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Mitigation Lessons Learned

WISCONSIN DEPARTMENT OF TRANSPORTATION

ERIN SCHWARK, PE – STATEWIDE WORK ZONE OPERATIONS ENGINEER

Lessons Learned for Work Zone Traffic Mitigation

Planning and designing for work zones can be challenging when dealing with constructability, traffic volume and other users of the transportation system. With traffic volumes increasing each year across our highways, it is becoming more difficult to complete construction with little impact to traffic. The presence of work zones can greatly reduce capacity, causing delay and queueing. As a result, drivers are faced with transitioning from free-flow conditions to slow moving conditions, and sometimes a driver's reaction is unpredictable.

Statistically, we know that crashes increase in work zones, which could be related to many different factors from the capacity of the work zone, the geometrics of the roadway or human factors. There are many different mitigation strategies that can be implemented in work zones to make the work zone safe for the motorists and workers.

According to the National Highway Traffic Safety Administration's (NHTSA), *Fatality Analysis and Reporting System (FARS) 2019 Annual Report*, approximately four out of every five work zone fatalities in 2019 involved a driver or passenger of a vehicle, which is about 82 percent.

The Final Rule on Work Zone Safety and Mobility was published on September 9, 2004, in the Federal Register. The rule 23 CFR 630 Subpart J addresses issues affecting work zone safety and mobility and requires all state and local governments that receive federal funding to comply with the provisions in the rule. With this rule, WisDOT adopted and implemented Transportation Management Plans (TMP) for all projects which layouts the strategies for managing the work zone impacts of the project.

As part of the TMP process, project teams are determining the best strategies to mitigate impacts to the traveling public while still being able to complete the construction and maintain a safe area for workers. Many different mitigation alternatives are initially analyzed before selecting a preferred staging plan. Depending on the type of construction, the following could be alternatives analyzed: lane closures, crossovers, full roadway closures with detours, flagging operations, nighttime work, narrowed lanes, lane shifts, temporary pavement, temporary structures, etc. When looking at different staging plans to mitigate impacts, project teams also need to consider the safety of the work zone and consider queueing or delay caused by the project.

There have also been many advancements in technology, and Smart Work Zones are a focus area when looking at different strategies to help provide motorists with real-time traffic information about work zones.

WisDOT has implemented many different traffic mitigation alternatives over the years. While many of the strategies have worked well, others may not have gone as well as planned. To document mitigation strategies used in Wisconsin, we gathered input statewide from different stakeholders to develop lessons learned for both design and construction staff to use when analyzing different staging alternatives.

The following sections will discuss many different strategies that have been used along with recommended practice when designing and implementing work zones to make the work zone safe for

all users. The guide is not intended to cover all strategies but discuss some of the more common strategies that occur on projects.

Findings

Meetings were held with regional WisDOT staff, Division of State Patrol (DSP) and consultants to gather feedback on what worked and didn't work well in work zones. We also asked for recommendations on how to improve work zones. We asked stakeholders to provide input on the following topics:

1. Work Zone Length
2. Shoulder Width and Shoulder Closures
3. Lane Width and Lane Closures
4. Barrier Wall
5. Contractor Ingress and Egress Points
6. Entrance and Exit Ramps
7. Rolling Closures
8. Speed/Enforcement
9. Freeway Service Team
10. Law Enforcement Mitigation
11. Smart Work Zones
12. Traffic Diversion
13. Crashes
14. Emergency Gates
15. Communication and Coordination
16. Temporary Pavement
17. Pavement Markings
18. Other Considerations

The above topics provided a good representation for consideration from the design process all the way to completion of the project in construction. These topics also covered lessons learned on both rural and urban projects, complex mega projects to smaller scaled projects that may not have as many impacts, varying traffic volumes and speed limits. Each topic is discussed in more detail below.

1. Work Zone Length

There have been many projects around the state that have had very long work zones, more than 15 miles, and projects that have had less than a mile in length. One of the main concerns was construction/driver fatigue in long work zones. When work zones are long, with narrow lanes, barrier on both sides, with minimal shy distance it requires drivers to focus more intensely when traveling through that area. It was mentioned that some relief should be provided in those longer work zones. The total distance of that relief was recommended to be greater than one mile without barrier or provide a full shoulder width to give drivers a sense of normalcy before going back into a narrow work zone.

