Auditing Work Zone Mobility Using Probe Vehicle Data

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Preface

While the use of Work Zone Mobility Audits (WZMA) are not regulated by the U.S Department of Transportation (USDOT) or the Federal Highway Administration (FHWA), adoption of WZMAs can be an effective method for assessing traffic operations in work zones, and developing countermeasures to reduce congestion or queuing which are associated with increased crash risk. The concepts and strategies defined in this document are based on both research and experience from academic, public sector, and private sector personnel. The goal of this document is to assist with current strategies and inform documents including the Manual on Uniform Traffic Control Device's (MUTCD) direction on temporary traffic control zones. Chapter 5G of the MUTCD discusses the principles that can be applied to work zones. These include disrupting the movement of traffic as little as possible, routine inspection and maintenance of traffic control elements, and assuring that the traffic control elements are operating effectively. The WZMA template discussed in this document can aid with the MUTCD principles.

Objectives

This document aims to introduce the concept of a Work Zone Mobility Audit and define the involved data for completing such an audit. Agencies have a difficult time assessing the operational performance of work zones. The document will share a brief history of work zone performance measures before discussing how to use scalable crowd sourced probe vehicle data to assess the performance of work zones. The document is organized in the following sections:

- Background and State of the Practice
- Mobility Audit Process
- Case Studies and Applications

Section Summaries

Section 1 of this document covers the background of work zone performance measures including examples of data, performance measures, and performance thresholds. The section also introduces existing tools that agencies are using to assess work zone mobility

Section 2 of this document introduces the concept of a work zone mobility audit and discusses options for agencies to complete these audits. The section introduces the work zone mobility audit template that was automated by Wayne State University. The section concludes by explaining the performance measures utilized in the audit.

Section 3 of this document introduces the Work Zone Mobility Audit template and tool developed by the Wayne State University Transportation Research Group. Case studies are presented and future applications are discussed. The section concludes by discussing the organizational capabilities to use the tool.

Section 1. Background - State of the Practice and Opportunities

Introduction and Background

Practitioners with a responsibility for work zone management are frequently challenged to describe traffic operations in a comparative setting; comparing conditions before work is initiated with conditions once the work zone traffic control is installed, comparing work zone events on different days of the week, or comparing the effect of different work zone traffic control strategies. This involves a process that simplifies the complex interactions of many different vehicles over a period into a simple metric that can be easily communicated amongst practitioners, agency leadership, and used to support executive decision-making. The goal of a Work Zone Mobility Audit is to display, in a clear and concise one to two-page report, the mobility of a single work zone throughout a project period. This report will allow practitioners to self-assess their performance during or at the conclusion of a construction project.

Traffic congestion on US freeways has mobility impacts (delay), environmental impacts (vehicle emissions), and safety impacts where slowed or stopped vehicles increase crash frequency. According to the FHWA, about 24 percent of nonrecurring freeway delays are due to work zone projects; as a result, equivalent to 888 million vehicle hours and 310 million gallons of fuel were lost in 2014 (*1*). Furthermore, work zone presence resulted in approximately 96,000 crashes on US roadways, which was an increase of 42 percent from approximately 68,000 work zone crashes in 2013 (*1*). US highways are aging, and agencies are beginning to invest more resources for the maintenance and enhancement of roads, which means that more construction and repair projects will be necessary in the near future; in addition, traffic congestion is increasing on US highways and the supply, or number of road-miles, will not match the growth in demand. Considering current and future work zone safety and mobility issues, the Moving Ahead for Progress in the 21st Century Act (MAP-21) called for all transportation agencies to establish a performance- and outcome-based approach to monitor work zone impacts; consequently, agencies have invested their resources in high impact work zone projects to reduce traffic congestion, increase system reliability, and also improve traffic safety (2). According to MAP-21, performance management will lead to efficient investment of Federal transportation funds by emphasizing national transportation goals. It will also escalate the accountability and transparency of the Federal-aid Highway program and improve project decision-making.

According to the FHWA final rule, 23 CFR part 630 subpart J on work zone safety and mobility (*3*), policy development to investigate safety and mobility impacts is requested by all state transportation agencies as early as possible in the project development process. This rule also allows agencies to design and implement different procedures and policies to find a solution for the probable impacts of their significant projects while complying with the mentioned rule. In compliance with this rule, numerous researchers have investigated effective practices in work zone assessment, data collection, and performance measurement (*4,5,6*). These reports describe possible work zone performance measures based on available work zone mobility data.

In the past, collecting work zone mobility data was done using manual labor-intensive data collection methods which typically involved personnel recording speed and queue length during preselected hours at work zone locations. Further developments in data collection technology introduced automated systems to collect mobility data. License plate recognition systems have been used to collect travel times of vehicles through work zones (*7*). Researchers at Texas A&M University developed an approach using GPS devices to monitor work zone mobility (*8*). Using roof-mounted GPS devices, travel time runs were performed to collect travel time, delay, and queue length information to be used as key mobility-based performance measures. Researchers at Purdue University used Bluetooth MAC address matching to measure the travel time of vehicles through work zones, while determining the impact law enforcement presence had on speeds (*9*). With the improvement and penetration of GPS enabled cell phones and navigation tools, third-party vendors have begun providing ubiquitous crowdsourced probe vehicle data, which provides a representative speed for roadway segments for continuous time intervals, as a rich source for mobility data. Researchers at Purdue University used this crowdsourced data to collect mobility data and examine the impact of an unexpected bridge closure in southern Indiana (*10*). The Vehicle Probe Project was initiated in 2008 by the I-95 Coalition with the goal of enabling a wide-variety of operational and planning applications that involves this high quality data source (*11*). Researchers at the University of Maryland conducted a pilot project for FHWA to examine the applications of probe data in work zone mobility monitoring (*14*). The authors found that this data is enough to support work zone performance measures. In 2013, the FHWA published information on data availability and opportunity for work zone performance measures (*6*). The publication illustrates that probe vehicle data can be used to assess mobility-based performance measures such as travel time reliability, delay, and queue length.

Although the previous efforts have shown that probe vehicle data are appropriate for work zone mobility monitoring, it would be beneficial for transportation agencies to use a framework which provides a systematic approach to evaluate the mobility of work zones. Using a systematic work zone monitoring approach would enable practitioners to actively monitor work zone traffic mobility, and proactively improve work zone traffic management strategies. In addition, using this probe vehicle dataset would provide an opportunity to evaluate both temporal and spatial elements of work zone mobility. The spatial analysis of work zone mobility helps practitioners identify work zone bottlenecks and problematic segments. The temporal analysis identifies hours of a day that work zone presence causes significant negative mobility impact.

Work Zone Mobility Fundamentals

State-of-Practice Evaluation

Proper work zone management techniques are key to the success of any construction project. This is evident with the amount of time and focus on the subject in recent transportation engineering literature. The goal of most transportation projects is the safe and efficient movement of people and goods. Work zone traffic management can similarly be separated into two distinct, but correlated, categories, safety and mobility. Safety has historically been characterized using the number of crashes and mobility has historically been characterized using delay, speed, travel times, and queue length measured in the field.

The current literature is summarized in a high-level table below (Table 1).

Table 1. High Level State of the Practice Summary

Topic	Description
Federal Ruling	A 2004 FHWA rule called for the development of procedures to address work zone issues. The rule called for agencies to develop an agency-level work zone safety and mobility policy, standard processes and procedures to address those policies, and traffic management plans (TMPs) for all significant work zone projects. (*15-18*)
Traffic Management Plans	As part of the 2004 FHWA rule, TMPs were requested for significant work zones. A TMP develops a set of strategies for the management of work zones. These include traffic control, public outreach, operational strategies, and traffic incident management. (*15-18*)
Work Zone Safety Audits	In conjunction with the new ruling, Work Zone Safety Audit procedures were developed, which defined a formal safety performance examination of an existing or future road intersection by an independent audit team.(*19,20*)
Data Analysis & Performance Measures	Numerous data sources are available for the assessment of work zones and work zone performance. Safety data includes crash details, worker injuries, inspection scores, and emergency dispatches. Mobility data includes queue characteristics, delay, speed, traffic flow, and customer feedback. (*21-35*)
Work Zone Traffic Analysis & Assessment	Implementation of data analysis in work zones is also helpful. A Work Zone Traffic Analysis is the process of evaluating the impact of mobility and safety within a work zone project. Numerous analytical methods have been developed to use work zone data to make informed transportation decisions (*36,37,38*)
Probe Vehicle Data	Third-party GPS data have allowed for the unprecedented assessment of roadway mobility. These data, provided by third party vendors, have led to new real-time and historical assessment techniques. FHWA has begun to develop uniform performance measures for the characterization of roadway mobility using this data source. (*35,39-42*)
Connected Vehicle Data and Deployments	Connected Vehicle Deployments are leading to innovative data sources that may be incorporated into Work Zone Safety Analysis. Three pilot deployments sponsored by USDOT are currently beginning the deployment stages and a Connected Work Zone in Michigan has also been introduced. (*43-46*)

Work Zone Mobility Data and Performance Measurement

Mobility is typically defined as a measure of impact on the traveling public [32]. Mobility data is rapidly evolving from a manual process to an automated one. Work zone mobility and operations data sources that are currently in use include [26]:

- Manual or electronic (i.e., camera) visual inspection of acceptable travel conditions
- Manual sampling of travel times, speeds, and queue lengths
- Electronic monitoring of speeds, volumes, and lane occupancies
- Electronic monitoring of elapsed travel times via Bluetooth or other technology
- User complaints

These data sources provide the means to develop the following mobility performance measures that are currently in use [26]:

- Delay per vehicle
- Queue length
- Duration of queue
- Volume to capacity ratio
- Level-of-service
- Volume (throughput)
- % time at free-flow speed
- % work zones meeting expectations for traffic flow
- User complaints

Mobility Performance Measures can be separated into numerous categories including [32]:

- Queuing – Queuing is commonly reported as maximum queue length, however it also can be reported as average queue length, average queue duration, % of time queuing occurs, % of time queue exceeds a certain length, or % of traffic that encounters a queue [27]. Queuing is advantageous because it is easily quantifiable, easily understood, and can be measured directly, either manually or via ITS.
- Delay – Delay is commonly reported in total vehicle hours of delay; however, it can also be quantified in average delay per vehicle, maximum per vehicle delay, or percentage of vehicles experiencing a given level of delay. Delay is correlated with queuing, and both could be considered when selecting performance measures [32].
- Reliability – Travel time reliability is a measure that considers the predictability of travel time on a roadway [29]. Recently, FHWA has released performance measure rules that incorporate reliability [42]. This will be discussed later in the report.
- User Perspective – User perspective is how the traveler views the performance of a work zone. User perspective can be measured using customer surveys or by measuring the number of complaints. Typically, if queuing and delay are minimized, the user perspective will stay positive.

Agencies have begun to use these mobility performance measures to create performance goals during construction projects. Table 2 shows a summary of documents and research from State DOTs labeling the preferred work zone mobility performance measures as well as example performance thresholds that are being implemented. It is important to understand the performance of work zone mobility using performance metrics such as delay, queue, or speed reductions, but it is even more important to clearly define a failing work zone using performance thresholds. The table below is not comprehensive but could give the reader some ideas for commonly used thresholds.

Table 2. State DOT Performance Measures and Example Thresholds

	Queue Length	Travel Time	Delay	Queue	Congestion	Volume	Speed	LOS	Reliability	V/C Ratio	Travel Time	Queue Duration	Capacity	Example Performance Thresholds	Source
Alabama	x	x												• Maintain zero queue	[54]
Alaska			x	x										• Maintain user delay to pre-construction levels (as practical)	[55]
Arizona	x		x											• Minimize delay and queue length	[56]
Arkansas					x										[57]
California			x											• 0 minute delay for most freeway projects • < 15 minute delay when an aggressive TMP is used • < 20 minute delay for flagging operations • < 30 minute delay for complex projects	[25]
Colorado	x		x												[58]
Connecticut	x		x			x	x								[59]
Delaware	x		x								x				[60]
Georgia	x		x								x			• < 30 minute delay or the delay threshold set by department head (lesser value used)	[61]
Hawaii			x		x										[62]
Idaho			x				x							• >=45 mph operating speed	[63]
Illinois	x		x											• 1.5 miles above non-work zone queues • 5 min/mile of project length with maximum of 30 minutes above the normal recurring daily traffic	[64]
Indiana	x		x		x			x						• =< 10 mph speed reduction • Queues cannot be present > 6 continuous hours or 12 total hours per day • 0.5 mile < queues < 1.0 miles in 4 continuous hours. • 1 mile < queues < 1.5 miles in 2 continuous hours. • queues > 1.5 miles not allowed.1.0 to 1.5 miles with delay for 2 hours or less • > 1.5 mile (in-interstate). congestion vsf>=0.7	[26,65,66]
Iowa			x	x					x					• < 10 minutes delay • various measure for queueing	[67]
Kansas			x											• < 30 minutes delay • < 30 minutes of detour additional travel time.	[68]
Kentucky	x		x											• < 3 mile of queue length • Detour exceeds 10 miles	[66,69]
Louisiana			x												[70]
Maine			x											• < 5 minutes average delay per vehicle	[71]
Maryland	x		x					x		x	x			• < 1.5 mile queues for 2+ consecutive hours or < 2 mile queue • < 15 minutes for arterials	[72]
Massachusetts			x									x		• < 12 minute delay • 1 hour of queue per day	[73]
Michigan			x											• < 10 minute delay • Detour threshold > 3 miles urban or > 10 miles rural • v/c > 0.8 considered significant • LOS no worse than D, or C if the current operation is LOS A	[74,75]
Minnesota	x		x			x					x			• Delay > 15 minutes is significant • Traffic stopped for greater than 15 minutes	[76]
Mississippi				x	x		x								[77]
Missouri	x		x												[66]
Montana	x		x											• Threshold = 15 min delay for urban & 10 min delay for rural	[78]
Nevada	x		x			x								• lane closure segments are not recommended to exceed 3.75 miles. • work zone segment may not exceed 5 miles. • < 30 minutes delay • traffic stop <20 min. • 5 to 10 min delay not preferred & delay > 10 min undesirable	[79]

	Queue Length	Travel Time	Delay	Queue	Congestion	Volume	Speed	LOS	Reliability	V/C Ratio	Travel Time	Queue Duration	Capacity	Example Performance Thresholds	Source
New Hampshire	×		×			×		×						• 5 to 10 minutes delay not preferred & delay > 10 minutes undesirable. • 15 minutes delay. when 20 mph below posted speed.	[80]
New Jersey			×											• < 15 minute delay	[66]
New Mexico						×					×				[81]
North Carolina	×						×					×		• queue length below 0.75 mile is acceptable • queue length between 0.75 and 2 miles is acceptable for up to two hours, longer than 2 miles is unacceptable. • queue is defined when traffic is either stopped or slowed more than 25 mph below the posted speed limit.	[82]
North Dakota			×					×						• <15 min delay. • LOS doesn't change for more than two levels, LOS D	[83]
Ohio	×													• < 15 min delay with aggressive TMP • < 30 min delay for complex projects. • 0.75 to 1.5 mile queue for 2+ consecutive hours • queues ≥ 1.5 miles are unacceptable • no speeds less than 10 mph due to work zone	[84]
Oklahoma			×												[85]
Oregon			×											• <20 minute delay • 10 mph speed reduction	[86]
Pennsylvania			×											• < 20 minutes delay 2 hours over base condition • 15 to 20 minutes delay limited to 2 consecutive hours	[87]
Rhode Island			×												[88]
South Carolina	×		×			×						×			[89]
South Dakota			×												[90]
Tennessee	×		×			×					×			• proprietary scoring system	[91]
Texas			×	×											[92]
Utah	×		×												[66]
Vermont	×		×				×							• < 3 mile queue	[93,94]
Virginia						×	×						×		[95]
Washington			×						×		×				[96]
West Virginia							×							• < 10 mph speed reduction	[97]
Wisconsin	×		×											• < 15 minutes delay • 0.75 to 1.5 miles with 2+ consecutive hrs • queues ≥ 1.5 miles are unacceptable	[98]
Wyoming			×											• < 20 minute maximum delay	[99]

*No documents were found for Florida, Nebraska, or New York

Introduction to Crowd Sourced Probe Vehicle Data

The widespread use of navigation applications are creating a rich data source that can be used for both real-time traffic mapping and by public agencies to manage roadways. Crowdsourced probe vehicle data always provide system-wide coverage. The data are created using timestamped locations that are collected on GPS receivers in cell phones or navigation devices. While operational, these devices provide location, speed, and trajectory data of the vehicle to a GPS service provider. These data are then gathered by third-party traffic service vendors and anonymized. The traffic service providers combine multiple sources of data into representative speeds linked to specific segments of roadway. These records are then made available on the internet and can be collected by consumers using various web protocols. These cloud data have a typical temporal resolution of one minute, while the spatial resolution varies but is most often approximately 1 mile. The third-party vendors who provide these data include: INRIX, HERE, TomTom, AirSage, and others.

