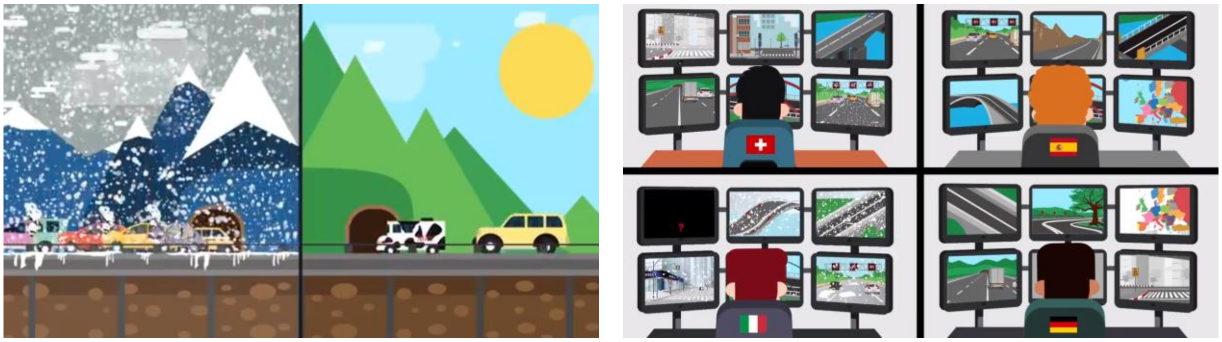
Currently, the majority of work zone performance data is a byproduct of traffic monitoring, incident management, or crash reporting systems. In these systems, “work zone” is usually a manually generated annotation, such as a checkbox on a crash report. In most cases, very little information about the characteristics of the work zone is available, in part because the databases are not designed to collect such information. This makes it very difficult to conduct a retrospective analysis that relates work zone design to work zone performance. This data gap can be addressed by collecting a more comprehensive set of work zone data elements. Data standards can help provide a clearly defined set of data elements describing this information.

Work Zone Elements of Intelligent Transportation System Data Interchange Standards

The DATEX II, Traffic Protocol Experts Group Generation 2 (TPEG2), Traffic Management Data Dictionary (TMDD), and International Traveler Information System (ITIS) data protocols are standards designed to disseminate traffic incident information. These intelligent transportation system (ITS) standards are best understood in the context of the workflows for traffic management centers, where an incident is detected and classified, relevant public safety agencies are notified, and information about the location and severity of the incident is disseminated through media such as dynamic message signs, radio broadcasts, in-dash navigation systems, and websites. As a result, ITS standards refer to "work zones" or "roadworks" as an incident type. Details deemed relevant to immediate consumption by road users and/or first responders are compiled (usually manually), and the standardized data are passed to dissemination systems such as radio traffic reports and in-dash navigation systems and, in some cases, to traffic management centers in neighboring jurisdictions.

DATEX II

In the 1990s, a set of protocols called DATEX was established by a consortium of European transportation agencies to facilitate the exchange of traffic-related data among the approximately 60 traffic management centers in Europe (Figure 5) (CEDR 2018). As ITS development continued, a voluntary standard (DATEX II version 1.0) was published in 2003 and revised in 2009 (version 2.0). In 2016, DATEX II was adopted as an official European standard under the auspices of Technical Committee 278 of the European Committee for Standardization (also known as CEN/TC 278). This status is accompanied by funding from the European Union for ongoing technical updates and expansion of the standard, including a significant revision in 2018 (DATEX II version 3.0, also known as standard CEN/EN 16157:2018).



Images: Datex II Coalition

Figure 5. Use of the DATEX II standard to facilitate center-to-center communication of incidents (including work zones) across jurisdictional boundaries.

DATEX II addresses several of the major challenges for traffic management in the European context, including the need to share traffic incident information freely among national traffic operations centers. In combination with related standards, it addresses the need to share information about incidents (including roadwork) without language barriers (Figure 5).

As a core element of the European ITS standards, DATEX II strongly influences the methods and terminology used worldwide by commercial mapping vendors to describe the location and severity of work zones and traffic incidents. This influence includes, for example, the vocabulary used by most automotive GPS systems to describe roadwork events.

DATEX II treats each roadworks site (work zone) as a traffic event, which is described with data elements such as ROADWORKS DURATION, ROADWORKS SCALE, UNDER TRAFFIC (as opposed to a full closure), URGENT ROAD WORKS (emergency repairs), MOBILITY (mobile versus stationary work zone), type of work, and MAINTENANCE VEHICLES ACTION. This was initially accomplished through an extensible markup language (XML) schema (Figure 6), and an equivalent JavaScript object notation (JSON) schema was introduced as an option in version 3.0.

```
public abstract class Roadworks
extends OperatorAction
implements org.jvnet.jaxb2_commons.lang.Equals, org.jvnet.jaxb2_commons.lang.HashCode, org.jvnet.jaxb2_commons.lang.ToString
```

Java class for Roadworks complex type.

The following schema fragment specifies the expected content contained within this class.

```
<complexType name="Roadworks">
  <complexContent>
    <extension base="{http://datex2.eu/schema/2_0RC2/2_0}OperatorAction">
      <sequence>
        <element name="roadworksDuration" type="{http://datex2.eu/schema/2_0RC2/2_0}RoadworksDurationEnum" minOccurs="0"/>
        <element name="roadworksScale" type="{http://datex2.eu/schema/2_0RC2/2_0}RoadworksScaleEnum" minOccurs="0"/>
        <element name="underTraffic" type="{http://datex2.eu/schema/2_0RC2/2_0}Boolean" minOccurs="0"/>
        <element name="urgentRoadworks" type="{http://datex2.eu/schema/2_0RC2/2_0}Boolean" minOccurs="0"/>
        <element name="mobility" type="{http://datex2.eu/schema/2_0RC2/2_0}Mobility" minOccurs="0"/>
        <element name="subjects" type="{http://datex2.eu/schema/2_0RC2/2_0}Subjects" minOccurs="0"/>
        <element name="maintenanceVehicles" type="{http://datex2.eu/schema/2_0RC2/2_0}MaintenanceVehicles" minOccurs="0"/>
        <element name="roadworksExtension" type="{http://datex2.eu/schema/2_0RC2/2_0}_ExtensionType" minOccurs="0"/>
      </sequence>
    </extension>
  </complexContent>
</complexType>
```

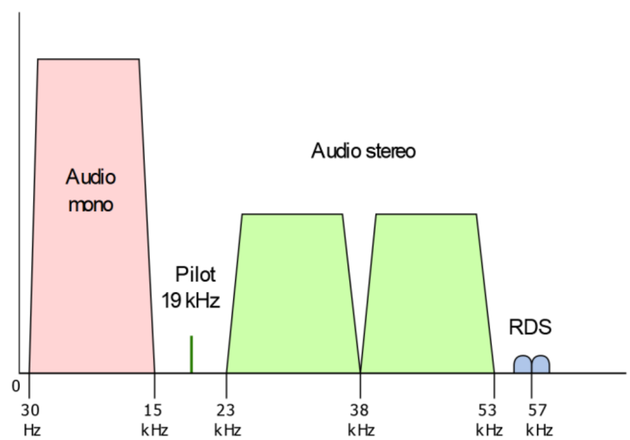
Figure 6. Example of DATEX II XML code

In a typical XML feed from DATEX II, the data are structured with one complex type and several descriptive data elements. For a work zone, the ROADWORKS complex type is used. In DATEX II version 2.0, this type is comprised of a total of 10 data elements, which are listed in detail in Appendix A. The available data elements describe the location, lane closures, maintenance vehicles, and type of roadwork activity. The DATEX II standard does not provide definitions of the enumerations (possible values) of these data elements. Some enumerations are self-explanatory, while others such as ROADWORKS SCALE (major/medium/minor) or ROADWORKS DURATION (short/medium/long) are ambiguous but can still be useful if an agency adopts a consistent set of working definitions.

One of the key features of DATEX II is that it is not a rigid set of specifications, but rather one that allows some flexibility to add new types of information exchanges as traffic management technologies evolve. For example, the core protocol supports 23 types of roadwork, and agencies can add more enumerations if they wish. The basic list includes several types of roadworks, ranging from bridges and roadsides to tunnels and waterworks. Another important data element is MAINTENANCE VEHICLES, which can be used to indicate the presence of one or more work vehicles on the roadway (e.g., mobile work operations, mowing, snow removal). The DATEX II standard provides a valuable structure to depict a work zone event, if the roadworks data elements are combined with general incident tracking features to compile relevant information about lane closure timings, location, and traffic parameters such as volume and speed.

Radio Data System Traffic Message Channel (RDS-TMC) and Traffic Protocol Experts Group Generation 2 (TPEG2)

The Radio Data System (RDS) was developed in the 1980s to provide text and digital messages that augment FM radio broadcasts. The system takes advantage of the fact that FM broadcasting stations are allocated 200 kilohertz of bandwidth, but only 53 kHz is required for the audio signal (Figure 7). Many US stations use the RDS Radio Text (RDS-RT) protocol to display song titles on the radio faceplate and the RDS Program Service (RDS-PS) to display the station name. The system has several additional capabilities, including silent transmission of traffic incident information to in-vehicle navigation systems on the RDS Traffic Message Channel (RDS-TMC).

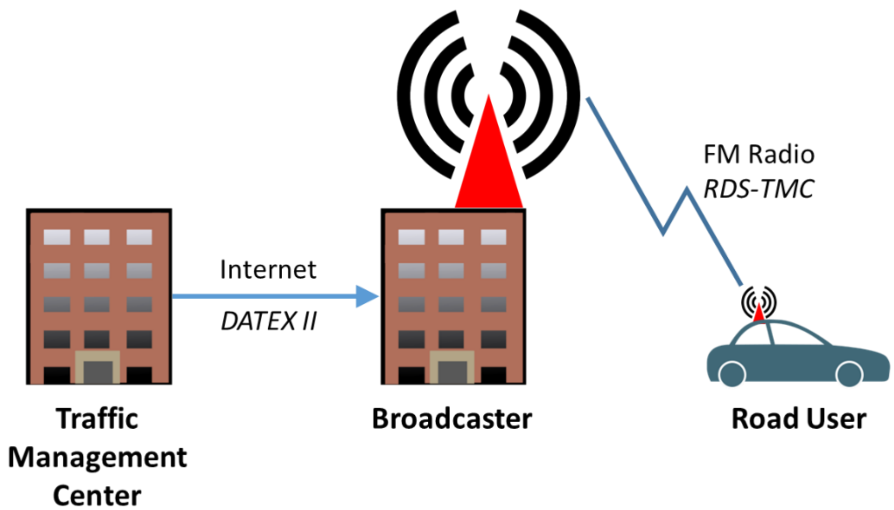


Arthur Murray/Wikimedia Commons

Figure 7. The RDS signal is an encoded non-audible overlay of the FM radio carrier frequency.

The RDS-TMC and TPEG2 traffic incident coding schemas were originally developed in Europe and subsequently attained global significance as core standards for in-vehicle navigation systems. The two schema (officially known as ISO 14819 and ISO/TS 21219, respectively) define standards for transmitting real-time traffic data to in-vehicle devices. They are implemented in the United States by GPS hardware manufacturers such as Garmin, and by GPS map vendors such as Here (formerly Nokia/Navteq) and TomTom, in partnership with auto manufacturers and participating FM radio stations.

European transportation agencies and broadcasters have collaborated on the development of traveler information systems since the 1980s. One of the key challenges of providing traffic incident information to European drivers is the diversity of languages across the continent. These include the 24 official languages of the 27 European Union countries; the national languages of non-European Union countries such as Norway, Russia, and the United Kingdom; regional languages such as Catalan, Gaelic, Walloon, and Welsh; and the many languages of immigrants and visitors. Cross-border tourism and commerce gives rise to vast numbers of drivers who traverse areas where they do not understand the local language. Electronic message encoding systems address this challenge by transmitting traffic data to in-vehicle devices using numerical codes (Appendix A), which are then filtered for relevance. If the information is relevant to the current drive it is displayed to the driver in the driver's preferred language. Currently, traffic incidents identified by traffic management centers are transmitted to national and local broadcasters using the DATEX II protocol which is converted to RDS-TMC by software in the radio transmitter (Figure 8).



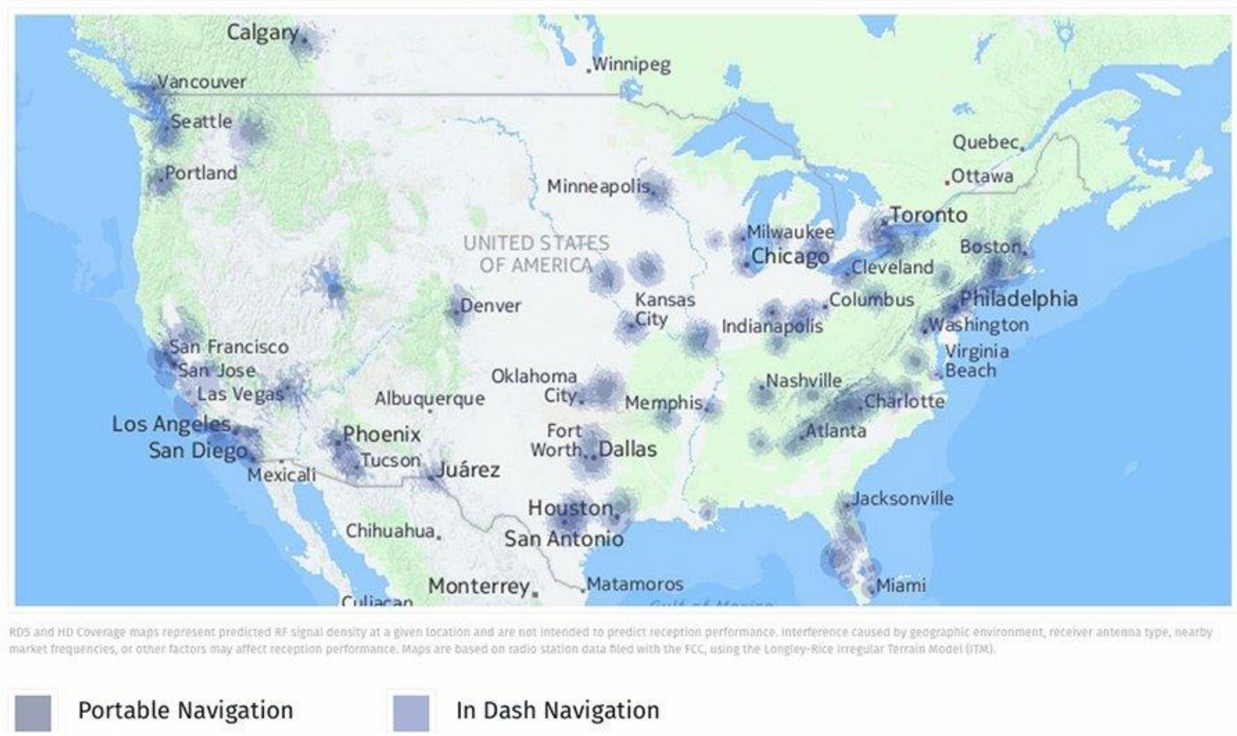
Icons: Kenny sh, Tomybrz, and Soshial/Wikimedia Commons

Figure 8. Traffic incident information can be transmitted from traffic management center to broadcaster using DATEX II and from broadcaster to road user with RDS-TMC.

Broadcasters then use RDS-TMC to encode and silently transmit these messages to drivers using portions of the FM radio bandwidth that are not required for standard audio programming (Figure 7).

When the signals are received by in-vehicle GPS units, they are decoded and filtered for relevance to the current location and route. Messages that are relevant to the current drive are displayed to each driver in that driver's preferred language. Thus, a truck driver from northeastern Spain, a Czech business traveler, and an American tourist who are all passing through France can be alerted to the same traffic incident in Catalan, Czech, and English, respectively, and none of these travelers needs to be fluent in French.

Although RDS-TMC originated in Europe, it is an international standard. An encrypted version of the protocol is currently used in the United States to transmit real-time traffic information to customers who subscribe to traffic services for their in-vehicle GPS navigation systems (Figure 9).



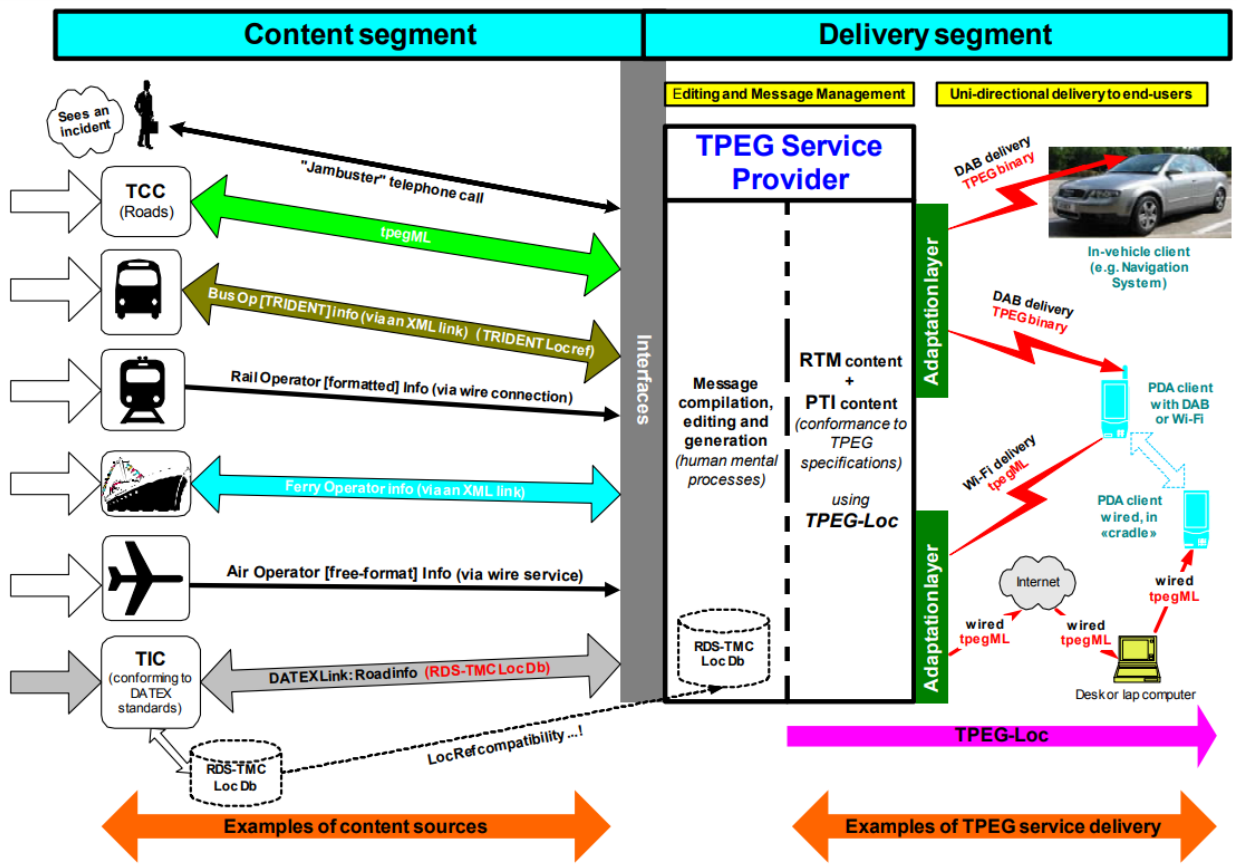
© 2021 HERE, from Barker 2016

Figure 9. Media markets with commercialized RDS-TMC traffic data coverage as of 2016

This service is provided in at least 98 metropolitan markets in the US and Canada (Saunders 2012, Barker 2016, 2wcom 2020, Garmin 2020). Thus, it seems likely that most of the built-in and aftermarket in-vehicle navigation devices sold in the US are capable of detecting and interpreting both encrypted and unencrypted RDS-TMC signals. Expanding coverage by partnering with additional broadcasters potentially provides a pathway for transportation agencies to disseminate work zone closure and delay information to in-vehicle GPS users who do not subscribe to traffic services or are operating in areas where subscription services are not provided by commercial broadcasters.

RDS-TMC and TPEG2 data elements relevant to work zone data management include the location, type, and severity of the traffic event, as well as any associated lane closures or traffic delays. The RDS-TMC message set currently comprises more than 1,500 traffic messages, of which about 540 are potentially relevant to work zones (Appendix A). In contrast to the extensible nature of DATEX II, these enumerations are permanently encoded in the end user's radio/GPS unit and thus cannot readily be modified by transportation agencies.

The TPEG2 protocol (Figure 10) is newer than the RDS-TMC protocol and is more expansive in terms of the types of messages that can be transmitted (European Broadcasting Union 2007).



European Association of Broadcasters

Figure 10. TPEG2 messaging process

For example, in addition to information about road conditions, the multipart TPEG2 standard defines protocols for transmitting real-time information about weather, parking, the status of public transportation services (bus, rail, ferry, aviation), and the location and price of motor fuels and electric vehicle recharging services.

While RDS-TMC messages require the end user's device to contain a library of electronic road maps, the TPEG2 location referencing system can be linked to online maps. TPEG2 also allows local landmarks to be identified in the message, as these are often easier for humans to interpret than grid coordinates. This allows the TPEG2 location referencing system to support storage and transmission of relatively detailed information about work zone locations.

Traffic Management Data Dictionary (TMDD)

The TMDD standard is used in the United States for exchange of ITS-related information between TMCs. All information compliant with the TMDD is structured in dialogs consisting of messages, which in turn consist of data frames described by data elements. The TMDD is designed to meet the needs of TMCs and external agencies for the exchange of traffic-related information. Its primary focus lies in the dissemination of event-related information, where an event is broadly described as an incident that can disrupt regular traffic conditions.

As defined in the TMDD, a work zone falls under the heading of an event that disrupts normal traffic conditions. Several data elements describe the status of the event, time of day, time schedule, type of event, and location. The TMDD is one of the few standards to address the complexity of event timing, with specific data elements for planned, actual, and recurring components of the schedule. Nevertheless, the standard does not address all aspects of a work zone. For example, no data elements describe the lane closures, detours, or speed limits assigned to work zones, and the TMDD does not provide any description of the activity at the work zone. Thus, the TMDD primarily supports information related to the presence, timing, and location of work zones. TMDD events are typically communicated using an XML schema (Figure 11).