Figure 1: Bi-Directional Traffic Separated by Barrier Wall, Narrowed Lanes, Temporary Pavement

It was also recommended to complete a study to review what the optimal length of a work zone should be to create a safe work zone for both workers and the traveling public. To do this, we would need detailed staging information as well as incident data to compare different projects to determine if there is a safer way to design a work zone based on overall length. When designing a work zone, consider staging the project to limit the total length of the work zone to start at one end of the project and move to the other closing smaller portions of the roadway versus closing a long stretch of roadway.

Consideration should also be given to crossovers, the number of crossovers and the need for them. As well as access points for contractor to safely get equipment and material to a work site. This will be discussed in more detail under the ingress and egress section.

2. Shoulder Width and Shoulder Closures

When shoulder widths are narrowed or removed, it does not provide an area for a stalled/disabled vehicle to stop in an emergency and does not provide an area for first responders to use to respond to a crash or incident. Concrete barrier temporary precast are typically installed to protect workers, to protect vehicles from drop-offs or traffic from the other direction, giving the work zone a *narrow* feel and creates less room for a vehicle to recover if they veer off the road.

It was mentioned several times by law enforcement that shoulders are very beneficial in providing space for first responders to respond to crashes and incidents. Without shoulders it can be very challenging for first responders to get to a crash when traffic is all queued up and forces them to drive the wrong way down the highway (when closed) or use emergency access points, if accessible.

In some work zones, the shoulder is used for vehicles to drive on to maintain capacity through the work zones, and the existing shoulder is reconstructed to provide a better surface condition for vehicles to drive on. Temporary pavement should be considered for shoulders that are not traffic ready, as shoulders are not meant to carry heavy traffic during the project.

Like the work zone length topic, consider a maximum limit of no shoulders to provide motorists a break when driving through long narrow work zones. If the project will have no shoulders over winter, consideration should be given for snow storage as well as snow plowing.

If there are places barrier wall does not need to be present, the recommendation would be to leave that area without barrier and start barrier further downstream when it is needed. One project observed there was little to no difference when a one-foot shoulder was installed compared to a two-foot shoulder. It was noted that there was a higher frequency of beam guard hits when there was little or no shoulder. Consider shoulder width when work is planning to take place in an area where there is beam guard.

When there is little or no shoulder room, it is hard to install fixed message signs (FMS). When designing the signing plan, make sure there is enough width in the area you plan to install the FMS.

Traffic is typically shifted to the shoulders for construction which can change vertical clearance under bridges as well as temporary vertical clearance when forms are set over the roadway.

3. Lane Width and Lane Closures

When capacity is reduced it typically generates queuing which could increase the likelihood a crash would occur because motorists are not expecting interrupted flow on an interstate or expressway. It

was recommended to try to maintain capacity, even if that requires little or no shoulder be provided during construction.

Lanes are narrowed to accommodate traffic through the work zone. It was mentioned that when the lane is narrowed at a bridge or bridge approach, there was a higher chance of the crash cushion, guardrail, or barrier wall to be hit due to the change in width. It was recommended to try to keep the lane width the same on bridges and bridge approaches to help mitigate possible hits in the work zone.

Figure 2: Crash Cushion at End of Barrier, Narrowed Work Zone at the Bridge

Closures are almost always required to complete construction and several options are typically considered including off-peak lane closures, continuous lane closures or full closures which require a detour. When there are viable alternate routes, full closures should always be considered. Full closures create a safer work area for the workers and could increase productivity in the work zone by completing the project quicker than if there were off-peak lane closures.

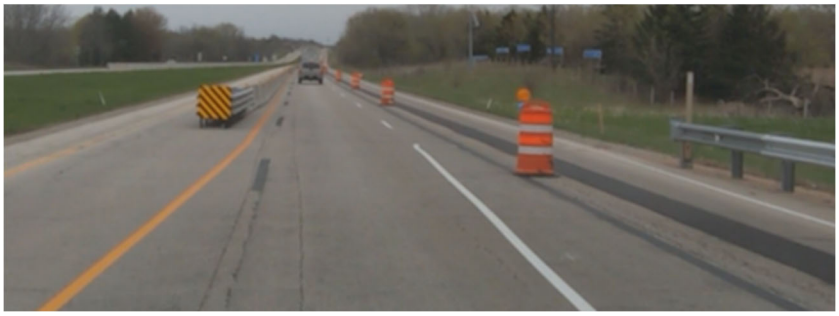
The total distance for a daily/nightly lane closure is recommended to not exceed more than 5 miles in length per several region standards. The chances of work taking place in all 5 miles in one time period is unlikely and the Department wants to make sure lanes are not closed for no reason whenever possible.