Most probe data is spatially defined in traffic message channels, or TMCs. Some data vendors have developed proprietary segmentation schemes to produce shorter segments, allowing for more granular traffic studies. TMC segments cover all the National Highway System (NHS) as well as most major arterials and some minor arterials nationwide. TMC codes are not defined for individual lanes [35].

States have begun using probe vehicle data to locate and understand congestion on interstates and arterials nationwide. In the past decade, states have begun creating mobility reports using these data to quantify congestion [35]. These mobility reports include work zones in their large-scale assessment, but now there is an opportunity to focus on specific events including weather, special events, and work zones.

Numerous state agencies have begun the development of custom dashboards to monitor and manage system mobility, which can also be used for work zone management. One leader of these efforts is the CATT Lab at the University of Maryland. They have developed a suite of performance management tools entitled Regional Integrated Transportation Information System (RITIS). These tools are used by agencies across the country for mobility assessment. Additionally, they have also created specific work zone dashboards that can be seen in Figure 1. Kentucky is another state who uses a real time dashboard to monitor work zone mobility. Figure 2 shows the GoKY Real-Time Traffic Information system used by the agency. Other private sector vendors, such as Iteris, have developed performance measure dashboards using third party crowdsourced probe vehicle data.

According to the I-95 Corridor Coalition's final report on data use and applications of probe vehicle data, the vision of traffic monitoring and management has recently evolved and taken a significant step forward [40].The goal of the Vehicle Probe Project was to find and enable a wide variety of operations and applications that use a high-quality data source to continuously monitor traffic without deploying and maintaining equipment in the right-of-way. Vehicle probe data provide a central source to enable traffic planning, operations, and performance measurement applications across a larger coverage area compared to other data sources which have limited geographic scope.

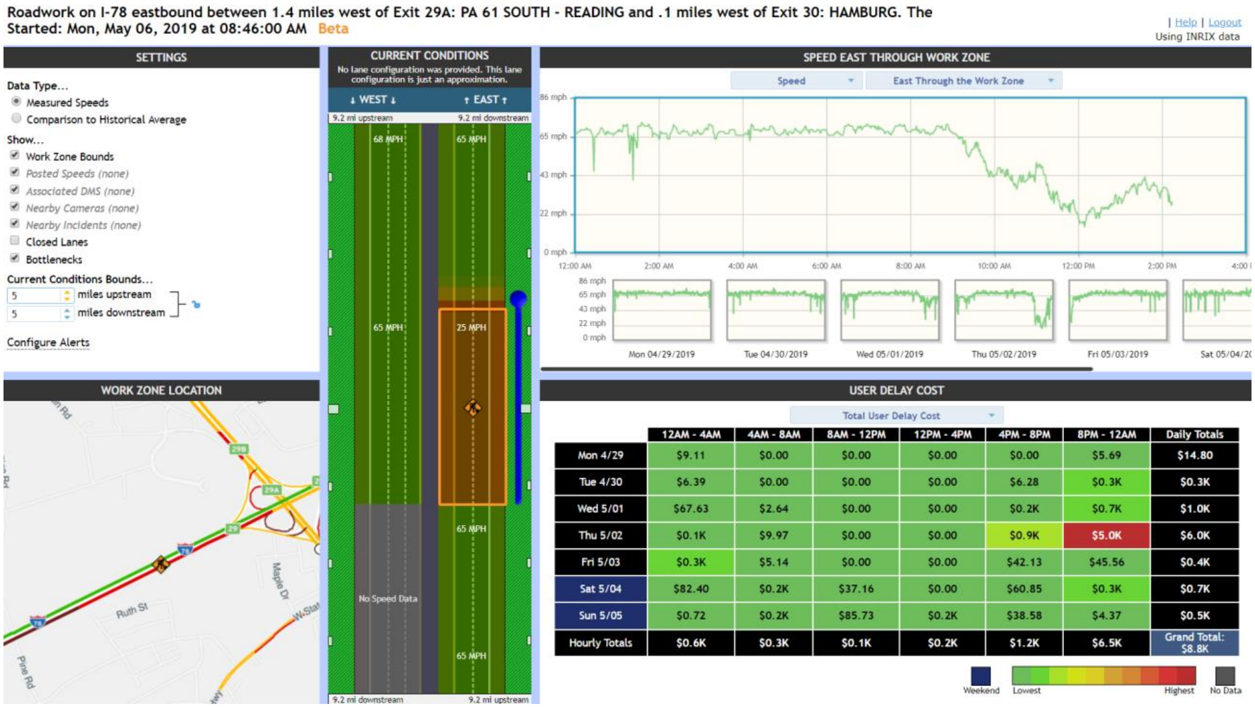


Figure 1. UMD/CATT Prototype Work Zone Performance Measure Application (Dashboard Concept) [48]

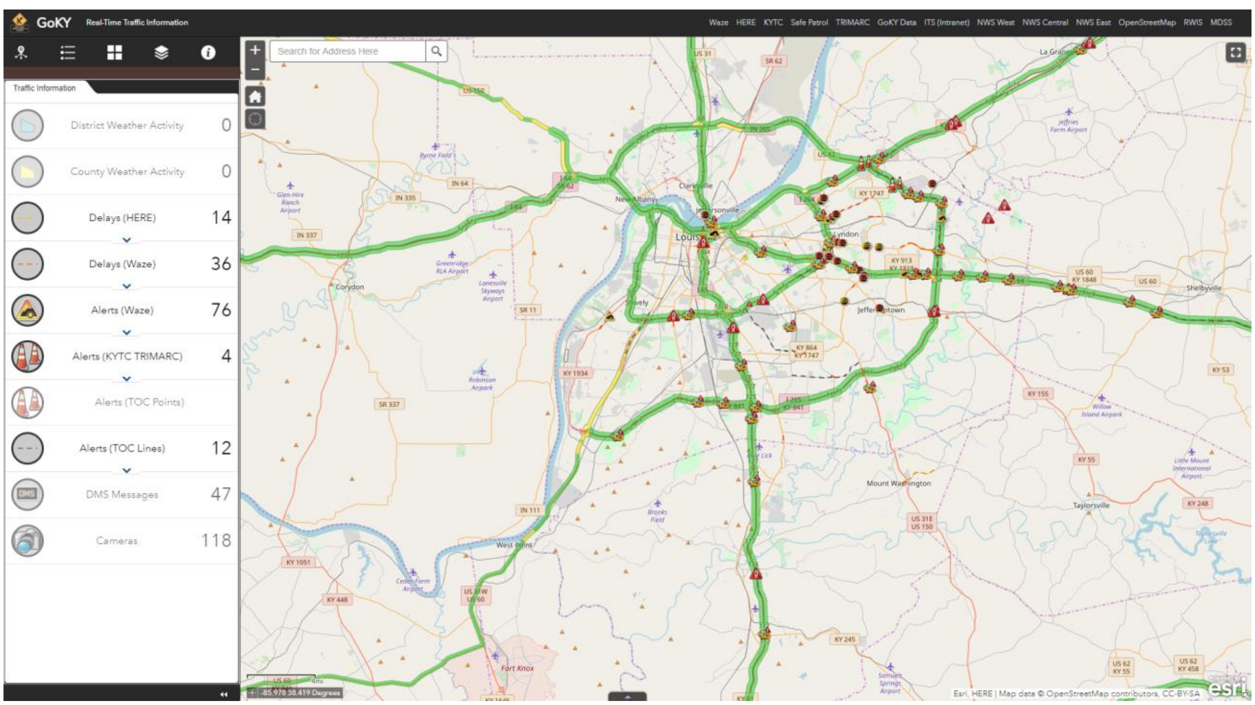


Figure 2. GoKY Real-Time Traffic Information [49]

National Performance Management Research Dataset

The National Performance Management Research Dataset (NPMRDS) is a dataset derived from vehicle/passenger probes that includes representative travel times on all mainline highway segments of the NHS. The dataset also provides specific travel times representative of freight trucks for Interstate segments nationwide. The dataset includes records that contain average travel times binned in five-minute increments for the entire data period. It does not include any imputed travel time data. The NPMRDS has been available since July 2013, and many State DOTs and Metropolitan Planning Organizations (MPOs) have been using the NPMRDS for over 3 years. The dataset is provided for the entire nation and is separated into four regions [27]. This dataset provides agencies no-cost data to use for the analysis of roadways. Additionally, third-party providers such as the CATT Lab at the University of Maryland provide analytics tools to use along with the dataset (Figure 3).

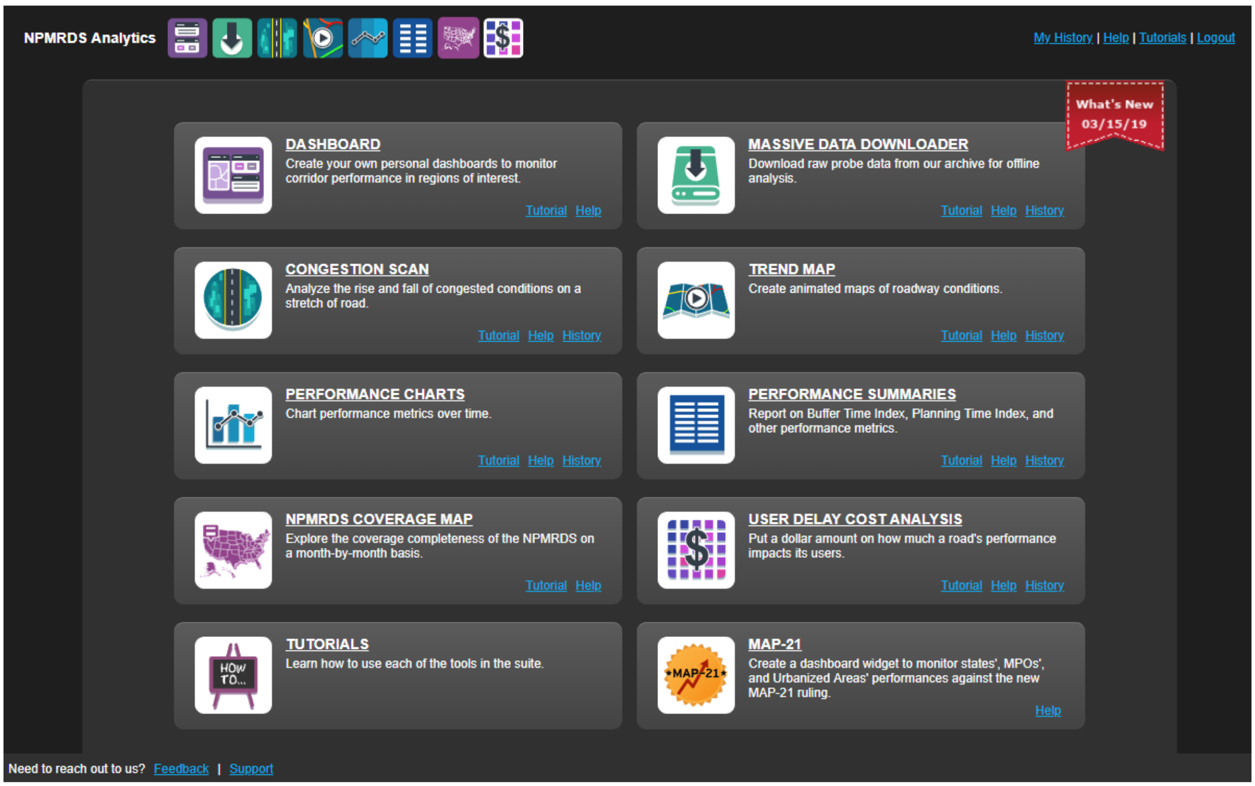


Figure 3. NPMRDS Analytics Suite [48]

National Rule

Building on MAP-21 and the Fixing America's Surface Transportation (FAST) Act, the FHWA final rulemaking report on "National Performance Management Measures" called for State DOTs and MPOs to establish a series of performance measures using probe-based mobility data [42]. The performance measures will be evaluated on the NHS to supplement the National Highway Performance Program.

The proposed performance measures incorporate travel time reliability as a key factor to characterize mobility. The proposed travel time reliability metric is the Level of Travel Time Reliability (LOTTR). It is defined at the 80^{th} percentile travel time of a segment divided by the 50^{th} percentile travel time (eq.1) [42]

$$\text{LOTTR} = \frac{\text{80th Percentile Travel Time}}{\text{50th Percentile Travel Time}} \quad \text{(Equation 1)}$$

This metric is expected for each segment of the NHS for the following time periods:

- Non-Holiday Weekend (Monday-Friday)
    - 6:00 to 10:00 AM
    - 10:00 AM to 4:00 PM
    - 4:00 to 8:00 PM
- Weekends (Saturday & Sunday)
    - 6:00 AM to 8:00 PM

The rule specifies that any missing or null travel times be replaced with typical travel times for that segment. The typical travel time is based on segment length and speed limit. State DOTs would identify the 50^{th} percentile and 80^{th} percentile travel times using a full calendar year of data for each time period. This would not differentiate between work zone and non-work zone periods. The use of the NPMRDS for these high-level metrics is promising for the future of data-driven transportation decisions. In the future, there will be opportunities to incorporate work zone management in these metrics.

Work Zone Mobility Performance Measures Importance

These performance measures are currently of interest to FHWA due to the release of the MAP-21 National Performance Management Measures (NPRM). Performance measurement is an important aspect being used to transform the Federal-aid Highway Program by providing a results-driven investment system. Expanding on the uses of these performance measure tools to incorporate work zones will provide numerous benefits to taxpayers including:

- Opportunities to assess and improve the mobility of existing and future work zones
- Designing or adjusting traffic management plans to better suit individual work zones
- Identification of flexible start times to improve work zone mobility
- Reduction in costs by avoiding physical infrastructure
- Opportunities to incentivize contractors based on performance data
- Providing implementation-ready information

Work Zone Mobility Audit Description

What is A Work Zone Mobility Audit?

A Work Zone Mobility Audit is an analysis of the mobility characteristics of a work zone using probe vehicle data. The WZMA computes mobility performance metrics using data from the year of the work zone compared to data from the year prior. These data are then analyzed to create a selection of graphics that describe the mobility through different temporal and spatial performance measures (Figure 4). The goal of a WZMA is to understand the practices and procedures that lead to poor performance traveling through a work zone, reduce queueing and congestion which can lead to crashes, and understand optimal times for workers to work on a roadway.

What is Necessary to Complete a WZMA?

Probe Vehicle Data:	• National Performance Measurement Research Dataset • Agency provided datasets: HERE, INRIX, TomTom, etc. • Other agency data: detector based
Work Zone Exposure Data:	• Project characteristics • Work zone event data • Traffic volumes
Data Storage and Analysis Tools:	• Database/server capable of storing large quantities of data • Data analysis software or proprietary dashboards

Why Perform A WZMA?

The Work Zone Mobility Audit is a useful tool in describing how and where mobility breaks down in work zones. By associating day-to-day construction notes with performance graphics, it is possible to identify effective practices for conducting work zone activities in a way that minimizes impacts on the traffic mobility. The use of these audits can also help mitigate institutional knowledge losses in instances where construction managers leave, retire, or are promoted. The spatial graphics can identify the roadway sections that experience compromised mobility resulting in increased congestion and travel times through the work zone corridor. The temporal graphics are tailored in a way that shows how a work zone affects traffic mobility at various time periods during the day.

Work Zone Traffic Mobility Performance Measures	
Delay Total Delay Delay per Vehicle Delay per VMT	**Queue** Max. Queue Length Max. Queue Duration Total Queue Duration
User Cost Passenger Vehicle Cost Commercial Vehicle Cost	**Reliability** LOTTR Buffer Index Planning Time Index
Speed Average Speed Speed Profiles	**Resiliency** Time to Recover Volume to Capacity

Figure 4. Work Zone Traffic Mobility Performance Measures

How is a WZMA Performed?

