2012

Very Short Duration Operations

Safety Guidebook

Center of Transportation Research
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1. Introduction

Texas has the most roadway mileage of any state in the nation, and maintenance is a major function of the Texas Department of Transportation (TxDOT). The safety of workers and motorists is a major concern and the Federal Highway Authority recognizes this challenge and makes provisions for work zone safety in the Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU). Setting up sufficient traffic control devices without severely interrupting traffic and sacrificing safety is a challenging task for traffic engineers, researchers, and maintenance workers.

Adequate safety is a concern for both workers and motorists during maintenance operations. As shown in Table 1, work zone accidents in Texas decreased steadily from 2002 to 2007 but increased again in 2008. Table 1 presents work zone accident data for various types of TxDOT operations, such as construction, maintenance, utility work, and work zones.

Table 1: Construction/Maintenance-related Fatalities in Texas

Year	Number of Fatalities
2008	134
2007	126
2006	146
2005	159
2004	162
2003	171
2002	197
2001	141
2000	155

(Source: 2008 Fatality Analysis Reporting System—Annual Report File and National Highway Traffic Safety Administration)

In order to increase safety of maintenance workers, the *Manual on Uniform Traffic Control Devices* (MUTCD) defines the standards used by road managers nationwide to install and maintain traffic control devices on all public streets, highways, bikeways, and private roads open to public traffic. According to Section 6G.02 (01-02) of the Manual [*1*], work duration is a major factor in determining the number and types of devices used in Temporary Traffic Control (TTC) zones, and the duration of a TTC zone is defined relative to the length of time a work operation occupies a spot location. Following are the five categories of work duration as defined in the MUTCD.

1. *Long-term stationary*: work that occupies a location more than 3 days.
2. *Intermediate-term stationary*: work that occupies a location more than one daylight period up to 3 days, or nighttime work lasting more than 1 hour.
3. *Short-term stationary*: daytime work that occupies a location for more than 1 hour within a single daylight period.
4. *Short duration*: work that occupies a location up to 1 hour.
5. *Mobile*: work that moves intermittently or continuously.

Note that operations of very short duration are not independently classified by the MUTCD, and they need to be defined. These types of operations typically last for a few minutes and the major challenge involved is workers setting up adequate traffic control treatment in a period of time such that installing and disassembling the traffic control devices does not take longer than the work activity to be performed. Previous studies *[2, 3, 4, 5]* observed that workers are reluctant to utilize extensive traffic control for activities that take only a few minutes to complete. In addition, the setup and removal of traffic control devices increases the workers' exposure to traffic. Adequate safety is therefore a concern for both workers and motorists in very short duration operations *[2]*. A **very short duration operation (VSDO)** is, therefore, defined as**:**

> ***A planned or urgent activity, to be executed in 15 minutes or less by a crew of one man and one truck or more, in which the hazard of not executing the work as a very short duration operation is greater than executing it.***

Activities categorized as VSDOs include debris removal, pothole patching, edge patching, delineator maintenance, warning sign placement, supervisor markings for future work, photography, data collection/surveys, and signal light replacement. For example, TXDOT patches over 500,000 potholes annually and removes debris from the roadway daily in almost every maintenance section in the state. These activities are normally completed within 15 minutes. Activities **not** classified within this new category of maintenance operations include short duration and mobile maintenance operations such as crack sealing, herbicide application, mowing/brush cutting, raised pavement marker replacement, snow and ice control, striping, sweeping, guardrail work, lighting maintenance, paving operations, signal work, and sign repair and installation.

An important determinant in the VSDO definition is that *the hazard of not executing the work as a VSDO should be greater than executing it* [2]. If suspending the work will not cause much hazard to the traveling public and executing it will endanger maintenance workers, then the guidelines

recommend not proceeding with the work as a VSDO. A better option would be to perform the work later in a safer condition or wait for assistance. The following hazards and concerns are identified by various studies [*2*, *3*, *4*, *5*] for short duration operations:

- high speed traffic,
- high traffic volumes,
- motorists ignoring or not understanding traffic control devices,
- inattentive motorists not noticing the work area or not taking precautions such as reducing speeds,
- effectiveness of current traffic control devices,
- visibility of work zone,
- proper setup and location of short term traffic control devices,
- maintenance vehicles being rear-ended by traffic,
- erratic vehicles entering the convoy or work area,
- last-ditch lane changing,
- lack of adequate training for new employees,
- roadway geometry, and
- environmental conditions.

These hazards and concerns are applicable to VSDOs as well. Specific guidance for VSDOs is undocumented and workers tend to use their own judgment in making critical time-sensitive decisions. A recent eyewitness account from a state other than Texas reports that a maintenance worker was killed while trying to remove a dead dog on a freeway ramp. Despite the worker having a spotter to watch for oncoming traffic, the worker ran in the same direction as the vehicle when the spotter yelled at the worker. Another eyewitness account in Texas describes a maintenance worker patching pavement failures on a road in a metropolitan area. The worker allegedly parked on a shoulder and would dart out into a travel lane with a shovel when no traffic was oncoming, dump patching material in a crack, and dash back to the shoulder. These two incidents are examples of the clear need for effective worker training in and guidelines on performing very short duration maintenance operations.

Reader's Guide to this Guidebook

This safety guidebook seeks to complement training modules that will educate maintenance workers on identifying work zone hazards. Identifying risk factors in VSDOs helps maintenance workers to better judge the condition of VSDOs and make more informed decisions on whether to conduct an operation as a VSDO or not. This safety guidebook provides

details and findings of shadowing activities conducted to reveal the current practice of VSDOs at TxDOT. This guidebook also presents a risk management process that enables maintenance workers to identify work zone hazards for VSDOs and improve their judgment about work zone conditions. Multiple scenarios illustrating the risks are presented, and related safety recommendations are also discussed. An expert panel was convened in April 2011 and March 2012 to generate these recommendations.

2. Shadowing Activities

Shadowing activities were conducted to help the research team learn about the current common practices of VSDOs and provide more applicable and practical guidance to the maintenance crews [2]. Findings from the shadowing activities provided an important basis for subsequent expert panel [*6*] discussions and the scenario-based risk assessment. Thirty VSDO observations were conducted and 15 unique samples, shown in Table 2, were documented during the shadowing activities in three TXDOT districts—one urban and two rural [2]. For each observation, the researchers recorded work duration and location, scenario description, actions taken, roadway geometry, location of the parking vehicles, traffic control procedures, and safety precautions.