4. Concrete Barrier Temporary Precast (CBTP)

In many cases when barrier is used in work zones the shy distance from the edge of travel lane to the temporary barrier wall is less than desired, typically one to two foot shy. The Smart Work Zone Pooled Fund Study submitted a problem statement to study the impacts of shoulder width (with and without barrier) as well as lane width. The outcome of that study will be documented once available for recommended widths.

It was recommended as a best practice, where feasible, to eliminate the crash cushions and extend the barrier wall which can result in less crash cushion hits and repairs. It was also mentioned that barrier wall was typically cheaper than crash cushions.

Figure 3: Crash Cushion at end of Barrier



When installing crash cushions, consider the thickness of the pavement. The pavement needs to be at a minimum 8 inches thick for the crash cushion to adhere to the pavement. Also, the designer must detail out where the crash cushions should be installed during in the design process.

If CBTP is installed and only required for a certain stage or duration, remove it when it is not needed. This will allow for more space on the shoulder creating a less constrained work zone for motorists.

5. Contractor Ingress and Egress and Emergency Access

Ingress and egress points are used by contractors to access their work site and could potentially be used by first responders if there is an incident in the work area. When in the design phase, create safe ingress and egress points by allowing for proper acceleration and deceleration of work vehicles into and out of a live lane of traffic so there are no impacts to the normal traffic flow. It is recommended to try to include these access points in the plans; but if not feasible, all access points should be reviewed and approved prior to the contractor implementing them in the field. When determining locations for access points, consider:

- using frontage roads or other roads running parallel to the roadway; and
- construction accessibility and what this access will be used for.

Figure 4: Contractor Access Point, Accessible Behind Barrier Wall

If the access points will also be used for first responders, number the access points and share an overview map with first responders in the area so they know where they can access the work area. Make sure the access points are also drivable for all types of vehicles.

There are smart work zone systems that can help mitigate issues with trucks entering the work zone, called a truck entering system. The truck entering system consists of detection (sensors or cameras) and either flashing beacon signs or portable changeable message signs. The system alerts upstream traffic that a slow-moving vehicle is entering the roadway. These can be used on high-volume, high speed roadways when the work zone will have a designated ingress/egress location for trucks to use.

6. Entrance and Exit Ramps

There were several different recommendations for designers to consider when accommodating entrance and exit ramps in work zones. The following should be considered:

- If there is only one receiving lane during nighttime/daytime closures and there is a good detour, close the on ramp to increase the safety.
- If there is not enough room for acceleration or deceleration, close the ramp.

Figure 5: On-Ramp without Proper Acceleration Length

Figure 6: Off-Ramp without Proper Deceleration Length

- If there is a sight distance issue, close the ramp for safety reasons.
- Do not close two consecutive ramps in a row so motorists and first responders can, at a minimum, enter or exit the roadway.
- Ramp volumes and mainline volumes when considering using a yield condition if there will be reduced lanes in an interchange area.

Law enforcement continue to use ramp gates at interchanges during incidents and find them to be very positive. They would like to continue to see these installed at on-ramps.

7. Rolling Closures

A few things should be considered when rolling closures are planned for the project. In almost all cases, lane closures are likely still needed for rolling closures, so traffic control should be factored in for closing lanes. Law enforcement is required for all rolling closures.

In some cases, depending on the contractor work, a full roadway closure may be better and safer for the motorists and the workers. Discuss rolling closures versus full closures with the contractor, and risks associated with each depending on the operation. What if their operation takes longer than the allowed 15-minute time period for a rolling closure? Will there be significant impacts to the motorists?

Factor in rural areas and urban areas, as well as on ramps in the area of the rolling closure and if it is better to use traffic control devices or law enforcement to close the ramp.