Step 1: Determine the performance measures of interest for use in your agency or district

Step 2: Acquire the probe data from a public or commercial vendor

Step 3: Compile the collected data using Excel or other preferred analysis tool

Step 4: Create appropriate graphics for quick reference

Step 5: Document and archive performance measures for future decision making

How to Implement WZMAs

Federal regulations 23 CFR 630 Subpart J calls for state highway agencies to have a policy in place for the systematic management of work zone impact on all Federal Aid Projects. New probe data sources allow for a scalable approach to document and understand issues regarding work zone mobility. The adoption of WZMAs will involve working within an agency to establish systematic performance measures and using automated performance analysis tools to turn data into information. Once the information is gathered in an easily digestible format, it can be used to identify issues and create recommendations to include in future work zone management plans. The information created can then be archived and used to both retain institutional knowledge regarding specific work zone habits and locations, and it can be used to perform longitudinal (both spatial and temporal) studies regarding work zone practices and performance. An example of the WZMA process is shown in Figure 5.

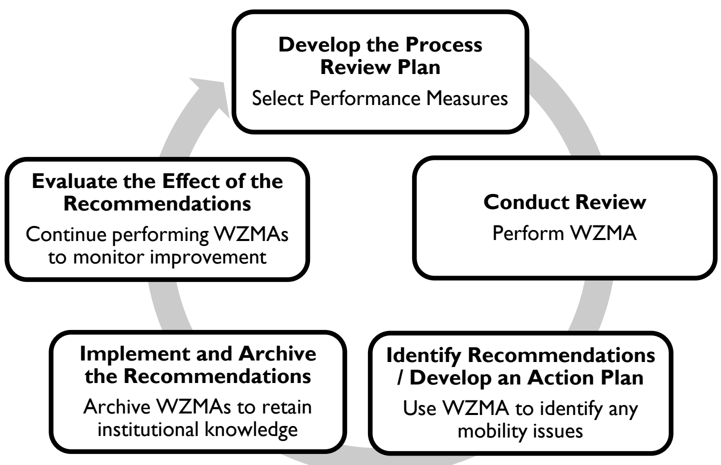


Figure 5. WZMA Process (Adopted from "Guidance for Conducting Effective Work Zone Process Reviews")

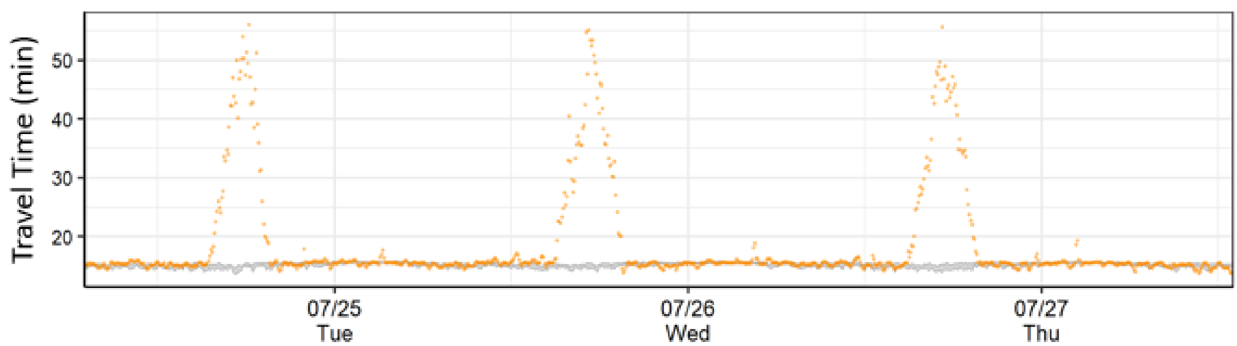
Work Zone Mobility Audit Template

The work zone mobility audit template is comprised of a series of metrics and visualizations that characterize the impact a work zone has on the mobility of a roadway. Page one (Figure 6) of the template includes general information about the work zone, a map, a scatter plot, a heatmap, and a series of cumulative distribution functions. Page two (Figure 7) of the template includes congestion profile graphics, eye graphs, and summary statistics. The approach used to quantify each of these metrics is explained below.

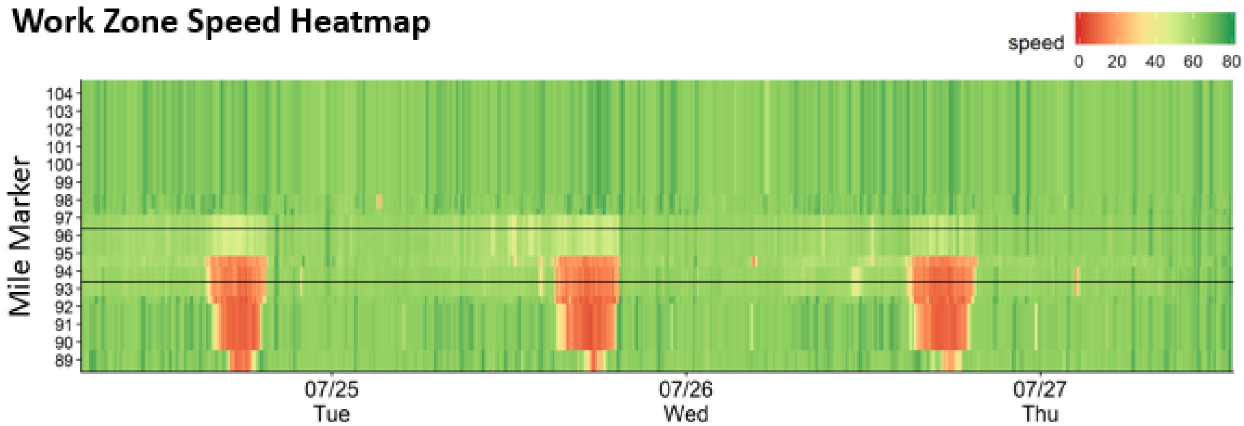
Work Zone Mobility Audit

Overview	Information
Work Zone ID	113238
County	Kent County
Roadway	I-69
Closure type	Single Lane Closure
Direction	Eastbound
Start Milemarker	93.4
End Milemarker	96.4
Workzone Start	2017-07-24 07:00
Workzone End	2017-07-27 13:00

Work Zone Travel Time vs Typical Traffic



Work Zone Speed Heatmap



Work Zone Travel Time Reliability

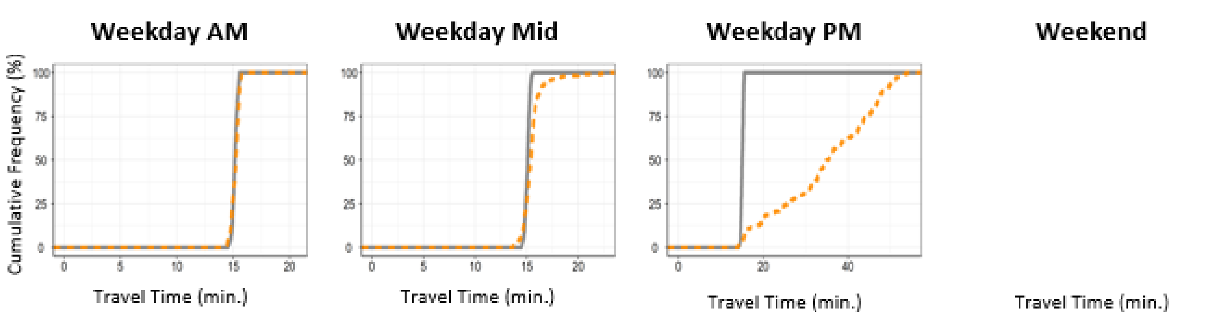
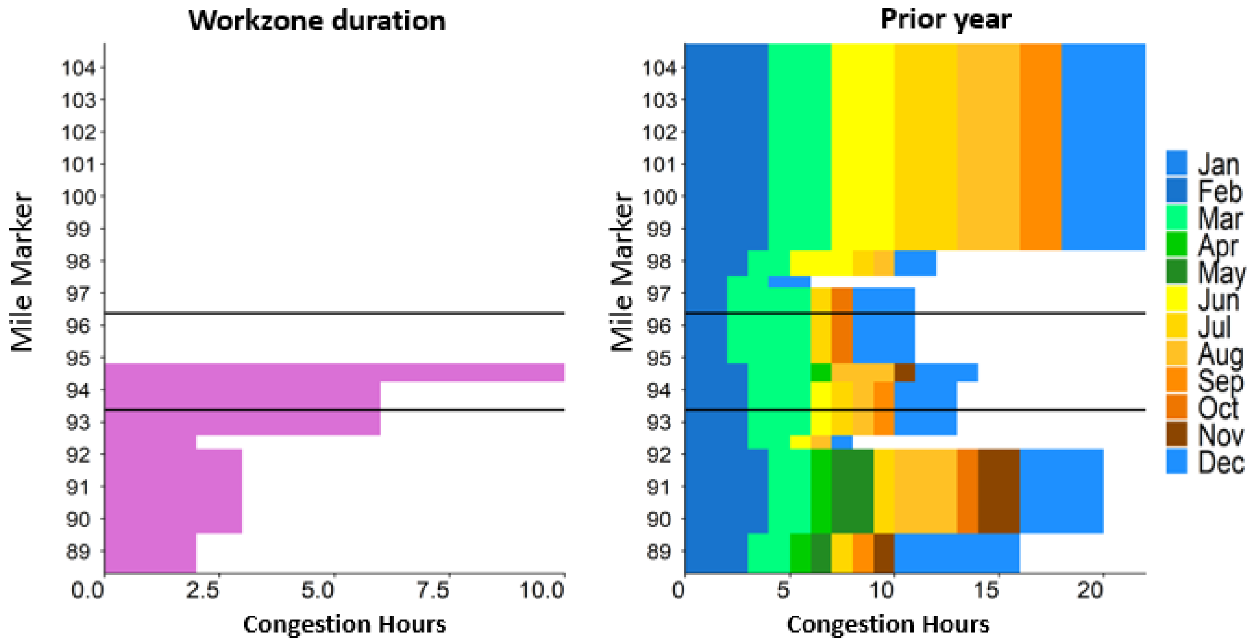
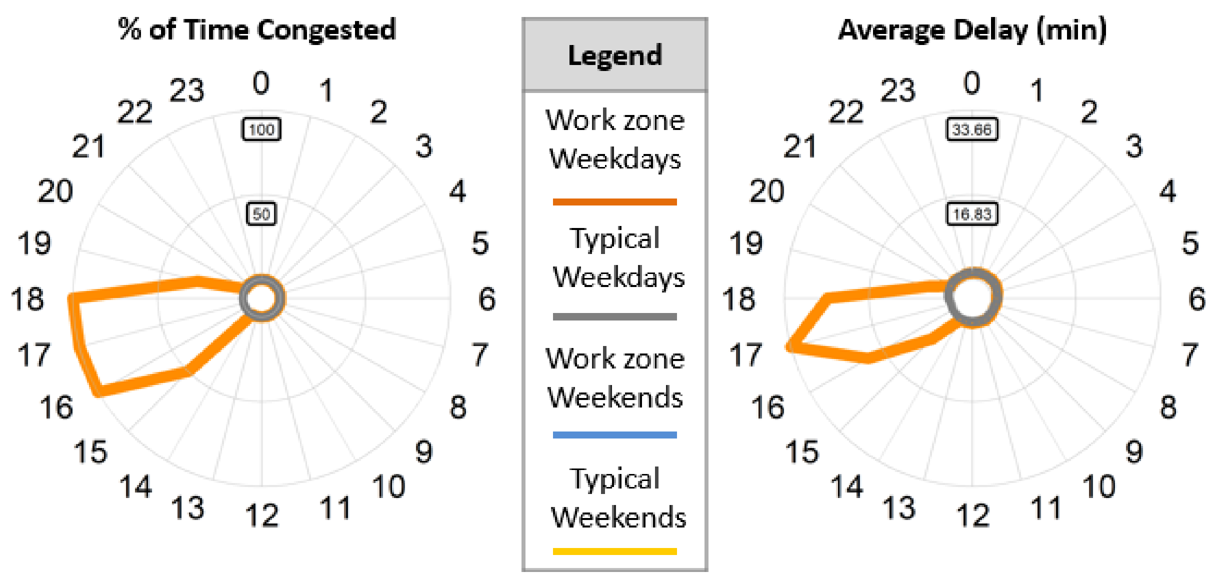


Figure 6. WZMA Template (page 1)

Work Zone Congestion: Spatial Characterization



Work Zone Congestion: Temporal Characterization



Delay & LOTTR Metrics

Stats	AM	Mid	PM	Weekend	Total
Avg Delay(min)	0.1	0.3	20.5		0.1
Max Delay(min)	0.8	25.6	41.1		41.1
Total Delay(min)	28.8	324.5	2908.5		3317.8
LOTTR	1.0	1.1	1.3		1.3

Queueing Metrics

Stats	Queue
Max Duration(min)	245.0
Total Duration(min)	715.0
Max Length(miles)	6.5
# of Queues	8.0

Figure 7. WZMA Template (page 2)

Work Zone Mobility Audit Performance Measures

Numerous types of performance measures can and have been chosen by various states, which were previously discussed. For the purpose of the work zone mobility audit tool, which will be shown later in this document, mobility performance measures are categorized into delay and queueing metrics. For the delay metrics, a corridor-based approach was used to assess travel time throughout the work zone period. These metrics are then compared with the typical corridor travel time to capture the impact of the work zone on traffic mobility. For the queueing metrics, a segment-based approach is used to assess mobility for each individual TMC segment separately. These metrics are defined in the following sections using simple and intuitive visualizations.

Delay Metrics

Probe vehicle data provides a representative speed for each TMC segment for a predefined time period, typically one-minute. Using the speed, travel time can be calculated for each TMC segment for each of the time bins. An average of those travel times over each five-minute bin can then be used to represent a segment's travel time. If all segments located in the work zone corridor had a representative travel time during each five-minute bin, then these travel times were added together to calculate the corridor's travel time during each five-minute bin. It is important to mention that if there is a missing travel time for one segment throughout the corridor, the travel time values cannot be added together to represent corridor's travel time. After calculating work zone travel time, a typical travel time was necessary to assess the work zone impact on mobility. This typical travel time, also called mobility baseline, is defined as the 50th percentile of travel times from the prior year of the work zone with the same season, day of week, hour of day, and five-minute bin.

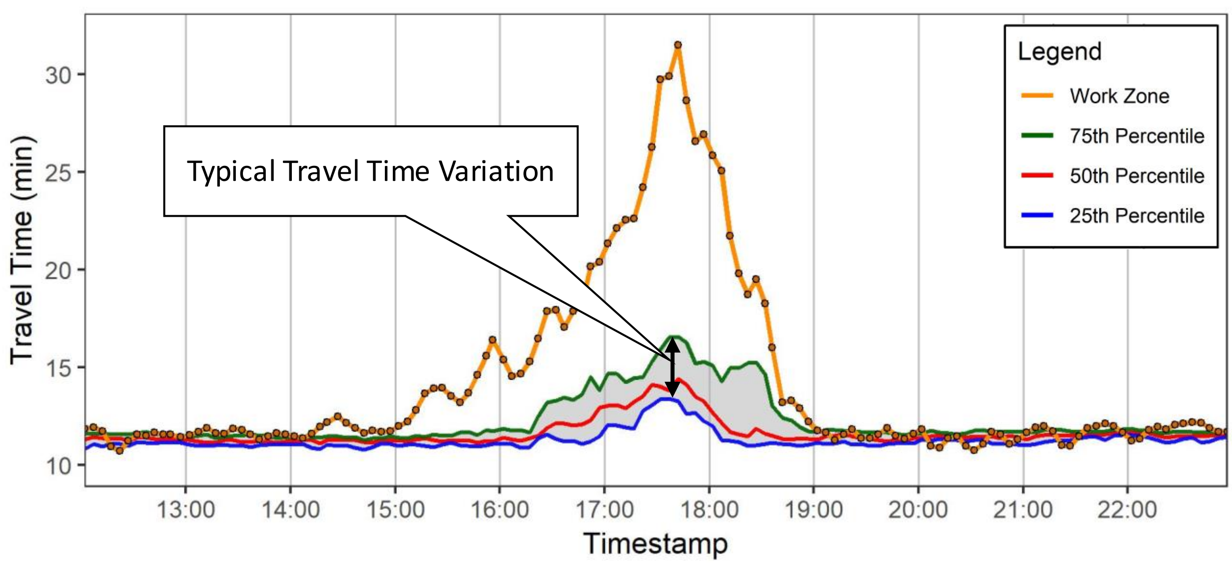


Figure 8. Work Zone Travel Time Variation

Figure 8 illustrates the work zone travel time along with the distribution of travel times from the prior year. The prior year travel times are pulled for the same season and day of week. For instance, for a work zone that happens this year during a summer month on a Monday afternoon, the travel time values for all Mondays during the previous summer are queried first. Then, these travel times are aggregated together for each hour of day, and each five-minute bin. Using these travel times, a distribution of travel time for each five-minute been is captured. The gray band on the Figure 8 shows the travel time variation for this corridor on a typical Monday. The blue line shows 25th percentile of travel times, and the green line shows 75th percentile of travel times as the lower and upper edge of the gray band, respectively. The 25th and 75th percentile of travel times were used to capture majority of travel times that were experienced in the prior year. Also, this approach, naturally, disregards outlier travel times which could be the result of a crash or another work zone from the prior year.