3.4.8.7.3 XML REPRESENTATION

```
<xs:simpleType name="Event-category">
        <xs:union>
                <xs:simpleType>
                        <xs:restriction base="xs:unsignedInt">
                                <xs:minInclusive value="1"/>
                                <xs:maxInclusive value="3"/>
                        </xs:restriction>
                </xs:simpleType>
                <xs:simpleType>
                        <xs:restriction base="xs:string">
                                <xs:enumeration value="planned"/>
                                <xs:enumeration value="current"/>
                                <xs:enumeration value="forecast"/>
                        </xs:restriction>
                </xs:simpleType>
                <xs:simpleType>
                        <xs:restriction base="xs:string">
                                <xs:enumeration value="insert-extension-values-here"/>
                        </xs:restriction>
                </xs:simpleType>
        </xs:union>
</xs:simpleType>
```

Figure 11. Example of TMDD event in XML format

International Traveler Information System (ITIS) (SAE J2540)

The ITIS standard described in SAE J2540 provides phrases for describing traffic-related events based on the customary vocabulary for traffic reports on US commercial radio stations. It includes a useful list of work activity categories. This standard is popularly used by data generators, data receivers, and equipment manufacturers to transmit messages using standard phrases. These phrases are also used by traffic management centers when transmitting messages compliant with the TMDD standard. The ITIS standard describes several data elements and lists their enumerations for use in transmission. Based on a review of the standard, six data elements linked to work zone activity were identified: work type, closures, alternate routes, incident response equipment, incident response status, and mobile (versus non-mobile) work operations. These data elements are listed in Appendix A.

Although DATEX II, the TMDD, and ITIS include many essential data elements to improve the detail of work zone descriptions, no single standard is holistic in its data coverage (Table 4).

Table 4. Comparison of existent standards for work zone data

Standard	DATEX II	TMDD	ITIS (SAE J2540)
Event Location	Open Location Referencing (Open LR)	Location Referencing Message Specification	Not covered
Event Status	Four status codes	Eight status codes	Eight status codes
Lane Closures	Number (but not position) of closed lanes	Referenced to J2540/ITIS codes	Lane closure data element included

Additionally, some of the enumerations (such as work types) are not consistent across the standards. A combination of data elements and enumerations from these existing standards would need to be created to describe all aspects relevant to work zone performance analysis. This is precisely the intent of the FHWA's Work Zone Data Initiative.

FHWA Work Zone Data Initiative

The present project reviewed version 1.1 of the FHWA's WZDI data dictionary, which summarizes various work zone data concepts and their relationships to the use cases. The work zone data concepts essential to implementating the use cases that are of interest to the present project can be organized into the following four categories:

- **Organization and project data** include information regarding the agencies and contractors responsible for the work zone activity, their contact information, the phases of the project, and the project's overall duration.
- **Location data** specify the location of the work zone in terms of roadway name and number, the specific location of any closures in the project area, planned versus actual location, and crash or incident locations.
- **Time data** are described in terms of the start and end times of work zone activities, with closures detailed up to one second via timestamps.
- **Activity/event data** provide insight into the activity type, traffic control devices set up, traffic speed, traffic volume, lane or shoulder closure descriptions, and detour information.

Table 2 summarizes the important work zone data concepts compiled from the FHWA's Work Zone Data Initiative. These data concepts reflect the different features of a work zone that can be documented or exchanged as information. In addition to the items identified in draft version 1.1

(early 2019), the present project team identified additional data elements that are likely to be needed for work zone performance monitoring applications, such as distinctions between work zone locations and closure locations. Data items not present in draft version 1.1 of the WZDI are highlighted in red in Table 5.

Table 5. Work zone data content descriptors

Descriptor	Data Element
Organization and Project	Owner agency
	Owner agency project manager
	Contractor/sub contractor
	Funding allocation status
	Expected Number of Phases
	Actual Number of Phases
	Expected phase duration
	Actual work duration
	Project ID
	Event ID
	Subevent ID
	Size of workforce
	Equipment assigned
Location Data Descriptors	Name of the roadway where event/subevent is located
	Roadway classification of roadway where event/subevent is located
	Facility type of roadway where event/subevent is located
	Direction of travel of event/subevent
	Planned begin location of event/subevent
	Planned end location of event/subevent
	Actual begin location of event/subevent
	Actual end location of event/subevent
	Upstream location of closure (first cone)
	Downstream location of closure (last cone)
	Equipment location (GPS)
	Crash/Incident location
Time Data Descriptors	Planned start date/time of event/subevent
	Planned end date/time of event/subevent
	Planned project duration
	Indicator for level of confidence in expected start date
	Recurring flag
	Actual start date/time of event/subevent
	Actual end date/time of event/subevent
	Status
	Date/time advance notice received
	Crash/Incident start date/time
	Crash/Incident end date/time

Descriptor	Data Element
Activity/Event Descriptors	General description of event/subevent
	General description of about maintenance of traffic approach
	Expected geometrics associated with each event/subevent
	Expected traffic control device(s) associated with each event/subevent
	Actual geometrics associated with each event/subevent
	Actual traffic control devices(s) associated with each event/subevent
	Indication that the maintenance of traffic requires coordination between the projects
	Reference to the projects that need to be coordinated with
	Planned number of lanes to be closed
	Description of planned lanes to be closed
	Total number of lanes
	Planned number of lanes to be open
	Planned number of short term lane closures
	Actual number of lanes to be closed
	Description of actual lanes to be closed
	Expected effect on travel time/delay/queuing
	Lane closure permit number
	Indicator that work involves cutting or otherwise affecting the pavement
	Temporary restrictions in place
	Reduce speed limit
	Feature that is modified relative to project plans
	Changes made to feature
	TTC used to make feature change
	Devices affected
	Indicator that signal timing has changed
	Description of signal timing change
	Detour route information
	Warning notifications
	List of changes to notify travelers
	Enforcement presence
	Number of activities requiring law enforcement support or flag indicating event/subevent needs law enforcement support
	Crash /incident severity
	Activity type
	Work zone type (mobile/stationary)
	Traffic speed - freeway - instantaneous
	Traffic speed - freeway - long-term average
	Traffic speed - urban arterial
	Traffic speed - two-lane rural highway
	Traffic volume - pre-construction
	Traffic volume - freeway - during construction
	Traffic volume - urban arterial - during construction
	Traffic volume - two-lane rural highway - construction
	Pieces of equipment in use

The standardized and consistent approach described by the WZDI assumes the availability of relevant data for the implementation of various field applications. Some of these data elements do not exist in current practice or are currently gathered only in specific environments. For example, the survey results described in the following chapter affirmed that many transportation agencies have traffic speed and volume data for urban freeways but lack comparable data for urban arterials. Consequently, in most cases it is difficult to determine how many drivers divert to parallel routes to avoid work zone congestion, the timing of diversions, the routes used, and whether drivers who divert actually experience reductions in travel time.

Agency Work Zone Data Management Practices

Although the research literature regarding work zone data management practices is limited, a previous SWZDI project conducted a nationwide survey to understand state DOT work zone data management practices and applications (Cheng et al. 2017). A comparison of practices across the 22 states that responded to the survey highlighted achievements and challenges in implementing work zone data management. The study recommended a more uniform approach for work zone data management by developing a work zone data management roadmap, defining a standard for work zone data elements, encouraging stakeholder collaboration, and providing support through federal agencies or state coalitions.

As described in the following chapter, the present project completed a follow-up survey to relate the availability of various types of work zone data elements to specific traffic environments (freeways, urban arterials, two-lane rural highways, and so forth). The survey also gathered information about transportation agency priorities among the various work zone data use cases.

AGENCY SURVEY AND INTERVIEWS

The present study sought information about work zone data environments and agency priorities through a two-stage information gathering process: a nationwide survey of state transportation agencies and follow-up interviews with selected work zone engineers who responded to the survey. The use cases presented in the survey were derived from those described in the FHWA Work Zone Data Initiative. The survey sought information about agency priorities for work zone data applications, available work zone data sources, and the extent of coverage for various data elements. It was conducted using Qualtrics online survey software (Qualtrics 2019) and was organized into 16 questions (mainly in tabular format) with an estimated completion time of 10 minutes. Respondents answered the questions using a five-point Likert scale.

Survey invitations were sent to traffic engineers, work zone planning engineers, work zone safety engineers, and transportation planners from all 50 US state transportation agencies. As shown in Figure 12, 26 states responded to the survey.

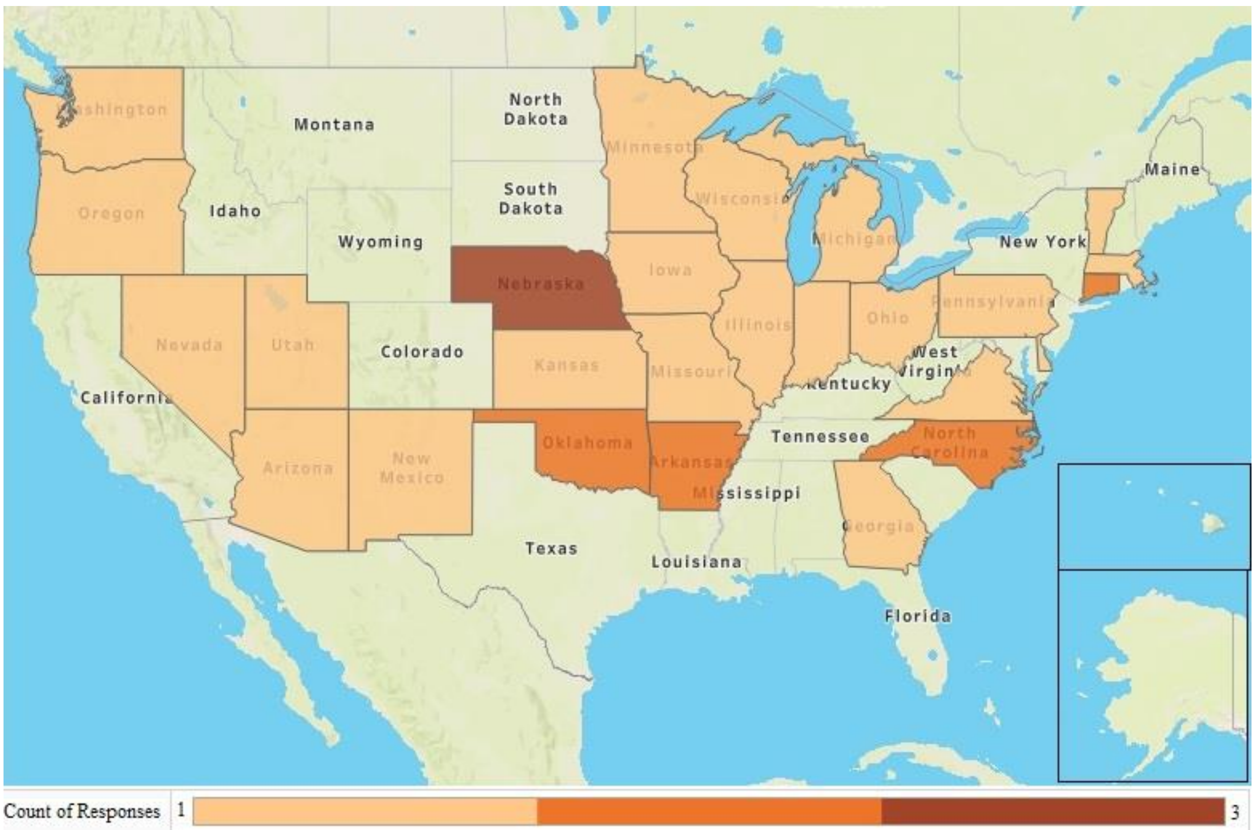


Figure 12. Survey respondent states

Figure 13 shows the major responsibilities of the survey respondents; the majority reported that they were involved in work zone design, followed by traffic engineering and traffic operations duties.

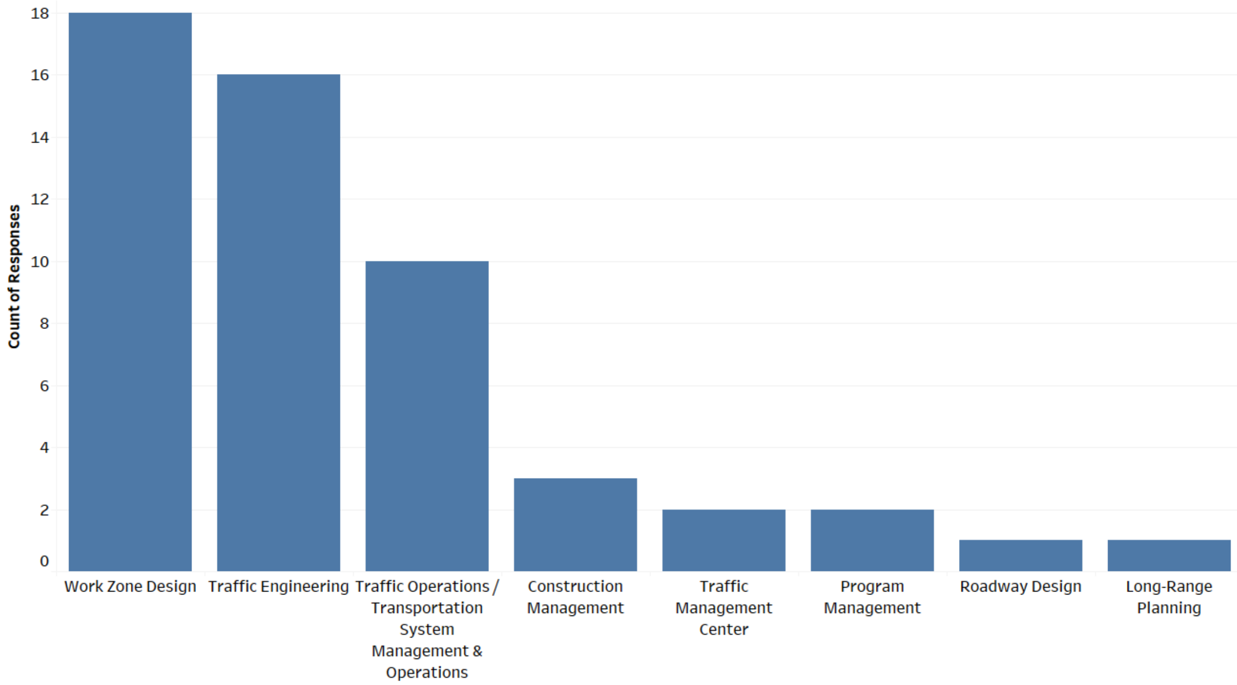


Figure 13. Responsibilities of survey respondents

Work Zone Data Use Cases

Several use cases were listed in the survey, and the respondent was asked to rate each choice on a five-point Likert scale. For the purposes of tabulation, these ratings were converted to a numerical scale: Extremely Important (5 points), Very Important (4 points), Moderately Important (3 points), Slightly Important (2 points), and Not at All Important (1 point). While most of these use cases are highlighted in the WZDI framework, a few were identified or consolidated through discussions with this project's TAC and other practitioners.

The use cases listed in the survey and the corresponding tabulation index numbers were as follows:

Real-Time System Management/Traveler Information Provision

1. Disseminate locations of lane closures to the public and/or first responders (police, fire, emergency medical services, etc.)
2. Disseminate anticipated start/end times for lane closures to the public and/or first responders

Mobility Performance Measurement

3. Monitor work zone traffic flow and identify the locations of work zone-related delays
4. Monitor traffic flow and delays on detours and alternate routes

Work Zone Impact Analysis

5. Determine the causes of traffic delays in/near work zones

6. Estimate the traffic impacts (queuing and delay) for future lane closures
7. Evaluate the effectiveness of TMPs
8. Monitor/evaluate road user safety in work zones, for example, by creating a record of crashes that occur in the work zone

Construction and Maintenance Contract Monitoring

9. Coordinate construction scheduling and closures for various projects internally, with neighboring jurisdictions, or with other levels of government
10. Issue lane closure permits to utilities, contractors, maintenance crews, etc.
11. Assign in-house construction/maintenance personnel to projects as efficiently as possible
12. Assess contractor (or agency employee) compliance with traffic control procedures
13. Create a detailed record of the location and timing of specific work activities such as milling and paving

In addition to the use cases listed above, respondents were offered the opportunity to provide freeform comments to describe any additional use cases of interest to their agency. Respondents were also asked to describe any automated systems they have in place for implementation of these use cases.

Work Zone Data Elements

The research team analyzed the data typically required to implement the use cases listed in Table 2. Based on that information, 15 main data concepts were chosen. Respondents were asked to indicate the extent to which their agency has available each type of data during construction. The ranking scale was as follows: None (1 point), Some Routes/Corridors (2 points), About Half of Route/Corridors (3 points), Most Routes/Corridors (4 points), and All Routes/Corridors (5 points). The 15 data elements listed in the survey were as follows:

1. Video camera images – freeways
2. Video camera images – arterials
3. Traffic speeds – freeways
4. Traffic speeds – arterials
5. Traffic volumes – freeways
6. Traffic volumes – arterials
7. General location of work zone
8. Expected overall duration of the project (including all construction stages and individual lane closures)
9. Specific location of each lane closure within the work zone
10. Planned start/stop times for each closure
11. Actual start/stop times for each closure
12. Type of work zone (mobile/stationery)
13. Type of work activities (paving, bridge work, maintenance, etc.)
14. Locations of incidents/crashes in the work zone
15. Project contact information such as name and phone number for the construction foreman, field engineer, etc.

Work Zone Data Sources

The survey also inquired about the technologies used to collect work zone data. Respondents were presented with a list of popular traffic data collection technologies and asked to identify the ones used by their agencies. Multiple selections were allowed, since it was anticipated that some agencies utilize several data collection technologies simultaneously. The data sources listed were as follows:

Traffic Speed

1. GPS probe data (Inrix, HERE, TomTom, etc.)
2. In-pavement loops
3. Side-fired radar (RTMS, Wavetronix, etc.)
4. Video-based speed detection
5. Bluetooth detectors
6. Toll tag readers

Traffic Volume

1. In-pavement loops
2. Side-fired radar (RTMS, Wavetronix, etc.)
3. Video-based traffic counters

Survey Respondents

Agencies from a total of 26 states responded to the survey. In five cases, there were two or more responses from the same state, yielding a total of 33 responses. The overlapping responses were typically from participants representing different functional or geographical areas within a state transportation agency, such as traffic operations and highway design or a headquarters office and a district/regional office. When more than one response was received from the same agency, the research team manually consolidated the results to provide a unified response for that state. The following consolidation criteria were used:

- If one participant offered no response for an item and another provided a response, the non-null response was scored.
- If the responses to Likert scale items differed by less than one point, the average value was scored.
- If the responses to Likert scale items differed by two points or more (e.g., one respondent choosing "extremely important" and the other choosing "not at all important"), the respondent's self-reported job duties were reviewed and precedence was given to the person most directly involved in work zone oversight.

Substantive Results

In addition to the respondents' demographic information described above, the survey had three substantive sections: priority of use cases, availability of data elements, and extent of data collection. As noted earlier, the Likert scale data were converted to a five-point numerical scale to facilitate comparison of use case priorities and data availability ratings.

The mean value of the use case scores provides an indication of the priorities for respondents as a whole (with higher values indicating higher priorities). Its standard deviation provides an indication of how similar the priorities are across agencies, with a small standard deviation indicating uniformity and a large one indicating that priorities differ across agencies.

Similarly, a high score for the availability of a data element or the extent of data collection indicates widespread availability of that type of information. A low standard deviation indicates that data availability and the extent of collection are similar across agencies, while a high standard deviation indicates differing data environments.

Priority of Work Zone Data Use Cases

The survey asked respondents to highlight the importance of each use case for implementation in their state. Aggregating their responses, as shown in Table 6, it was identified that respondents showed high interest in the use cases under Real-Time System Management/Traveler Information Provision and Mobility Performance Measurement. The scores for these use cases also had the lowest standard deviations, indicating a high level of agreement on the level of importance. The darkest shading indicates use cases with the highest scores followed by use cases with progressively lighter shading.

Table 6. Percentage of responses and priority of use cases

Use Case Category	Use Case	Extremely Important	Very Important	Moderately Important	Slightly Important	Not at all Important	Score	Standard Deviation
Real-Time System Management/ Traveler Information Provision	Disseminate locations of lane closures to the public and/or first responders (police, fire, emergency medical services, etc.)	55%	36%	6%	0%	0%	4.50	0.61
	Disseminate anticipated start/end times for lane closures to the public and/or first responders	48%	27%	15%	6%	0%	4.29	0.85
Mobility Performance Measurement	Monitor work zone traffic flow and identify the locations of work zone-related delays	58%	39%	0%	0%	0%	4.63	0.46
	Estimate the traffic impacts (queuing and delay) for future lane closures	39%	48%	9%	0%	0%	4.27	0.64
	Monitor traffic flow and delays on detours and alternate routes	30%	45%	15%	6%	0%	4.08	0.88
	Determine the causes of traffic delays in/near work zones	12%	58%	27%	0%	0%	3.87	0.59

Use Case Category	Use Case	Extremely Important	Very Important	Moderately Important	Slightly Important	Not at all Important	Score	Standard Deviation
Construction and Maintenance Contract Monitoring	Monitor/evaluate road user safety in work zones, for example by creating a record of crashes that occur in the work zone	39%	36%	18%	3%	0%	4.20	0.71
	Coordinate construction scheduling and closures for various projects internally, with neighboring jurisdictions, or with other levels of government	18%	52%	24%	3%	0%	3.90	0.79
	Assess contractor (or agency employee) compliance with traffic control procedures	33%	30%	24%	3%	6%	3.87	1.14
	Evaluate the effectiveness of TMPs	24%	39%	15%	15%	3%	3.76	1.10
	Create a detailed record of the location and timing of specific work activities such as milling or paving	24%	24%	27%	18%	3%	3.59	1.10
	Issue lane closure permits to utilities, contractors, maintenance crews, etc.	15%	36%	24%	18%	3%	3.53	0.97
	Assign in-house construction/ maintenance personnel to projects as efficiently as possible	9%	24%	42%	15%	6%	3.16	0.95
	Determine staffing requirements for work zone law enforcement	12%	27%	33%	12%	12%	3.13	1.14

With a score of 4.63, respondents identified “Monitoring work zone traffic flow and identifying the locations of work zone-related delays” as the most important use case. This use case was rated as Extremely Important by 58% of the respondents. This result was expected, since work zone congestion is a frequent source of road user dissatisfaction and can contribute to work zone crashes. Traffic flow monitoring for major routes currently exists in many parts of the United States, either through agency traffic information centers or through commercial traffic data applications that make use of data derived from road users’ GPS-equipped devices. In general, these services are reactive in nature, reporting delays that are currently being experienced by road users. Other important use cases within the category of mobility performance measurement included estimating the queueing and delay for future work zones and monitoring delays on detours and alternate routes.

Respondents ranked the use cases related to real-time system management/traveler information provision highly. This category is comprised of two closely related activities: disseminating lane closure locations to the public and first responders and disseminating closure start/end times. The importance of these use cases was expected; closure location information can allow travelers to modify trip routing or trip timing proactively to avoid traffic delays. This information becomes even more actionable when accompanied by closure timing information, which can help road users and first responders anticipate the level of congestion that will exist when they reach a closure. For example, congestion is likely to diminish after a closed lane reopens. Based on responses to other elements of the survey and interviews, many agencies have only partial information about closure locations, and very few have the ability to track and report closure timing in detail.