8. Speed and Enforcement

There was a lot of feedback from law enforcement pertaining to enforcement of speed limits through the work zone. Several concerns were expressed that it can be very challenging to enforce the speed limit when the work zones are long and have little to no shoulder room to pull a vehicle over. Drivers can also become argumentative if you follow them to a location outside of the work zone to issue a citation for something, they did several miles back. There is also a loss of effectiveness in enforcement when you must follow a vehicle for 10+ miles to pull them over.

Some projects are designed to include temporary emergency pullouts, while these are good for incidents, they are not necessarily good for pulling motorists over. The timing becomes a challenge as to when to stop the vehicle as well as it creates an unsafe condition when entering or exiting the emergency pullout, because there is not enough room for deceleration or acceleration.

Enforcement in short work zones with active work is very effective. If space allows, law enforcement can either sit in the work zone or just outside the work zone and pull the motorist over immediately after the work zone or shortly after.

When the work zone has a higher traffic volume or is congested, it becomes more difficult to do speed enforcement. Work zone speed limit enforcement should consider traffic volume and congestion. Data can be collected and reviewed to look at incidents and speed data. This data may be able to provide law enforcement information as to where there are issues in the work zone that should have targeted enforcement.

Compliance of the work zone speed limit is always a concern in work zones. Drivers will drive the speed they feel comfortable at, so it is important to set the appropriate work zone speed limit based on the conditions of the work zone. Factors such as length of the work zone, shoulder width, type of work, etc., should all be considered when setting a work zone speed limit. Law enforcement suggested installing more speed limit signs in work zones to inform motorists of the work zone speed limit.

Ensure the project is accurately displaying the correct speed limit. There have been times there were two posted speed limits in work zones because either the contractor forgot to cover/uncover a sign and left a different speed limit sign posted. It is important to have the same speed limit conveyed to the motorists as well as to law enforcement so the speed limit can be enforced. Digital speed limit signs could be used during daily/nightly lane closures to ensure the speed limit is correct throughout construction.

9. Freeway Service Team

The freeway service team (FST) was determined to be very beneficial to have in work zones. The FST vehicles are equipped with a variety of equipment and have different capabilities than a law enforcement vehicle. The FST can assist with disabled vehicles, pushing vehicles out of the travel lane,

reset barrier wall, etc. The other benefit from FST is the ability to determine a cost/benefit ratio of cost per assist to determine if the FST is effective in the work zone.

Performance measures can also be developed and detailed measurables are able to be easily obtained. With FST, it was mentioned that clearance time can be significantly reduced. It was recommended that FST be used when there are higher volumes or during the peak hours to get the best cost/benefit. The project should also consider location of drop sites and turnaround locations for FST. If they are too far away, FST may not be justified.

10. Law Enforcement Mitigation

Traffic mitigation contracts are set-up with law enforcement in work zones that could have delay exceeding 15 minutes above regular recurring delay or require rolling closures as part of the construction staging. Law enforcement in work zones can enforce the speed limit, assist with incident response as well as be a presence to increase the safety of the work zone. When volumes are low, it was mentioned that using law enforcement was not the most cost-effective strategy. There were also concerns about dedicated enforcement during congested periods as it is much harder for law enforcement to patrol the entire zone due to the heavy traffic.

11. Smart Work Zones

Smart work zones are effective in alerting motorists of traffic conditions ahead. There are many different types of smart work zone systems that can be used in work zones to help inform motorists of queueing and delay. Dynamic late merge systems can be used in work zones that are anticipating regular queuing with a lane closure to help mitigate queue lengths as well as inform motorist of slow or stopped traffic ahead. Travel time systems through the work zone or on alternate routes can also be used to inform motorists of their delay. And finally, queue warning systems can be used to inform motorists of stopped or slow traffic ahead to help prevent and reduce rear-end crashes in work zones, which are the predominant type of crashes in work zones. Smart work zones can also be modified to accommodate any type of work zone. Refer to FDM 11-50-25 for more detailed information, https://wisconsindot.gov/rdwy/fdm/fd-11-50.pdf#fd11-50-25 or the standard detail drawings.

It was recommended to deploy more smart work zones, such as queue warning systems, to help prevent end of queue crashes, which are often severe.

