IDAHO TRANSPORTATION DEPARTMENT

RESEARCH REPORT

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Work Zone Positive Protection Guidelines for Idaho

By

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16. Abstract

The Code of Federal Regulation (CFR) Title 23 Part 630 Subpart K - Temporary Traffic Control (630.1102–630.1110) rule states that positive protection shall be considered where work zone conditions place workers at increased risk from motorized traffic and where positive protection devices can significantly improve safety. This project developed Idaho-specific work zone positive protection guidelines that Idaho Transportation Department (ITD) staff can use when designing work zone traffic management plans. The guidelines address conditions where positive protection device (i.e. devices that contain and/or redirect vehicles and meet the federal crashworthiness evaluation criteria) application can be recommended on the basis of reduced work zone crash costs. For sites where such conditions do not exist, guidelines are provided regarding intrusion and crash reduction countermeasures (e.g., closer channelizing device spacing and supplemental speed management devices) that could be employed. These guidelines are based on the theory of encroachment hazard analysis, which was conducted using the Roadside Safety Analysis Program (Version 3, NCHRP 22-27, 2012).

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METRIC (SI*) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS					APPROXIMATE CONVERSIONS FROM SI UNITS				
Symbol	When You Know	Multiply By	To Find	Symbol	Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH					LENGTH		
in	inches	25.4		mm	mm	millimeters	0.039	inches	in
ft	feet	0.3048		m	m	meters	3.28	feet	ft
yd	yards	0.914		m	m	meters	1.09	yards	yd
mi	Miles (statute)	1.61		km	km	kilometers	0.621	Miles (statute)	mi
		AREA					AREA		
in^2	square inches	645.2	millimeters squared	cm^2	mm^2	millimeters squared	0.0016	square inches	in^2
ft^2	square feet	0.0929	meters squared	m^2	m^2	meters squared	10.764	square feet	ft^2
yd^2	square yards	0.836	meters squared	m^2	km^2	kilometers squared	0.39	square miles	mi^2
mi^2	square miles	2.59	kilometers squared	km^2	ha	hectares (10,000 m^2)	2.471	acres	ac
ac	acres	0.4046	hectares	ha					
		MASS (weight)					MASS (weight)		
oz	Ounces (avdp)	28.35	grams	g	g	grams	0.0353	Ounces (avdp)	oz
lb	Pounds (avdp)	0.454	kilograms	kg	kg	kilograms	2.205	Pounds (avdp)	lb
T	Short tons (2000 lb)	0.907	megagrams	mg	mg	megagrams (1000 kg)	1.103	short tons	T
		VOLUME					VOLUME		
fl oz	fluid ounces (US)	29.57	milliliters	mL	mL	milliliters	0.034	fluid ounces (US)	fl oz
gal	Gallons (liq)	3.785	liters	liters	liters	liters	0.264	Gallons (liq)	gal
ft^3	cubic feet	0.0283	meters cubed	m^3	m^3	meters cubed	35.315	cubic feet	ft^3
yd^3	cubic yards	0.765	meters cubed	m^3	m^3	meters cubed	1.308	cubic yards	yd^3
Note: Volumes greater than 1000 L shall be shown in m^3									
		TEMPERATURE (exact)					TEMPERATURE (exact)		
^{o}F	Fahrenheit temperature	5/9 (^{o}F-32)	Celsius temperature	^{o}C	^{o}C	Celsius temperature	9/5 ^{o}C+32	Fahrenheit temperature	^{o}F
		ILLUMINATION					ILLUMINATION		
fc	Foot-candles	10.76	lux	lx	lx	lux	0.0929	foot-candles	fc
fl	foot-lamberts	3.426	candela/m^2	cd/cm^2	cd/cm^2	candela/m^2	0.2919	foot-lamberts	fl
		FORCE and PRESSURE or STRESS					FORCE and PRESSURE or STRESS		
lbf	pound-force	4.45	newtons	N	N	newtons	0.225	pound-force	lbf
psi	pound-force per square inch	6.89	kilopascals	kPa	kPa	kilopascals	0.145	pound-force per square inch	psi

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List of Abbreviations, Acronyms, and Symbols