In this study, the 50th percentile of travel times was used as a representative typical travel time. Delay is defined when work zone travel time exceeds the typical travel time. The delay metrics such as total delay, average delay, and maximum delay are then calculated, comparing work zone travel time with the defined typical travel time. Figure 9 shows work zone travel times (orange line) compared with typical travel times (red line). The gray area between red and orange line shows the total delay caused by the work zone presence. It is worth mentioning that if work zone travel time falls below the typical travel time, there is no delay accounted for the work zone.

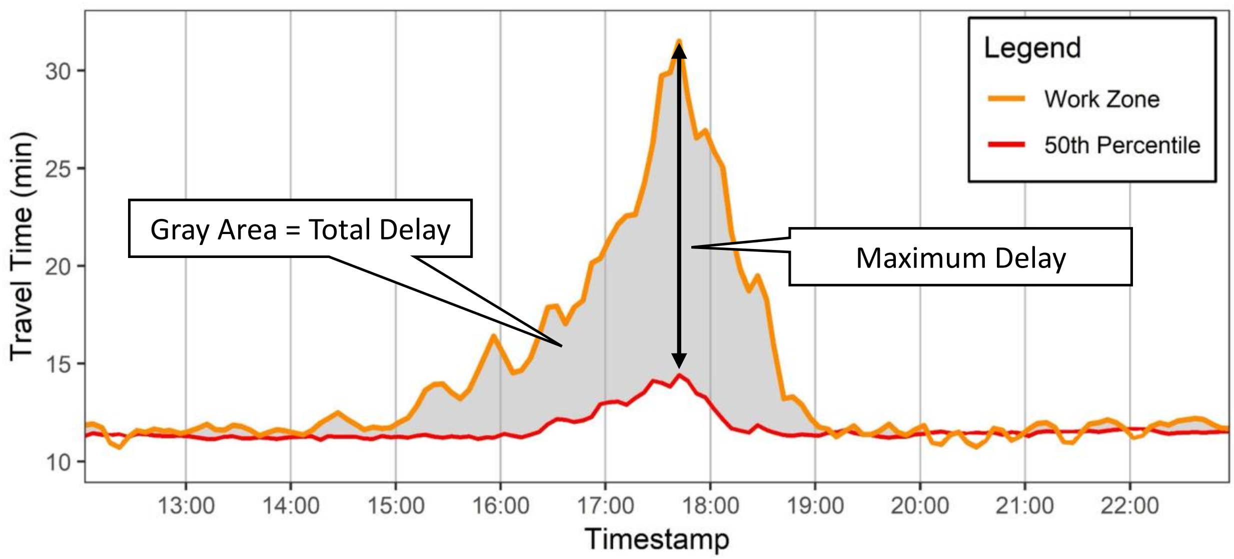


Figure 9. Work Zone Delay

Scatter Plot

Scatter plots are used to highlight the travel times throughout the entire work zone. Figure 10 highlights an example of the scatter plots used in the WZMA template. Orange dots illustrate travel time that was observed when a work zone was present. The gray band shows a range of travel times (25th percentile-75th percentile) which were observed in the year prior to work zone with the same season, day of week, hour of day, and five-minute bin.

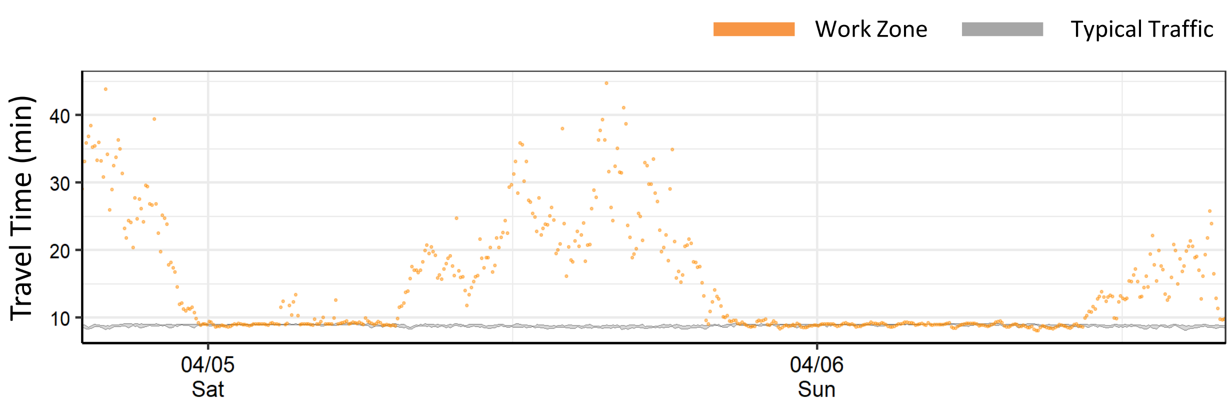


Figure 10. Work Zone Travel Times

Heatmap

Heatmaps illustrate the speed of all the segments over the course of the work zone (Figure 11). Mile markers are listed on the Y axis, while time is listed on the X axis. The colors on a heat map show the segment's speed at a corresponding time (X axis). The color scheme used in heatmap shows high-speed segments (speed = 80) with green. As the segment's speed reduces, the color changes toward red. For instance, if a segment's speed is zero miles per hour (mph), then red is used to illustrate the representative speed. Heatmaps are a valuable choice for traffic mobility visualization because they can be used to identify queue length and duration. They also can be used to evaluate the recovery time and resiliency of the road network after a severe queueing event.

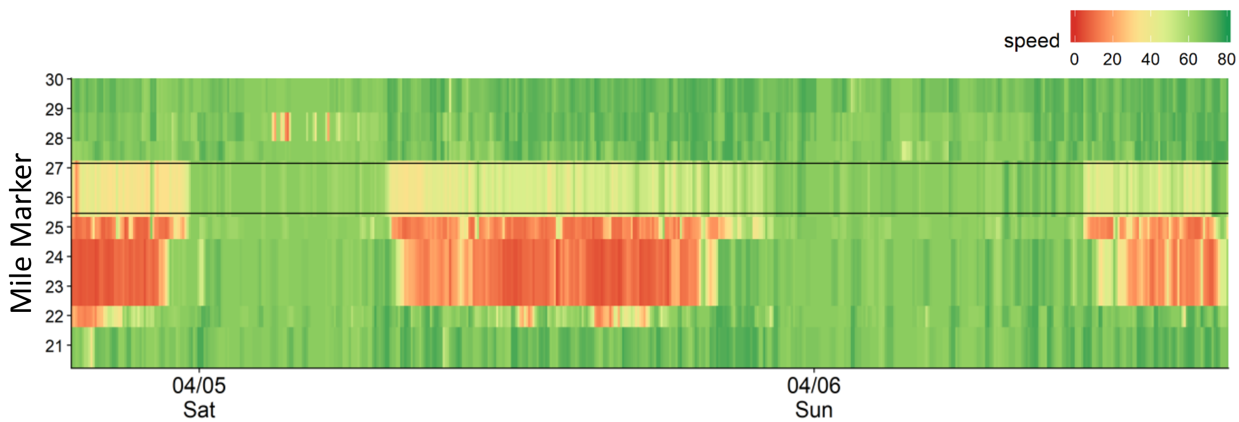


Figure 11. Work Zone Congestion Heat Map

Cumulative Distribution Functions

Cumulative distribution functions (CDF) are used to provide a glimpse of travel time reliability in each time period defined by FHWA. The X axis on the CDF shows travel times observed during the target time period, while the Y axis shows percentile values for those travel time values on the X axis. Figure 12 shows an example of a CDF. The orange line shows the travel time variation when a work zone was present. The gray line shows the travel time distribution from the previous year. The slope of the line on this graph illustrates the reliability of travel time for that corridor. For instance, a vertical line means that the corridor has been providing almost the same travel time for travelers (most reliable). while a more horizontal line means that there was fluctuation in travel time (least reliable).

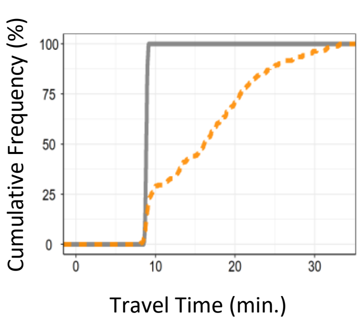
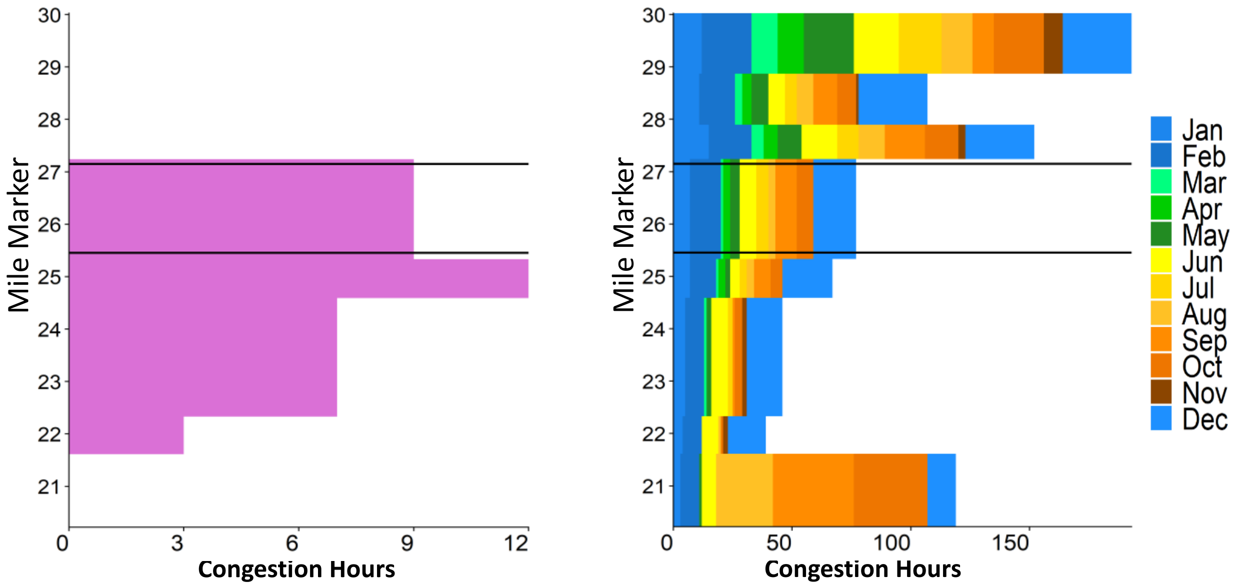


Figure 12. Work Zone Cumulative Distribution Function

Congestion Profile Graphs

Congestion profile graphs provide a spatial quantification of congestion that happened in each segment. The profile graph shows stacked congestion-hours for each segment throughout the work zone duration. The X axis shows the magnitude of congestion, while the Y axis shows the location of each segment, represented by highway mile markers. Also, horizontal black lines on the graph represent work zone start and end locations. The prior year graph shows cumulative congestion-hours that happened in each segment aggregated for each month. Congestion in the WZMA is defined as speeds less than 45 mph. Figure 13 shows an example of a congestion profile graph.



a) Work Zone Duration

b) Prior Year

Figure 13. Congestion Profile Graphs

Eye Graphs

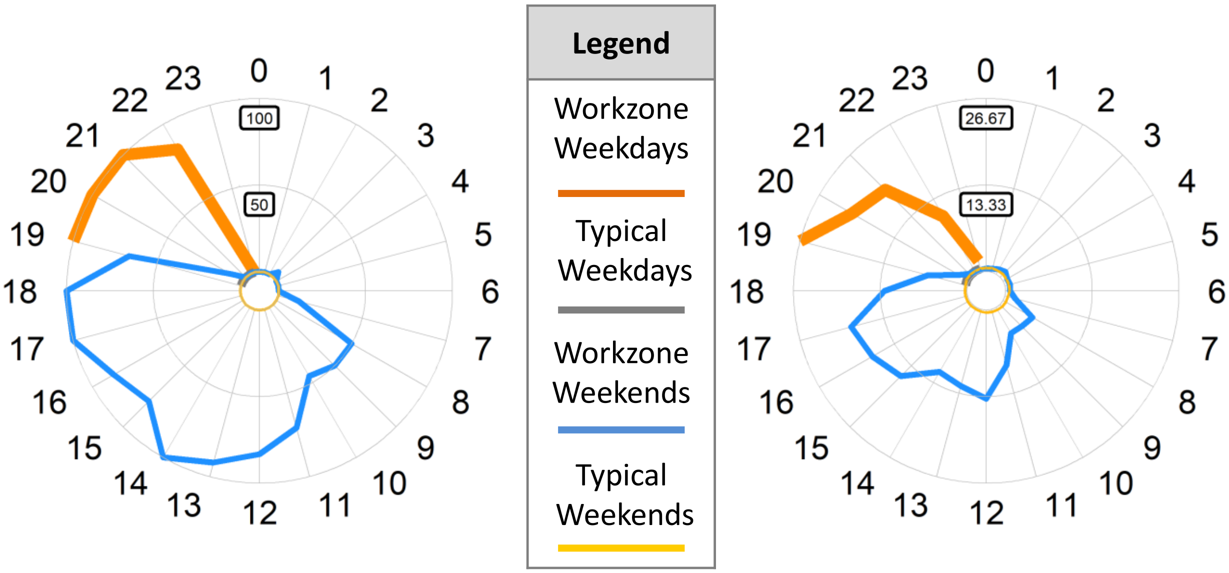
The eye graphs summarize mobility performance based on each hour of day over the course of the work zone. The graphs also provide the mobility metrics for typical traffic conditions. Using this graph, it is possible to quickly identify underperforming hours of a day. Knowing these problematic hours can assist agencies in the planning stages to avoid conducting work zone activities during these hours. Hours of day is found on the outer edge of this graph, while the radius illustrates the magnitude of a mobility metric. This graph uses four lines to represent traffic mobility metrics in typical and work zone condition, separated based on weekdays and weekends.

Congestion

The congestion eye graph uses a single speed threshold of 45 mph to quantify the percentage of time a corridor is experiencing congestion. Figure 14a shows an example of an eye graph for a work zone occurring Friday to Sunday. There is not typically congestion on the corridor, however the work zone causes congestion. Eye graphs accumulate these congested periods for all work zone segments, and then plot these stacked time durations for each hour of day.

Delay

The delay eye graph visualized the average delay during the work zone. In this chart, cumulative typical delay and work zone delay are plotted using gray and orange colors respectively. Using the 50th percentile of historical travel time values as typical traffic conditions, work zone delay is defined when work zone travel time exceeds the typical travel time. The delay eye graph (Figure 14b) captures the differences between work zone travel time and typical travel time and then averages these values for each hour of the day.



a) % of Time Congested

b) Average Delay

Figure 14. Eye Graphs

Summary Statistics

The summary statistic section of the WZMA provides an overview of the metrics used to quantify the work zone impact on traffic mobility. This section consists of two parts in which delay and queue metrics are summarized.

Delay Metrics

Four time periods were used in the WZMA to quantify delay metrics. These time periods are morning (06:00-10:00), mid-day (10:00-16:00), evening (16:00-20:00), and weekend (06:00-20:00). For each of these time periods, the following metrics are summarized.

Average Delay

The average delay metric uses all the delay records that were observed throughout the lifetime of the work zone for each of the defined time periods. These are then averaged to acquire average delay for that time period.

Maximum Delay

For each time period, the longest delay that was experienced by travelers is captured as the maximum delay.