Figure 7: Basic Queue Warning System

12. Traffic Diversion

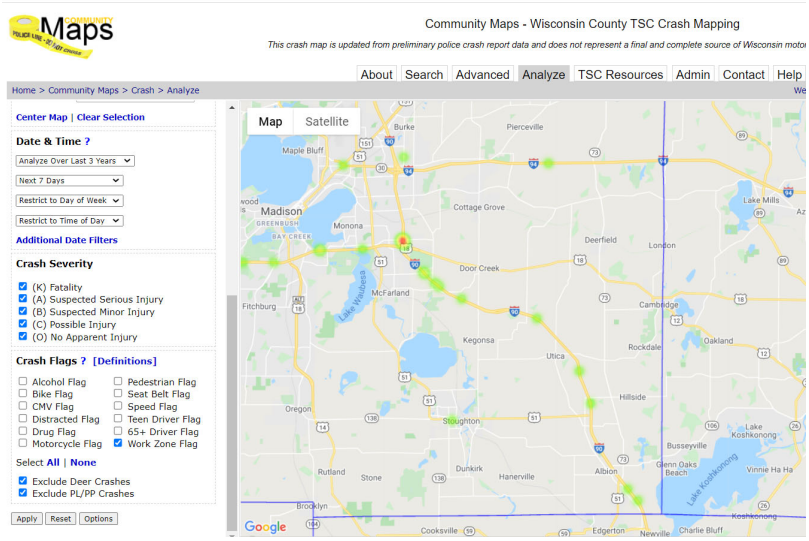
When designing work zones and determining traffic impacts, consider how much diversion the project might get depending on how many alternate routes are nearby, alternate routes and local roads. If there are not any viable routes, there most likely will not be good diversion. This is most often the case on rural interstate highways. If the project experiences diversion, collect data on how effective it was to reducing delay on the mainline. Also note in the TMP if there were problems on the alternate route, or if there were improvements completed along the alternate route to improve traffic flow (revised signal timings, extended turn lanes, etc.).

13. Crashes

One of the biggest issues with crashes is knowing when they happen. If the project team is not aware of a crash, it will be hard for the team to review the work zone to make sure the work zone was set up according to the contract.

Law enforcement has also used predictive analytics to determine where crashes were happening in work zones and were able to stage officers in the area to be ready to respond in the event of an incident.

Figure 8: Community Maps, Predictive Analytics



There were concerns from law enforcement and first responders that in some work zones it is very challenging to respond to the incident. It can be frustrating when there are injuries, and they cannot get to them because traffic is queued and there is no viable shoulder to drive on to respond. To help with these issues consecutive entrance/exit ramps should not be closed, provide more accessible access points for all types of vehicles, and provide shoulders to allow vehicles to move over when law enforcement needs to get through. In some projects the access points were not fit for squad cars to use based on the terrain and could cause damage to the cars.

The project needs to have an incident management plan on how to respond to crashes and clearly communicate and work with first responders to ensure the plan is feasible. This planning starts in the design phase and is not completed until construction has completed. The plan should be updated when there are changes that deviate from the original plan.

14. Emergency Swing Gates (Median)

According to the Division of State Patrol, these median emergency swing gates did not add much value when they were added to a project. To use the gates, both directions of the roadway needed to be shut down, which still requires several troopers/officers to assist and block traffic. It was noted it can be challenging for fire trucks and commercial motor vehicles to make the turn as well.

15. Communication and Coordination

During design and all throughout construction, communication is a key component to a successful project. As part of the project an Incident Response Communication Plan should be developed if the project warrants one based on FDM guidance. It is important to coordinate with first responders (Fire, EMS, Law Enforcement), local towns/cities/villages, adjacent projects, large traffic generators in the area, county highway departments, contractors, WisDOT staff, mapping providers, etc. The following information should be communicated with all entities:

- Construction Activities: lane closures, ramp closures, full closures, traffic stage changes, etc.
- Intelligent Transportation Systems locations and abilities (DMS, FTMS, cameras)
- Alternate Route Maps
- Detour Routes
- Emergency Access Points

If the project is very large, it was recommended to have one main point of contact for traffic incident management, so everyone knows who to contact and it doesn't change by time of day or who is working. It was also found beneficial to have weekly meetings to discuss upcoming construction as well as listen to what could be improved from previous incidents or activities.

16. Temporary Pavement

When switching traffic onto temporary pavement to maintain lanes in the work zone make sure during design considerations are given for drainage, snow storage, snow removal, snow melt, ice and any areas that could be in a shadow.