Based on shadowing observations, VSDOs can be characterized into three different categories, each defined by the location of operation:

1. Operations on or beyond the shoulder
2. Operations within a traveled way with a shoulder
3. Operations within a traveled way without a shoulder, e.g., bridges

Table 2. A Summary of 15 Unique Observations

Observation	Work Duration	District Area	Number of Workers and Trucks	Traffic Control Devices
Operations on or beyond the shoulder				
Observation 1: Picking up a dead wild pig in the median	5 minutes	Urban	Two workers and two trucks	Truck-mounted flashing light bars
Observation 2: Picking up a dead deer in the median	2 minutes	Rural	Two workers and one truck	Truck-mounted flashing light bars
Observation 3: Setting up warning sign at a high way entrance	10 minutes	Urban	Two workers and two trucks	Truck-mounted flashing light bars, portable message sign
Observation 4: Picking up a trash bag on three-	5 minutes	Urban	One worker and one truck	Truck-mounted arrow boards and

Observation	Work Duration	District Area	Number of Workers and Trucks	Traffic Control Devices
lane divided highway				flashing lights
Observation 5: Removing rubber from the shoulder	Less than 1 minute	Rural	One worker and one truck	Truck-mounted flashing light bars
Observation 6: Removing pallets from the road	Less than 1 minute	Rural	One worker and one truck	Truck-mounted flashing light bars
Observation 7: Removing plant growing on the shoulder	5 minutes	Rural	One worker and one truck	Truck-mounted flashing light bars
Observation 8: Removing dead cow from the shoulder	Less than 5 minutes	Rural	Four workers and two trucks	Truck-mounted flashing light bars, truck-mounted message board, backhoe, and a flagger-person
Observation 9: Helping other vehicles	3 minutes	Rural	One worker and one truck	Truck-mounted flashing light bars
Operations within a traveled way with a shoulder				
Observation 10: Pothole patching	3 minutes	Rural	One worker and one truck	Truck-mounted flashing light bars
Observation 11: Removing dead animal from middle of the roadway	Less than 1 minute	Rural	Two workers and one truck	Truck-mounted flashing light bars
Observation 12: Removing rubber from the roadway	Less than 1 minute	Rural	One worker and one truck	Truck-mounted flashing light bars
Operations within a traveled way without a shoulder				
Observation 13: Picking up debris along the shoulder of a bridge	2 minutes	Urban	Three workers and two trucks	Truck-mounted flashing light bars
Observation 14: Picking	Less than 1	Rural	Three workers	Truck-mounted

Observation	Work Duration	District Area	Number of Workers and Trucks	Traffic Control Devices
up debris along the bridge	minute		and two trucks	flashing light bars
Observation 15: Picking up multiple objects on exit ramp	5 minutes	Urban	Four workers and three trucks	Truck-mounted arrow boards and flashing lights, two trucks with attenuators

In general, operations on or beyond the shoulder pose fewer hazards to maintenance workers and the traveling public. If operations are conducted within a traveled way and the road has a shoulder, the maintenance vehicles are usually parked on the shoulder and the workers step out of the vehicles and walk into the traveled way to perform tasks without any extra safety protection. Operations within a traveled way without a shoulder often involve temporary lane closure.

Typically, VSDOs are not differentiated from other maintenance operations; no particular crew is assigned to perform only this kind of operation. Maintenance crews at TxDOT usually perform a variety of tasks during a typical day; therefore, only some of the observations recorded could be considered VSDOs. Typical scenarios and important findings from the shadowing are described in the following subsections.

2.1. Typical Scenarios

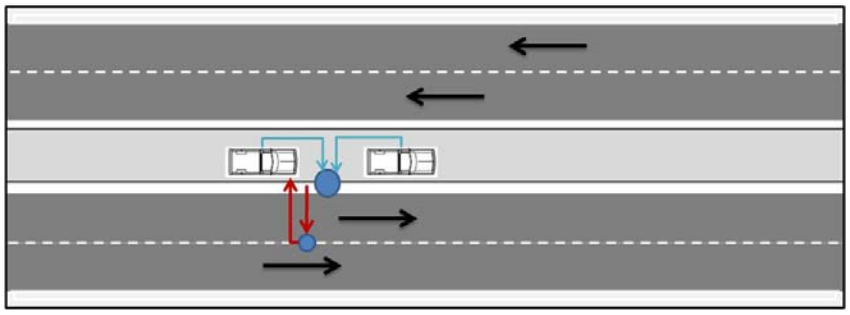
While shadowing, the researchers identified typical VSDO activities performed by TxDOT, which include picking up dead animals/debris on the shoulder or in the middle of the roadway, picking up multiple objects along the shoulder, pothole patching, and setting up warning signs. These activities do not cover all VSDOs currently performed but, to some extent, reveal the current state of practice in VSDOs and provide insights into the need for specific guidance to the maintenance workers. Tables 3 through 5 summarize the information recorded.

2.2.1. Scenario 1: Picking up dead animals on the shoulder or within a traveled way

Observation 1 involved picking up a dead animal along the shoulder adjacent to the median, which is a common operation performed by TxDOT maintenance workers (see Table 3). The operation took 5 minutes. Two trucks (one work truck and the shadow vehicle) and two workers were used in this operation. As shown in Figure 1, two maintenance workers walked out of the truck and shoveled the dead pig into a plastic bag. The crew leader noticed some

leftover parts in the middle of the roadway. During gaps in the traffic, he walked out into the travel lane to perform the necessary task (see Figure 2). This action was identified as a risky behavior because the worker walked directly into the travel way to pick up remains without any extra protection. The only traffic control device used in this operation was the truck-mounted flashing light bars.

Table 3: Summary of Observation 1

Observation 1: Picking up a dead wild pig in the median	
Observation classification	Operations on or beyond the shoulder
Duration	5 minutes
Illustration	
Roadway geometry	Four-lane divided, level and straight
Location of work	On the shoulder and in the travel way
Work vehicle location	In the median area attaching the shoulder
Traffic control devices	Truck-mounted flashing light bars
Traffic control procedures	1. Two maintenance workers walked out of the truck and shoveled the dead pig into a plastic bag. 2. The crew leader noticed some leftover parts in the middle of the roadway. He looked for a gap in the oncoming traffic stream and walked out into the travel lane conduct the necessary task.
Safety precautions	N/A

Pictures	 **Figure 1: Work Procedures of Observation 1**  **Figure 2: Picking leftover parts within the travel way**

2.2.2. Scenario 2: Pothole patching

Observation 2 involved patching a pothole in the middle of the roadway and on the shoulder (see Table 4). The operation took 3 minutes and one truck and one worker were used. As shown in Figure 3, the maintenance worker walked out of the truck and deposited patching materials in the pothole. To do this, the maintenance worker looked for an opening in the oncoming traffic stream to walk out into the travel lane and complete the necessary task. This action was

identified as a risky behavior because the worker walked directly into the traveled way to do the job without any extra protection. After placing the patching material, the maintenance worker backed up on the road with his truck to compact the patch. This activity is also identified as a hazardous action as backing up on roads is dangerous. The only traffic control device used in this operation was truck-mounted flashing light bars.