Total Delay

The total delay metric adds all the delay records for each of the time periods to provide a cumulative delay that was caused by a work zone. Total delay in the WZMA template is different than what is typically defined as the total delay. Volume is not considered in this calculation. Instead, total delay is calculated as if one vehicle drove the corridor every 5 minutes throughout the life of the work zone. If accurate hourly counts were collected by a DOT, vehicle-hours of delay could easily be calculated.

Level of Travel Time Reliability

The FHWA recommends agencies keep the transportation network reliable for users. To measure travel time reliability, the Level of Travel Time Reliability (LOTTR) metric was used for each of the defined time periods. Using this metric, agencies can track the variation in travel time caused by a work zone. The FHWA recommends agencies use 1.5 as a threshold for the LOTTR metric. High variation in LOTTR not only causes user dissatisfaction but it can also create hazardous traffic conditions since travelers are facing an unexpected traffic condition.

Queueing Metrics

Queueing metrics are among the most important mobility metrics since the presence of a queue creates dangerous traffic conditions for travelers. When a queue forms on a highway, travelers who are approaching the back of queue are facing a high risk of rear-end type crashes, which may lead to additional secondary traffic congestion and crashes.

Using the segment-based approach, the queueing condition is defined when at least one segment has a speed below 15 mph. The queueing metrics used in this study attempt to quantify different aspects of the queueing condition including maximum queue duration, total queue duration, maximum queue length, and number of queue events. These metrics are discussed in the following sections. All these metrics are calculated using a segment-based approach.

Number of Queueing Events

The Number of Queueing Events metric counts the number of distinct times that a queue occurs on a roadway. In this metric, a 10-minute threshold was used to separate major queueing events from each other. For instance, if the gap between two queueing events was 5 minutes, those two queueing events were combined into one.

Maximum Queueing Duration

The Maximum Queue Duration metric captures the longest duration (minutes) in which the queueing condition was present on a roadway. For example, if the maximum queue duration was 40 minutes, it means that at least one segment had a speed below 15 mph for 40 consecutive minutes.

Total Queueing Duration

The Total Queueing Duration metric captures and adds all the time durations that a queueing condition was present on the roadway throughout the duration of the work zone.

Maximum Queue Length

The Maximum Queue Length metric uses the cumulative length of segments that were experiencing a queueing condition at each time interval. Then, it returns the highest value as the maximum queue length for a work zone.

Programmatic Approach to Work Zone Mobility Audits

The work zone mobility audit template used in this report is just one of many options to create a sustainable practice of capturing, monitoring, and archiving the mobility performance of a work zone. The template involves a substantial amount of data pre-processing, which will be highlighted in this section. Figure 15 shows the schematic of the data and data processing that is necessary to create a WZMA.

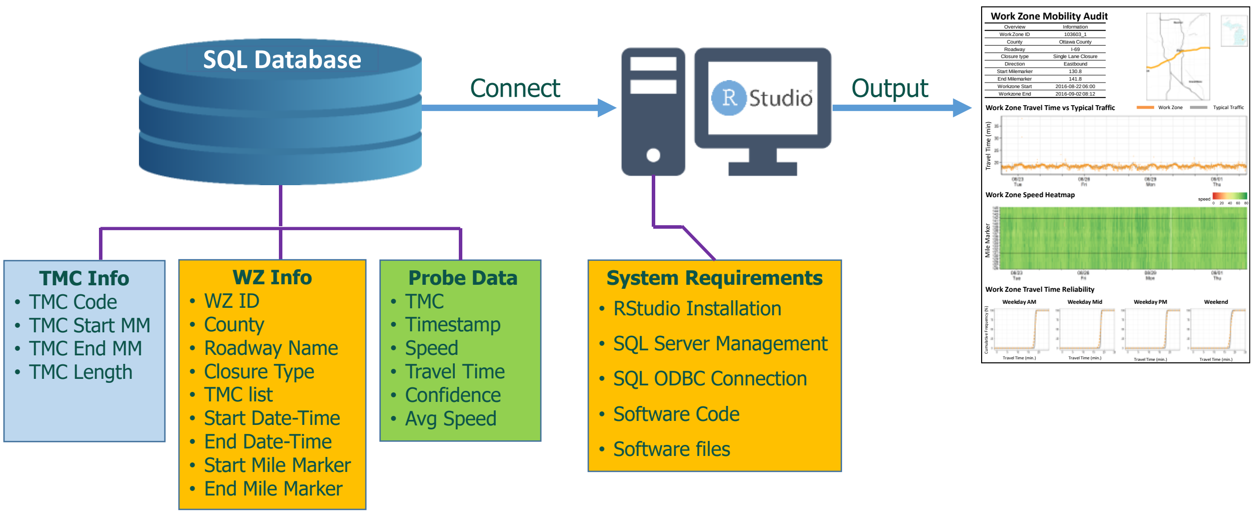


Figure 15. Work Zone Mobility Audit Schema

The four main pieces involved to create a WZMA are as follows:

A. TMC Information
B. Probe Data
C. Work Zone Information
D. Work Zone Assessment Tool

TMC Information

The raw TMC Info file contains the TMC codes and their corresponding information such as length, start and end latitude and longitudes, roadway name, and direction. However, to provide a recognizable spatial reference it is beneficial to include the starting and ending mile markers of each segment, which are not provided by the data providers. This information is extracted from the Michigan TMC shapefile, and through a GIS joining procedure, the mile markers of TMC's are found.

Speed Data

The raw speed data file has the timestamp, TMC code, speed, travel time, and confidence score features. Since many travel time values were missing, post processing is done by using the TMC length from the TMC Info table to calculate the travel time based on the speed column. This calculated travel time will be used in the corridor-based approach to calculate travel time for the work zone corridor.

Work Zone Information

The raw work zone information file contains information obtained from a Michigan dataset that has been cleaned and joined with the TMC Info file based on TMC codes to create the work zones to be assessed. The TMC codes that make up the work zone are appended with a buffer zone to create the final TMC list. This TMC list alongside the work zone start and end date/times will be used to create queries during the assessment.

The TMC selection process for work zones can be problematic because a work zone will not necessarily begin at the beginning of a segment. Figure 16 shows the recommended selection process for work zone TMCs. It is recommended to select at least 5 miles upstream and 3 miles downstream of the starting and ending points of the work zone, respectively.

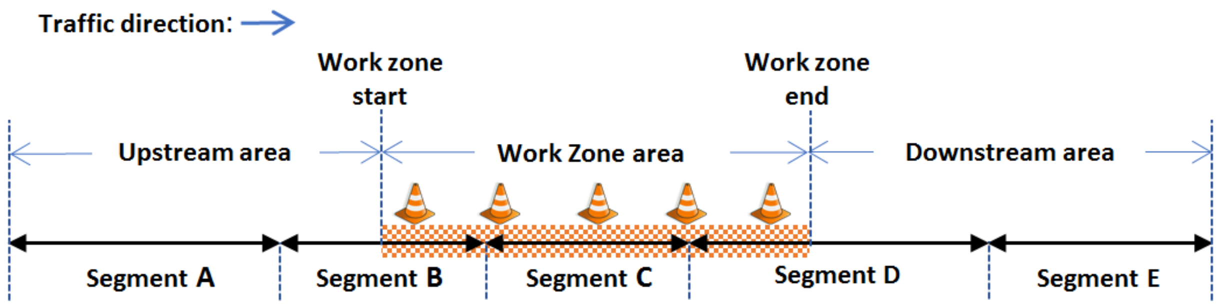


Figure 16. TMC Info and Selection

Work Zone Assessment Tool

The TMC information, Work Zone Information, and Speed Data tables created in the previous steps will be used in the tool to assess the work zones. The assessment tool carries out the following main functions:

1- Create an information table about the work zone such as: work zone ID, county, roadway name, start and end mile marker, start and end datetime of the work zone, closure type, and direction of traffic, which will be shown on the first page of the assessment report
2- Create the work zone geographic maps using the Michigan TMC and County shapefiles
3- Query from the database to get speed and travel time information for the work zone location and duration
4- Query from the database to get the prior year distribution of speed and travel time info for the work zone location
5- Create figures such as heat map, scatter plot, cumulative travel time, congestion profiles, and eye charts
6- Create summary tables showing the behavior of traffic during AM, PM, mid-day, and weekend periods
7- Create a two-page report where all these figures and tables are shown
8- Create a spreadsheet which shows all the results from previous tables for each work zone assessed

Case Studies

This section provides a series of WZMA sample case studies which were chosen based on different work zone traffic mobility scenarios. Each of these case studies shows the applicability of the WZMA in terms of identifying various traffic mobility impacts and highlights the impact in terms of duration, severity, and frequency. These case studies are as follow:

- Work zone with recurrent and severe traffic congestion
- Weekend work zone with severe traffic congestion
- Work zone with moderate impact on traffic congestion
- Work zone with no impact on traffic congestion

A brief summary of these work zone impacts is provided prior to the WZMA of these case studies.

Case 1: Work zone with recurrent and severe traffic congestion

This case study provides an overview of a single lane closure on the I-196 interstate highway which was conducted in August of 2016 between mile marker 68 and 70. Work zone activities lasted for 21 days including 5 weekend days and 16 weekdays. This corridor historically exhibited minor traffic congestion on typical weekdays and moderate traffic congestion on typical weekends. However, the presence of the work zone caused severe traffic congestion during weekdays and moderate traffic congestion on weekends.

Throughout this project, severe traffic congestion happened in both morning and evening peak hours on weekdays, and minor traffic impact occurred on weekends. This lane closure increased travel time the most during the AM and PM peak periods at 8:00 AM and 5:00 PM by almost eleven minutes on average. Also, travelers experienced severe delay up to 45 and 54 minutes for AM and PM peaks respectively. In terms of travel time reliability, this work zone created an unreliable traffic condition throughout weekdays. Travelers experienced the worst unreliable traffic condition in AM peak, with an LOTTR of 1.6.

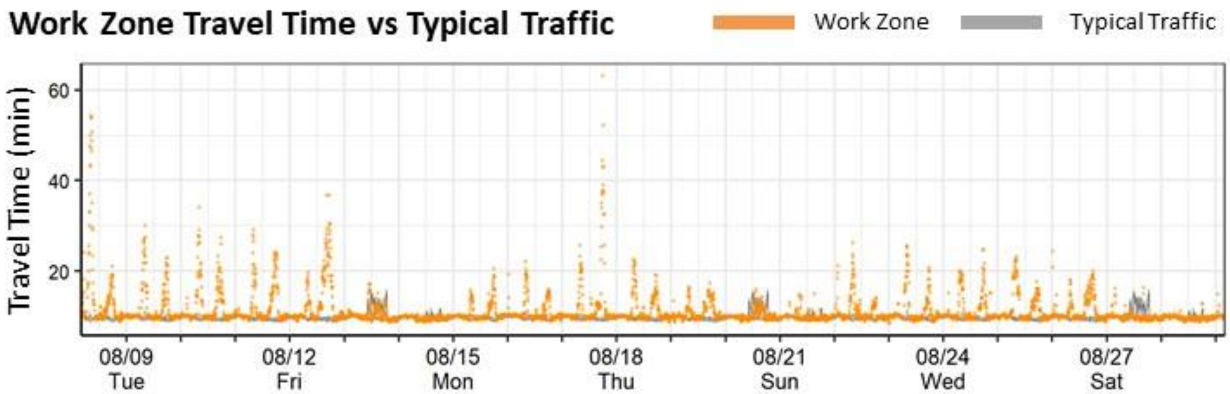
In addition, this lane closure resulted in 84 queueing events with a maximum queue length of 4.7 miles. The longest queueing event lasted approximately 5 hours on this corridor. Throughout the lifetime of this project, there were 77 hours that the corridor's traffic experienced queueing condition.

Case 1: Work zone with recurrent and severe traffic congestion, page 1.

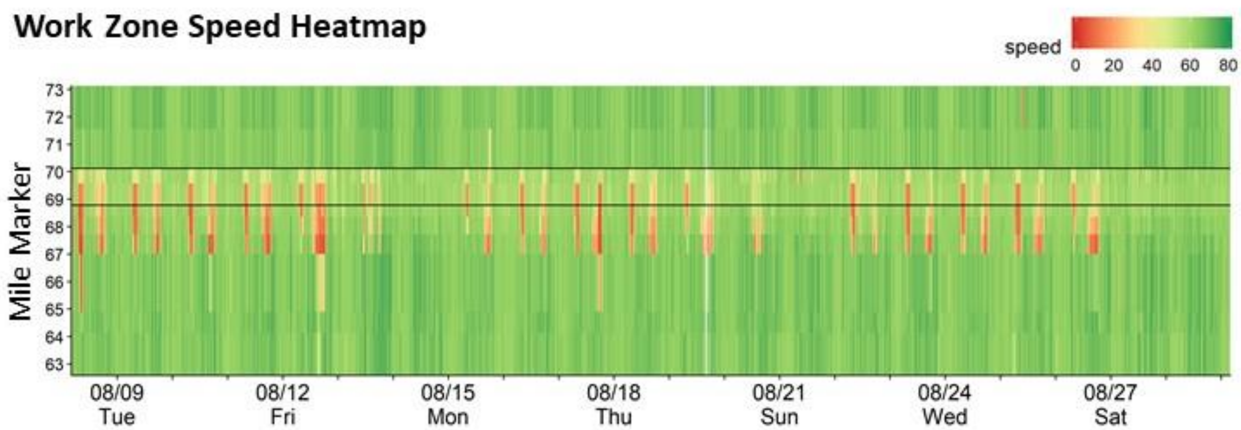
Work Zone Mobility Audit

Overview	Information
Work Zone ID	104524
County	Oakland County
Roadway	I-196
Closure type	Single Lane Closure
Direction	Eastbound
Start Milemarker	68.8
End Milemarker	70.1
Workzone Start	2016-08-08 04:00
Workzone End	2016-08-29 04:00

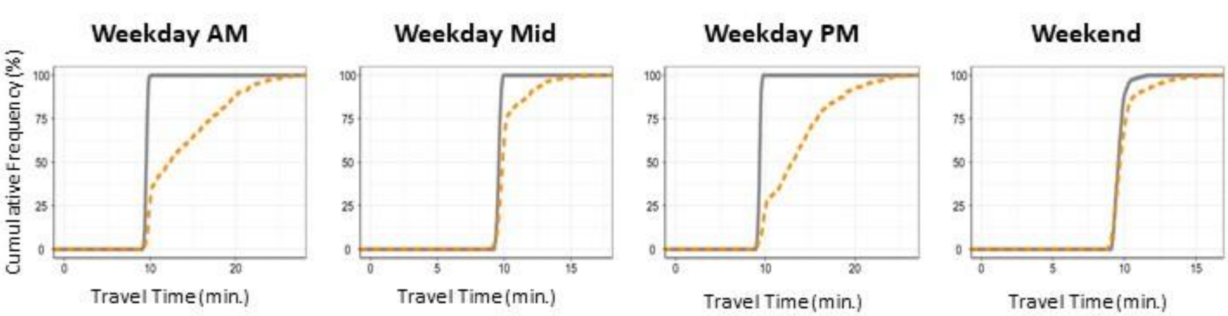
Work Zone Travel Time vs Typical Traffic