Monitoring road user safety (crashes in the work zone) was also a highly ranked use case. Follow-up interviews indicate that a few agencies (notably the Michigan DOT [MDOT]) have systems in place to provide work zone oversight personnel with next-day access to crash reports. In contrast, other agencies reported considerable time lags in obtaining crash report data from law enforcement agencies, making it more difficult to incorporate safety information into near-term work zone management decisions.

Most of the remaining use cases fall in the category of construction and maintenance contract monitoring, with rankings ranging from Slightly Important to Very Important. Notable use cases included coordinating construction activities across jurisdictional or regional boundaries, assessing compliance with traffic control specifications and procedures, and monitoring the effectiveness of TMPs. Follow-up interviews indicated that the salience of the cross-jurisdictional coordination use case varied geographically, with the use case given particular importance where major metropolitan areas straddle state lines, such as along the I-95 corridor in the northeastern United States.

Two use cases listed in Table 6 had markedly lower priority scores than the remaining items. These were assigning in-house construction/maintenance personnel to projects as efficiently as possible and determining the staff levels required for work zone law enforcement.

Availability of Data Elements

To assist in determining the feasibility of implementing various use cases, the survey listed 15 work zone data elements that are likely to be required to support some or all use cases. Respondents were asked to identify data sources that are available in existing electronic databases during construction. The latter distinction was included because some data sources, such as permanent infrastructure-based traffic sensors, could be taken out of service during construction. The list included data elements describing project information, work zone location, lane closures, and traffic flow. The survey responses provided indications of missing or incomplete data elements, supporting the subsequent gap analysis.

As shown in Table 7, respondents were asked to rate the availability of each type of data for their state using a subjective Likert scale, which was converted to a five-point numerical scale for scoring purposes.

Table 7. Percentage of respondent states with data element availability

Data Elements	All Routes/ Corridors	Most Routes/ Corridors	About Half of Routes/ Corridors	Some Routes/ Corridors	No Routes/ Corridors	Score	Standard Deviation
Project contact information such as the name and phone number for the construction foreman, field engineer, etc.	21%	42%	12%	9%	3%	3.51	1.42
General location of work zone	21%	36%	6%	18%	9%	3.38	1.5
Traffic speeds - freeways	21%	21%	3%	42%	3%	3.31	1.41
Expected overall duration of the project (including all construction stages and individual lane closures)	15%	39%	3%	24%	12%	3.12	1.37
Traffic volumes - freeways	18%	18%	9%	42%	6%	3.12	1.25
Locations of incidents/crashes in the work zone	15%	33%	9%	27%	6%	3.10	1.37
Video camera images - freeways	6%	24%	18%	45%	0%	2.97	1.01
Type of work activities (paving, bridge work, maintenance, etc.)	15%	33%	12%	15%	12%	2.96	1.51
Planned start/stop times for each closure	12%	18%	18%	30%	12%	2.82	1.32
Traffic volumes - arterials	15%	9%	3%	55%	12%	2.68	1.3
Type of work zone (mobile or stationary)	9%	18%	15%	30%	15%	2.59	1.36
Specific location of each lane closure within the work zone	3%	12%	15%	33%	30%	2.31	1.17
Traffic speeds - arterials	3%	9%	6%	58%	12%	2.18	1.11
Video camera images - arterials	6%	0%	6%	70%	6%	2.12	1.05
Actual start/stop times for each closure	6%	12%	3%	36%	30%	2.01	1.26

The mean and standard deviation of each of these scores were computed to provide an indicator of the uniformity of data element availability among the respondent states. A high standard deviation indicates that the element is likely to be available in some states and not available in others.

The survey responses indicated that the most widely available data element is project contact information, such as the name, title, and telephone number for the project manager and contractor's representative. In real-time traffic management applications, this can provide a point of contact to verify issues detected by traffic monitoring systems or to check the status of closures that appear to have finished early or overrun their expected completion times. In lane closure permitting systems such as the Wisconsin Lane Closure System (WisLCS), this information is tracked to provide a record of who requested a closure (e.g., a specific contractor or road maintenance person) and who approved it. Contact information is also useful for project coordination and administration, and as a result this data element is required or desirable for most of the other construction and maintenance contract monitoring use cases. Overall, 21% of respondents said such contact information is available for all routes/corridors across the state and 42% said the data were available for most corridors/routes.

There are various methods for defining the location of a work zone. These include the name and route number of the roadways involved, endpoints in terms of landmarks such as cross-streets, geospatial coordinates for the project endpoints, mileposts, or a set of Plus Codes (Google Maps 2020) defining the grid squares affected by the project. A distinction can be made between the general location of a work zone (typically the project limits, such as a five-mile corridor on Highway 999 from County Road A to County Road F) and the specific location of a closure within the work zone (for example, the left lane of northbound Highway 999 for two miles from County Road C to County Road E). The general location of the work zone is helpful for uses such as coordination with other nearby projects and general monitoring of traffic disruptions associated with the project.

In the survey, 21% of respondents indicated that the general location of the work zone is available for all routes/corridors, and 36% said it is available for most routes/corridors. In follow-up interviews, most participants indicated that the activities with unknown locations tend to be smaller maintenance projects. Although these projects usually have relatively minor traffic impacts, interview respondents said there are instances where they compound the effects of a more substantial closure or traffic incident nearby. A similar sentiment was expressed for projects involving streets and highways under local jurisdiction, which often act as reliever routes in cases of congestion on a freeway or other major route.

Basic information regarding the work zone, such as type, activities, and overall duration, could be helpful in categorizing work zones for post-construction assessments and monitoring the effectiveness of TMPs. The responses to these questions yielded bimodal distributions, with 59% of respondents indicating that expected project duration is available for all or most routes and 36% indicating that the information is available for some or no routes. A total of 47% of the respondents indicated that type of work activities is available for all or most routes, while 27% indicated that the information is available for only some or none of the routes.

The survey responses indicated that the majority of agencies currently have limited ability to distinguish work zones involving mobile work operations, such as pavement striping and pothole patching, from work zones involving stationary work. A total of 45% of respondents indicated that information distinguishing mobile from stationary work is available for none or only some of the work zones, while 27% said that the information is available in most or all cases.

Traffic speeds and traffic volumes are essential data elements for the mobility performance measurement use cases. The survey affirmed that most agencies have better access to traffic speeds, which are easier to obtain than traffic volumes. Speed data can be commercially purchased from vendors allied with the providers of in-vehicle GPS devices, but collecting traffic volume data requires infrastructure-based sensors such as in-pavement inductive loops or side-fired radar units mounted along the roadside. Both data elements are important for high-priority use cases that involve monitoring traffic performance in or near a work zone. These are dynamic data elements that can change rapidly over the course of a day.

The survey separated these two elements for freeways and arterials; as expected, the respondents indicated greater availability of speed and volume data for freeways (which are usually under state jurisdiction) than for arterials (which are often under municipal jurisdiction). Comparison of the responses for these data elements highlights that data coverage is not uniform, even within individual states. Follow-up interviews affirmed that data were more widely available for urban freeways than rural freeways, with very sparse speed or volume data for two-lane rural highways.

The location and timing of traffic incidents and traffic crashes are important for monitoring work zone safety. A third of survey respondents answered that these data are available for most routes.

Roadside video cameras allow traffic management center personnel to monitor traffic conditions and incident response operations remotely. Video images can also contain information such as work zone location, lane closure configuration, and activity type. Computer vision algorithms that can extract information from camera images are currently advancing rapidly. Therefore, the survey inquired about the extent to which agencies have video images capturing freeways and arterials. Survey responses indicated that video coverage on freeways and arterials is available for some routes, but most agencies reported that they archive the raw video only for a few days at most.

Lane closure information is sparsely available across the states. This information is dynamic in nature and requires manual entry for timely monitoring. Very few states have a database in place to collect these data, and even if they do the database is static, with data entered at the beginning of the operation.

Data Collection Devices

The third part of the survey inquired about the traffic speed and traffic volume data collection techniques currently in use. As shown in Figure 14, the most widely used speed monitoring techniques were probe data (used in 70% of respondent states), side-fired radar (61%), in-pavement loops (39%), Bluetooth readers (39%), video-based speed detection (15%), and toll tag readers (9%).

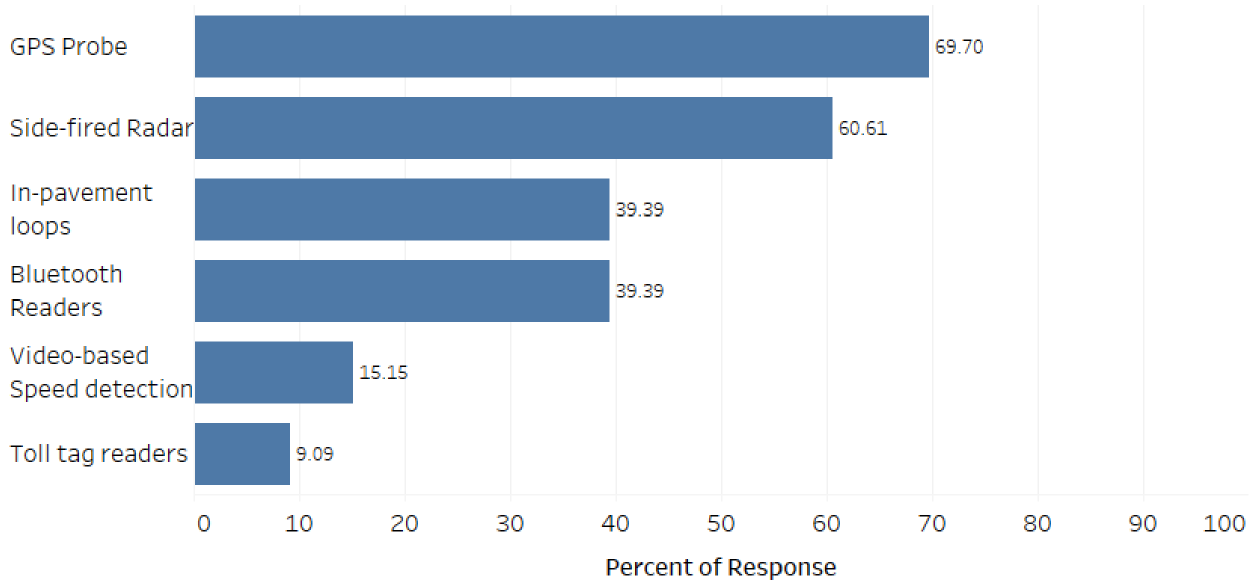


Figure 14. Survey responses for traffic speed collection devices

The figure shows that many states appear to be using different data collection techniques in different geographical areas.

As shown in Figure 15, side-fired radar was the most widely used traffic volume data collection technique (used in 63% of respondent states), followed by in-pavement loops (55%) and video-based traffic counters (33%).

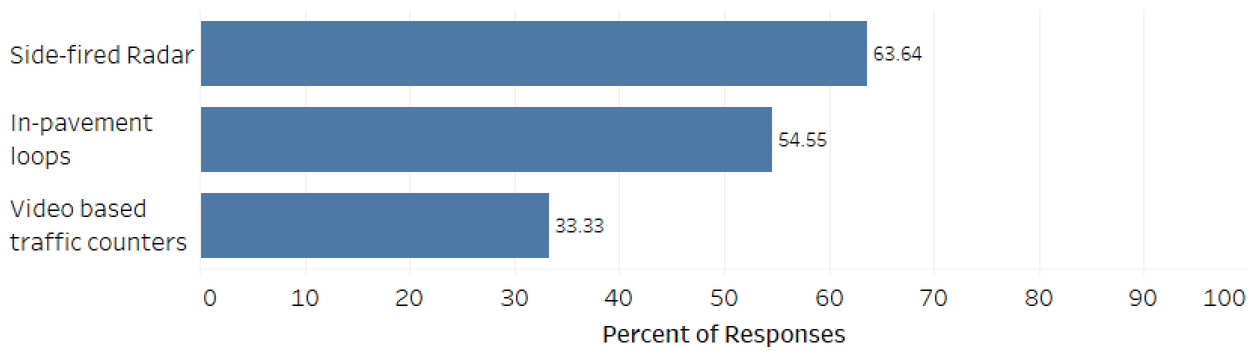


Figure 15. Survey responses for traffic volume collection devices

Stakeholder Interviews

To obtain more insight into the work zone data management practices across the US, the project team conducted personal interviews with DOT professionals. Work zone engineers from respondent states were contacted for follow-up interviews (typically 40 to 60 minutes each) regarding their survey responses. Respondents were asked to elaborate about the use cases most relevant to their state's work zone operations, the current state of their work zone data, their thoughts on implementation of the FHWA Work Zone Data Initiative, and the feasibility of and need for work zone data management in their state.

Iowa

To gather perspectives from Iowa DOT, the project team spoke with Willy Sorenson, ITS engineer. Sorenson was also a member of the TAC for this project. The key points of the discussion were as follows:

- Although the Iowa DOT got a relatively late start on implementing its traffic management center, the state benefited greatly from the experiences of Minnesota, Missouri, Wisconsin, and other states.

- Iowa currently purchases travel time data from Inrix for the entire state highway system, but the available sample sizes generally limit the reliable real-time information to urban freeways, major Interstate corridors such as I-35 and I-80, and heavily traveled expressways such as US 20 and US 30. There are a few real-time traffic sensors on major arterial corridors in the Dubuque and Des Moines areas, but they are owned by municipalities and have not been integrated with the traffic management center. There is a very limited amount of travel time data for rural two-lane highways, and there are few real-time traffic volume sensors in Iowa. The Iowa DOT retains traffic video for approximately 24 hours; the video files are overwritten with newer video when the memory on the storage devices becomes full.

- The Iowa DOT would like to build a lane closure system similar to the Wisconsin system. New central system software for the traffic management center is currently being planned; the implementation of a lane closure system would occur later.

- Sorenson takes a pragmatic approach to work zone data applications. "If there is data, someone will find a good use for it." The Iowa DOT is aware of the need for more detail about work zone start/stop times and is funding research on ways to derive start/stop times from field devices such as smart arrow boards.

- The Iowa DOT has a severe shortage of construction inspectors, and many of the inspectors are responsible for multiple concurrent projects. As a result, on-site data for closure details would probably need to be collected by the contractor. Ways to motivate contractors to collect the data consistently require consideration.

Michigan

To gather perspectives from Michigan DOT, the project team spoke with Chris Brookes, the state's work zone delivery engineer, based at MDOT headquarters in Lansing. The key points of the discussion were as follows:

- MDOT would like to have better data about work zone traffic performance. Currently, the tendency is to start with restrictive hours of work and then give the contractor a wider time window if there is not a lot of congestion. If better information was available, it would be easier to extend work times based on actual conditions. This would improve consistency among field engineers. While excessive work zone delays result in documented complaints from the public, there is no record of projects where the traffic management worked well. As a result, "no one notices good work," and the agency is missing out on the factors of success from well-performing work zones.

- Michigan has experimented with two different queue warning systems. One generates queue warning information by combining traffic volume, speed, and occupancy; the other uses speed only. These systems have the ability to archive data, but no one is using those data. Each vendor uses different software, but some are not compatible with the state's computer firewall. MDOT would like to be able to ingest data from the queue warning systems, but that is not yet possible.

- A task force is currently developing "use statements" (guidelines) for work zone ITS features, including queue warning systems, rumble strips for flagging operations and freeway speed reduction, and radar speed trailers.

- The availability of traffic speed and volume data varies greatly across the state. Good data are available for freeways in Grand Rapids and the greater Detroit area, but data are limited in the rest of the state. Arterial data are limited, and there is a very limited amount of data for two-lane roadways. For pre-construction analysis, special traffic counts are sometimes requested through MDOT's planning group, but these data can be difficult to obtain later.

- Work zone engineers do not have all the traffic volume data they need for in-depth analysis. In many locations, they only have annual average daily traffic (AADT), not hourly volumes. As a result, agency personnel have to make assumptions about when the peak hour occurs and how much of the daily traffic occurs during the peak. Hourly detail is needed, and half-hourly data would be even better.

- Michigan has implemented a process for reviewing crashes that occur in work zones. Each day, co-op students review all new law enforcement crash reports that are flagged as occurring in work zones. If a law enforcement officer fails to correctly mark a crash as having occurred in a work zone, the crash will be overlooked unless the work zone engineers have personal knowledge of the crash. It would be helpful if there were a way for law enforcement officers to include photos in crash reports.

- Work zone performance evaluation in Michigan is hampered by a lack of detail regarding actual work activities. Most projects usually have an inspector on site, but this is not consistent. Extracting information from inspectors' daily reports/logs has to be done manually, and the log entries are sporadic and often cryptic. As a result, there is no usable record of closure start/stop times (15 minutes can make a difference between congested and uncongested conditions). Intermittent closures and instances of early/late finish are not well tracked. The state has implemented an instance of RITIS, the Regional Integrated Transportation Information System, which provides some scenario maps but not a lot of closure details. There is also an online database of lane closures that focuses on the needs of the traffic management center; it is not updated daily.

- Michigan is currently working on improving data integration, and the state's lane closure software was rewritten to support this. The state might also try to implement a system called Orange IQ, which allows electronic signs to be used as work zone closure indicators; this would provide a way to check the accuracy of the data in the lane closure system, which is currently only about 50% accurate.

- In summary, Brookes said, "The information is there, it's in 20 different places, and the quality of it is questionable."

North Carolina

To gather perspectives from North Carolina, the project team spoke with Karmen Dias. Dias is a project design engineer with responsibilities for traffic management and work zone traffic control in the North Carolina DOT (NCDOT) Western Region, based in Garner. The key points of the discussion were as follows:

- NCDOT currently does not have an automated process or electronic database for lane closure approvals. Work zone process reviews are conducted every two years, mainly through manual analyses.

- NCDOT's primary source of traffic performance information is probe data from Here (formerly Nokia/Navteq). The state also has continuous count stations for many segments on the Interstate highway system and is working toward the goal of having one in each county for every major Interstate. These stations are generally kept in service during work activities. A very limited amount of traffic count data is available for arterials. Dias is generally satisfied with the quality of NCDOT's traffic data.

- NCDOT is currently exploring the use of smart arrow boards or GPS-equipped traffic control drums that can provide an indication of the location and timing of lane closures. The agency's traffic operations center would acquire the location data from the devices and use it to provide the public with more detailed information about closure location and timing. The data format and details of how the devices would interface with the existing NCDOT traffic operations infrastructure and software has not yet been determined; the interoperability guidance currently being developed by the Massachusetts DOT may be of interest to North Carolina.

Kansas

To gather perspectives from the Kansas DOT (KDOT), the project team spoke with Garry Olson, ITS engineer, who also served as a member of the TAC for this project. The main points of the discussion are summarized as follows:

- Most Kansas roadways have adequate capacity, so the deployment of work zone performance monitoring has been somewhat limited. Most construction coordination is being done at the local/district level, with little headquarters involvement. Lane closure charts identifying the hours when a lane closure is unlikely to cause major delays have been prepared for the freeways in and around Kansas City, Topeka, and Wichita. Alternate routes are selected based on the availability of additional capacity. Traffic control inspection is a daily responsibility of local construction inspectors, who address issues such as missing cones, improper signs, etc.

- KDOT usually has about three high-impact construction projects each year. The agency has implemented smart work zone deployments for some of these projects. For example, a project in Wichita used a system that displayed a comparison of the travel time through the work zone and the time for an alternate route. KDOT has also used zip merge systems that provide some work zone performance data.

- KDOT has public information components for larger projects but is cautious about disseminating work start/stop times because of concerns about the accuracy of that information. KDOT also wants to make sure that any messages posted on dynamic message signs are relevant to travelers.

- Trailer-mounted cameras are deployed to monitor some work zones. Video is streamed to the traffic management center but is not recorded.

- For larger projects, crashes that occur in work zones are generally reviewed to determine whether there is a need for changes in signing, traffic control devices, work zone layout, etc.

- Post-construction evaluations typically focus on high-impact projects that included a smart work zone feature.

- KDOT rarely has adequate information about work zone delays. The agency attempted to include a special provision that required contractor personnel to determine work zone travel times using floating car runs, but it did not work out well. KDOT’s long-range range goal is to improve monitoring of what is happening on all roadways in the state. Olson remarked, “We’d like to have better and more consistent reporting of work zone conditions statewide.”

Pennsylvania

To gather perspectives from Pennsylvania, the project team spoke with Dan Farley, Chief of the Traffic Operations Deployment and Maintenance Section for the Pennsylvania DOT (PennDOT). The key points of the discussion were as follows:

- Farley reported that PennDOT has a system for tracking construction-related closures, but it is not a true lane closure management system. Consequently, the agency does not have a large amount of data about closure locations. In 2018, funding was obtained to develop a lane closure system jointly with the Pennsylvania Turnpike Commission and the Ohio Turnpike Commission. This system will be called the Lane Reservation and Traveler Information System. An initial challenge is that the phrase “work zone” means different things to designers and traffic engineers, and there is a need for consistent definitions.

- Interagency coordination is an important issue in Pennsylvania, particularly near the state borders and along the I-95 corridor, which connects the Philadelphia area with the New York metropolitan area to the north and the Baltimore-Washington-Arlington metro area to the south. Often the same prime contractors and traffic control subcontractors work across state lines, so work zone management applications and processes need to be consistent.

- PennDOT is currently in the process of developing work zone data collection and decision support tools to help automate closure decision making. An application that supports closure requests could be a useful feature of this tool and might also be useful for incident and emergency management. To support interagency coordination, the tool should have a well-defined concept of operations and should be consistent with the Work Zone Data Exchange protocols currently being developed for the FHWA.

- Probe data (Inrix XD) is the primary source of travel time data throughout Pennsylvania. Many of PennDOT’s other systems are built around this data source. The data quality for the limited access roadway network (freeways and tollways) is generally satisfactory, since most of the state has high traffic volumes with a considerable proportion of trucks.

- The Inrix data feed includes arterials, but the usability varies, so the probe data are augmented with Bluetooth readers for some arterials. Arterial data quality is not good when there are oversaturated conditions (such as when a work zone coincides with a football game day in State College, Pennsylvania) because the probe data vendors remove vehicles from the data sample if they are stationary for too long. The granularity of the arterial data has improved in recent years due to shorter segmentation (now around 1,500 ft). Work zone data do not seem to be too badly affected by the issues associated with removing stationary vehicles from the data set, except during crashes.

- Portable cameras can be connected to the state’s Advanced Traffic Management System (ATMS) traffic management center platform, and video feeds from some of these cameras are displayed on the state’s 511 traveler information website. A traffic alerts dashboard, real-time speed dashboard, and queue dashboard are all generated in RITIS using data from Inrix, Waze, and internal data sources.

- Queue warning has been a priority for PennDOT. Some standalone queue warning systems (such as Ver-Mac) have been deployed, but PennDOT is transitioning away from proprietary systems. The agency is working on standardizing connectivity and connections to ATMS and the traffic management center. PennDOT is looking for a holistic approach using existing data and Q-Free software. The agency has built a travel time module using Inrix XD as the source.