Table 4: Summary of Observation 2

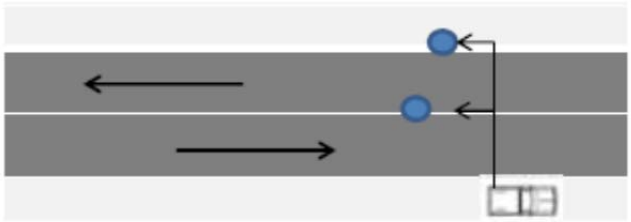
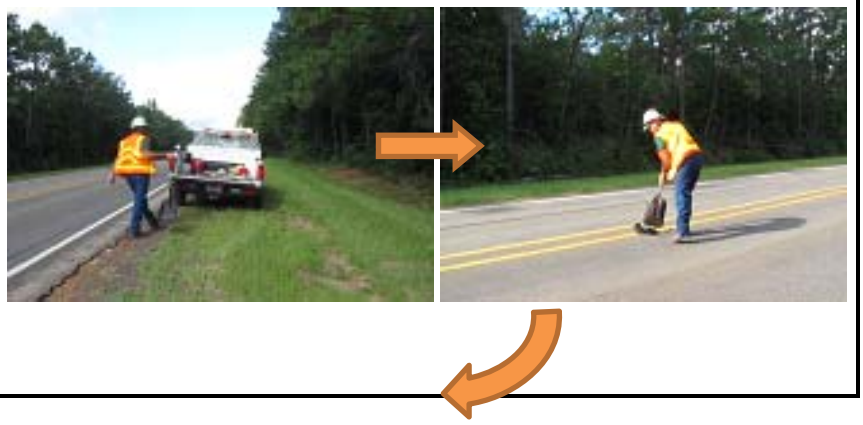
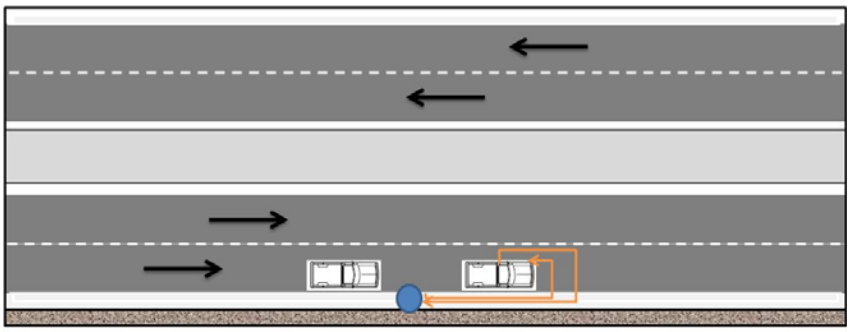
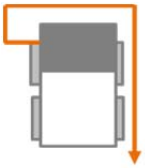
Observation 2: Pothole Patching	
Observation classification	Operations within a traveled way with a shoulder
Duration	3 minutes
Illustration	
Roadway geometry	Two-lane rural road, level and straight
Location of work	In the middle of the roadway
Work vehicle location	On the shoulder
Traffic control devices	Truck-mounted flashing light bars
Traffic control procedures	One maintenance worker walked out of the truck and placed material in the pothole. Then he rolled over the pothole with his truck to compact the patch
Safety precautions	N/A
Pictures	

Figure 3: Work Procedures of Observation 2

2.2.3. Scenario 3: Picking up debris on a bridge

Observation 3 involved picking up debris along the shoulder (see Table 5). The operation took 5 minutes. Two trucks (a cage truck and the shadow vehicle) and two workers were used in this operation. Some safety precautions were taken, but hazardous situations still existed. Because the work location was on a concrete bridge, the worker was in the narrow space between the trucks and the concrete barrier (shown in Figure 4). In this situation, if the shadow truck were struck by an oncoming vehicle, the worker could be trapped.

Table 5: Summary of Observation 3

Observation 3: Picking up debris along the shoulder	
Observation classification	Operations within a traveled way without a shoulder, e.g., bridges
Duration	2 minutes
Illustration	
Roadway geometry	Four-lane divided (on the bridge), level and straight
Location of work	On the right shoulder
Work vehicle location	In the travel way (on a bridge with solid barrier rail and a narrow shoulder, approximately 3 ft)
Traffic control devices	Truck-mounted flashing light bars
Traffic control procedures	The cage truck operator exited the truck into the adjacent travel lane, walked around the front of his truck, then walked back toward the rear of his truck to pick up the debris. 
Safety precautions	• The shadow truck stopped approximately 50 ft behind the cage truck and the arrow board was raised. • The shadow truck operator turned the steering wheel to the left (so that if the shadow truck was hit from the rear, it would travel into the adjacent travel lane and not impact the cage truck or cage truck operator). *It was noted that during the second litter pickup on the bridge, the maintenance crew leader in the shadow truck parked much closer to the cage truck and did not turn the steering wheel to the left. However, he was talking with the researchers, which likely distracted him from his normal mode of operations.

Pictures	 **Figure 4: Work Procedures of Observation 3**

2.2. Shadowing Findings

The shadowing observations revealed the current state of practice in VSDOs and provided insights into the need for specific guidance to the maintenance workers conducting VSDOs. The main findings from the shadowing are summarized and described in this section [2].

i) Duration of work

All operations recognized as VSDOs were conducted within 15 minutes, and 93% of all these operations took no more than 5 minutes. VSDOs often take only a few minutes

(usually less than 5 minutes) and workers are usually reluctant to utilize extensive traffic control that will take longer to set up and remove than to perform the work.

ii) Crew and equipment

Most of the VSDOs were conducted with one truck and one worker. Only a few operations used one truck and two workers. Especially in rural areas, VSDOs often involved just one man and one truck and limited traffic control devices were used during the operations. The most commonly used traffic control device was a truck-mounted flashing light bar, which may not be bright enough during daytime. Only in specific situations would supplemental traffic control devices be used. For instance, when removing a dead cow from the shoulder in a rural area, two trucks mounted with flashing light bars and a flagger were used as attention grabbers, and a back-hoe was used to lift the animal. As limited traffic control devices are used by maintenance crews, the motorists usually pass by without paying much attention to the work zone and the maintenance crews. As a result, more or better traffic control devices are needed to draw the attention of the traveling public.

iii) Location for parking maintenance vehicle

Maintenance crew vehicles are usually parked near the work location. However, in some cases, much safer places were available for maintenance workers to park their vehicles. Maintenance workers should be advised to park their vehicles in the safest available place. In addition, while shadowing, the researchers observed workers sometimes backing up to pick up objects after they drove past the objects. According to TxDOT policy, drivers are not supposed to back up in situations like these as it poses a danger to both workers and other road users. The policy requires that drivers make a U-turn, drive back to the location of the object, and perform the task.

iv) Request for assistance

Information such as location of an object (within the traveled way, on or beyond the shoulder, or in the median) may not be known until the crew arrives at the work zone, and the reported object type may not be known or described properly before dispatch. Hence, at times the crew and equipment on the scene are not adequate to perform the work. For urban high-volume high-speed roadways, if no crew members or truck-mounted attenuators are available, and the object is deemed dangerous to the traveling public, the crew may call 911 or a related public agency for assistance. On rural low-volume high-speed roadways, workers usually pick up objects without any other assistance except for flashing lights on their trucks.

v) Communication systems

The research team found the communication system to be inadequate and unsafe for workers. In addition to communicating with the vehicle-mounted internal radio system, workers typically used one or more cell phones to talk to other crew members while driving. Workers also used cell phones while on foot at the work zone.