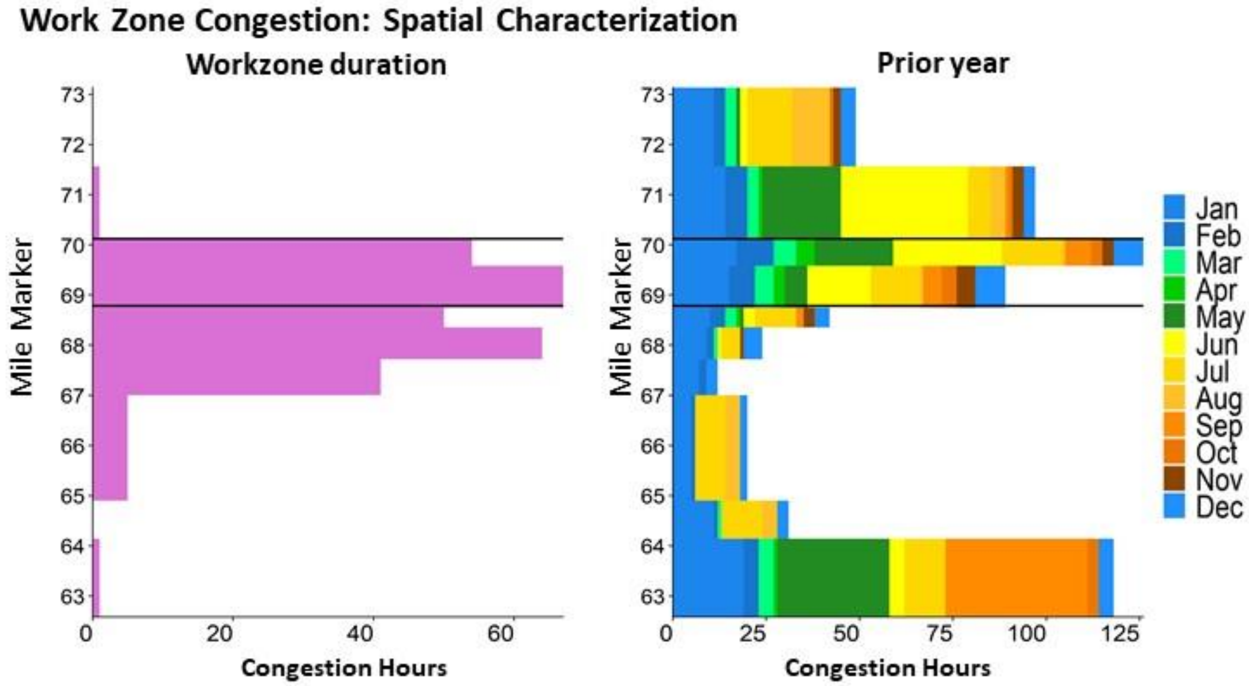
Work Zone Speed Heatmap

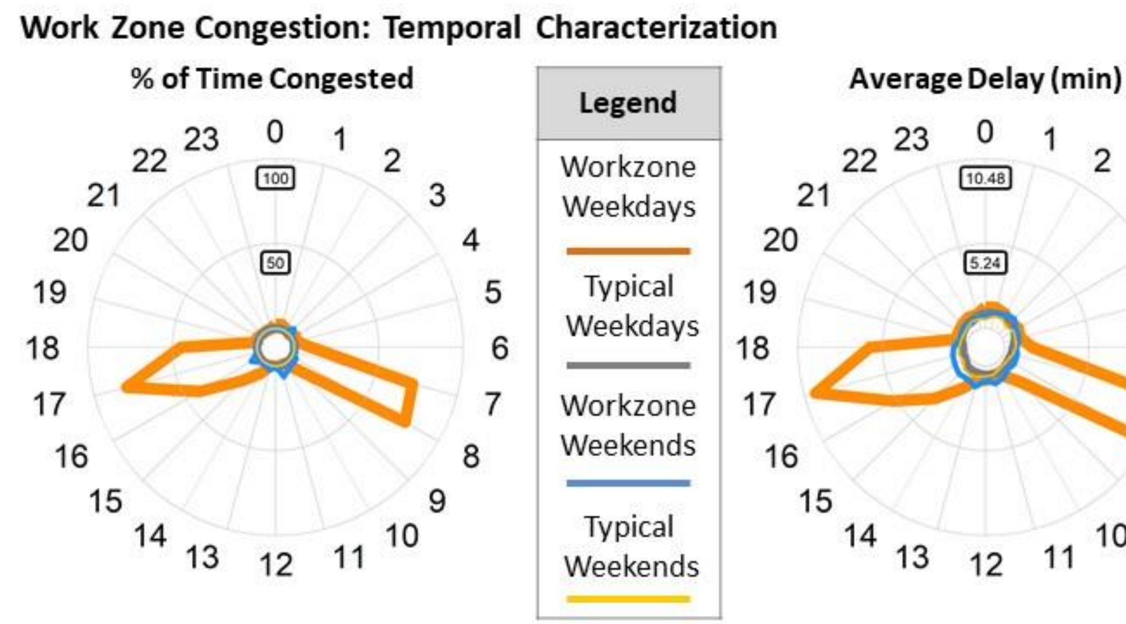


Work Zone Travel Time Reliability



Case 1: Work zone with recurrent and severe traffic congestion, page 2.





Delay & LOTTR Metrics

Stats	AM	Mid	PM	Weekend	Total
Avg Delay(min)	3.1	0.3	3.9	0.1	0.2
Max Delay(min)	44.8	16.7	53.8	7.3	53.8
Total Delay(min)	3790.9	996.6	3709.9	510.3	9725.1
LOTTR	1.6	1.2	1.4	1.1	1.3

Queueing Metrics

Stats	Queue
Max Duration(min)	285.0
Total Duration(min)	4650.0
Max Length(miles)	4.7
# of Queues	84.0

Case 2: Weekend work zone with severe traffic congestion

This case study shows a work zone project which was performed on the eastbound direction of I-94 from mile marker 195 to mile marker 201. In this project, two traffic lanes were closed over a weekend in August of 2016. This corridor experiences no traffic congestion on typical weekends; however, the presence of a work zone caused severe traffic congestion and queueing.

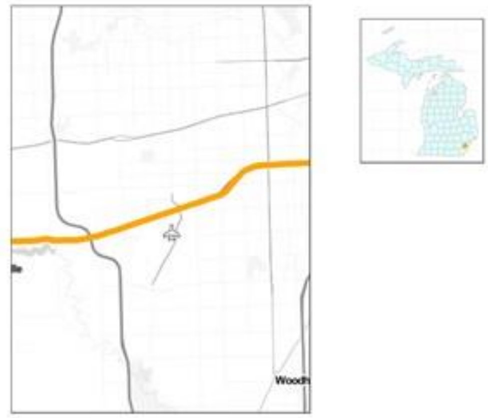
Throughout this project, severe traffic congestion was experienced by travelers from 11 AM to 5 PM. This lane closure caused an average delay of 7 minutes and a maximum delay of 29 minutes. In terms of travel time reliability, this work zone created an unreliable traffic condition throughout the weekend, with an LOTTR of 1.4.

The most problematic hours during this weekend occurred from 11 AM to 5 PM, with 100% congested condition. In addition, this lane closure resulted in 8 queueing events with a maximum queue length of 5 miles. The longest queueing event lasted about 10 hours on this corridor. Throughout the lifetime of this project, there were 20 hours that the corridor's traffic experienced a queueing condition.

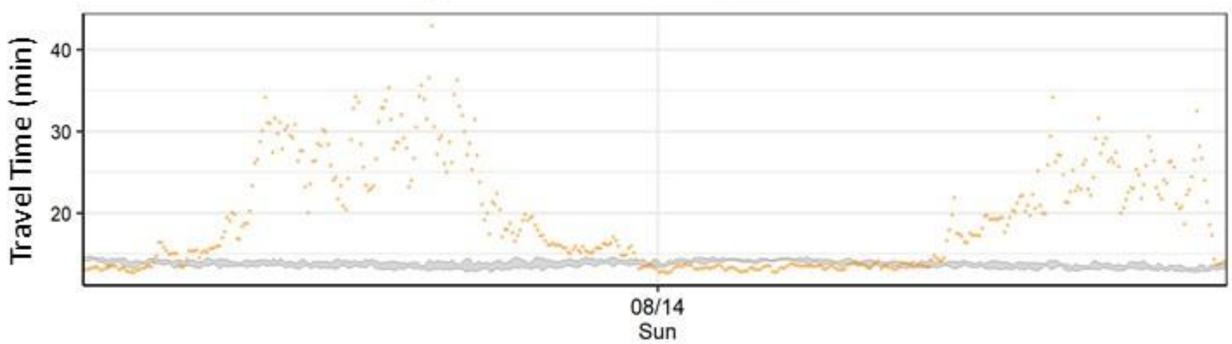
Case 2: Weekend Work zone with severe traffic congestion, page 1.

Work Zone Mobility Audit

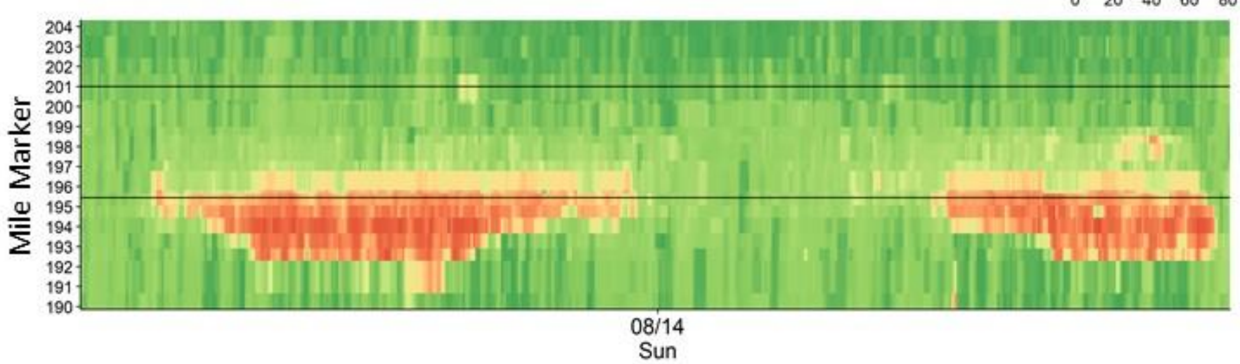
Overview	Information
Work Zone ID	104704
County	Oakland County
Roadway	I-94
Closure type	Double Lane Closure
Direction	Eastbound
Start Milemarker	195.4
End Milemarker	201
Workzone Start	2016-08-13 05:00
Workzone End	2016-08-14 18:49



Work Zone Travel Time vs Typical Traffic



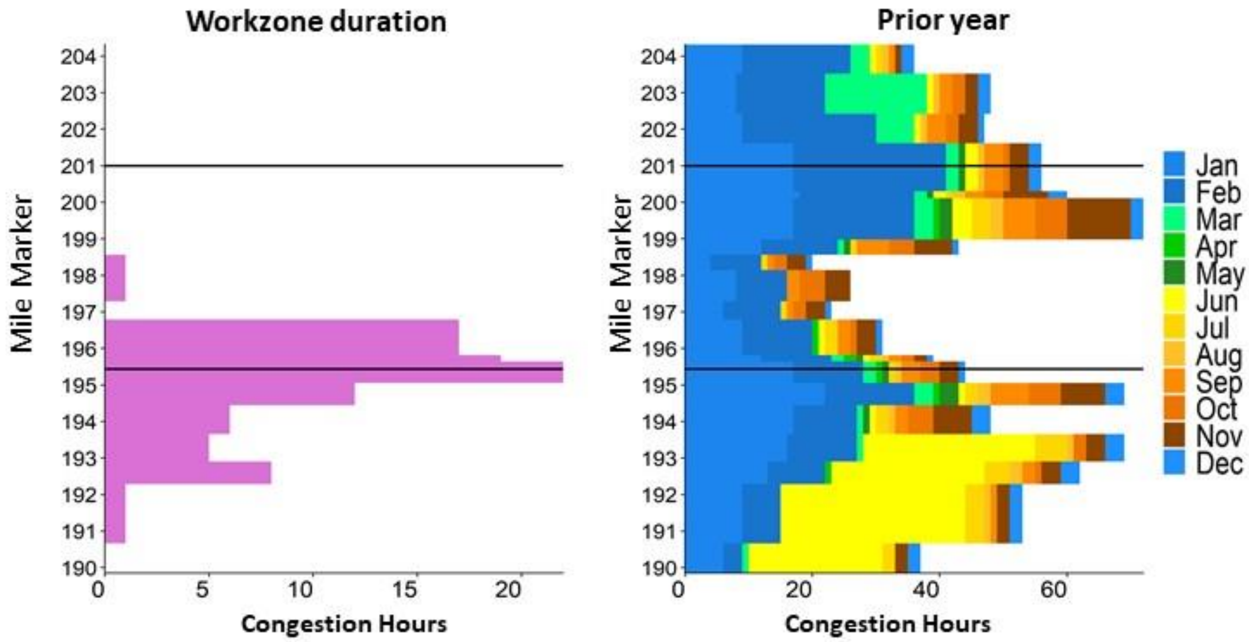
Work Zone Speed Heatmap



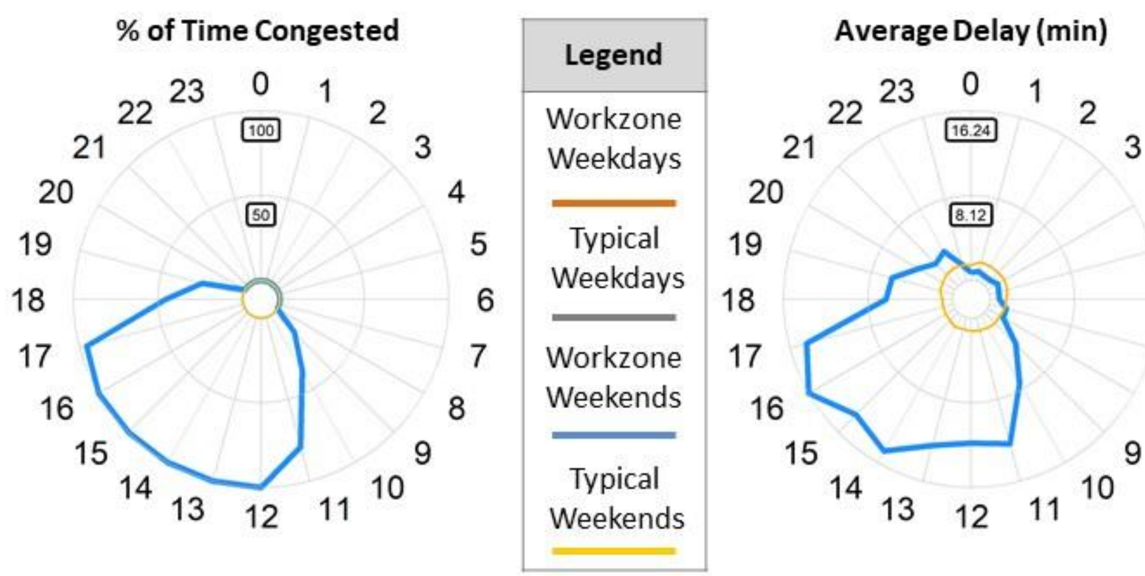
Work Zone Travel Time Reliability

Case 2: Weekend Work zone with severe traffic congestion, page 2.

Work Zone Congestion: Spatial Characterization



Work Zone Congestion: Temporal Characterization



Delay & LOTTR Metrics

Stats	AM	Mid	PM	Weekend	Total
Avg Delay(min)				7.2	3.3
Max Delay(min)				29.5	29.5
Total Delay(min)				2547.3	2624.6
LOTTR				1.4	1.6

Queueing Metrics

Stats	Queue
Max Duration(min)	575.0
Total Duration(min)	1200.0
Max Length(miles)	5.0
# of Queues	8.0

Case 3: Work zone with moderate impact on traffic congestion

This case study shows a work zone project which was performed on northbound I-75 from mile marker 73 to mile marker 76. In this project, single traffic lanes were closed for more than two weeks during the summer of 2016. This corridor experiences moderate congestion on typical weekends during peak hours and minor traffic congestions on weekend. The presence of a work zone on this corridor caused a moderate increase in traffic congestion.

Throughout this project, moderate increases in traffic congestion were experienced by travelers during PM peak hours. This lane closure caused an average delay of 2.6 minutes and maximum delay of 20 minutes during the PM peak hour. In terms of travel time reliability, this work zone created an unreliable traffic condition throughout the PM peak hours, with an LOTTR of 1.5.

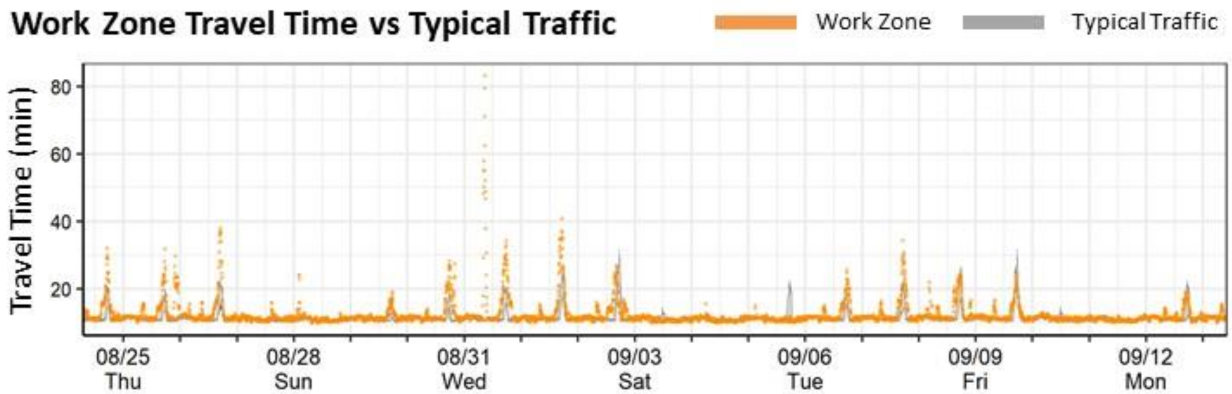
The most problematic hours during this work zone were from 4 PM to 5 PM, which were congested 80% of the time. In addition, this lane closure resulted in 39 queueing events with a maximum queue length of 6.8 miles. The longest queueing event lasted about 3 hours on this corridor. Throughout the lifetime of this project, there were 38 hours that the corridor's traffic experienced queueing condition.