- PennDOT is not yet using smart arrow boards due to concerns about the limited number of vendors and pricing. The agency is currently experimenting with Haas Alert, a product from a vehicle warning light manufacturer that integrates GPS and a cellular modem into the vehicle's warning lights. This product provides time and location information when the flashing amber beacons on work vehicles are activated, which could be used to identify sites with the potential for stopped/slowed traffic. The Haas Alert system is currently linked to Waze and could be tied to a fleet management system. The system is currently in use by the Pennsylvania Turnpike Authority using a per-vehicle-per-day pricing model. Advance messaging to approaching vehicles could be advantageous for contractors, utilities, and local governments by providing an additional safety factor for the agency/company. The system could also provide information about the speed of work vehicle convoys during mobile work operations.

- PennDOT is trying to avoid "siloed" and proprietary work zone applications. The agency's philosophy is that work zones are part of its core business, and the same business rules should apply for work zones and other day-to-day applications. This approach will allow PennDOT to begin using its 511 system to provide travelers with information about the locations of work zone slowdowns and to provide data feeds to commercial services such as Waze. Temporary traffic control vendors are not too happy about this: the vendors want to sell/rent proprietary standalone systems.

- PennDOT recently implemented a permanent queue warning system that alerts a message board. From a technical perspective, this is very similar to a work zone application. The agency has developed the software but has not yet deployed it and plans to test it in work zones next year to provide travel time information and queued traffic warnings. If the testing is successful, the same system could be deployed on permanent or portable message signs.

- A software module for permanent variable message signs has been built. PennDOT also recently conducted a pilot project on temporary ramp meters using the same logic as for a permanent ramp meter.

- Regarding analytics, all Inrix data are being archived through the I-95 Corridor Coalition on the RITIS platform and are also being archived separately by PennDOT. The latter allows the agency to do its own analytics by combining Inrix data with work zone information, Waze data, and crash data. PennDOT is using this to identify opportunities to improve work zone traffic management.

- PennDOT is also looking at secondary crashes in work zones (back-of-queue crashes) to determine the distance from the back of the queue to the crash location and the most critical times when crashes occur. This analysis has shown that most crashes occur during the first 15 minutes of congestion, with a secondary spike after 1 hour. Microsoft Power VI is being used to do the advanced analytics.

- Post-construction performance management and performance reviews are as important as real-time performance reporting. PennDOT is thinking about how this information will be used in the future for CAV applications.

- Within the PennDOT organization, the Operations, Planning, and Work Zone Design units are all stakeholders in work zone data applications. Data need to be easily shared across multiple platforms, and interoperability issues need to be addressed. For instance, the isolated queue management systems that were unconnected to the rest of the traffic monitoring system were not as useful as they would been with an open data-sharing model. Transfers need to occur at the raw-data level so that multiple systems can share data. In addition, smart systems need to be affordable; current proprietary business models are problematic in terms of cost-effectiveness.

- Regarding work zone data use cases related to law enforcement, PennDOT has a Memorandum of Understanding with the Pennsylvania State Police that allows each agency to identify locations where police resources are needed to address work zone safety issues. Once a request is made, PennDOT has to identify a funding source for the police presence. Requests made to the PennDOT Central Office are evaluated to see if there is justification for police to be on site for queue warning, enforcement, or both. If approved by PennDOT, the state police also review the request. With preapproval, construction project managers can request police presence in the work zone two weeks in advance of the time when it is needed. Police resources are stretched thin, so manpower is not always available; each local state police troop determines whether it has the resources to cover the request. Therefore, enhanced enforcement is treated as a secondary countermeasure because the project engineer cannot assume police will always be available. About 85 sites per year are covered for at least one day. Automated enforcement has been authorized in Pennsylvania and will be the preferred option for work zone enforcement.

Utah

To gather perspectives from Utah, the project team spoke with Glenn Blackwelder, Traffic Operations Engineer for the Utah DOT (UDOT). The key points of the discussion were as follows:

- UDOT's approach to work zone traffic management strongly emphasizes minimizing traveler delays. Almost all projects include a pre-construction analysis to determine the allowed hours of work based on local traffic conditions. This is supported by UDOT's extensive network of traffic volume and speed sensors and its large library of traffic count data. Typically, the work schedule is set conservatively, and if there is no excessive queueing the hours of work are expanded incrementally (usually 15 to 30 minutes at a time) to provide more flexibility for the contractor.

- Since all projects begin with a conservative set of hours of work, UDOT is probably less concerned than other state agencies about collecting detailed information on traffic delays. Nevertheless, many projects include a contractor incentive based on reducing delay below the levels anticipated in the pre-construction analysis. Currently, the incentive is based mainly on the project engineer's perception of how well the work zone is operating rather than on any attempt to measure the delays. Another challenge is that there are not enough inspectors available to cover every work site continuously.

Wisconsin

To gather perspectives from the Wisconsin DOT (WisDOT), the project team spoke with Erin Schwark, Statewide Work Zone Operations Engineer. Schwark was also a member of the TAC for this project. The key points of the discussion were as follows:

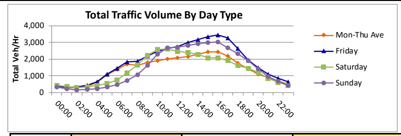
- Wisconsin has an extensive permanent traffic sensor network that collects traffic volumes and speeds on the urban freeway system and portions of the rural system, but real-time data collection on the two-lane highway system is very limited. Most of the alternative routes for major freeways are under local jurisdiction and have not been equipped with permanent volume/speed sensors. Temporary Bluetooth sensors have been installed on the alternate routes for a few major projects. Wisconsin currently makes limited use of probe data for a few corridors.

- Pre-construction analysis in Wisconsin is supported by the Wisconsin Hourly Traffic Data Portal (Figure 16), which provides access to hourly data from hundreds of automatic traffic recorders and thousands of coverage count stations throughout the state.

Wisconsin Department of Transportation *Continuous Count*

Monthly Average Hourly Volume by Day of Week **Sep 2020**

Location	I-94 - 2.0 MI E OF USH 63 - HERSEY	Segment ID	5530
Site #	550002	Seasonal Factor Group	3
Region	NW	Daily Factor Group	3
County	ST. CROIX	Axle Factor Group	21
Funct. Class	R Principal Arterial - Interstate	Growth Factor Group	1



Hour	Sundays			Mondays			Tuesdays			Wednesdays			Thursdays			Fridays			Saturdays		
	Pos Dir	Neg Dir	*Total*	Pos Dir	Neg Dir	*Total*	Pos Dir	Neg Dir	*Total*	Pos Dir	Neg Dir	*Total*	Pos Dir	Neg Dir	*Total*	Pos Dir	Neg Dir	*Total*	Pos Dir	Neg Dir	*Total*
00:00-00:59	148	172	*320*	122	166	*288*	169	192	*360*	175	185	*361*	190	198	*387*	195	222	*417*	200	236	*436*
01:00-01:59	103	105	*208*	88	139	*228*	138	162	*300*	150	164	*313*	145	169	*314*	147	188	*335*	154	202	*356*
02:00-02:59	76	95	*171*	87	134	*221*	122	161	*283*	124	177	*302*	131	179	*310*	131	207	*337*	127	168	*295*
03:00-03:59	79	99	*178*	109	192	*301*	154	228	*383*	151	263	*414*	160	266	*426*	160	258	*418*	141	185	*326*
04:00-04:59	101	126	*227*	152	310	*463*	195	413	*608*	218	429	*647*	220	436	*656*	221	420	*641*	183	235	*418*
05:00-05:59	163	153	*316*	312	605	*917*	369	726	*1,095*	369	764	*1,132*	406	764	*1,170*	405	692	*1,097*	261	285	*546*
06:00-06:59	259	196	*455*	491	695	*1,186*	571	883	*1,454*	568	873	*1,441*	570	894	*1,464*	614	826	*1,439*	419	338	*757*
07:00-07:59	406	294	*700*	716	781	*1,497*	807	900	*1,707*	810	967	*1,777*	822	1,005	*1,827*	897	937	*1,835*	699	458	*1,156*
08:00-08:59	618	443	*1,061*	791	731	*1,522*	810	862	*1,672*	778	875	*1,653*	834	864	*1,698*	1,005	872	*1,877*	987	662	*1,649*
09:00-09:59	942	693	*1,635*	1,054	763	*1,817*	927	811	*1,738*	893	858	*1,751*	981	874	*1,855*	1,252	938	*2,190*	1,271	945	*2,216*
10:00-10:59	1,242	1,051	*2,293*	1,169	882	*2,051*	959	830	*1,789*	944	820	*1,764*	1,087	920	*2,007*	1,439	1,033	*2,472*	1,409	1,153	*2,561*
11:00-11:59	1,379	1,291	*2,670*	1,205	1,053	*2,258*	993	865	*1,858*	982	855	*1,837*	1,133	913	*2,047*	1,516	1,111	*2,628*	1,383	1,228	*2,611*
12:00-12:59	1,346	1,365	*2,710*	1,214	1,156	*2,370*	1,009	904	*1,914*	1,023	878	*1,901*	1,144	993	*2,137*	1,569	1,188	*2,757*	1,234	1,231	*2,465*
13:00-13:59	1,336	1,462	*2,798*	1,216	1,250	*2,465*	1,028	929	*1,957*	1,065	917	*1,982*	1,249	964	*2,213*	1,739	1,245	*2,984*	1,201	1,203	*2,404*
14:00-14:59	1,324	1,597	*2,921*	1,218	1,318	*2,536*	1,110	972	*2,082*	1,147	980	*2,127*	1,315	1,168	*2,483*	1,788	1,394	*3,181*	1,145	1,145	*2,289*
15:00-15:59	1,314	1,679	*2,993*	1,254	1,351	*2,605*	1,223	1,026	*2,248*	1,206	1,025	*2,231*	1,428	1,188	*2,616*	1,909	1,438	*3,346*	1,014	1,081	*2,096*
16:00-16:59	1,298	1,719	*3,018*	1,200	1,312	*2,512*	1,217	1,051	*2,267*	1,203	1,067	*2,269*	1,453	1,192	*2,645*	1,957	1,483	*3,440*	1,009	1,074	*2,083*
17:00-17:59	1,056	1,609	*2,665*	1,018	1,291	*2,309*	1,045	983	*2,028*	1,077	968	*2,045*	1,301	1,106	*2,407*	1,823	1,451	*3,274*	881	1,023	*1,904*
18:00-18:59	924	1,417	*2,341*	799	1,011	*1,810*	821	771	*1,592*	846	781	*1,627*	1,095	952	*2,047*	1,424	1,228	*2,651*	739	893	*1,632*
19:00-19:59	768	1,151	*1,918*	634	767	*1,401*	624	636	*1,260*	664	684	*1,348*	813	784	*1,597*	1,047	892	*1,939*	650	788	*1,438*
20:00-20:59	544	873	*1,417*	462	618	*1,080*	480	515	*995*	508	551	*1,060*	601	692	*1,292*	709	764	*1,473*	533	665	*1,198*
21:00-21:59	351	627	*977*	361	457	*818*	395	436	*830*	415	437	*852*	454	589	*1,043*	516	601	*1,116*	376	496	*872*
22:00-22:59	245	420	*665*	288	337	*626*	319	341	*660*	329	348	*677*	344	425	*769*	395	455	*849*	264	356	*620*
23:00-23:59	169	260	*428*	214	248	*463*	239	239	*478*	249	250	*499*	269	313	*582*	275	367	*641*	191	239	*430*
Daily Total	**16,189**	**18,894**	***35,082***	**16,176**	**17,566**	***33,741***	**15,725**	**15,835**	***31,561***	**15,896**	**16,115**	***32,011***	**18,144**	**17,846**	***35,990***	**23,131**	**20,206**	***43,337***	**16,467**	**16,287**	***32,754***
AM Peak	**942**	**693**	***1,635***	**1,054**	**781**	***1,817***	**927**	**900**	***1,738***	**893**	**967**	***1,777***	**981**	**1,005**	***1,855***	**1,252**	**938**	***2,190***	**1,271**	**945**	***2,216***
Hour	09:00	09:00	*09:00*	09:00	07:00	*09:00*	09:00	07:00	*09:00*	09:00	07:00	*07:00*	09:00	07:00	*09:00*	09:00	09:00	*09:00*	09:00	09:00	*09:00*
MD Peak	**1,379**	**1,597**	***2,921***	**1,218**	**1,318**	***2,536***	**1,110**	**972**	***2,082***	**1,147**	**980**	***2,127***	**1,315**	**1,168**	***2,483***	**1,788**	**1,394**	***3,181***	**1,409**	**1,231**	***2,611***
Hour	11:00	14:00	*14:00*	14:00	14:00	*14:00*	14:00	14:00	*14:00*	14:00	14:00	*14:00*	14:00	14:00	*14:00*	14:00	14:00	*14:00*	10:00	12:00	*11:00*
PM Peak	**1,314**	**1,719**	***3,018***	**1,254**	**1,351**	***2,605***	**1,223**	**1,051**	***2,267***	**1,206**	**1,067**	***2,269***	**1,453**	**1,192**	***2,645***	**1,957**	**1,483**	***3,440***	**1,014**	**1,081**	***2,096***
Hour	15:00	16:00	*16:00*	15:00	15:00	*15:00*	15:00	16:00	*16:00*	15:00	16:00	*16:00*	16:00	16:00	*16:00*	16:00	16:00	*16:00*	15:00	15:00	*15:00*
Daily Peak	**1,379**	**1,719**	***3,018***	**1,254**	**1,351**	***2,605***	**1,223**	**1,051**	***2,267***	**1,206**	**1,067**	***2,269***	**1,453**	**1,192**	***2,645***	**1,957**	**1,483**	***3,440***	**1,409**	**1,231**	***2,611***
Hour	11:00	16:00	*16:00*	15:00	15:00	*15:00*	15:00	16:00	*16:00*	15:00	16:00	*16:00*	16:00	16:00	*16:00*	16:00	16:00	*16:00*	10:00	12:00	*11:00*
% of Total	8.5%	9.1%	*8.6%*	7.8%	7.7%	*7.7%*	7.8%	6.6%	*7.2%*	7.6%	6.6%	*7.1%*	8.0%	6.7%	*7.3%*	8.5%	7.3%	*7.9%*	8.6%	7.6%	*8.0%*
Daily Ave	**675**	**787**	***1,462***	**674**	**732**	***1,406***	**655**	**660**	***1,315***	**662**	**671**	***1,334***	**756**	**744**	***1,500***	**964**	**842**	***1,806***	**686**	**679**	***1,365***

Hour	Mon-Thurs Average			Mon-Fri Average			7 Day Average		
	Pos Dir	Neg Dir	*Total*	Pos Dir	Neg Dir	*Total*	Pos Dir	Neg Dir	*Total*
00:00-00:59	164	185	*349*	170	192	*363*	171	196	*367*
01:00-01:59	130	158	*289*	134	164	*298*	132	161	*293*
02:00-02:59	116	163	*279*	119	172	*291*	114	160	*274*
03:00-03:59	144	237	*381*	147	241	*388*	136	213	*349*
04:00-04:59	196	397	*593*	201	402	*603*	184	338	*523*
05:00-05:59	364	715	*1,078*	372	710	*1,082*	326	570	*896*
06:00-06:59	550	836	*1,386*	563	834	*1,397*	499	672	*1,171*
07:00-07:59	789	913	*1,702*	811	918	*1,729*	737	763	*1,500*
08:00-08:59	803	833	*1,636*	844	841	*1,685*	832	758	*1,590*
09:00-09:59	964	826	*1,790*	1,021	849	*1,870*	1,046	840	*1,886*
10:00-10:59	1,040	863	*1,903*	1,120	897	*2,017*	1,178	955	*2,134*
11:00-11:59	1,078	921	*2,000*	1,166	959	*2,125*	1,227	1,045	*2,272*
12:00-12:59	1,098	983	*2,081*	1,192	1,024	*2,216*	1,220	1,102	*2,322*
13:00-13:59	1,140	1,015	*2,154*	1,259	1,061	*2,320*	1,262	1,138	*2,400*
14:00-14:59	1,198	1,109	*2,307*	1,316	1,166	*2,482*	1,292	1,225	*2,517*
15:00-15:59	1,278	1,147	*2,425*	1,404	1,205	*2,609*	1,335	1,255	*2,591*
16:00-16:59	1,268	1,155	*2,423*	1,406	1,221	*2,627*	1,334	1,271	*2,605*
17:00-17:59	1,110	1,087	*2,197*	1,253	1,160	*2,413*	1,172	1,204	*2,376*
18:00-18:59	890	879	*1,769*	997	948	*1,945*	950	1,007	*1,957*
19:00-19:59	684	718	*1,402*	756	753	*1,509*	743	814	*1,557*
20:00-20:59	513	594	*1,107*	552	628	*1,180*	548	668	*1,216*
21:00-21:59	406	480	*886*	428	504	*932*	410	520	*930*
22:00-22:59	320	363	*683*	335	381	*716*	312	383	*695*
23:00-23:59	243	262	*505*	249	283	*532*	229	274	*503*
Daily Total	**16,485**	**16,840**	***33,326***	**17,814**	**17,514**	***35,328***	**17,389**	**17,536**	**34,925**
AM Peak	**964**	**913**	***1,790***	**1,021**	**918**	***1,870***	**1,046**	**840**	***1,886***
Hour	09:00	07:00	*09:00*	09:00	07:00	*09:00*	09:00	09:00	*09:00*
MD Peak	**1,198**	**1,109**	***2,307***	**1,316**	**1,166**	***2,482***	**1,292**	**1,225**	***2,517***
Hour	14:00	14:00	*14:00*	14:00	14:00	*14:00*	14:00	14:00	*14:00*
PM Peak	**1,278**	**1,155**	***2,425***	**1,406**	**1,221**	***2,627***	**1,335**	**1,271**	***2,605***
Hour	15:00	16:00	*15:00*	16:00	16:00	*16:00*	15:00	16:00	*16:00*
Daily Peak	**1,278**	**1,155**	***2,425***	**1,406**	**1,221**	***2,627***	**1,335**	**1,271**	***2,605***
Hour	15:00	16:00	*15:00*	16:00	16:00	*16:00*	15:00	16:00	*16:00*
% of Total	7.8%	6.9%	*7.3%*	7.9%	7.0%	*7.4%*	7.7%	7.2%	*7.5%*
Daily Ave	**687**	**702**	***1,389***	**742**	**730**	***1,472***	**725**	**731**	***1,455***

Figure 16. Typical report from the Wisconsin Hourly Traffic Data Portal

- The Wisconsin Lane Closure System (WisLCS, Figure 17) has been operational since 2008 and will be further enhanced in early 2022. The system is used to request and accept lane closures. Lane closure requests are typically initiated by a contractor and entered by the project team or by a county highway maintenance crew, since the maintenance of state highways is performed by counties in Wisconsin. Requests are reviewed by WisDOT staff and, if found to be reasonable, approved by regional traffic engineers. Information from WisLCS is shared with the state traffic management center, 511, and other third parties to provide work zone lane closure information.

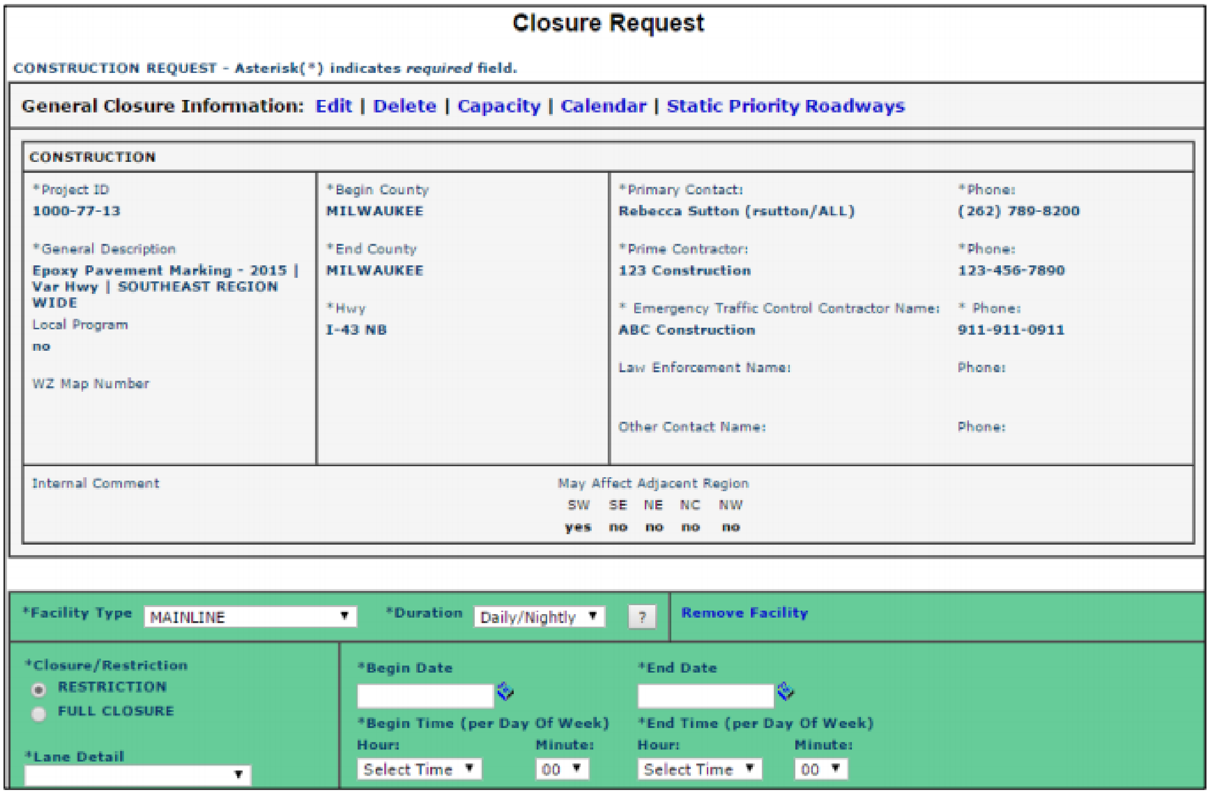


Figure 17. WisLCS closure request

- In the past, many of the WisLCS requests were very general, covering a long section of roadway and an extended period of time when work might be occurring. In recent months, Schwark has encouraged closure approvers to require greater specificity and detail. Currently, WisLCS tracks planned (not actual) closure start/stop times. Although the system has the capability to track closures on county and municipal routes, it is rarely used for that purpose.

- In the future, Schwark hopes to link WisLCS with the Wisconsin Transportation Management Plan (WisTMP) system that is used to generate transportation management plans electronically. This would reduce redundant data entry by allowing closure details from WisTMP to be pushed to WisLCS. WisDOT also hopes to be able to link GPS-equipped field devices such as iPins, iCones, and smart arrow boards to WisLCS to provide more detail on actual closure locations.