The shadowing findings suggest that more practical guidelines should be developed and more efficient and effective devices, which are easy to apply or adapt to current practice, should be used. Safety precautions and guidance need to be provided and stressed in the risky scenarios in which accidents are likely to happen and the consequent severity is high.

3. Risk Management Process

Through shadowing activities and consultation with an expert panel, the research team identified the risk factors impacting maintenance workers and motorists during VSDOs. A scenario-based risk management process was designed to elicit risk mitigation strategies. *Risk* refers here to the potential for an accident that harms workers or drivers during a VSDO. *Scenario* is used here to describe a possible set of conditions under which accidents are likely to occur.

The objective of the scenario-based risk management process is to stimulate thinking about possible dangerous conditions and accident occurrences, assumptions related to these occurrences, and potential opportunities, risks, and courses of action. The results introduce the worst scenarios under which accidents are likely to occur and provide recommendations of additional safety precautions to the maintenance workers performing VSDOs.

As illustrated in Figure 5, the risk management process includes five steps: 1) risk identification, 2) risk assessment, 3) risk analysis, 4) mitigation strategies, and 5) evaluation [7]. The first step identifies the sources of risks in VSDOs. The second step assesses and prioritizes the risks; the risks that are most likely to occur and have serious consequences are considered in the subsequent analysis. The causes of those risks are analyzed and mitigation strategies are proposed, which will be evaluated and refined in a new cycle.

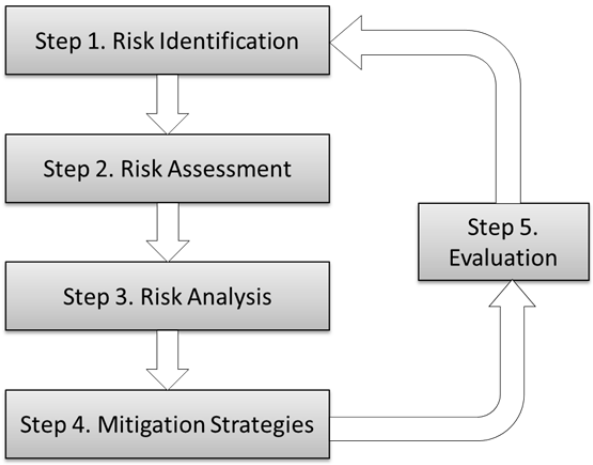


Figure 5: The Risk Management Process

3.1. Risk Identification

The first step in risk management is to identify types and sources of risk. A fault tree diagram was used for risk identification. Fault tree analysis is a top-down, deductive failure analysis that uses a graphical model of events to facilitate detailed analysis of system or component failure

[*8*]. Figure 6 shows the fault tree diagram for safety risk identification during VSDOs. As shown in the diagram, if a worker misjudges the conditions of the roadway at the same time a motorist fails to properly control his/her vehicle, then an accident is likely to occur. The worker may misjudge the traffic volume, traffic speed, duration of work, or a combination of these factors. The driver may also fail to avoid an accident due to not seeing the worker or being unable to avoid hitting the worker after seeing the worker. The severity level of accident increases with the traffic speed. When the traffic speed is low, there is less danger; when the traffic speed is high, the consequences of an accident can be severe.

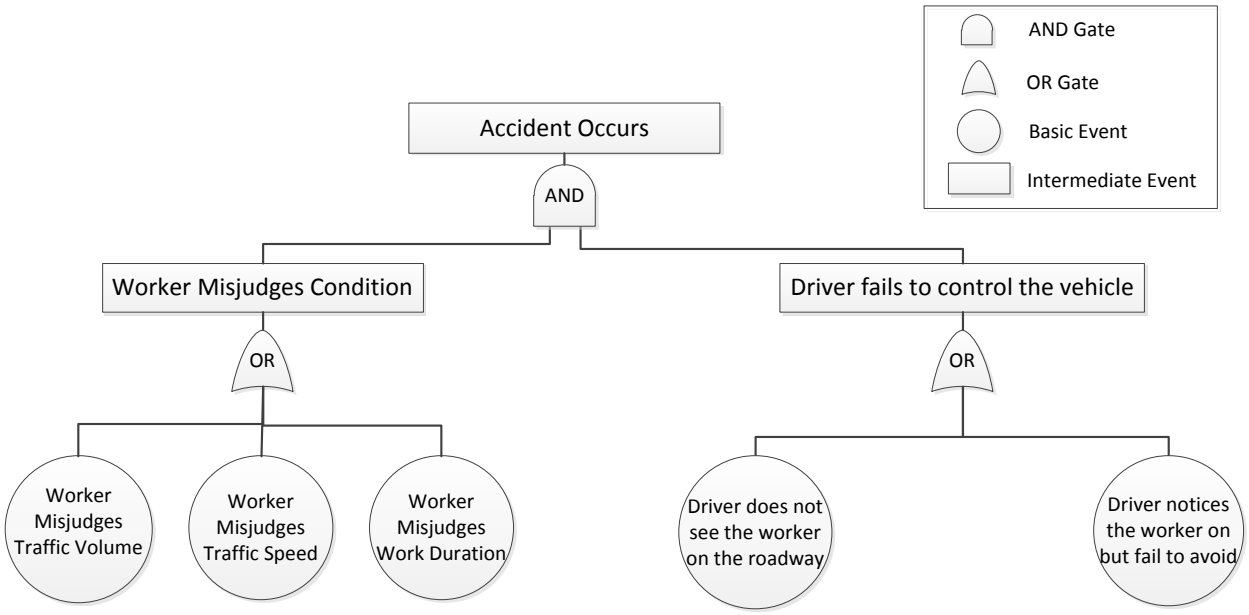


Figure 6: A Fault Tree Diagram for VSDO Safety Risk Identification

3.1.1. Factors that contribute to risk

The expert panel members identified factors that need to be considered when developing strategies for VSDOs. Traffic volume, traffic speed, time of day, and type of roadway were identified as the four most important factors for VSDO considerations because of the broad variability of these four factors. For example, if traffic volume and speeds are low, then the working conditions are considered relatively safe; on the other hand, if both traffic volume and speeds are high, then the workers tend to face a much more significant safety risk.

Table 6 shows a detailed explanation of all the risk factors and the evaluation criteria for each factor. In order to narrow the scope and still provide helpful guidance to the workers, these risk factors were further refined and prioritized.