AADT	Annual Average Daily Traffic
AIS	Abbreviated Injury Severity
AASHTO	American Association of State Highway and Transportation Officials
CDOT	Colorado Department of Transportation
CFR	Code of Federal Regulations
EFCCR	Equivalent Fatal Crash Cost Ratio
FHWA	Federal Highway Administration
ITD	Idaho Transportation Department
MAP-21	Moving Ahead for Progress in the 21st Century
MP	Mile Point
MSE	Mechanically Stabilized Earth
MVKT	Million Vehicle Kilometers Traveled
NCHRP	National Cooperative Highway Research Program
PCB	Portable Concrete Barrier
PDO	Property Damage Only
PRV	Penetration, Rollover, or Vault
ROR	Run-Off-the-Road
RDG	Roadside Design Guide
RSAP	Roadway Safety Analysis Program
RSS	Rollover Same Side
SI	Severity Index
TMA	Truck Mounted Attenuator
TTI	Texas A&M Transportation Institute
TxDOT	Texas Department of Transportation
VSL	Value of Statistical Life

Executive Summary

The Code of Federal Regulation (CFR) Title 23 Part 630 Subpart K - Temporary Traffic Control (630.1102 – 630.1110) rule states that positive protection devices (i.e. devices that contain and/or redirect vehicles and meet the federal crashworthiness evaluation criteria) shall be considered where work zone conditions place workers at increased risk from motorized traffic and where positive protection devices can significantly improve safety. However, more specific requirements are not provided; states are responsible for developing general agency or project-specific decision frameworks for determining situations, locations, and types of positive protection to use (e.g., traditional portable concrete barrier (PCB) or one of the newer steel, water-filled, or low-profile barriers). It is also required that states consider techniques intended to reduce the likelihood that a vehicle intrusion into the work zone will occur at all.

A review of available literature showed that early efforts in this area either did not consider the risks and costs of the crashes involving a worker or equipment, or placed workers and equipment in various assumed locations within the work zone for analysis. Both these approaches limit their usefulness in evaluating the potential need for positive protection in future projects that are not exactly of the type that was modeled in the assessments. A survey of state highway agencies revealed that all state highway agencies had some form of basic guidelines in place for common positive protection devices (e.g., portable concrete barriers, truck/trailer-mounted attenuators, or longitudinal barrier end treatments).[1] However, only a few states such as Arkansas, New Hampshire, and Virginia, had a more detailed guidance on when to use positive protection devices and which device to use.

This project developed Idaho-specific Work Zone Positive Protection Guidelines that the Idaho Transportation Department (ITD) staff can use when designing work zone traffic management plans. The guidelines address conditions where positive barrier application can be recommended on the basis of reducing costs of work zone crashes. For sites where such conditions do not exist, the guidelines address intrusion and other crash reduction countermeasures (e.g., closer channelizing device spacing or supplemental speed management devices) that could be employed. The worksheets and spreadsheet tool developed as part of this project will help in implementing these guidelines. These guidelines could be integrated as an appendix into ITD’s Work Zone Safety and Mobility Program document, and referred to in the Work Zone Assessment and Impacts Management chapter.[2]

Chapter 1
Introduction

Statement of Problem

On December 5, 2007, the Federal Highway Administration (FHWA) published the Code of Federal Regulations (CFR) Title 23 Part 630 Subpart K - Temporary Traffic Control (630.1102–630.1110) with an effective date of December 4, 2008.[3] The objective of the rule is to "decrease the likelihood of highway work zone fatalities and injuries to workers and road users."[4] The new rule establishes work zone requirements related to 5 items for Federal-aid projects:

1. General agency guidance or project-specific measures identified through engineering studies to determine the need for positive protection.
2. Exposure control measures to avoid or minimize worker exposure to motorized traffic and motorist exposure to work activities.
3. Other traffic control strategies to minimize work zone crashes (including uniformed law enforcement officers).
4. Safe entry/exit of work vehicles onto/from the travel lanes.
5. Contract pay items to ensure availability of funds for these provisions.

The rule includes a list of 15 factors for state transportation agencies (DOTs) to consider when developing guidance for the use of positive protection, exposure control measures, and other traffic control strategies (or combinations of them). At a minimum, positive protection shall be considered where work zone conditions place workers:

- At increased risk from motorized traffic (e.g., tunnels and bridges that limit worker escape routes.
- Long-duration projects on high-speed facilities that place workers in close proximity to motorized traffic).
- Where positive protection devices can significantly improve safety (e.g., to protect a pavement edge drop-off that will be in place overnight or longer).