Ensure lane shifts and crossovers are properly designed and smooth for the driver. When crossovers are not smooth it can create the potential for crashes to occur in that area.

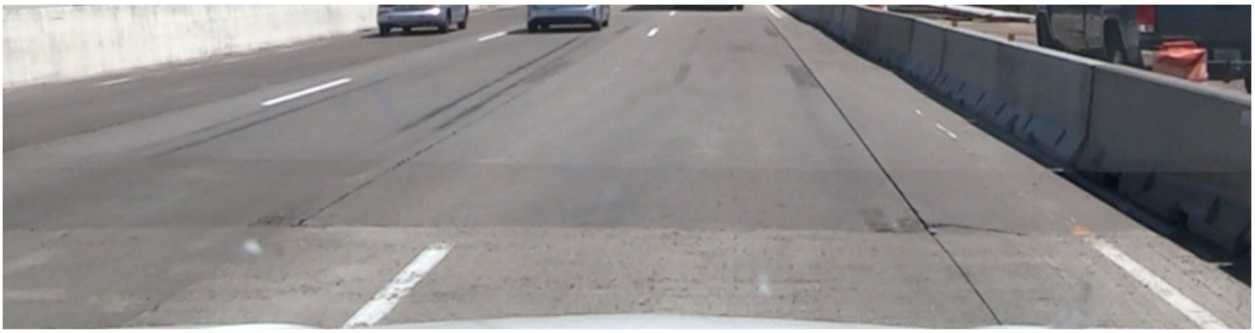
Figure 9: Temporary Pavement

17. Pavement Markings

Make sure pavement markings are visible and placed appropriately. Pavement markings ensure motorists stay in their lanes and understand where to drive in a work zone. Also remove any pavement markings that are not needed to eliminate driver confusion.

Figure 10: Pavement Markings Left in Place

Figure 11: Missing Pavement Markings (End Lines and Skips)



18. Other Considerations

During the process of gathering more information about mitigation in work zones, there were several lessons learned discussed that should be considered in the design process and are listed below:

- Existing Pavement Considerations
    - Review the existing pavement conditions. When traffic is shifted, have narrowed lanes, or temporary pavement the surface condition for the driver can create the potential for increased crashes due to the surface of the pavement.
- Make sure the entire plan is buildable
    - Review the plan with construction staff as they may be able to provide additional insight on constructability.
- Traffic control quantities for all locations –
    - It is important to include quantities for temporary traffic control that will be used during construction, like temporary signals and temporary cameras.
- Consider the pipe depth construction to help determine how it can be constructed and how much time is required.
    - If the pipe is being constructed across a roadway, consider the time for road closures and lane closures to complete the stage.

- Work zones for bridges are safer and easier to build with no traffic under them
- You always need more closures than you expect
    - When planning for lane closures for certain stages, consider adding additional
- Full closures are likely needed for a traffic switch
    - When the plan calls for stage changes, a full closure may be needed to complete the stage change.
- Standard traffic control inspection form
    - Ensure the project team is inspecting the traffic control items on a regular basis and making sure the contractor is correcting anything that doesn't meet standards.
- Standard PCMS messages
    - Request the messages during the design process and have the messages approved before 90% approval of the plan. Do not use messages that should be dynamic, ex: Expect Delays, Slow Traffic Ahead.
- Temporary signing on the back of existing sign bridges
    - If traffic will be shifted into opposite lanes for a stage, consider using the back of an existing sign bridge to place signs for the temporary condition. Check with the Bureau of Structures prior to adding additional signs.
    - Wind load and vertical clearance issues
- Extended closure timeframes may be needed for placement of steel girders
    - Plan and coordinate ahead of time the placement of steel girders and how they will be placed, rolling closure or full closure. Develop a back-up plan in the event it takes longer to place than expected.

Conclusion

A safe, effective work zone requires careful planning, coordination, communication with stakeholders, monitoring, and a willingness to change. The bottom line is it takes continuous coordination and communication between the designers, construction engineers and the boots-on-the-ground personnel in the field to learn what has worked in the past and what changes can be made to improve work zone safety. This document has noted many lessons learned from specific projects that can be utilized in future work zone projects. Changing technologies and constructability methods will increase opportunities to mitigate the impacts of work zones.