Table 6: Detailed Descriptions of the Influencing Factors

Ranking	Influencing Factor	Sub-dimension	Definition
1	Traffic Volume	High	Workers perceive that there is NOT enough time to walk to and from the work zone (between traffic) and finish the job safely
		Medium	Workers perceive that there is enough time to walk to and from the work zone (between traffic) and finish the job safely, but with extra safety precautions
		Low	Workers perceive that there is enough time to walk to and from the work zone (between traffic) and finish the job safely
2	Traffic Speed	High	Workers perceive that there is NOT enough time to walk to and from the work zone (between traffic) and finish the job safely
		Medium	Workers perceive that there is enough time to walk to and from the work zone (between traffic) and finish the job safely, but with extra safety precautions
		Low	Workers perceive that there is enough time to walk to and from the work zone (between traffic) and finish the job safely
3	Time of Day	Day	With sufficient visibility
		Night	With limited visibility
4	Type of Road	Two-lane undivided	There is no median or other strip of land or divider between the two directions of traffic
		Multilane undivided	A multi-lane road with only striping (but no median) between the two directions of traffic flow

Ranking	Influencing Factor	Sub-dimension	Definition
		Multilane divided	A multi-lane road with a median or other type of divider between the two directions of traffic flow
5	Weather Condition	Clear	High visibility and good condition for outdoor maintenance work
		Rain/fog/snow	Low visibility and poor condition for outdoor maintenance work
6	Vision-Blocking Objects	Yes	Curves, hills, or other objects that obstruct the view between workers in the work zone and the upcoming traffic
		No	Nothing obstructs the view between workers in the work zone and the upcoming traffic
7	Location of Work	On or beyond the shoulder or in the median	Worker can perform the work without entering active travel lanes (e.g., picking up a dead pig on the shoulder)
		Within a traveled way with a shoulder	Worker has to perform the work by entering into the active travel lanes with a shoulder (e.g., removing tire straps from the roadway with shoulders)
		Within a traveled way without a shoulder	Worker has to perform the work by entering into the active travel lanes without a shoulder (e.g., picking up debris along the bridge without a shoulder)
8	Roadway Geometry	Straight and flat	Does not have vision-blocking objects; the speed of the upcoming traffic is predictable
		Curves/hills	Has vision-blocking objects; the speed of the upcoming traffic is less predictable
		Intersections	Has traffic coming from four different directions

Ranking	Influencing Factor	Sub-dimension	Definition
9	Pavement Surface Condition	Dry	Maximum friction coefficient is available
		Wet	Maximum friction coefficient is reduced
		Icy	Maximum friction coefficient is greatly reduced
10	Availability of Refuge	Yes	Worker has a place to escape from potential traffic hazards
		No	Worker does not have a place to escape from potential traffic hazards

3.2. Risk Assessment and Analysis

To determine the worst combinations of traffic speed and volume, the graph shown in the Figure 7 was developed. As illustrated in the figure, the worst-case scenario, where a worker may misjudge traffic conditions, is when traffic speeds are high and traffic volume is either low or medium (see Table 6 for description of traffic conditions). This scenario is common primarily in rural and farm-to-market (FM) roads.

Also, as shown Figure 7, the probability of a maintenance worker misjudging a traffic condition decreases significantly when both traffic speed and volume are low. In addition, the figure shows that a maintenance worker can appropriately judge the work zone condition when the speed is low and traffic volume is high, but there is not enough time to safely execute the maintenance work as a VSDO.

Furthermore, panel members unanimously agreed that VSDOs should not be performed when both traffic speeds and volumes are high. The panel proposed that if the risk involved in undertaking a VSDO was greater than the risk of doing nothing, workers should either reschedule the task or request additional assistance. Assistance may include truck-mounted attenuators, additional workers, and law enforcement involvement.

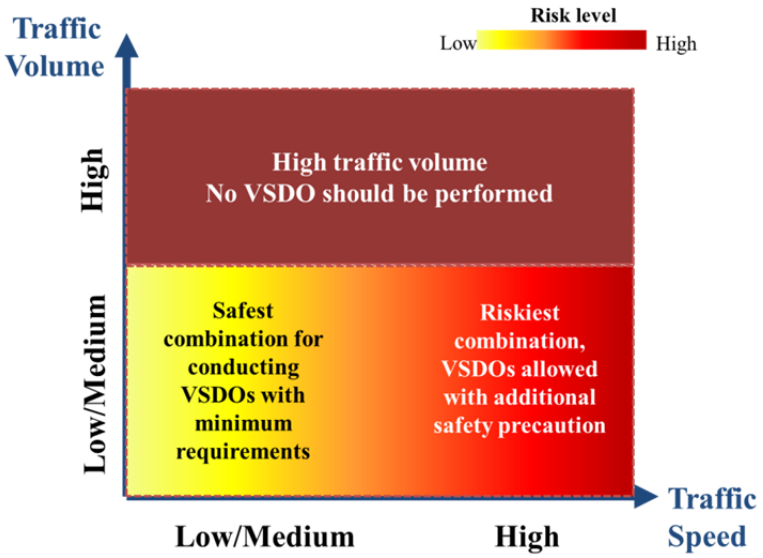


Figure 7: Traffic Speed and Volume Graph

In addition, these other factors have an impact on workers' judgment and drivers' ability to control their vehicles:

1. Limited visibility such as foggy weather,
2. Medium traffic volume and high traffic speed,
3. Low traffic volume and high traffic speed, and
4. Icy pavement surface.

Based on the varying conditions of VSDOs, a decision flowchart was developed to help maintenance workers decide whether a maintenance operation should be considered as a VSDO or not [2]. The decision flowchart, shown in Figure 8, tries to increase maintenance worker awareness during the VSDO decision-making process.