GAP ANALYSIS

Data Sources and Availability

The transportation agency survey described in the previous section gathered information about priorities for work zone data applications and the availability of data to support them. The primary data elements are summarized in Table 8.

Table 8. Data elements, sources, and availability

Data Element	Typical Sources	Typical Availability
Traffic Speeds	Probe data (Here, Inrix, TomTom), radar, inductive loops, Bluetooth, or toll tag reidentification (rare)	Good coverage of major freeways, poor coverage of arterials and rural highways
Traffic Volumes	Infrastructure sensors (inductive loops or radar), short-duration counts from pneumatic tubes or portable magnetometers; queue warning system data collected but infrequently used	Limited coverage of major freeways, poor coverage of arterials and rural highways
Incidents	Law enforcement crash reports, traffic operations center logs	Data availability often lags days, weeks, or months behind incident occurrence
Lanes Open	Most states: No data A few states: Partial data from closure permits, no data for county/municipal roads	Some states experimenting with GPS-enabled work zone devices
Work Activity	Electronic field logs	Field logs often incomplete or not georeferenced

Although specific data sources vary from state to state, the table indicates the availability that is typical in most of the respondent states.

The survey and interviews indicate that, in general, the most readily available data element is freeway traffic speeds. Freeway traffic volumes are readily available in states that use infrastructure sensors but sparse in states that use probe data. Traffic incident and crash reports are available in most states, but there is often a considerable time lag between the occurrence of a crash and the availability of the crash report. Few, if any, states have good data on the actual location, timing, and extent of lane closures. Some states are experimenting with GPS-enabled traffic cones or similar devices to help collect closure details; currently, this effort appears to focus on monitoring the upstream location where the closure begins, with much less emphasis on gathering information about the downstream location where the closure ends.

Data Gaps

Table 9 compares the readily available data with the functional requirements for several of the use cases that received the highest importance ratings. For brevity, the first column of the table combines two very similar use cases: traffic monitoring for work zones and traffic monitoring for alternate routes. Thus, Table 9 incorporates 9 of the 10 most highly rated use cases derived from the FHWA Work Zone Data Initiative report. The tenth use case is monitoring contractor compliance with traffic control requirements; this use case was excluded from Table 9 because it is not primarily an electronic data exchange function (determining compliance requires manual on-site inspection, except when the temporary traffic control devices used at the site are visible from traffic monitoring video).

Table 9. Current data availability for major work zone performance monitoring use cases

Use Case	Monitor work zone and alt. route traffic flow, identify locations of delays	Disseminate lane closure locations to public, first responders	Disseminate anticipated lane closure start/end times to public, first responders	Estimate traffic impacts (queuing, delay) for future lane closures	Evaluate work zone traffic safety	Coordinate construction scheduling internally or with other jurisdictions	Determine causes of work zone delays	Determine TMP effectiveness
Survey importance score	4.63 / 4.08	4.50	4.29	4.27	4.20	3.90	3.87	3.76
Traffic speed - freeway	✓ [teal]			Desirable	✓ [teal]	Desirable	✓ [teal]	✓ [teal]
Traffic speed - urban arterial	✓ [yellow]			Desirable	✓ [yellow]	Desirable	✓ [yellow]	✓ [yellow]
Traffic speed - two-lane rural highway	✓ [red]			Desirable	✓ [red]	Desirable	✓ [red]	✓ [red]
Traffic volume - pre-construction				✓ [teal]	✓ [teal]	✓ [teal]	✓ [teal]	✓ [teal]
Traffic volume - freeway - during construction					✓ [yellow]	Desirable	✓ [yellow]	✓ [yellow]
Traffic volume - urban arterial - during constr.					Desirable	Desirable	✓ [red]	✓ [red]
Traffic volume - two-lane rural hwy - constr.					Desirable	Desirable	✓ [red]	✓ [red]
Crash/incident start time	Desirable				✓ [red]	Desirable	✓ [red]	✓ [red]
Crash/incident end time	Desirable				✓ [red]	Desirable	✓ [red]	✓ [red]
Crash/incident severity	Desirable				✓ [red]	Desirable	✓ [red]	✓ [red]
Number of lanes open/closed	Desirable	✓ [red]	✓ [red]	Planned Loc	✓ [red]	Desirable	✓ [red]	✓ [red]
Upstream location of closure (first cone)	Desirable	✓ [red]	✓ [red]	Planned Loc	✓ [red]	✓ [red]	✓ [red]	✓ [red]
Downstream location of closure (last cone)	Desirable	✓ [red]	✓ [red]	Planned Loc	✓ [red]	✓ [red]	✓ [red]	✓ [red]
All closure coordinates at intersections	Desirable	✓ [red]	✓ [red]	Planned Loc	✓ [red]	✓ [red]	✓ [red]	✓ [red]
Boundaries of two-way one-lane operation	Desirable	✓ [red]	✓ [red]	Planned Loc	✓ [red]	✓ [red]	✓ [red]	✓ [red]
Intended closure start time	Desirable		✓ [yellow]		✓ [yellow]	✓ [yellow]		Desirable
Actual closure start time	Desirable		✓ [red]		✓ [red]		✓ [red]	✓ [red]
Intended closure end time	Desirable		✓ [yellow]		✓ [yellow]	✓ [yellow]		Desirable
Actual closure end time	Desirable		✓ [red]		✓ [red]		✓ [red]	✓ [red]
Reason for early/late closure end time	Desirable		Desirable		Desirable		✓ [red]	✓ [red]
Project ID number	✓ [teal]				✓ [teal]		✓ [teal]	✓ [teal]
Contact info for contractor and field engineer	✓ [teal]				Desirable	✓ [teal]		
Work type (mobile/stationary)	Desirable				✓ [yellow]	✓ [yellow]	✓ [yellow]	✓ [yellow]
Work activity/characteristics	Desirable				Desirable	✓ [yellow]	✓ [yellow]	✓ [yellow]
Size of on-site workforce	Desirable				Desirable			Desirable
Types of heavy equipment in use	Desirable				Desirable			Desirable

Current Data Availability Codes	
Required and generally available	✓ [teal]
Required and sometimes available	✓ [yellow]
Required but rarely available	✓ [red]
Not required for use case	[grey, empty]

As shown in Table 9, there are four major sets of data availability gaps:

- Traffic speeds for non-freeway facilities
- Traffic volumes during construction
- Lane closure details such as location and actual start/stop times
- Detailed location and start/stop times for crashes that occur in or near work zones

Traffic Speeds and Volumes

Most agencies reported that they currently have very little traffic monitoring on urban arterials, rural two-lane highways, and similar facilities. This hampers evaluations of work zone performance because it is often unclear how traffic diverted from work zones affects other nearby facilities. Practitioners reported that monitoring devices are sometimes installed on roadways designated as alternate routes for high-impact work zones.

Lane Closure Details

Numerous use cases are currently hampered by a lack of information about lane closure details, such as the precise location of the closure, the number of closed lanes, and the actual start/stop times. A few states reported that they are able to obtain information about the planned location and timing of lane closures from their lane closure systems, but in general these states do not have information about the actual start/stop times. The interviews with the WisDOT and MDOT representatives drew attention to a distinction between issuing an authorization to close lanes (which could cover a generalized work area and an extended timeframe) and monitoring the specific times and locations of closures within the area covered by the permit. Thus, it appears that few, if any, agencies are currently able to monitor closure details at the level of granularity required for use cases such as dissemination of closure information, safety evaluation, and collection of operational performance information. This lack of closure details is also potentially problematic for future CAV applications (CEN Technical Committee 278 2018).

Incident and Crash Details

Law enforcement reports provide information about the location and timing of traffic crashes, but some of the state officials interviewed for this project identified significant time lags between crash occurrence and crash report availability. In some states, the GPS coordinates of the crash are not readily available. Although state crash report forms typically have a field identifying whether the crash occurred in a work zone, practitioners indicated that the work zone flag is not always accurate. If detailed information about closure locations and timing were available, work zone crashes could be derived geospatially. In principle, richer data about work zone crashes and non-crash incidents could be obtained if on-site personnel logged these events.

DISCUSSION

The objective of this study was to identify (and begin resolving) gaps between existing work zone data sources and the data required for high-priority work zone data use cases. The survey of state transportation agencies indicated that use cases related to the dissemination of lane closure information, causes of traffic delays, factors affecting work zone safety, pre-construction analysis, and reviews of transportation management plan effectiveness are highly relevant to the business needs of most state transportation agencies. Improving interjurisdictional coordination is important in some states, particularly if a major urban area straddles the state line.

Nearly all of the data sources currently being used for work zone monitoring and analysis are byproducts of data systems developed for other purposes. For example, freeway speeds and video are typically obtained to support permanent freeway traffic incident management systems.

Unfortunately, the existing data sources are not sufficient for many of the work zone use cases that agencies identified as high priorities. The main data gaps that were identified are as follows:

- Traffic speeds for non-freeway facilities
- Traffic volumes during construction, especially for non-freeway facilities
- Lane closure details such as location and actual start/stop times
- Detailed location and start/stop times for incidents and crashes that occur in or near work zones

Options for Addressing Data Gaps

From a technical perspective, the traffic speed and traffic volume data gaps are relatively easy to resolve: speed and volume information can be obtained by installing additional permanent or temporary sensors in the field. Where traffic volumes are sufficient to provide reasonable sample sizes, traffic speed data could also be obtained from probe data vendors. Thus, the problem with collecting sufficient traffic speed and volume data appears to be mainly one of setting priorities and determining how to allocate the cost of additional data collection among stakeholders. For some use cases, it is possible to muddle through without additional volume and speed data, though this can degrade the usefulness of the resulting information streams and analyses.

Lack of lane closure details is a significant impediment to more effective work zone monitoring and analytics. Currently, a few states are experimenting with deriving data about the location and timing of lane closures from GPS devices installed in maintenance vehicles, arrow boards, traffic control drums, barricades, vertical panels, traffic cones, or pins. These devices will presumably be linked to manually generated information such as the work zone configuration, type of work operation (mobile/stationary), number of closed lanes, and so forth.

In principle, a single smart device can be used to determine the GPS coordinates of the upstream end of a simple linear closure, with a second device to identify the downstream end of the closure. More complex topologies such as interchanges, intersections, and arterial corridors have multiple access points, so additional GPS-enabled devices would be required for these situations. As the number of devices increases, so does the complexity of keeping records to ensure that the position of each device is interpreted correctly. For example, if a work zone begins on the freeway mainline and continues past two exit ramps, smart cone 1 might represent the upstream end of the closure on the freeway mainline, cone 2 the downstream end of the closure on the mainline, and cones 3 and 4 the downstream ends of the closure at the two ramp terminals.

An alternative to the use of linked devices is to develop a mobile-friendly work zone data entry page to collect real-time information about closure location, timing, and extent. Accessed from a smartphone, tablet, or laptop, the app could be used to enter closure information manually or to link smart devices with a specific closure or mobile operation. Sketches defining a conceptual prototype for the app were developed and are presented in Appendix B.

Crash location and severity information is typically available from law enforcement reports, but the survey and interviews conducted for the present project indicated that this information is not always timely and sometimes lacks accuracy. The field data collection app could be used to collect information about crashes in work zones and to create a record of non-crash incidents affecting work zone traffic flow (such as vehicle breakdowns). Although non-crash incidents are sometimes significant in terms of work zone performance, in general the details of these incidents are not currently available from any source.

By combining real-time crash and incident information with real-time information about closure status, agency managers and analysts would obtain a more complete picture of the factors contributing to delays in individual work zones and a more complete record of well-performing work zones. For example, the data would make it easier to determine whether a traffic delay was closure related, incident related, or associated with the simultaneous combination of a closure and an incident. Such information could support post-incident debriefings and post-construction work zone performance reviews.

Although many state transportation agencies have traditionally focused most of their work zone monitoring efforts on freeway closures, closures on urban arterials and two-lane rural highways can also have substantial effects on road user safety and mobility. In these cases, the spatial extent of a closure is not limited to a single road segment (Figure 18).

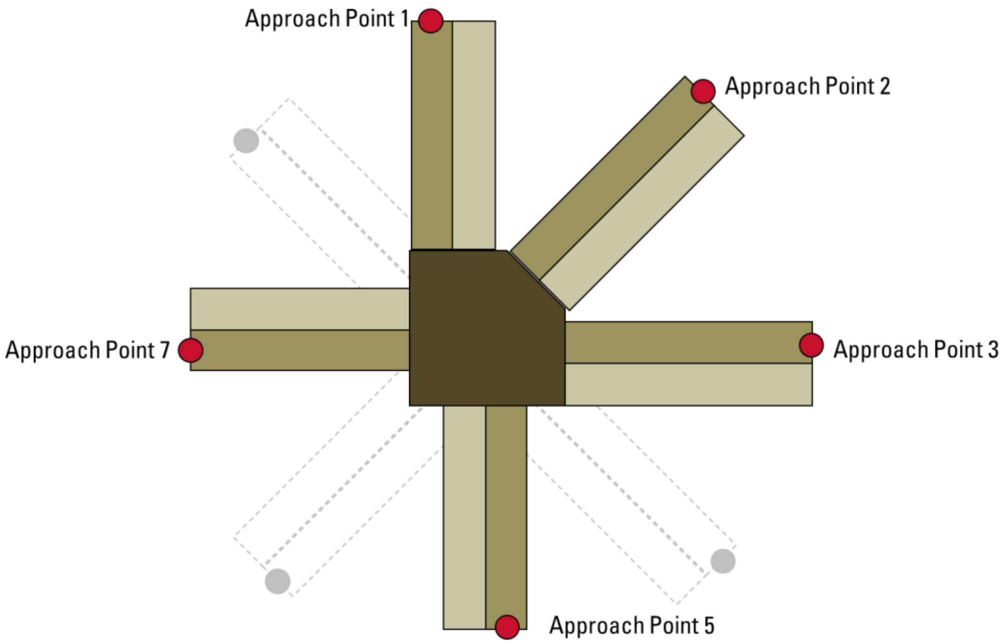


Figure 18. Potential lane closures at an intersection

For example, a closure at an intersection or interchange can affect multiple approaches and can involve restrictions on multiple movements (for example, prohibiting southbound and westbound left turns). Methods for accommodating these more complicated cases require consideration in the app and database architecture. In urban situations, it might also be desirable to create a detailed record of closures involving sidewalks and bicycle paths/lanes.

The current lack of a unified global standard for work zone data interchange presents technical challenges. Some of the work zone data collection devices and services currently in use are based on proprietary standards. Others, such as the TMDD and ITIS protocols, are in limited or partial use. The European DATEX II standard provides a relatively comprehensive set of work zone data elements, and extensions of the protocol could be implemented to improve compatibility with ITIS. The FHWA Work Zone Data Initiative is in the process of developing a similar set of data interchange standards for the United States. A key challenge will be integration with legacy systems.

Figure 19 provides a conceptual overview of the potential relationships between various data sources and work zone automation systems.

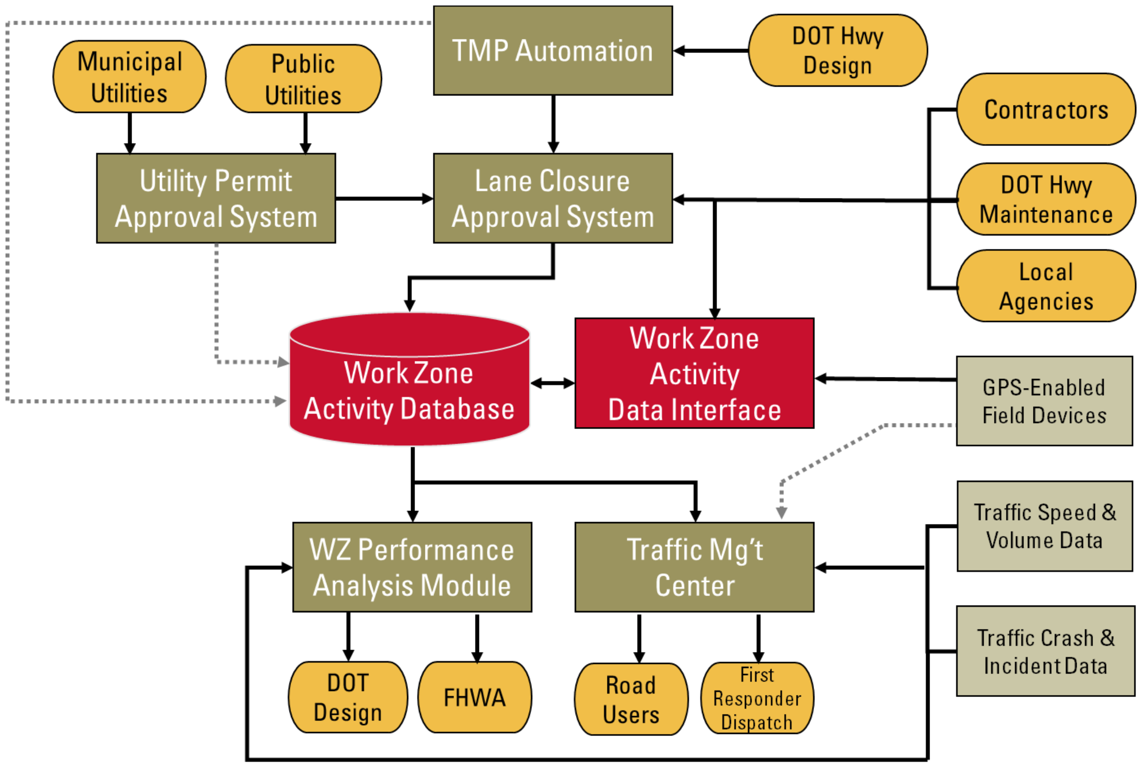


Figure 19. Potential relationships and dependencies for work zone data systems

Although no state has currently implemented all of the components of a comprehensive suite of work zone management systems, Figure 19 provides an overview of the likely data flows at full build-out. The work zone activity database identified by the red cylinder would provide a central repository for information that helps users apply the data ingested from other systems. The data collection app, identified by the red rectangle, would facilitate recording work zone information that is currently known only to on-site personnel.

Desirable data elements for the activity database include the following:

- Lane closure locations
- Precise closure start/stop times
- Configuration of open (or closed) lanes (number, position, and width of lanes remaining open)
- Configuration details (lateral shifts, turn lane closures, etc.)
- Road surface condition (milled surface, uneven lanes, etc.)
- Type and intensity of work operations (type of work, stationary or mobile)
- Whether the work activities are visible to traffic
- Aberrations such as delivery/removal of cranes and other large, heavy equipment
- Timing of incidents and crashes in the work zone

A future phase of this project could evaluate the practicality of collecting information of this type through an app. Consideration can also be given to whether the data should be collected by agency personnel, by contractor personnel, or through some other arrangement. Methods for ensuring consistent use of the app also require consideration, though these methods might ultimately vary from jurisdiction to jurisdiction.

If the app requires contractor participation, it is likely that contractors will view it more favorably if they see value for their own operations. Potential benefits to the contractor in using the app include the following:

- Documenting progress and creating a record of completed activities
- Creating a record of closures that were completed on time or early
- Explaining the causes of construction delays
- Creating a record of site presence and lane closures, which could potentially be useful in defending against liability claims
- Creating records of on-site personnel and on-site equipment to support productivity analysis

Conclusions and Recommendations

An in-depth analysis of available work zone data sources and data interchange standards affirmed that the lack of detailed information about the actual location, configuration, and timing of lane closures is a major impediment to work zone performance monitoring and reporting.

Further development of the data collection app is recommended. It is anticipated that the tool would be developed in several phases. Development could begin with proof-of-concept implementation of a system to collect the most essential work zone data. A modular approach could be adopted so that new functions and features can be added if additional software development funding becomes available in the future. For example, some of the states contacted for this project expressed interest in integrating the lane closure data collection tool with lane closure permitting systems, and these functions might be a future add-on. Similarly, states that make use of open-source TMC central system software (such as IRIS, the Intelligent Roadway Information System [IRIS Coalition 2020]) might want to move toward tight integration with their traffic monitoring systems. To support interoperability, the app should be designed to support a work zone data repository that is compliant with relevant technical standards.