Case 3: Long-term work zone with moderate impact on traffic congestion, page 1.

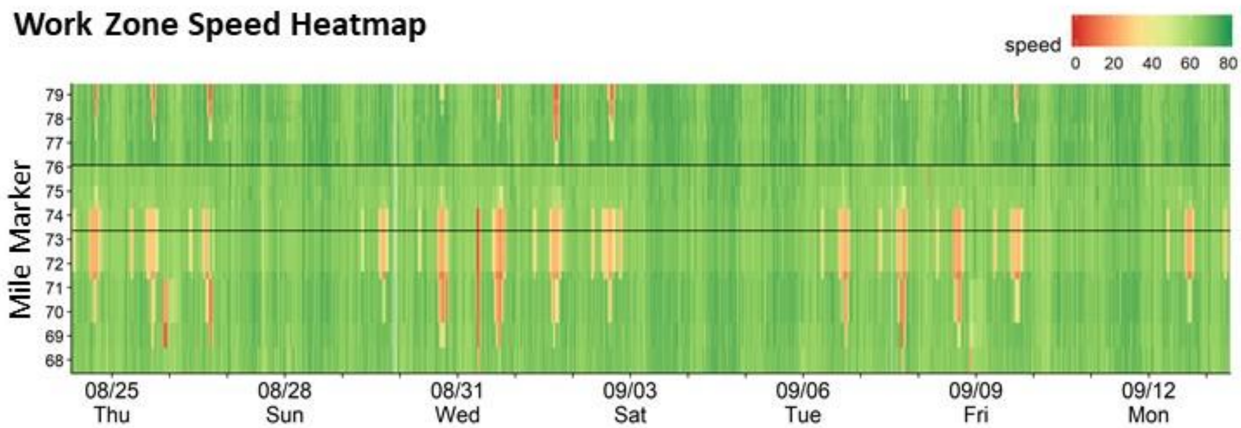
Work Zone Mobility Audit

Overview	Information
Work Zone ID	104811
County	Kent County
Roadway	I-75
Closure type	Single Lane Closure
Direction	Northbound
Start Milemarker	73.4
End Milemarker	76.1
Workzone Start	2016-08-24 07:00
Workzone End	2016-09-13 10:00

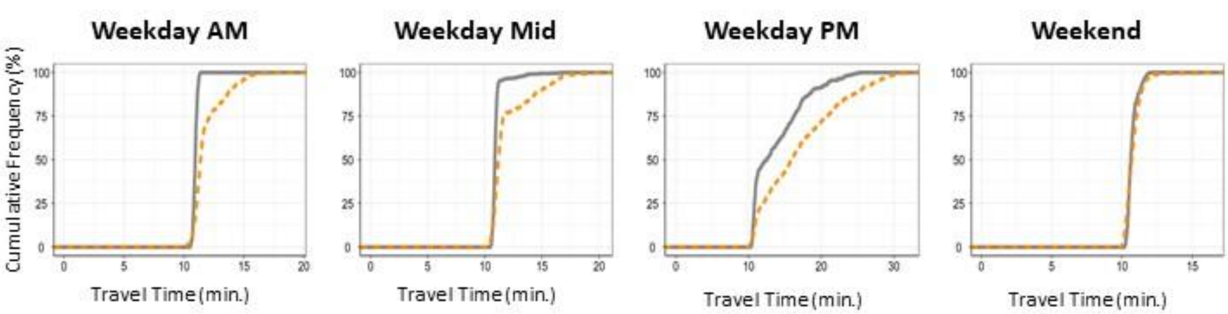
Work Zone Travel Time vs Typical Traffic



Work Zone Speed Heatmap

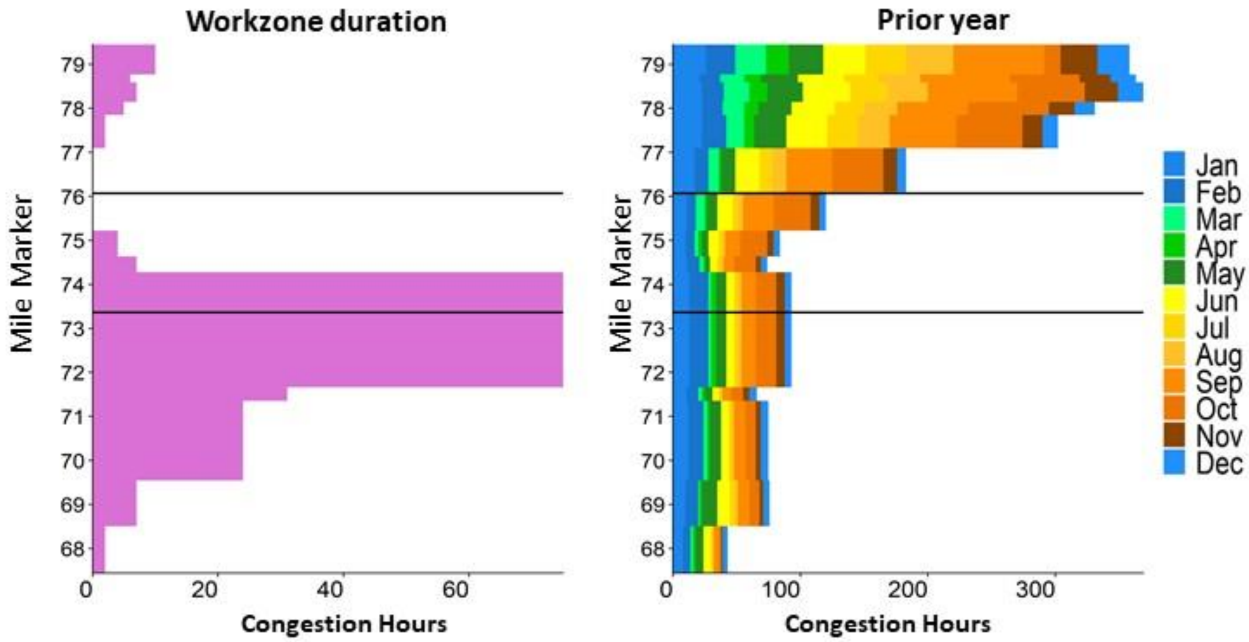


Work Zone Travel Time Reliability

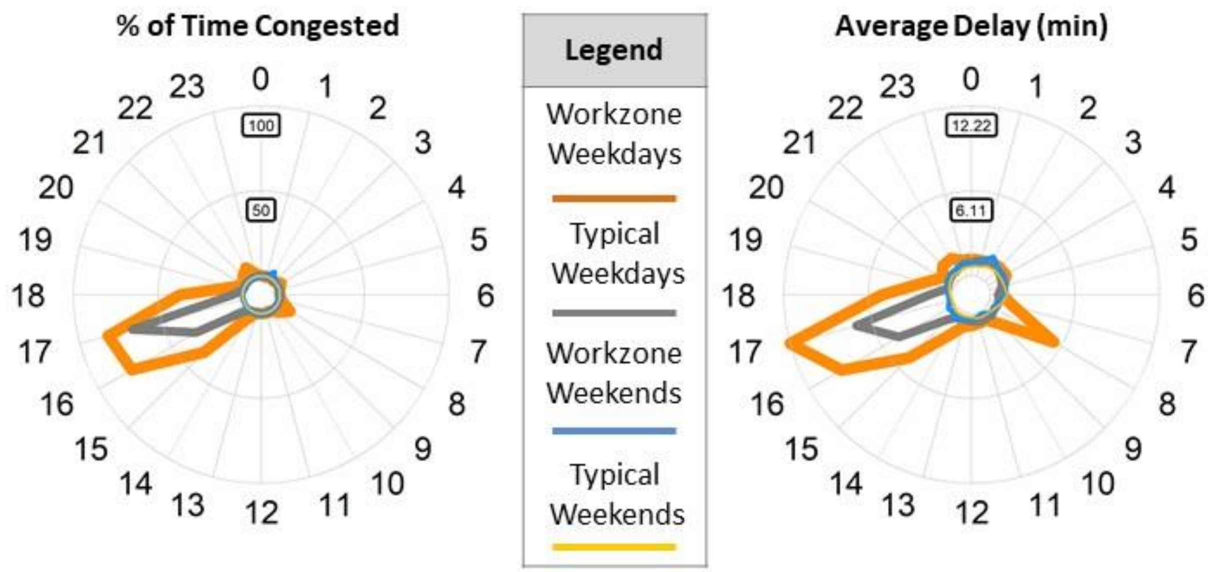


Case 3: Long-term work zone with moderate impact on traffic congestion, page 2.

Work Zone Congestion: Spatial Characterization



Work Zone Congestion: Temporal Characterization



Delay & LOTTR Metrics

Stats	AM	Mid	PM	Weekend	Total
Avg Delay(min)	0.5	0.3	2.6	0.0	0.3
Max Delay(min)	72.5	11.0	19.9	5.2	72.5
Total Delay(min)	1338.8	1139.8	2841.9	243.1	6675.8
LOTTR	1.2	1.3	1.5	1.1	1.2

Queueing Metrics

Stats	Queue
Max Duration(min)	185.0
Total Duration(min)	2300.0
Max Length(miles)	6.8
# of Queues	39.0

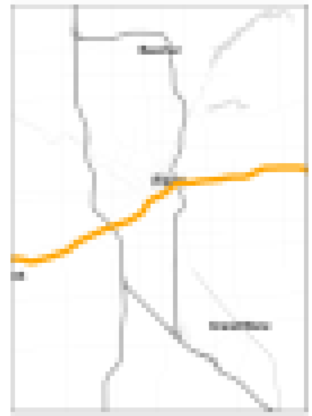
Case 4: Work zone with no impact on traffic congestion

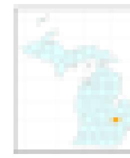
This case study shows a work zone project which was performed on eastbound I-69 from mile marker 130 to mile marker 141. In this project, single traffic lanes were closed for 10 days during summer of 2016. This corridor experienced no traffic congestion on typical weekdays and weekends. The presence of a work zone on this corridor did not cause any increase in traffic congestion.

Case 4: Work zone with no impact on traffic congestion, page 1.

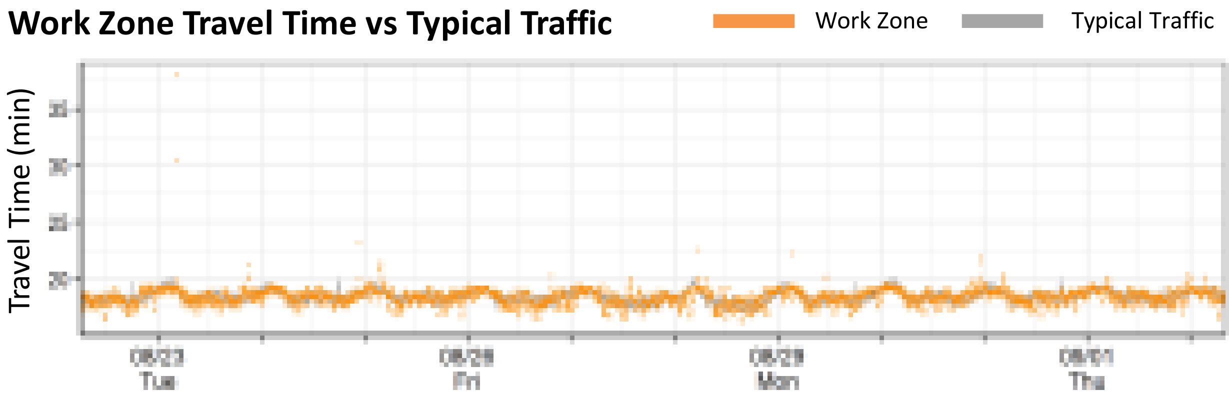
Work Zone Mobility Audit

Overview	Information
Work Zone ID	103603_1
County	Ottawa County
Roadway	I-69
Closure type	Single Lane Closure
Direction	Eastbound
Start Milemarker	130.8
End Milemarker	141.8
Workzone Start	2016-08-22 06:00
Workzone End	2016-09-02 08:12

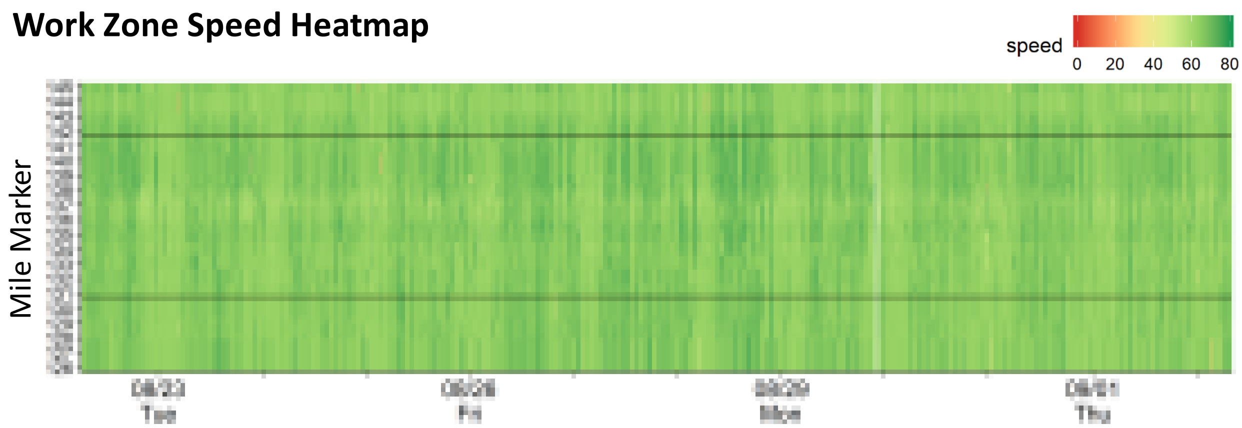




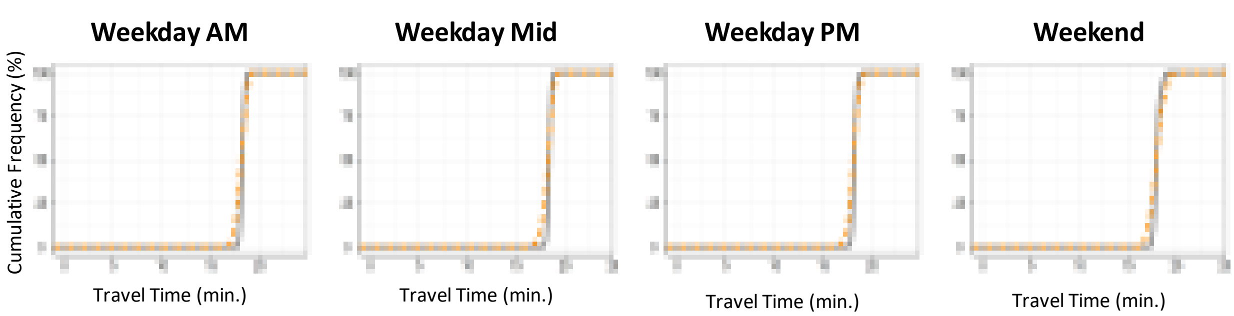
Work Zone Travel Time vs Typical Traffic