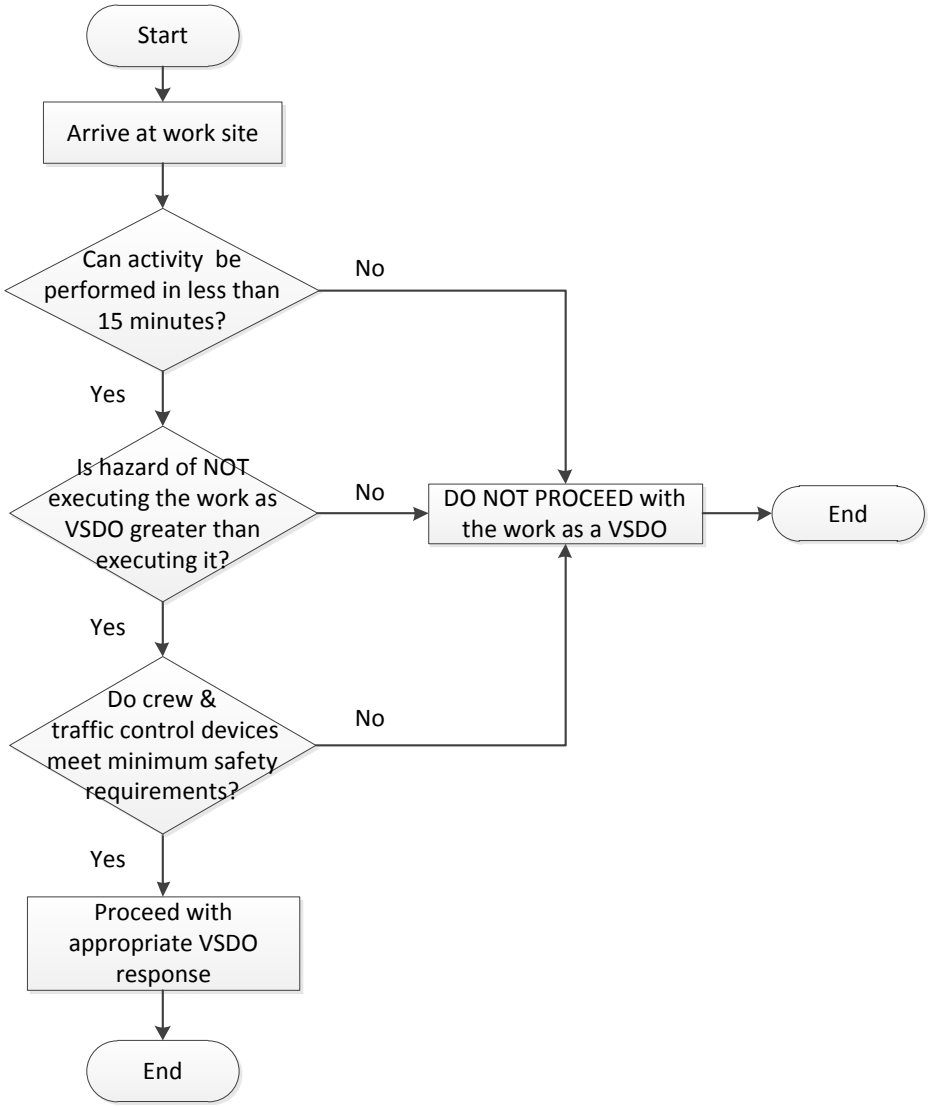


Figure 8: Decision Flowchart for Proceeding with Work as a VSDO

The decision flowchart seeks to answer three main questions:

Question 1: Can the activity be performed in less than 15 minutes?

As stated in the definition, VSDOs are usually performed within 15 minutes. If the task is estimated to take less than 15 minutes to complete, then the crew can perform the work as a VSDO and proceed to the next question. If the answer is "no," the workers should follow the instructions for that specific type of maintenance operation as described in the MUTCD.

Question 2: Is hazard of NOT executing the work as a VSDO greater than executing it?

According to the definition of VSDOs, the hazard of *not* executing the work as a VSDO should be greater than executing it. If immediate execution of the work as a VSDO is hazardous to the maintenance workers, then the recommendations suggest that work as a VSDO not proceed. A better option would be to perform the work later in a safer condition or after adequate assistance is obtained. The following situations are considered reasons for ***not*** performing the task as a VSDO.

1) **No immediate danger to the travelling public**. For example, a piece of cardboard on the roadway cannot be considered a danger to motorists. On the other hand, a ladder dropped in the middle of the roadway can pose a danger.
2) **Inadequate sight distance for workers in the work zone**. Curved or hilly roadway sections where a maintenance worker cannot see oncoming traffic and motorists do not have sufficient time to react appropriately can be considered a hazard to the worker's safety.
3) **High traffic volumes and traffic speeds**. High traffic volumes and speeds are dangerous for workers performing tasks without any enhanced safety equipment. Additional crew members, special traffic control devices, or law enforcement involvement may be needed in this situation
4) **No refuge available**. When the work is located on a section of roadway with no shoulders (e.g., narrow bridges), performing a VSDO can be considered hazardous due to the lack of refuge from oncoming vehicles.
5) **Unfavorable weather conditions**. Examples include snowy or icy weather, or dense fogs.
6) **Insufficient lighting conditions**. Poor visibility poses safety hazards to both maintenance workers and the traveling public and thus it is not recommended that the crew perform the work as a VSDO.

Question 3: Do crew and traffic control devices meet minimum requirements?

If the number of crew members and traffic control devices is insufficient for the task to be performed safely, the work should not proceed as a VSDO. Each scenario is unique, so minimum requirements may differ based on the operation. Workers should therefore proceed with the appropriate VSDO response for that particular scenario. For example, two workers and a truck mounted with a high intensity flashing light bar might be adequate for picking up a dead animal from the middle of a straight road segment in a rural area. The same setup may not be sufficient, however, for picking up a dead animal within a traveled way with high traffic volume in an urban area where law enforcement or additional resources will be required.

If the answers to all three questions are "yes," then performing the task is comparatively safe with appropriate VSDO response. Otherwise, the work should not be performed as a VSDO. In order to provide more practical guidelines for maintenance workers, safety precautions and guidance need to be provided and stressed in the risky scenarios in which accidents are likely to happen and the consequent severity is high. Therefore, several practical safety guidance scenarios were developed for the most urgent cases and the results can easily be adjusted to efficiently deliver information to maintenance workers. This scenario-based safety analysis can provide useful guidance to the workers for proactive prevention of accidents in VSDOs.

3.3. Mitigation Strategies: Scenario Development and Safety Recommendations

This section provides the results of scenario development and safety recommendations. As defined earlier, *scenario* is used to describe a possible set of conditions under which accidents are likely to occur. Different scenarios representing the most common and worst-case VSDOs were developed. For each scenario, conditions of risk factors such as traffic volume, traffic speed, time of day, type of road, weather condition, level of emergency, severity of danger, amount of vision blocking, work location, roadway geometry, pavement condition, and availability of refuge are described. In the following scenarios, minimum safety requirements include one man and one truck mounted with a light bar (as shown in Figure 9).

Figure 9: Minimum Truck Requirements for VSDO

Also, traffic volume in the following scenarios is defined according to these three levels:

a. *High*: there is not enough time to walk to and from the work zone and finish the job safely.

b. *Medium*: There is enough time to walk to and from the work zone and finish the job safely, but with safety precautions.

c. *Low*: There is enough time to walk to and from the work zone and finish the job safely.

3.3.1. Scenario I: Typical VSDOs on a travel-lane or shoulder

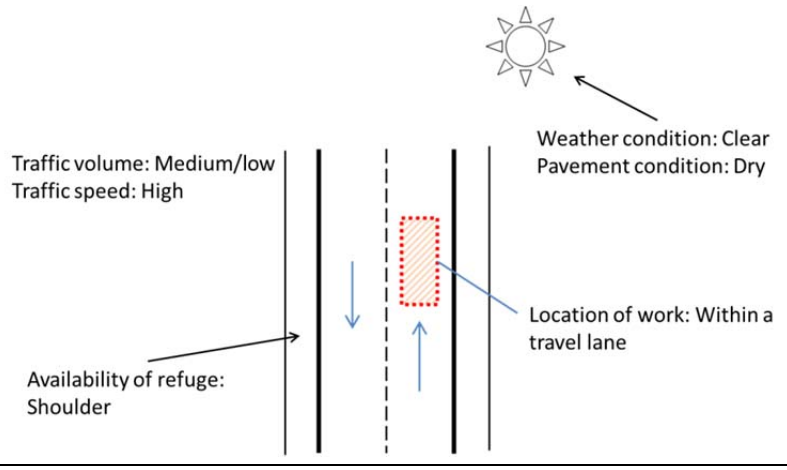
Conditions

Researcher observations during shadowing activities indicate that a large portion of VSDOs are performed on straight roadways during clear days when traffic volume is medium or low and traffic speed is high. In this scenario, there is no vision-blocking issue (e.g., curve or hill) and a shoulder can be considered a refuge. See Table 7 and Figure 10.