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APPENDIX A: WORK ZONE-RELATED ENUMERATIONS IN NATIONAL AND INTERNATIONAL ITS STANDARDS

Radio Data System Traffic Message Channel (RDS-TMC) Messages Related to Roadway Maintenance and Construction

Code	Description
1	traffic problem
2	queuing traffic (with average speeds Q). Danger of stationary traffic
24	bridge closed
25	tunnel closed
26	bridge blocked
27	tunnel blocked
28	road closed intermittently
39	reopening of bridge expected (Q)
41	(Q) overtaking lane(s) closed
42	(Q) overtaking lane(s) blocked
51	roadworks, (Q) overtaking lane(s) closed
52	(Q sets of) roadworks on the hard shoulder
53	(Q sets of) roadworks in the emergency lane
55	traffic problem expected
56	traffic congestion expected
57	normal traffic expected
62	(Q) burst pipe(s)
64	burst pipe. Danger
70	traffic congestion, average speed of 10 km/h
71	traffic congestion, average speed of 20 km/h
72	traffic congestion, average speed of 30 km/h
73	traffic congestion, average speed of 40 km/h
74	traffic congestion, average speed of 50 km/h
75	traffic congestion, average speed of 60 km/h
76	traffic congestion, average speed of 70 km/h
80	heavy traffic has to be expected
81	traffic congestion has to be expected
82	(Q sets of) roadworks. Heavy traffic has to be expected
83	closed ahead. Heavy traffic expected
88	traffic congestion forecast withdrawn
89	message cancelled
91	delays (Q) for cars
101	stationary traffic
102	stationary traffic for 1 km
103	stationary traffic for 2 km
104	stationary traffic for 4 km
105	stationary traffic for 6 km
106	stationary traffic for 10 km

Code	Description
107	stationary traffic expected
108	queuing traffic (with average speeds Q)
109	queuing traffic for 1 km (with average speeds Q)
110	queuing traffic for 2 km (with average speeds Q)
111	queuing traffic for 4 km (with average speeds Q)
112	queuing traffic for 6 km (with average speeds Q)
113	queuing traffic for 10 km (with average speeds Q)
114	queuing traffic expected
115	slow traffic (with average speeds Q)
116	slow traffic for 1 km (with average speeds Q)
117	slow traffic for 2 km (with average speeds Q)
118	slow traffic for 4 km (with average speeds Q)
119	slow traffic for 6 km (with average speeds Q)
120	slow traffic for 10 km (with average speeds Q)
121	slow traffic expected
122	heavy traffic (with average speeds Q)
123	heavy traffic expected
124	traffic flowing freely (with average speeds Q)
125	traffic building up (with average speeds Q)
126	no problems to report
127	traffic congestion cleared
128	message cancelled
129	stationary traffic for 3 km
130	danger of stationary traffic
131	queuing traffic for 3 km (with average speeds Q)
132	danger of queuing traffic (with average speeds Q)
133	long queues (with average speeds Q)
134	slow traffic for 3 km (with average speeds Q)
135	traffic easing
136	traffic congestion (with average speeds Q)
137	traffic lighter than normal (with average speeds Q)
138	queuing traffic (with average speeds Q). Approach with care
139	queuing traffic around a bend in the road
140	queuing traffic over the crest of a hill
142	traffic heavier than normal (with average speeds Q)
143	traffic very much heavier than normal (with average speeds Q)
345	(Q) secondary accident(s)
392	(Q) secondary accident(s). Danger
405	no through traffic
406	(Q th) entry slip road closed
407	(Q th) exit slip road closed
408	slip roads closed
409	slip road restrictions
410	closed ahead. Stationary traffic
411	closed ahead. Stationary traffic for 1 km

Code	Description
412	closed ahead. Stationary traffic for 2 km
413	closed ahead. Stationary traffic for 4 km
414	closed ahead. Stationary traffic for 6 km
415	closed ahead. Stationary traffic for 10 km
416	closed ahead. Danger of stationary traffic
417	closed ahead. Queuing traffic
418	closed ahead. Queuing traffic for 1 km
419	closed ahead. Queuing traffic for 2 km
420	closed ahead. Queuing traffic for 4 km
421	closed ahead. Queuing traffic for 6 km
422	closed ahead. Queuing traffic for 10 km
423	closed ahead. Danger of queuing traffic
424	closed ahead. Slow traffic
425	closed ahead. Slow traffic for 1 km
426	closed ahead. Slow traffic for 2 km
427	closed ahead. Slow traffic for 4 km
428	closed ahead. Slow traffic for 6 km
429	closed ahead. Slow traffic for 10 km
430	closed ahead. Slow traffic expected
431	closed ahead. Heavy traffic
432	closed ahead. Heavy traffic expected
433	closed ahead. Traffic flowing freely
434	closed ahead. Traffic building up
435	closed ahead. Delays (Q)
436	closed ahead. Delays (Q) expected
437	closed ahead. Long delays (Q)
466	slip roads reopened
467	reopened
468	message cancelled
469	closed ahead
471	(Q) entry slip road(s) closed
474	(Q) exit slip road(s) closed
478	connecting roadway closed
479	parallel roadway closed
480	right-hand parallel roadway closed
481	left-hand parallel roadway closed
482	express lanes closed
483	through traffic lanes closed
484	local lanes closed
485	connecting roadway blocked
486	parallel roadway blocked
487	right-hand parallel roadway blocked
488	left-hand parallel roadway blocked
492	no motor vehicles
493	Restrictions

Code	Description
494	closed for heavy trucks (over Q)
495	closed ahead. Stationary traffic for 3 km
496	closed ahead. Queuing traffic for 3 km
497	closed ahead. Slow traffic for 3 km
498	blocked ahead. Stationary traffic for 3 km
499	blocked ahead. Queuing traffic for 3 km
500	(Q) lane(s) closed
501	(Q) right lane(s) closed
502	(Q) centre lane(s) closed
503	(Q) left lane(s) closed
504	hard shoulder closed
505	two lanes closed
506	three lanes closed
514	roadway reduced (from Q lanes) to one lane
515	roadway reduced (from Q lanes) to two lanes
516	roadway reduced (from Q lanes) to three lanes
517	Contraflow
518	narrow lanes
519	contraflow with narrow lanes
521	(Q) lanes closed. Stationary traffic
522	(Q) lanes closed. Stationary traffic for 1 km
523	(Q) lanes closed. Stationary traffic for 2 km
524	(Q) lanes closed. Stationary traffic for 4 km
525	(Q) lanes closed. Stationary traffic for 6 km
526	(Q) lanes closed. Stationary traffic for 10 km
527	(Q) lanes closed. Danger of stationary traffic
528	(Q) lanes closed. Queuing traffic
529	(Q) lanes closed. Queuing traffic for 1 km
530	(Q) lanes closed. Queuing traffic for 2 km
531	(Q) lanes closed. Queuing traffic for 4 km
532	(Q) lanes closed. Queuing traffic for 6 km
533	(Q) lanes closed. Queuing traffic for 10 km
534	(Q) lanes closed. Danger of queuing traffic
535	(Q) lanes closed. Slow traffic
536	(Q) lanes closed. Slow traffic for 1 km
537	(Q) lanes closed. Slow traffic for 2 km
538	(Q) lanes closed. Slow traffic for 4 km
539	(Q) lanes closed. Slow traffic for 6 km
540	(Q) lanes closed. Slow traffic for 10 km
541	(Q) lanes closed. Slow traffic expected
542	(Q) lanes closed. Heavy traffic
543	(Q) lanes closed. Heavy traffic expected
544	(Q)lanes closed. Traffic flowing freely
545	(Q)lanes closed. Traffic building up
546	roadway reduced (from Q lanes) to one lane. Stationary traffic

Code	Description
547	roadway reduced (from Q lanes) to one lane. Danger of stationary traffic
548	roadway reduced (from Q lanes) to one lane. Queuing traffic
549	roadway reduced (from Q lanes) to one lane. Danger of queuing traffic
550	roadway reduced (from Q lanes) to one lane. Slow traffic
551	roadway reduced (from Q lanes) to one lane. Slow traffic expected
552	roadway reduced (from Q lanes) to one lane. Heavy traffic
553	roadway reduced (from Q lanes) to one lane. Heavy traffic expected
554	roadway reduced (from Q lanes) to one lane. Traffic flowing freely
555	roadway reduced (from Q lanes) to one lane. Traffic building up
556	roadway reduced (from Q lanes) to two lanes. Stationary traffic
557	roadway reduced (from Q lanes) to two lanes. Danger of stationary traffic
558	roadway reduced (from Q lanes) to two lanes. Queuing traffic
559	roadway reduced (from Q lanes) to two lanes. Danger of queuing traffic
560	roadway reduced (from Q lanes) to two lanes. Slow traffic
561	roadway reduced (from Q lanes) to two lanes. Slow traffic expected
562	roadway reduced (from Q lanes) to two lanes. Heavy traffic
563	roadway reduced (from Q lanes) to two lanes. Heavy traffic expected
564	roadway reduced (from Q lanes) to two lanes. Traffic flowing freely
565	roadway reduced (from Q lanes) to two lanes. Traffic building up
566	roadway reduced (from Q lanes) to three lanes. Stationary traffic
567	roadway reduced (from Q lanes) to three lanes. Danger of stationary traffic
568	roadway reduced (from Q lanes) to three lanes. Queuing traffic
569	roadway reduced (from Q lanes) to three lanes. Danger of queuing traffic
570	roadway reduced (from Q lanes) to three lanes. Slow traffic
571	roadway reduced (from Q lanes) to three lanes. Slow traffic expected
572	roadway reduced (from Q lanes) to three lanes. Heavy traffic
573	roadway reduced (from Q lanes) to three lanes. Heavy traffic expected
574	roadway reduced (from Q lanes) to three lanes. Traffic flowing freely
575	roadway reduced (from Q lanes) to three lanes. Traffic building up
576	contraflow. Stationary traffic
577	contraflow. Stationary traffic for 1 km
578	contraflow. Stationary traffic for 2 km
579	contraflow. Stationary traffic for 4 km
580	contraflow. Stationary traffic for 6 km
581	contraflow. Stationary traffic for 10 km
582	contraflow. Danger of stationary traffic
583	contraflow. Queuing traffic
584	contraflow. Queuing traffic for 1 km
585	contraflow. Queuing traffic for 2 km
586	contraflow. Queuing traffic for 4 km
587	contraflow. Queuing traffic for 6 km
588	contraflow. Queuing traffic for 10 km
589	contraflow. Danger of queuing traffic
590	contraflow. Slow traffic
591	contraflow. Slow traffic for 1 km

Code	Description
592	contraflow. Slow traffic for 2 km
593	contraflow. Slow traffic for 4 km
594	contraflow. Slow traffic for 6 km
595	contraflow. Slow traffic for 10 km
596	contraflow. Slow traffic expected
597	contraflow. Heavy traffic
598	contraflow. Heavy traffic expected
599	contraflow. Traffic flowing freely
600	contraflow. Traffic building up
601	contraflow. roadway reduced (from Q lanes) to one lane
602	contraflow. roadway reduced (from Q lanes) to two lanes
603	contraflow. roadway reduced (from Q lanes) to three lanes
604	narrow lanes. Stationary traffic
605	narrow lanes. Danger of stationary traffic
606	narrow lanes. Queuing traffic
607	narrow lanes. Danger of queuing traffic
608	narrow lanes. Slow traffic
609	narrow lanes. Slow traffic expected
610	narrow lanes. Heavy traffic
611	narrow lanes. Heavy traffic expected
612	narrow lanes. Traffic flowing freely
613	narrow lanes. Traffic building up
614	contraflow with narrow lanes. Stationary traffic
615	contraflow with narrow lanes. Stationary traffic. Danger of stationary traffic
616	contraflow with narrow lanes. Queuing traffic
617	contraflow with narrow lanes. Danger of queuing traffic
618	contraflow with narrow lanes. Slow traffic
619	contraflow with narrow lanes. Slow traffic expected
620	contraflow with narrow lanes. Heavy traffic
621	contraflow with narrow lanes. Heavy traffic expected
622	contraflow with narrow lanes. Traffic flowing freely
623	contraflow with narrow lanes. Traffic building up
624	lane closures removed
625	message cancelled
630	open
631	road cleared
632	entry reopened
633	exit reopened
634	all roadways reopened
635	motor vehicle restrictions lifted
636	traffic restrictions lifted (reopened for all traffic)
637	emergency lane closed
638	turning lane closed
639	crawler lane closed
640	slow vehicle lane closed

Code	Description
641	one lane closed
648	(Q person) carpool lane closed
650	carpool restrictions changed (to Q persons per vehicle)
651	(Q) lanes closed. Stationary traffic for 3 km
652	(Q) lanes closed. Queuing traffic for 3 km
653	(Q) lanes closed. Slow traffic for 3 km
654	contraflow. Stationary traffic for 3 km
655	contraflow. Queuing traffic for 3 km
656	contraflow. Slow traffic for 3 km
658	contraflow removed
659	(Q person) carpool restrictions lifted
660	lane restrictions lifted
661	use of hard shoulder allowed
662	normal lane regulations restored
663	all roadways cleared
664	roadway closed
665	both directions closed
666	intermittent short term closures
671	bus lane available for carpools (with at least Q occupants)
672	message cancelled
675	(Q) salting vehicles
678	heavy vehicle lane closed
679	heavy vehicle lane blocked
680	reopened for through traffic
681	(Q) snowplows
701	(Q sets of) roadworks
702	(Q sets of) major roadworks
703	(Q sets of) maintenance work
704	(Q sections of) resurfacing work
705	(Q sets of) central reservation work
706	(Q sets of) road marking work
707	bridge maintenance work (at Q bridges)
708	(Q sets of) temporary traffic lights
709	(Q sections of) blasting work
710	(Q sets of) roadworks. Stationary traffic
711	(Q sets of) roadworks. Stationary traffic for 1 km
712	(Q sets of) roadworks. Stationary traffic for 2 km
713	(Q sets of) roadworks. Stationary traffic for 4 km
714	(Q sets of) roadworks. Stationary traffic for 6 km
715	(Q sets of) roadworks. Stationary traffic for 10 km
716	(Q sets of) roadworks. Danger of stationary traffic
717	(Q sets of) roadworks. Queuing traffic
718	(Q sets of) roadworks. Queuing traffic for 1 km
719	(Q sets of) roadworks. Queuing traffic for 2 km
720	(Q sets of) roadworks. Queuing traffic for 4 km

Code	Description
721	(Q sets of) roadworks. Queuing traffic for 6 km
722	(Q sets of) roadworks. Queuing traffic for 10 km
723	(Q sets of) roadworks. Danger of queuing traffic
724	(Q sets of) roadworks. Slow traffic
725	(Q sets of) roadworks. Slow traffic for 1 km
726	(Q sets of) roadworks. Slow traffic for 2 km
727	(Q sets of) roadworks. Slow traffic for 4 km
728	(Q sets of) roadworks. Slow traffic for 6 km
729	(Q sets of) roadworks. Slow traffic for 10 km
730	(Q sets of) roadworks. Slow traffic expected
731	(Q sets of) roadworks. Heavy traffic
732	(Q sets of) roadworks. Heavy traffic expected
733	(Q sets of) roadworks. Traffic flowing freely
734	(Q sets of) roadworks. Traffic building up
735	closed due to (Q sets of) roadworks
736	(Q sets of) roadworks. Right lane closed
737	(Q sets of) roadworks. Centre lane closed
738	(Q sets of) roadworks. Left lane closed
739	(Q sets of) roadworks. Hard shoulder closed
740	(Q sets of) roadworks. Two lanes closed
741	(Q sets of) roadworks. Three lanes closed
742	(Q sets of) roadworks. Single alternate line traffic
743	roadworks. roadway reduced (from Q lanes) to one lane
744	roadworks. roadway reduced (from Q lanes) to two lanes
745	roadworks. roadway reduced (from Q lanes) to three lanes
746	(Q sets of) roadworks. Contraflow
747	roadworks. Delays (Q)
748	roadworks. Delays (Q) expected
749	roadworks. Long delays (Q)
750	(Q sections of) resurfacing work. Stationary traffic
751	(Q sections of) resurfacing work. Stationary traffic for 1 km
752	(Q sections of) resurfacing work. Stationary traffic for 2 km
753	(Q sections of) resurfacing work. Stationary traffic for 4 km
754	(Q sections of) resurfacing work. Stationary traffic for 6 km
755	(Q sections of) resurfacing work. Stationary traffic for 10 km
756	(Q sections of) resurfacing work. Danger of stationary traffic
757	(Q sections of) resurfacing work. Queuing traffic
758	(Q sections of) resurfacing work. Queuing traffic for 1 km
759	(Q sections of) resurfacing work. Queuing traffic for 2 km
760	(Q sections of) resurfacing work. Queuing traffic for 4 km
761	(Q sections of) resurfacing work. Queuing traffic for 6 km
762	(Q sections of) resurfacing work. Queuing traffic for 10 km
763	(Q sections of) resurfacing work. Danger of queuing traffic
764	(Q sections of) resurfacing work. Slow traffic
765	(Q sections of) resurfacing work. Slow traffic for 1 km

Code	Description
766	(Q sections of) resurfacing work. Slow traffic for 2 km
767	(Q sections of) resurfacing work. Slow traffic for 4 km
768	(Q sections of) resurfacing work. Slow traffic for 6 km
769	(Q sections of) resurfacing work. Slow traffic for 10 km
770	(Q sections of) resurfacing work. Slow traffic expected
771	(Q sections of) resurfacing work. Heavy traffic
772	(Q sections of) resurfacing work. Heavy traffic expected
773	(Q sections of) resurfacing work. Traffic flowing freely
774	(Q sections of) resurfacing work. Traffic building up
775	(Q sections of) resurfacing work. Single alternate line traffic
776	resurfacing work. roadway reduced (from Q lanes) to one lane
777	resurfacing work. roadway reduced (from Q lanes) to two lanes
778	resurfacing work. roadway reduced (from Q lanes) to three lanes
779	(Q sections of) resurfacing work. Contraflow
780	resurfacing work. Delays (Q)
781	resurfacing work. Delays (Q) expected
782	resurfacing work. Long delays (Q)
783	(Q sets of) road marking work. Stationary traffic
784	(Q sets of) road marking work. Danger of stationary traffic
785	(Q sets of) road marking work. Queuing traffic
786	(Q sets of) road marking work. Danger of queuing traffic
787	(Q sets of) road marking work. Slow traffic
788	(Q sets of) road marking work. Slow traffic expected
789	(Q sets of) road marking work. Heavy traffic
790	(Q sets of) road marking work. Heavy traffic expected
791	(Q sets of) road marking work. Traffic flowing freely
792	(Q sets of) road marking work. Traffic building up
793	(Q sets of) road marking work. Right lane closed
794	(Q sets of) road marking work. Centre lane closed
795	(Q sets of) road marking work. Left lane closed
796	(Q sets of) road marking work. Hard shoulder closed
797	(Q sets of) road marking work. Two lanes closed
798	(Q sets of) road marking work. Three lanes closed
799	closed for bridge demolition work (at Q bridges)
800	roadworks cleared
801	message cancelled
802	(Q sets of) long-term roadworks
803	(Q sets of) construction work
804	(Q sets of) slow moving maintenance vehicles
805	bridge demolition work (at Q bridges)
806	(Q sets of) water main work
807	(Q sets of) gas main work
808	(Q sets of) work on buried cables
809	(Q sets of) work on buried services
810	new roadworks layout

Code	Description
811	new road layout
812	(Q sets of) roadworks. Stationary traffic for 3 km
813	(Q sets of) roadworks. Queuing traffic for 3 km
814	(Q sets of) roadworks. Slow traffic for 3 km
815	(Q sets of) roadworks during the day time
816	(Q sets of) roadworks during off-peak periods
817	(Q sets of) roadworks during the night
818	(Q sections of) resurfacing work. Stationary traffic for 3 km
819	(Q sections of) resurfacing work. Queuing traffic for 3 km
820	(Q sections of) resurfacing work. Slow traffic for 3 km
821	(Q sets of) resurfacing work during the day time
822	(Q sets of) resurfacing work during off-peak periods
823	(Q sets of) resurfacing work during the night
824	(Q sets of) road marking work. Danger
825	(Q sets of) slow moving maintenance vehicles. Stationary traffic
826	(Q sets of) slow moving maintenance vehicles. Danger of stationary traffic
827	(Q sets of) slow moving maintenance vehicles. Queuing traffic
828	(Q sets of) slow moving maintenance vehicles. Danger of queuing traffic
829	(Q sets of) slow moving maintenance vehicles. Slow traffic
830	(Q sets of) slow moving maintenance vehicles. Slow traffic expected
831	(Q sets of) slow moving maintenance vehicles. Heavy traffic
832	(Q sets of) slow moving maintenance vehicles. Heavy traffic expected
833	(Q sets of) slow moving maintenance vehicles. Traffic flowing freely
834	(Q sets of) slow moving maintenance vehicles. Traffic building up
835	(Q sets of) slow moving maintenance vehicles. Right lane closed
836	(Q sets of) slow moving maintenance vehicles. Centre lane closed
837	(Q sets of) slow moving maintenance vehicles. Left lane closed
838	(Q sets of) slow moving maintenance vehicles. Two lanes closed
839	(Q sets of) slow moving maintenance vehicles. Three lanes closed
840	water main work. Delays (Q)
841	water main work. Delays (Q) expected
842	water main work. Long delays (Q)
843	gas main work. Delays (Q)
844	gas main work. Delays (Q) expected
845	gas main work. Long delays (Q)
846	work on buried cables. Delays (Q)
847	work on buried cables. Delays (Q) expected
848	work on buried cables. Long delays (Q)
849	work on buried services. Delays (Q)
850	work on buried services. Delays (Q) expected
851	work on buried services. Long delays (Q)
852	construction traffic merging
853	roadwork clearance in progress
854	maintenance work cleared
855	road layout unchanged

Code	Description
856	construction traffic merging. Danger
859	(Q) unlit vehicle(s) on the road
860	danger of (Q) unlit vehicle(s) on the road
901	(Q) obstruction(s) on roadway (something that does block the road or part of it)
902	(Q) obstructions on the road. Danger
916	road surface in poor condition
1026	subsidence. Danger
1027	sewer collapse. Delays (Q)
1028	sewer collapse. Delays (Q) expected
1029	sewer collapse. Long delays (Q)
1030	sewer collapse. Danger
1031	burst water main. Danger
1032	gas leak. Danger
1034	clearance work. Danger
1041	surface water hazard
1042	loose sand on road
1043	loose gravel
1054	slippery due to loose sand on roadway
1055	mud on road. Danger
1056	loose gravel. Danger
1059	road surface in poor condition. Danger
1065	driving conditions improved
1070	snow cleared
1071	road conditions forecast withdrawn
1072	message cancelled
1482	people on roadway. Danger
1601	delays (Q)
1602	delays up to 15 minutes
1603	delays up to 30 minutes
1604	delays up to one hour
1605	delays up to two hours
1606	delays of several hours
1607	delays (Q) expected
1608	long delays (Q)
1609	delays (Q) for heavy vehicles
1610	delays up to 15 minutes for heavy truck(s)
1611	delays up to 30 minutes for heavy truck(s)
1612	delays up to one hour for heavy truck(s)
1613	delays up to two hours for heavy truck(s)
1614	delays of several hours for heavy truck(s)
1615	service suspended (until Q)
1616	(Q) service withdrawn
1617	(Q) service(s) fully booked
1618	(Q) service(s) fully booked for heavy vehicles
1619	normal services resumed

Code	Description
1620	message cancelled
1621	delays up to 5 minutes
1622	delays up to 10 minutes
1623	delays up to 20 minutes
1624	delays up to 25 minutes
1625	delays up to 40 minutes
1626	delays up to 50 minutes
1627	delays up to 90 minutes
1628	delays up to three hours
1629	delays up to four hours
1630	delays up to five hours
1631	very long delays (Q)
1632	delays of uncertain duration
1680	delays (Q) have to be expected
1681	delays of several hours have to be expected
1682	closed ahead. Delays (Q) have to be expected
1683	roadworks. Delays (Q) have to be expected
1687	delays of several hours for heavy trucks have to be expected
1688	long delays have to be expected
1689	very long delays have to be expected
1690	delay forecast withdrawn
1691	message cancelled
1695	current trip time (Q)
1696	expected trip time (Q)
1700	(Q) slow moving maintenance vehicle(s)
1741	convoy causing slow traffic. Delays (Q)
1760	convoy. Delays (Q) expected
1761	convoy causing long delays (Q)
1768	Vehicles carrying hazardous materials have to stop at next safe place!
1769	hazardous load warning cleared
1851	temporary width limit (Q)
1852	temporary width limit lifted
1854	traffic regulations have been changed
1858	snowplow. Delays (Q)
1871	temporary axle load limit (Q)
1872	temporary gross weight limit (Q)
1873	temporary gross weight limit lifted
1874	temporary axle weight limit lifted
1881	temporary length limit (Q)
1882	temporary length limit lifted
1883	message cancelled
1908	switch your car radio (to Q)
1975	overtaking prohibited for heavy vehicles (over Q)
1976	overtaking prohibited
1977	allow emergency vehicles to pass in the heavy vehicle lane

Code	Description
1978	heavy vehicle lane available for all vehicles
1979	police directing traffic via the heavy vehicle lane
1980	overtaking prohibited for heavy trucks (over Q)
1981	drivers of heavy trucks (over Q) are recommended to stop at next safe place
1982	buslane closed
2006	closed for vehicles with less than three occupants (not valid for trucks)
2007	closed for vehicles with only one occupant (not valid for trucks)