Work Zone Speed Heatmap

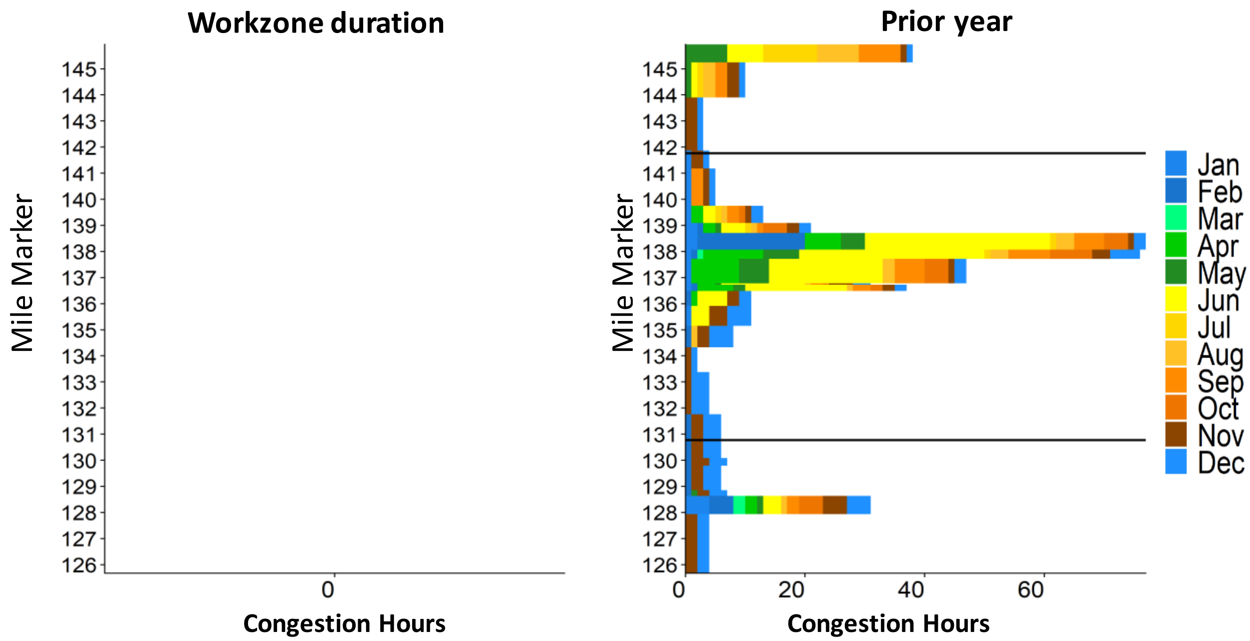


Work Zone Travel Time Reliability

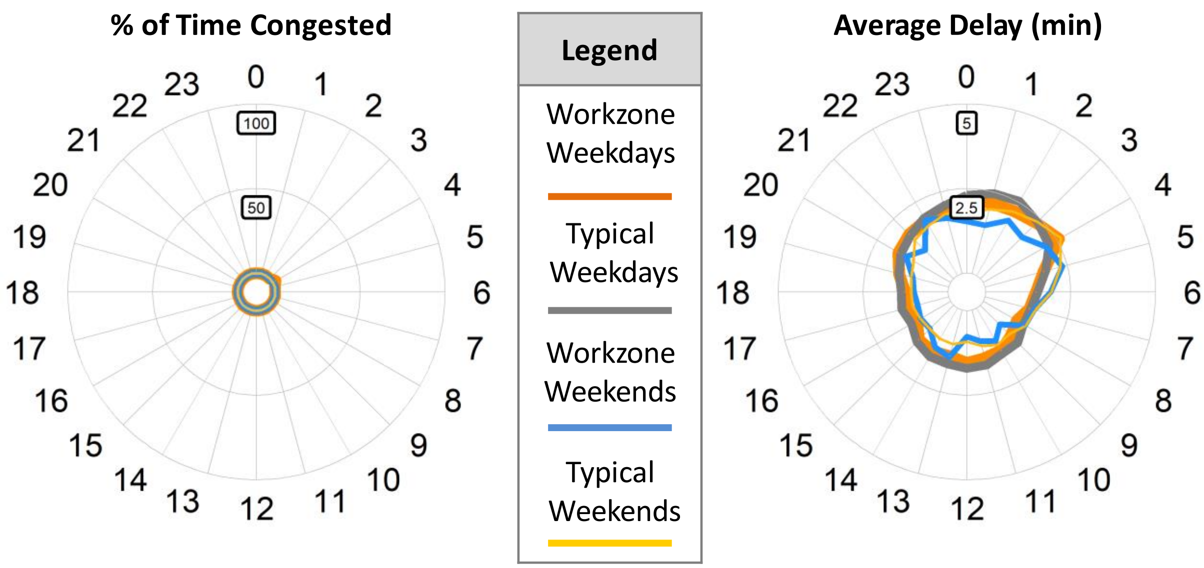


Case 4: Work zone with no impact on traffic congestion, page 2.

Work Zone Congestion: Spatial Characterization



Work Zone Congestion: Temporal Characterization



Delay & LOTTR Metrics

Stats	AM	Mid	PM	Weekend	Total
Avg Delay(min)	0.0	0.0	0.0	0.0	0.0
Max Delay(min)	1.0	2.2	2.1	2.0	18.6
Total Delay(min)	64.1	92.1	65.5	80.4	535.9
LOTTR	1.0	1.0	1.0	1.0	1.0

Queueing Metrics

Stats	Queue
Max Duration(min)	10.0
Total Duration(min)	30.0
Max Length(miles)	1.3
# of Queues	5.0

Organization Capability

The technical capabilities for an agency to adopt the work zone mobility audit tool are straightforward. It is suggested an agency has a server, crowd sourced probe vehicle data, and an engineer or data scientist with a working knowledge of data base management. Accompanying this document are a series of recorded webinars that discuss both the interpretation of the work zone mobility audit and the step by step approach to setting up the tool on a computer. The goal of this tool is to improve agency understanding of work zone mobility and serve as a baseline for the advancement of Transportation Systems Management and Operations (TSMO) practices.

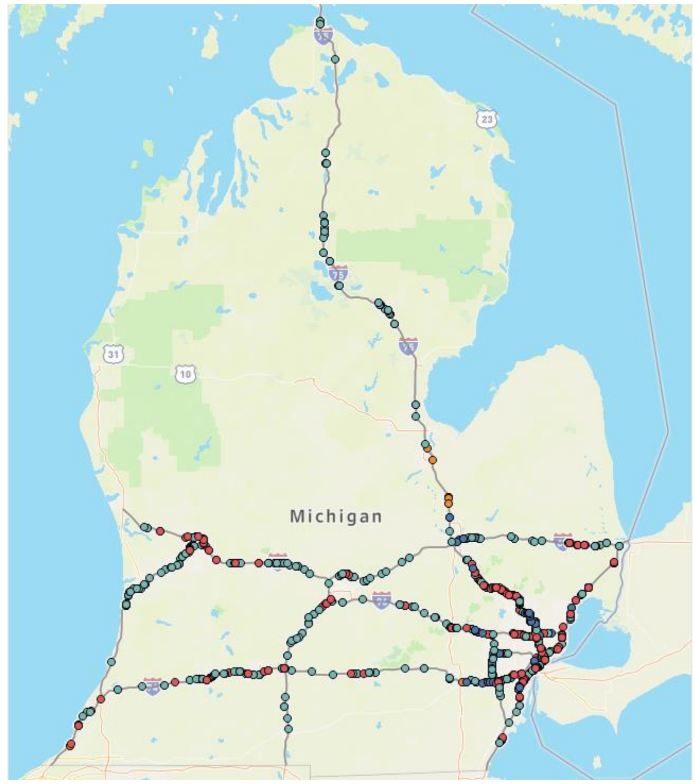
Using the Capability Maturity Framework (CMF), this tool hopes to improve the issues agencies currently experience related to work zone mobility. The specific AASHTO defined capability the WZMA tool is targeting is the use of performance measurement including measures definition, data acquisition, and data utilization. The tool aims to drive the use of crowd sourced probe vehicle data from an ad hoc or champion driven approach to a standardized strategy within an agency. This corresponds to a shift from CMF level 1 to CMF level 3. As agencies begin to adopt the WZMA, future development and stakeholder engagement will be key to reaching full sustainable priority, or level 4.

Tool Applications

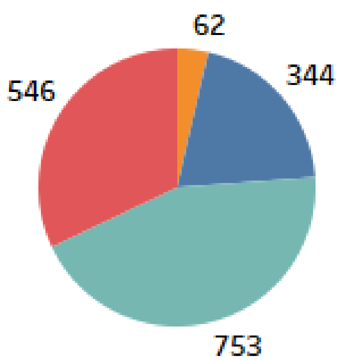
The WZMA tool was designed as a quick and scalable approach to create after-action work zone mobility reviews. Although this is the primary use case, there are certainly other uses which are listed below:

- *Before and After Assessments* – The impact of other operational challenges on roadways besides work zones can be assessed using the WZMA tool. These challenges include crashes, weather events, seasonal travel, or special events.
- *Detour Route Assessment* – If there is a desirable parallel route or a detour as a result of a work zone, the WZMA tool can be used to assess the performance of the other route.
- *Work Zone Ranking* – Since the WZMA tool creates a list of summary statistics for each work zone that is processed, these statistics can be used to determine the highest and lowest impact work zones with respect to roadway mobility. Figure 17 shows a breakdown of the 1,705 work zones in the state of Michigan that were assessed as a part of the WZMA tool testing. Figure 18 shows a prototype dashboard used to rank work zones by various performance metrics.
- *Identification of Significant Projects* – Determining performance thresholds has often been a challenge for agencies because of a lack of comprehensive data for work zones. This tool can be used to identify construction that has a significant impact relative to all other construction projects in a state or region.
- *Statewide Work Zone Planning* – The documentation of work zone performance can lead to enhanced planning techniques for an agency. Gathering information about types of construction on various roadways at various times may lead to a better understanding of the optimal work zone methods.

1,705 work zone case studies from 2014-2018



Count of work zones for each category:



Count of work zones for each highway based on categories:

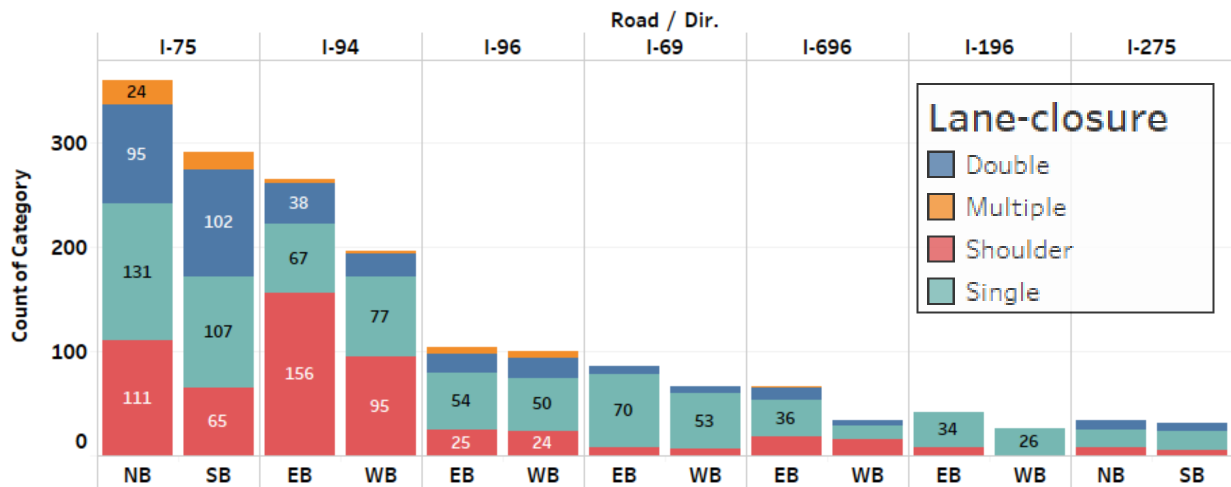


Figure 17. Summary Statistics of Work Zone Case Studies

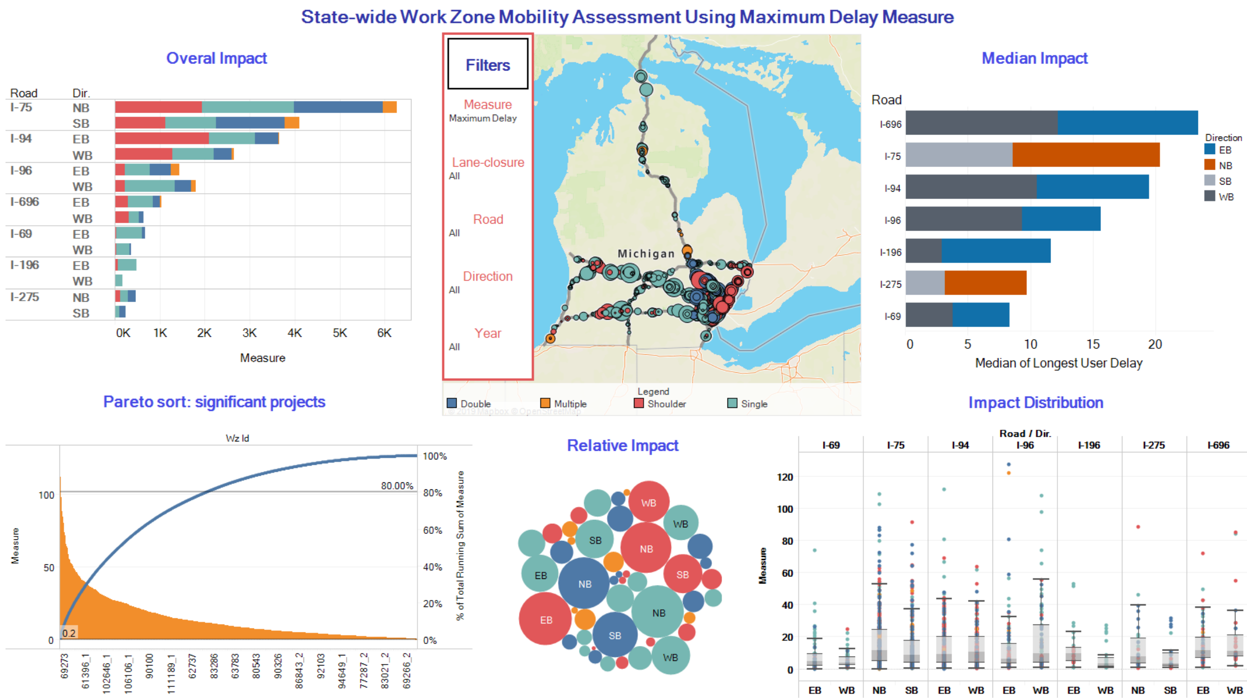


Figure 18. Prototype Work Zone Ranking Dashboard

Key Findings

Probe vehicle data provide a substantial opportunity for the consistent and sustainable assessment of work zones nationwide. This project investigated what states are currently using to assess work zone mobility and used those ideas to create a tool to assist in the process of auditing work zone mobility. Throughout the process, a few key findings were understood and could be considered as agencies go on to adopt their own form of a work zone mobility audit.

- **Data are important -** Throughout the process it was difficult to find and understand where work zones were occurring, what work was happening on what day, and what type of work zone setup was present. As more technology is embedded into work zones, it will be possible to have very granular work zone data to use, which will help in the assessment of work zone mobility. It is recommended that agencies begin to develop a strategic plan to determine what information could be collected for every work zone. The more information that is collected, the better the analysis that can be performed.
- **Performance Measures and Thresholds -** Throughout the literature and industry review process, it became apparent that every agency had different opinions when it comes to performance measures and performance measure thresholds. The tool for this project was designed to include as many performance measures as possible, with some flexibility in the coding to pick different performance thresholds. It is suggested that an agency decides what the priorities are for performance measurement and then defines an appropriate threshold. Some examples are shown in Table 2 of this report.
- **Automation is possible -** Whether an industry-powered platform like RITIS or iPems is used, a university partner develops a process, or the tool provided with this report is adjusted, automating this process is possible. A WZMA can be something that takes very little time and effort. It can be a valuable tool for after-action reviews or pre- and post-construction meetings.

- **Measuring and Managing -** A WZMA will give agencies the ability to quickly measure most work zones on interstates. This will allow agencies to better manage consultants and contractors when they are performing construction in the future.

Additional Resources

- Regional Integrated Transportation Information System (RITIS) - https://ritis.org/traffic/
- Iteris iPems - https://www.iteris.com/products/performance-analytics/ipems
- Federal Highway Administration: http://www.ops.fhwa.dot.gov/wz/index.asp
- National Work Zone Safety Information Clearinghouse: http://www.workzonesafety.org/
- American Road and Transportation Builders Association: http://www.artba.org/
- American Traffic Safety Services Association: http://www.atssa.com/
- Institute of Transportation Engineers: http://www.ite.org/
- National Highway Institute: http://www.nhi.fhwa.dot.gov/home.aspx
- Texas Transportation Institute: http://tti.tamu.edu
- Transportation Research Board: http://www.trb.org/

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