Expert Panel Safety Recommendations

The minimum requirement for this scenario is one maintenance worker, with a truck equipped with a high intensity light bar. Based on discussions in the Expert Panel meeting, the maintenance vehicle should be parked in a safe place. Experts believed that a shoulder is not a safe place and the vehicle should be parked as far away from traffic as is practical. Also, they mentioned that the vehicle should be parked before the work zone.

Table 7: Summary of Scenario I

	Description
Conditions	

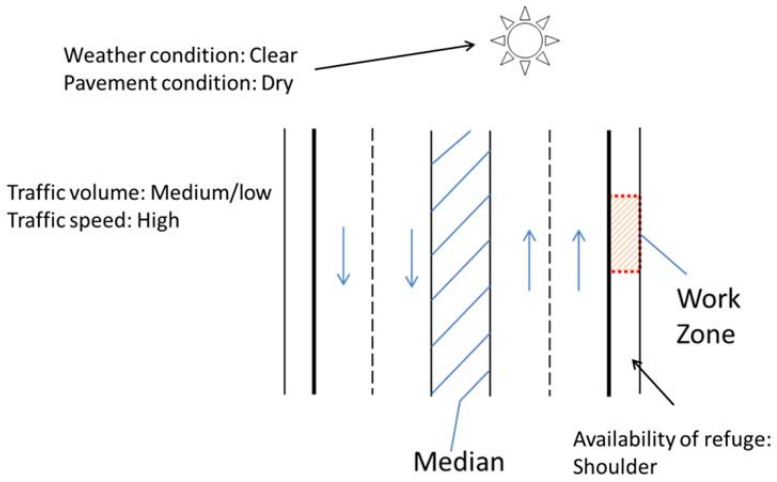
<table>
<tr>
<td></td>
<td> 

Figure 10: Scenario I Illustration</td>
</tr>
<tr>
<td>Safety Recommendations</td>
<td>
• Minimum requirement
o One truck, one worker
o Truck should have a high intensity light bar.
• Where to park the maintenance vehicle?
o The closest possible parking space is favorable (in this situation, light bars would be more effective).
o A maintenance worker should park his vehicle on the same side where he wants to work.
• Minimum requirement
o One truck, one worker
▪ A worker should monitor oncoming traffic.
o Truck should have a high intensity light bar.
• Where to park the maintenance vehicle?
o The maintenance vehicle should be parked in a safe place.
▪ The shoulder is not a safe place.
▪ As far away as traffic as practical
• The maintenance vehicle should be parked before the work zone.
</td>
</tr>
</table>

3.3.2. Scenario II: VSDOs with vision-blocking geometry

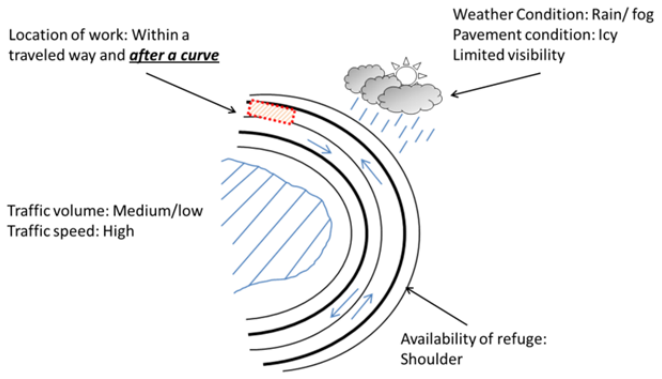
Conditions

This scenario reflects a higher risk than that of Scenario I due to limited visibility caused by the geometry of the roadway. Curvature or steep slopes increase the risk when conducting a VSDO because of reduced stopping sight distance. This scenario also includes other risk factors such as icy pavement, low to medium traffic volume, high traffic speed, and limited visibility because of bad weather. See Table 8 and Figure 11.

Expert Panel Safety Recommendations

This scenario reflects an unsafe situation where extra precautions are required. In this situation, the risk of poor judgment on a worker's part is high. Conducting the maintenance work as a VSDO depends on how much time a worker should spend doing the work and the work zone situation. Also, a maintenance worker judgment about conducting a VSDO is based on the gear and personnel available upon arriving at the work zone. For this scenario, at least two maintenance crew members should be present. One worker can act as a flagger whiles the other conducts the work. The flagger should be able to see the other worker at all times, and also be easily noticeably by oncoming motorists. The flagger should be positioned before the curve or hill.

Table 8: Summary of Scenario II

	Description
Conditions	 **Figure 11: Scenario II Illustration**

Safety Recommendations	• A flagger (if a maintenance crew has two workers) o In this case, radio headset should be used for better communication between flagger and maintenance worker. • Flare kits should be placed before the curve/hill. • A flagger should use devices to increase his/her visibility, such as a safety baton and flashing LED paddles. • Special traffic sign • Risk of making bad judgment is high. • Could be done as a VSDO depending on the gear and personnel available upon arriving at the work zone

3.3.3. Scenario III: VSDOs without places of refuge

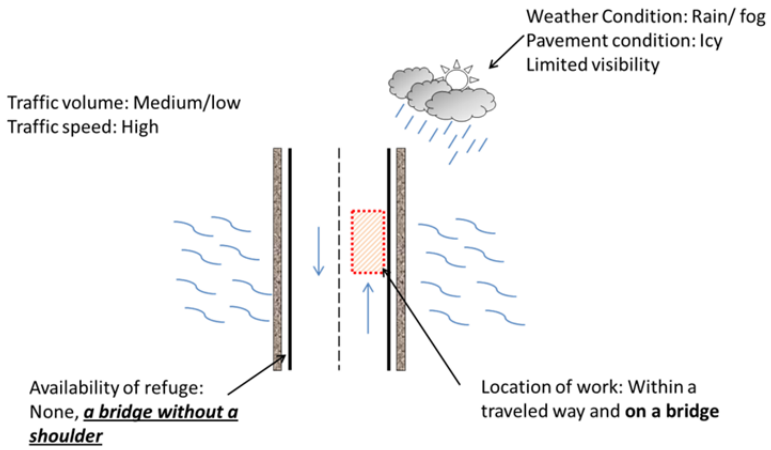
Conditions

This scenario reflects a higher risk condition than typical VSDOs (described in Scenario I) due to non-availability of refuge space. Non-availability of refuge alone significantly increases the risk of conducting a VSDO. This scenario also includes other risk factors such as icy pavement, high traffic volume and speed, and limited visibility due to weather conditions. See Table 9 and Figure 12.