Source: OpenStreetMap Foundation 2014

DATEX II

Data Element	Enumeration
Duration	Short/Medium/Long
Scale	Major/Medium/Minor
Under Traffic	True/False
Urgent Roadworks	True/False
Mobility	Mobile/Stationary
Types of Work	Bridge, Buried Cables, Buried Services, Crash Barrier, Gallery, Gantry, Gas Main Work, Interchange, Junction, Level Crossing, Lighting System, Measurement Equipment, Noise Protection, Road, Roadside Drains, Roadside Embankments, Roadside Equipment, Road Signs, Roundabout, Toll Gate, Tunnel, Water Main
Maintenance Vehicle Actions	MV Merging into Traffic, Salt and Grid Spreading, Slow Moving, Snow Clearing, Stopping to Service Equipment

Traffic Management Data Dictionary (TMDD) Enumerations

Data Element	Enumeration
Event Category	Planned (Incident/Construction/Event) Current
Event Effective Period Qualifier	Morning, Afternoon, Evening, Night, Day Time, Off-Peak Periods, At-Peak Periods, Until Further Notice, Morning Peak, Afternoon Peak, Midday Periods
Event Incident Status	Planned, Confirmed, Current, Updated, Cancelled, Ended, Postponed, Reopened
Event Severity	Major, Minor
Event Timeline Schedule Days of the Week	Sunday – Saturday
Event Timeline Schedule Times	HH (0-23)MM(0-59)
Data Link Restrictions	Speed Limit Advisory, Speed Limit, Speed Limit Truck, Restriction Length, Restriction Height, Restriction Width, Restriction Weight, Restriction Weight Axle, Restriction Axle Count
Road Weather	Wind Direction, Wind Speed, Wind Gust Speed, Air Temperature, Dew Point, Temperature, Max Temperature, Min Temperature, Relative Humidity, Atmospheric Pressure, Percip-Rate, Snowfall Accum Rate, Visibility, UV-Index
Event Times	Sequence Time, Start Time, Alternate Start Time, Alternate End Time, Expected Start Time, Expected End Time, Recurrent Times, Planned Event Continuous Flag
Event Type (ITIS Codes)	Closures, Roadwork, Alternate Route, Incident Response Equipment
Event Location	Area, Landmark, Link or Points, Geocoordinates

International Traveler Information System (ITIS) (SAE J2540)

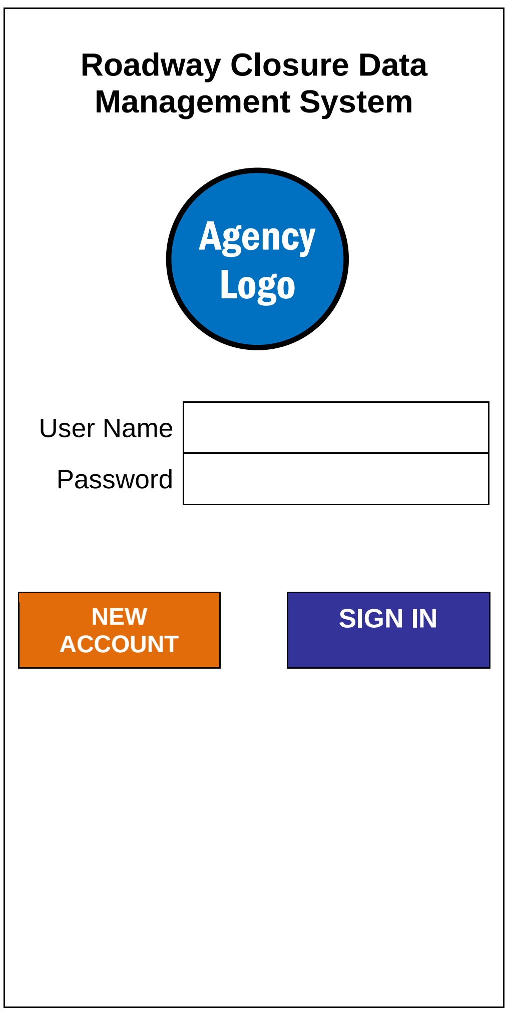
Data Element	Enumeration
Alternate Route	Detour Where Possible, No Detour Available, Follow Signs. Follow Detour Signs, Detour in Operation, Follow Local Detour, Compulsory Detour, Consider Alternate Route
Closures	Closed to Traffic/Open to Traffic, Closed/Open, Closed Ahead, Closed Intermittently, Closed for Repairs, Closed for the Season, Blocked/Reopen to Traffic, Blocked Ahead, Reduced to One Lane, Reduced to Two Lanes, Reduced to Three Lanes, Collapse Out, Clearing, Cleared from Road
Incidence Response Equipment	Dozer Or Plow, Tractor, Construction Vehicle, Heavy Tow, Light Tow, Flatbed Tow, Mobile Crane, Snow Plow, Steam Roller, White Lining Vehicle, Road Grader, Snow Blower, Rotary Snow Blower
Incident Response Status	Initial Response, Follow-up Response, Confirmed Report, Unconfirmed Report, Clearance Work in Progress, Event Cleared, Traffic Clearing, Incident Closed
Mobile Situation	Slow Moving Maintenance Vehicles, Snow Plows, Winter Maintenance Vehicles
Types of Work	Road Construction, Major Road Construction, Long Term Road, Construction, Paving Operations, Work in the Median, Road Reconstruction, Opposing Traffic, Narrow Lanes, Construction Traffic, Merging, Single Line Traffic Alternating Directions, Road Maintenance Operations, Road Marking Operations, Road Widening, Cracks, Crack Remove, Bumps, Drop Off, Storm Drain, Maintenance Operations, Constructions, Demolition Work, Seismic Retrofit, Overgrown Trees, Grass, Shrubs, Blasting, Avalanche Control, Water Main Work, Gas Main Work, Work on Underground Cables, Work on Underground Services, New Road Construction Layout, New Road Layout, Temporary Lane Markings, Temporary Traffic Lights, Emergency Maintenance, Utility Types

APPENDIX B: WORK ZONE DATA COLLECTION TOOL

To close the gap between existing data sources and the data required for high-priority work zone use cases, this project developed a series of sketches that envision an easy-to-use mobile or web-based lane closure data collection tool.

This appendix presents the preliminary set of data entry screens and related user interface details. The sequence of the screens demonstrates the sequence that would typically be followed by a new user who is managing a lane closure.

Recognizing the agency resource constraints identified through this project's surveys and interviews and affirmed by the project's technical advisory committee (TAC), the sketches are built around the idea that most closures will need to be self-reported by contractors, maintenance crews, utility crews, etc. Thus, the proposed tool anticipates a carrot-and-stick business model that would require self-reporting of closures while also generating information that is useful to contractors' crew chiefs and managers.



1. Home Screen: New User

The main login screen for the app/website.

2. User Profile Screen

User Profile

First Name	Jane
Middle Initial	Q
Last Name	Doe
Job Role	Contractor - Foreman
Organization	Doe Construction, Inc.
Address 1	123 N Fourth Street
Address 2	Anytown
State	US
Zip	54321
Cell Phone	555-555-1111
Other Phone	555-555-2222
Email	jane@doe-builds.com
User Name	janedoe123
Password	**********
Confirm PW	**********

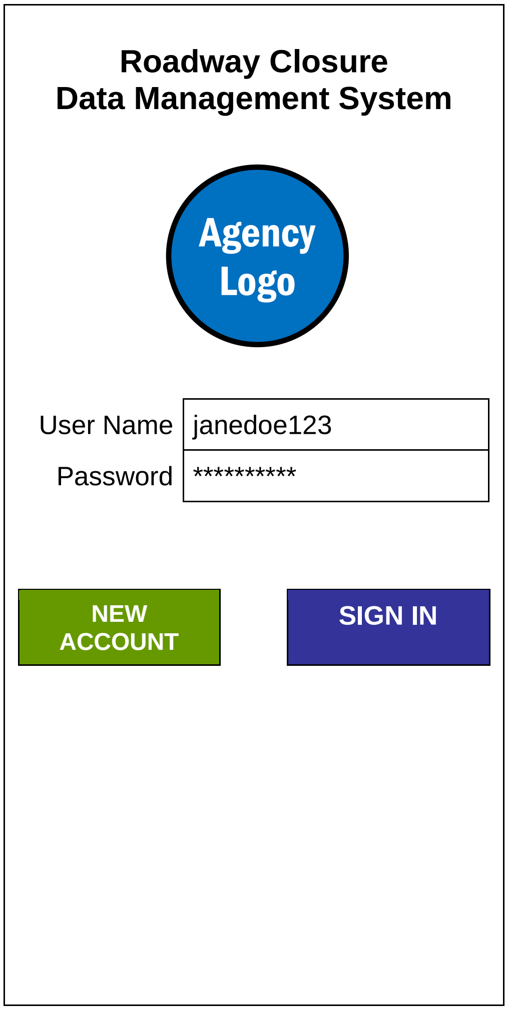
CANCEL CONTINUE

Through this screen, users establish their credentials for the app/website.

Let’s add a new user, Jane Doe, who works for Doe Construction. Let’s assume Jane’s father John Doe started the company several years ago, and Jane and her siblings are in the process of learning the business so they can take it over when John retires.

Since we know that Doe Construction is a contractor and Jane’s role is Foreman, we can customize some of the subsequent displays to suppress irrelevant choices.

Now that Jane has entered her user info, she can click the CONTINUE button to finish creating her account.

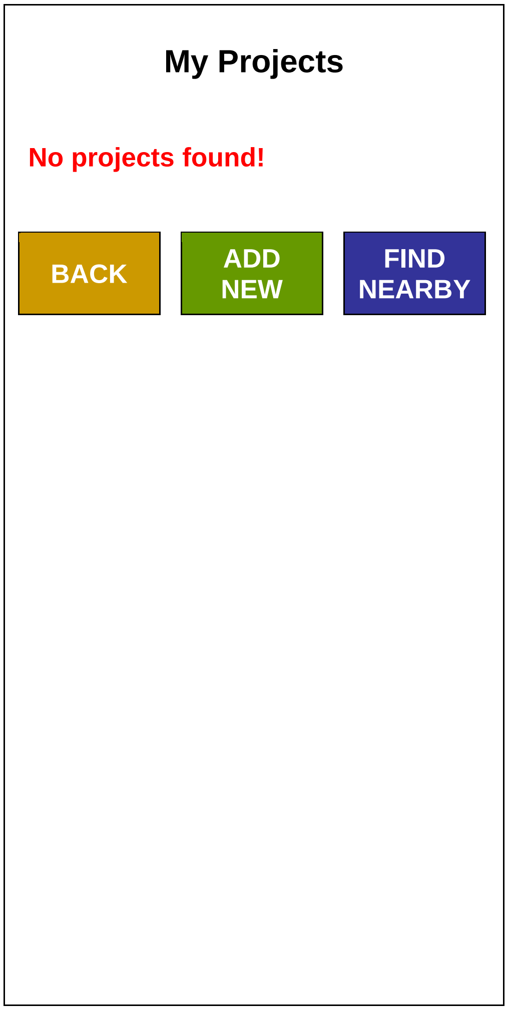


3. Home Screen: User Login

After credentialing, the user is returned to the main screen to log in.

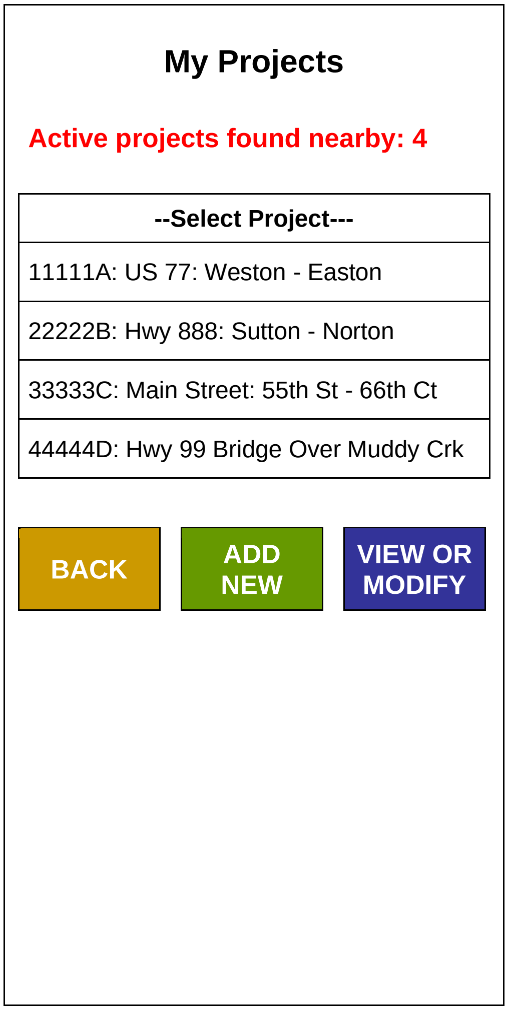
4. Select Activity Screen: Add First Project

To get started, Jane needs to select the project where the lane closure will occur.



5. My Projects Screen: Null Project Set

As a new user, there are no projects associated with Jane's account, so she taps the FIND NEARBY button.



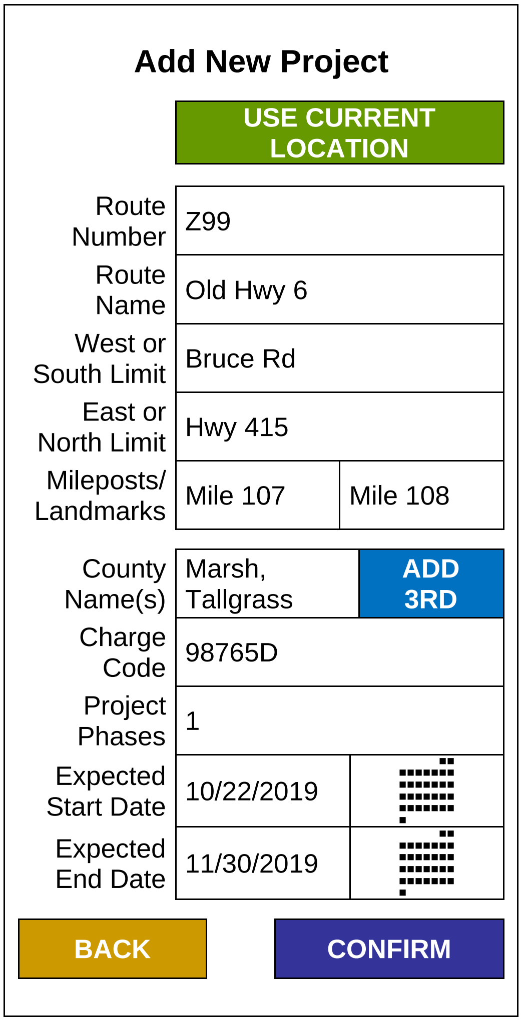
6. My Projects Screen: Autopopulated Project List

A query of data on the DOT server shows that Doe Construction was the successful bidder on four current projects located within a preset distance (perhaps 100 miles) of Jane's current location.

If Jane worked for the DOT instead of a contractor, this might show projects that are within 20 miles of the user's current location or in the district/region where the employee is based.

The project Jane is working on is on the local system, so it didn't show up on the DOT bid list. Jane taps the ADD NEW button.

7. Add New Project Screen



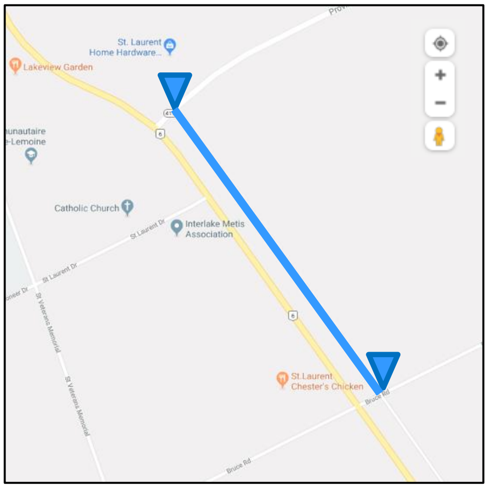
Jane taps the USE CURRENT LOCATION button, and the app finds that her truck is sitting on County Highway Z99, also known as Old Highway 6. This info is added to the Route Number and Route Name fields automatically. Then Jane manually enters the project limits.

Mileposts or landmarks can be used as descriptors or to tie the project to reference point–based GIS systems.

GPS data show that Highway Z99 runs along the county line of Marsh and Tallgrass Counties, so those associations are added automatically. Jane adds her charge code and indicates that this is a one-phase project.

By tapping the calendar icon, Jane can add the start and end dates for the project.

Confirm Project Location



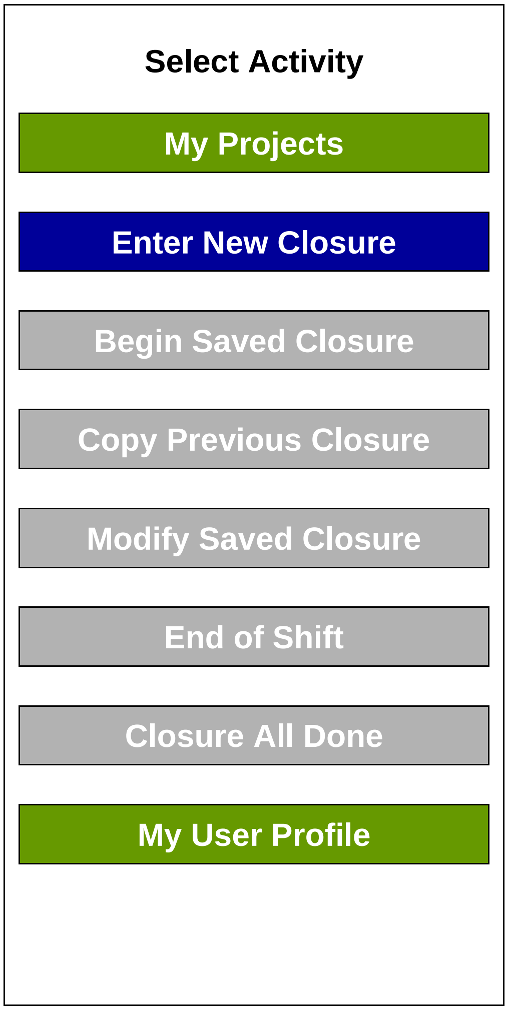
Dist: 1.21 miles (1.96 km) Legs: 1

BACK | ADD LEG | CONFIRM

8. Confirm Project Location Screen

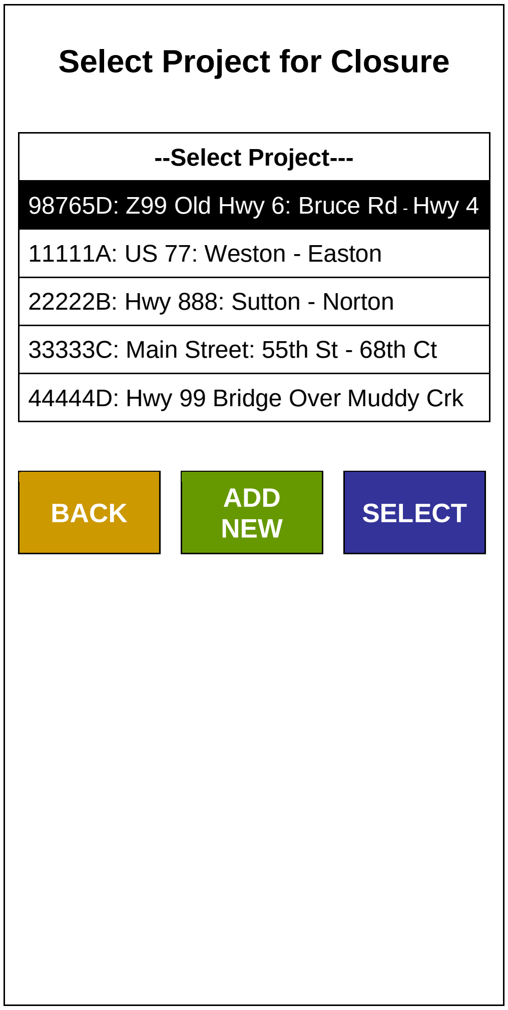
Based on the data provided on the previous screen, the app displays the project location and length data.

Jane taps CONFIRM to indicate that the information is correct.



9. Select Activity Screen: Entering First Closure

Jane can now set up a closure that will be associated with the project.



10. Select Project for Closure Screen

The Z99 project now appears on Jane's project list.

Enter New Closure

Road No: **Z99**
Road Name: **Old Hwy 6**
South Limit: **Bruce Rd**
North Limit: **Hwy 415**
Job Length: **1.21 miles (1.96 km)**
Job Legs: **2**

Dist: 0.73 miles (1.18 km) Legs: 1

BACK | ADD LEG | CONFIRM

11. Enter New Closure Screen

Jane uses the map pins to identify the location of the closure within the project limits.

Add Site Photo to Closure

Z99 Old Hwy 6: Bruce Rd – Hwy 415
Closing 0.73 of 1.21 job miles
Closing 1 of 1 job legs

Date: 06/22/2018 05:57:32PM
GPS: 42.97445 -90.03414
User: Doe, Jane Q.

SKIP PHOTOS | RETAKE PHOTO | SAVE PHOTO

SAVE AND TAKE ANOTHER

12. Add Site Photo to Closure Screen

Jane can add site photo(s) to show what is being worked on, to document that the traffic control is set up properly, etc.

Photo metadata such as the date, time, and GPS coordinates are obtained from the EXIF file associated with the photo.

13. Enter Closure Details Screen

Enter Closure Details

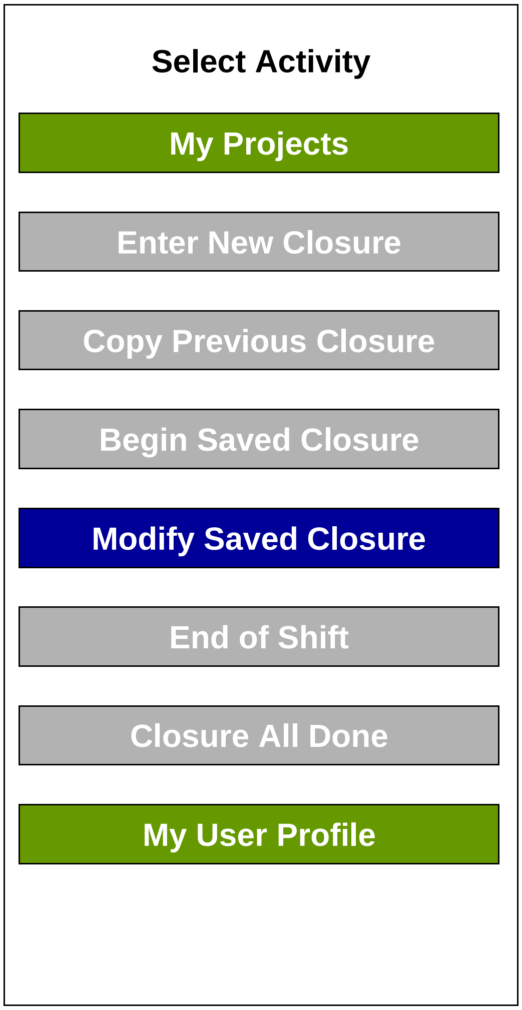
Z99 Old Hwy 6: Bruce Rd – Hwy 415
Closing 0.73 of 1.21 job miles
Closing 1 of 1 job legs

Affected Directions
☑ to NW ☐ to NE
☑ to SE ☐ to SW

BACK | SAVE & STOP | CONFIRM & CONT

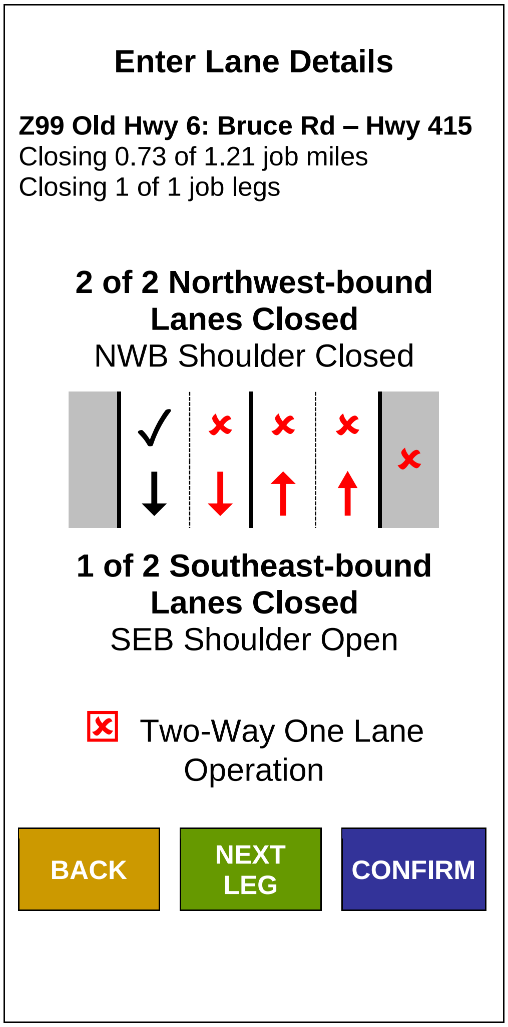
Based on the map data, the system knows that Z99 runs on a northwest-southeast alignment. Jane clicks the two checkboxes to indicate that both directions will be impacted by the closure.

Jane is ready to add the closure timing information but needs to take a phone call, so she taps the SAVE & STOP button.



14. Select Activity Screen: Modifying a Saved Closure

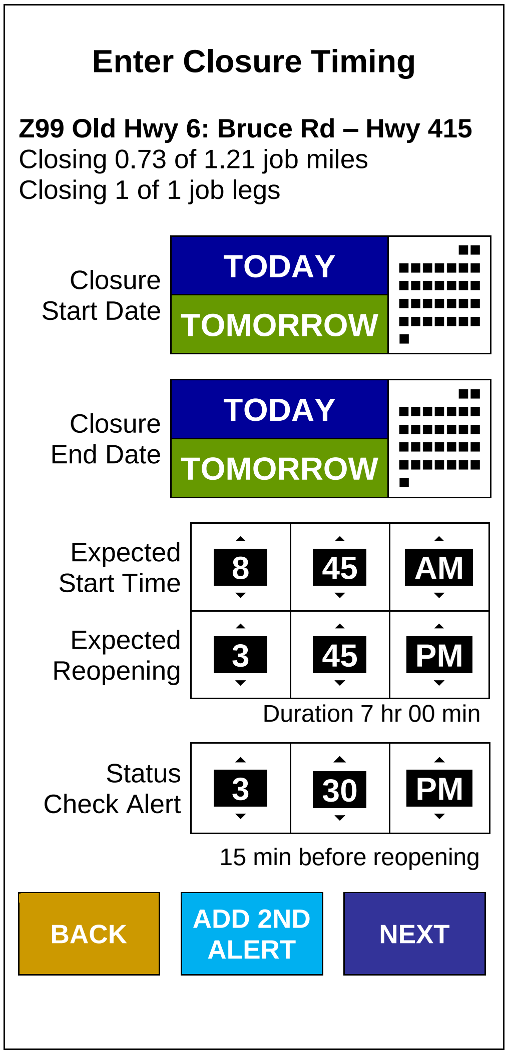
After taking the call, Jane clicks the MODIFY SAVED CLOSURE button to finish setting up the closure.



15. Enter Lane Details Screen

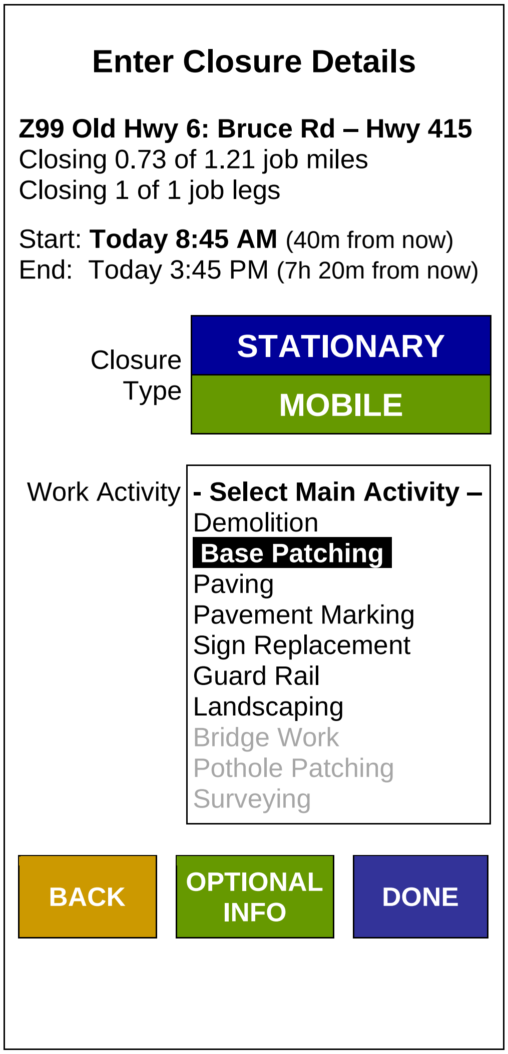
The system is tied to a database with lane configuration data. Jane taps the appropriate icons to indicate that the two northwest-bound lanes, the northwest-bound shoulder, and one southwest-bound lane will be closed and that there will be two-way one-lane operation during the closure.

If the site had not been in the lane configuration database, Jane would have needed to select the lane configuration from a menu.



16. Enter Closure Timing Screen

Next, Jane tells the system when the closure will occur and asks it to send her an alert 15 minutes before the scheduled end time.

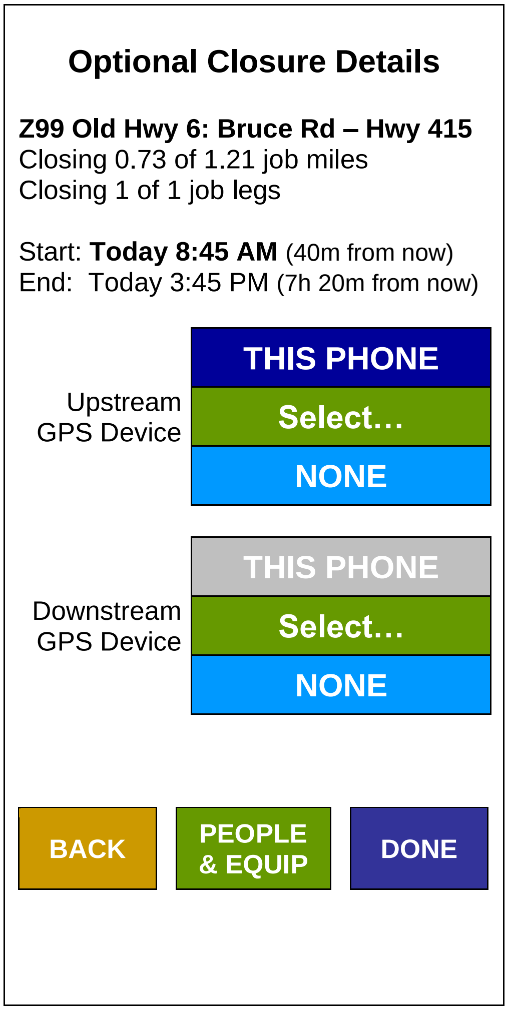


17. Enter Closure Details Screen

This screen gathers information about the characteristics of the work currently underway. This is the last mandatory data entry screen.

Jane indicates that this closure will be STATIONARY and the work activity will be BASE PATCHING.

Some of the work types are greyed out because the DOT database indicates that Doe Construction does not perform bridge work or minor maintenance.



18. Optional Closure Details Screen

Optionally, Jane can associate GPS devices with the upstream and downstream ends of the closure. These might be phones, trucks, iCones, smart arrowboards, etc.

People & Equipment

Z99 Old Hwy 6: Bruce Rd – Hwy 415
Closing 0.73 of 1.21 job miles
Closing 1 of 1 job legs

Start: **Today 8:45 AM** (40m from now)
End: Today 3:45 PM (7h 20m from now)

People

Doe Construction – Crew #1
- ☑ Barrett-Brown, Elizabeth
- ☐ Clemens, Samuel “Mark”
- ☑ Doe, Jane Q. (foreman)
- ☑ Tolstoy, Leon

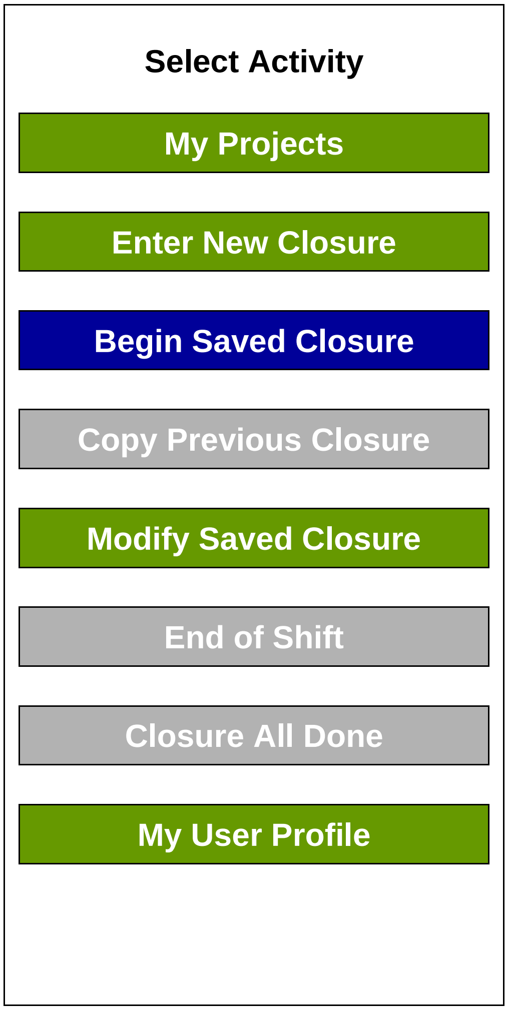
Doe Construction – Crew #2
- ☐ Douglas, Frederick
- ☐ Eliot, George (foreman)
- ☐ Whitman, Walter

Equip
- ☐ Backhoe #205
- ☑ Excavator #251
- ☑ Truck #129
- ☐ Truck #142
- ☑ Paver #301
- ☐ Roller-Compactor #515
- ☑ Roller-Compactor #519

BACK **DONE**

19. People & Equipment Screen

Doe Construction uses this optional screen to track how well the company’s people and equipment are being utilized. The company uses these data to find opportunities to reduce costs and might also use the data to determine when to invest in additional construction equipment.



20. Select Activity Screen: Starting the Physical Closure

All of the closure info is entered and ready for work to begin.

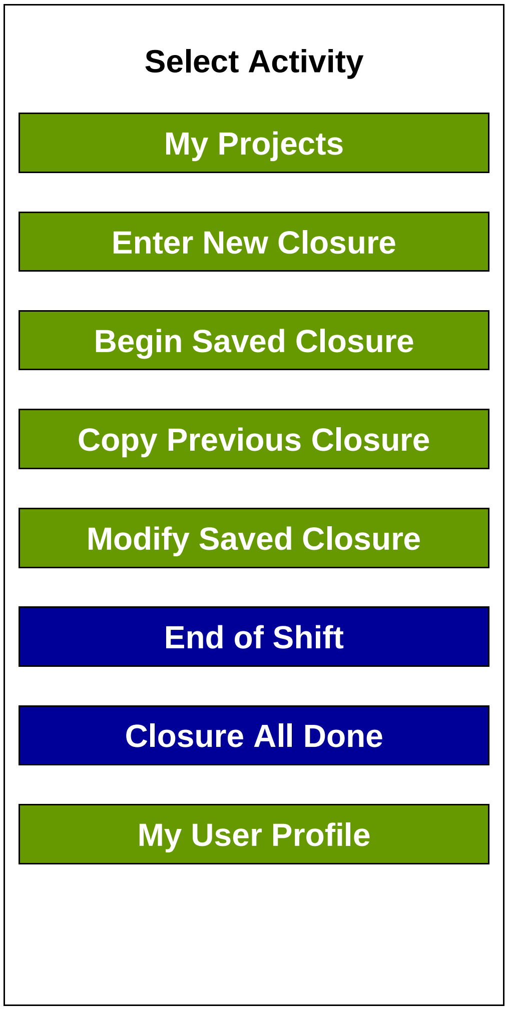
21. Scheduled Closure Alert

The closure is scheduled to begin at 8:45 a.m.

At 8:30 a.m., the system generates an alert to remind Jane that her project is about to begin. Jane can start the closure or snooze the alert if the crew is not ready.

The status information is automatically transmitted to the DOT traffic management center.

22. Select Activity Screen: Initiating a Personnel Change



At lunch time, Jane needs to go to another jobsite, so she taps the END OF SHIFT button to change the personnel associated with this closure.

Change People & Equipment

Z99 Old Hwy 6: Bruce Rd – Hwy 415
Closing 0.73 of 1.21 job miles
Closing 1 of 1 job legs

Start: Today 8:45 AM (3 h 30m ago)
End: **Today 3:45 PM (2h 30m from now)**

People

Doe Construction – Crew #1
- ☑ Barrett-Brown, Elizabeth
- ☐ Clemens, Samuel "Mark"
- ☐ Doe, Jane Q. (foreman)
- ☑ Tolstoy, Leon

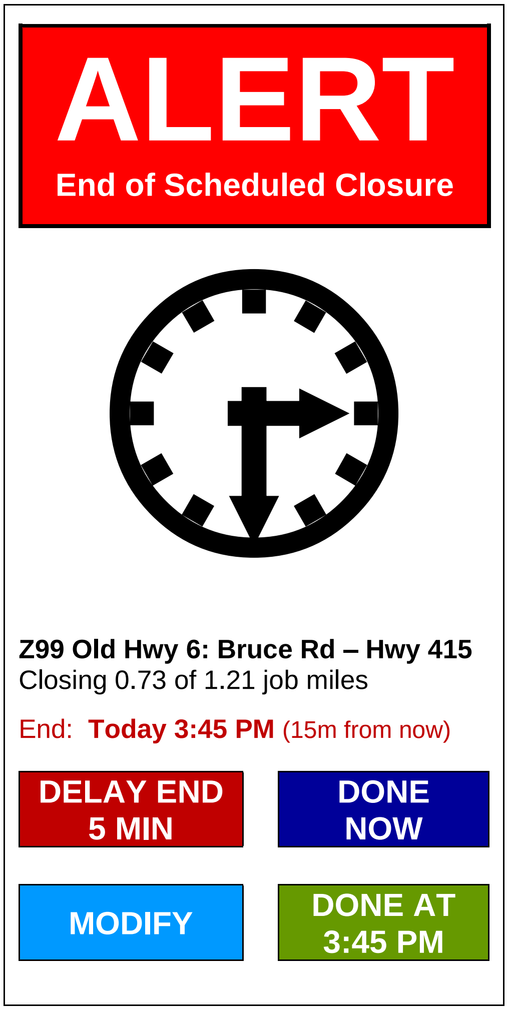
Doe Construction – Crew #2
- ☐ Douglas, Frederick
- ☑ Eliot, George (foreman)
- ☐ Whitman, Walter

Equip
- ☐ Backhoe #205
- ☐ Excavator #251
- ☐ Truck #129
- ☑ Truck #142
- ☑ Paver #301
- ☑ Roller-Compactor #515
- ☑ Roller-Compactor #519

BACK **DONE**

23. Change People & Equipment

Jane can use the CHANGE PEOPLE & EQUIPMENT screen to indicate that George Eliot will be in charge of the project for the rest of the day.



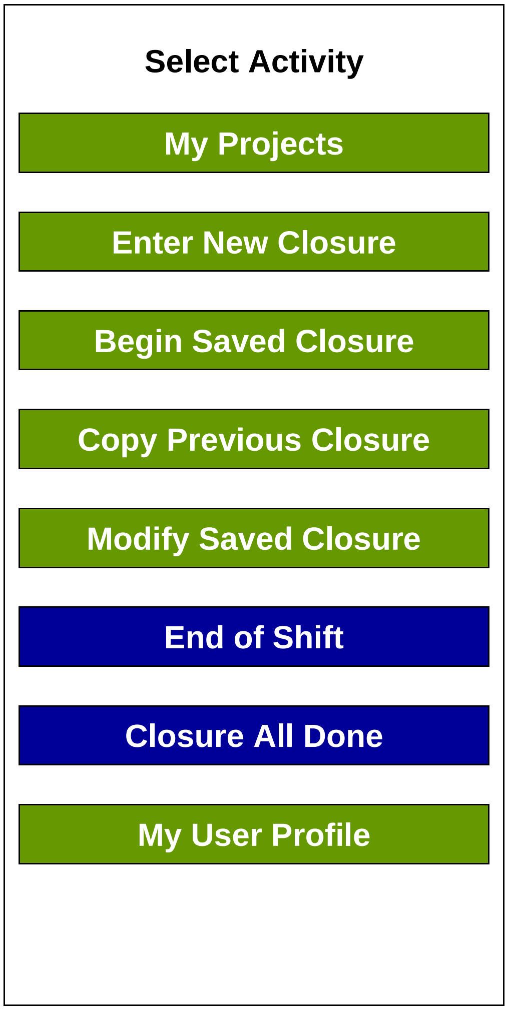
24. Alert: End of Scheduled Closure

The closure is scheduled to end at 3:45 p.m.

At 3:30 p.m., George gets a reminder that the closure is scheduled to end in a few minutes.

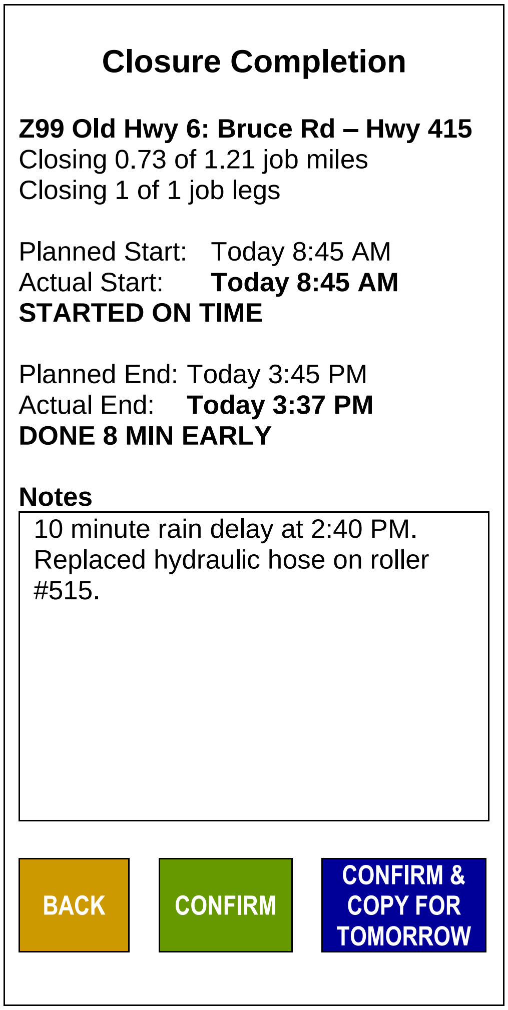
If George advances or delays the scheduled end time, the change is automatically transmitted to the DOT traffic operations center.

The crew is on track to finish by 3:45, so George taps the DONE AT [SCHEDULED TIME] button.



25. Select Activity Screen: Ready to Reopen Lanes

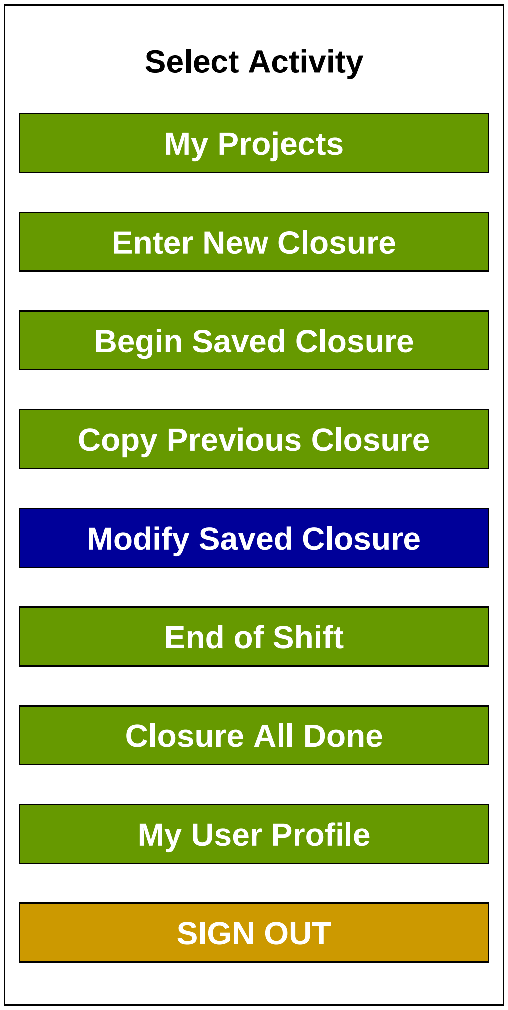
At 3:37 PM, the crew has wrapped up for the day and reopened the lanes, so George taps the CLOSURE ALL DONE button.



26. Closure Completion Confirmation Screen

The system provides a comparison of the planned and actual start and end times.

George adds some freeform notes about the day’s activities and then presses the COPY FOR TOMORROW button, which duplicates all of the location and timing information so it can be used for the next closure.



27. Select Activity Screen: Modify or Sign Out

If tomorrow's closure will be the same as today's, George can sign out. Or, if need be, she can tap the MODIFY SAVED CLOSURE button to adjust the start/stop times, the specific lanes that will be closed, etc.

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