Expert Panel Safety Recommendations

This scenario reflects an unsafe situation where extra precautions are required. In this situation, additional help is required, such as a truck-mounted attenuator or law enforcement involvement. If both traffic volumes and speeds are low, and there are no visibility limitations, the maintenance worker can conduct the maintenance work as a VSDO with a truck-mounted high intensity flashing light bar.

Table 9: Summary of Scenario III

	Description
Conditions	 **Figure 12: Scenario III Illustration**
Safety Recommendations	• Truck-mounted attenuator (TMA) • Vehicle-mounted dynamic message signs • In this situation, one additional worker should be used. • Radio headset for communication • This scenario represents a high-risk situation. • Extra help is needed. • If traffic volume is low and visibility is not limited, it can be done as a VSDO.

3.3.4. Scenario IV: VSDOs on a multilane roadway without a median

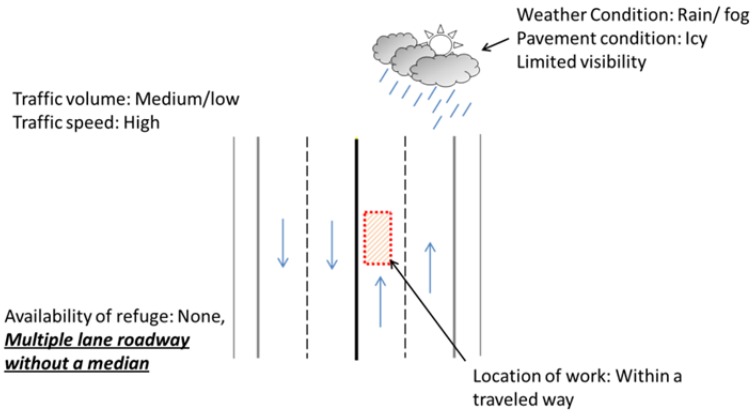
Conditions

This scenario reflects a higher risk condition than Scenario I due to location of work zone, on a multilane roadway without a median. This scenario also reflects other risk factors such as icy pavement, high traffic volume and speed, and limited visibility due to weather conditions. See Table 10 and Figure 13.

Expert Panel Safety Recommendations

This scenario reflects a dangerous situation because the work zone is located on a travel-lane. If the traffic volume and speed is low, the task can be treated as a VSDO. In this case, the safety recommendations for Scenario I are applicable.

Table 10: Summary of Scenario IV

	Description
Conditions	 **Figure 13: Scenario IV Illustration**
Safety Recommendations	• Two TMAs parked in opposite directions facing the work site • Vehicle-mounted dynamic message signs • This scenario represents a risky scenario because of work zone location. • If traffic volume and speed are low, it can be done as a VSDO, applying the same safety recommendations as for Scenario I.

3.3.5. Scenario V: VSDOs at an intersection with two-way roads

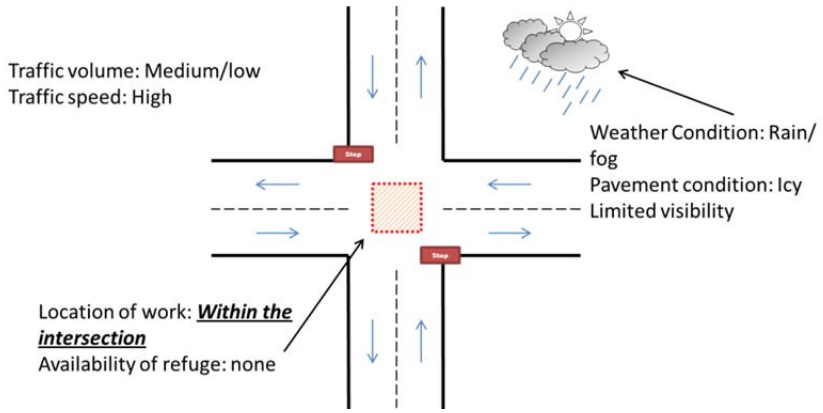
Conditions

This scenario reflects a higher risk condition than typical VSDOs (described in Scenario I) due to work zone location at an intersection with two-way roads. This scenario also includes other risk factors such as icy pavement, high traffic volume and speed, and limited visibility because of weather conditions. See Table 11 and Figure 14.

Expert Panel Safety Recommendations

This scenario represents a risky situation. If traffic volume is low, this scenario can be treated as a VSDO. Also, if the particular work zone situation is assessed as low risk, the work can be conducted as a VSDO. If a second worker is available, he can be used as a flagger. In this scenario, a maintenance vehicle should be parked at one of the intersection corners.

Table 11: Summary of Scenario V

	Description
Conditions	 **Figure 14: Scenario V Illustration**
Safety Recommendations	• `Two TMAs parked in opposite directions facing the work site • Vehicle-mounted dynamic message signs • Two flaggers o In this case, radio headset should be used for better communication between flagger and maintenance worker. • Portable message signs to be installed before the intersection • If traffic volume is low, it can be done as a VSDO. • If the work zone condition represents a low-risk situation, it can be done as a VSDO. • A maintenance vehicle can be parked at one of the intersection corners.

4. Conclusion

Texas has the most roadway mileage of any state in the nation, and maintenance is a major function for TxDOT. Adequate safety is a concern for both workers and motorists during maintenance operations. VSDOs have the potential to interrupt traffic flow and can pose a safety risk for both workers and drivers. One of the challenges of VSDOs is that workers are reluctant to utilize extensive traffic control for activities that take only a few minutes to complete.

This study has defined VSDOs as *a planned or urgent activity, to be executed in 15 minutes or less by a crew of one man and one truck or more, in which the hazard of not executing the work as a VSDO is greater than executing it.* In order to improve maintenance worker assessment of VSDO risks, this study presents a risk management process that enables maintenance workers to identify and respond to work zone hazards for VSDOs. The study defined the factors underlying maintenance workers' misjudgment and drivers' inability to control their vehicles, and the related risks to conducting VSDOs. Identifying risk factors in VSDOs helps maintenance workers better judge conditions and make more informed decisions about whether to conduct an operation as a VSDO or not.

Through shadowing activities and consultation with an expert panel, the research team identified factors that impact risk to maintenance workers and motorists during VSDOs. A scenario-based risk management process was designed to elicit risk mitigation strategies. *Risk* refers to the potential for an accident that harms workers or drivers during a VSDO. *Scenario* is used to describe a possible set of conditions under which accidents are likely to occur. The objective of the scenario-based risk management process is to stimulate thinking about possible dangerous conditions and accident occurrences, assumptions relating these occurrences, and potential opportunities, risks, and courses of action.

This guidebook introduces the worst scenarios under which accidents are likely to occur and recommends additional safety precautions to maintenance workers when performing VSDOs. The scenarios are to ensure maintenance worker safety in VSDOs, especially when workers are inexperienced and their judgment skills are at an early stage of development.

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