However, more specific requirements are not provided; states are responsible for developing general agency or project-specific decision frameworks for determining situations, locations, and types of positive protection to use (e.g., traditional portable concrete barrier (PCB) or one of the newer steel, water-filled, or low-profile barriers). It is also recommended that states consider techniques intended to reduce the likelihood that a vehicle intrusion into the work zone will occur at all. Section 1405 of the Highway Authorization Bill, Moving Ahead for Progress in the 21st Century (MAP-21) also describes a need for regulations about when positive protection is to be used in work zones, although the language in that bill was essentially addressed through the previous CFR 23 Part 630 Subpart K rulemaking process.[(4)]

Currently, Idaho-specific guidance is needed to assist ITD staff members who are designing work zone traffic management plans (TMPs) to determine the best solution for moving traffic safely through work zones. Guidance is especially needed regarding PCB (the most common type of positive protection device – portable concrete barrier) use in work zones. In addition, guidance is needed on application of more recent technologies such as steel barriers and low-profile concrete barriers, which are more portable and thus less costly to install, move, and remove. Finally, in some work zones, alternatives to physical barriers that could reduce vehicle-intrusion risk into the work zone (e.g., law enforcement, speed trailers, and enhanced usage of portable changeable message signs (PCMS)) may actually be more practical and cost effective for ITD to implement.

Project Objectives

The objective of this project was to develop Idaho-specific Work Zone Positive Protection Guidelines that ITD staff can use when designing work zone traffic management plans. The guidelines address conditions where positive barrier application can be recommended on the basis of reduced work zone crash costs. For sites where such conditions do not exist, the guidelines address intrusion and other crash reduction countermeasures (e.g., closer channelizing device spacing and supplemental speed management devices) that could be employed.

Research Approach

In this project, researchers conducted several analyses to assess the safety and cost implications of providing positive protection in work zones. These analyses are based on the theory of encroachment hazard analysis, which will be explained in detail in the Chapter 3. The results from these analyses were used to develop guidance on when and where positive protection should be used and where other safety countermeasures are more appropriate.

Contents of this Report

Chapter 2 provides background on current guidelines and practices nationally, and implementation of Texas Department of Transportation (TxDOT) guidelines for positive protection in work zones. The methodology and results of analyses performed are described in Chapter 3 of this report. Chapter 4 provides a set of recommended guidelines and an assessment of how these guidelines would apply to a set of 3 test work zone locations. Lastly, Chapter 5 provides a summary of the results and conclusions from the project. A set of worksheets and supporting documentation for implementing the guidelines, suitable as a stand-alone document for inclusion in ITD manuals, is provided as an Appendix. A spreadsheet tool with the worksheets is also included.

Chapter 2
Background

Review of Texas Research and Current Implementation Status

The Texas A&M Transportation Institute (TTI) recently completed a research study for TxDOT to develop improved implementation guidelines for positive protection use in work zones.[5] The impetus for that project was the change to 23 CFR 630 Subpart K that placed additional emphasis on the consideration of positive protection use to reduce worker and road user fatalities and injuries in work zones. One of the requirements of the new regulations was the need for agencies to develop general guidance or project-specific measures. These were to be identified through engineering studies to determine the need for positive protection in work zones. In the TxDOT project, researchers considered worker and construction equipment safety risk and protection needs, separate from other features that could necessitate barrier use (e.g., pavement drop-offs). A mechanism for tailoring the amount, location, and duration of various hazards within work zones for an overall assessment of the appropriateness of PCB protection and other more portable barrier technologies (such as steel barriers and low-profile concrete barriers) was established. The researchers developed an intrusion crash severity index (an ordinal scale of 0 to 10 that is linked to the probability or percentages of injury for different injury levels - PDO, injury, and fatality) using work zone crash data from the New York State Department of Transportation to model various configurations of work space and lateral drop-off locations from travel lanes using the Roadside Safety Analysis Program (RSAP). The study found that positive barrier use can be justified solely on the basis of protecting the work space from intrusions, or on the basis of consideration of pavement edge drop-off and other work space intrusion cost reductions combined. We/TxDOT considered as a drop-off in the guidance (I know we used a very deep one for the analysis, but we'd want to state what we'd consider the lower value of what we think our analysis represented, maybe 6 inches based on what I say below). If consideration of positive barriers is based on pavement drop-off and other work space intrusions, positive barrier use guidance is based on whether the work area is located closer to the travel lanes than the drop-off condition or farther away.

Historically, TxDOT has provided positive protection guidance only in terms of protecting drop-off hazards in work zones. A graph included in the TxDOT *Roadway Design Manual* identifies minimum traffic exposure levels (expressed in vehicles per day [vpd] per year of the project) and lateral distances to drop-offs under which positive protection (typically PCB) is to be used.[6] The guidance recommended by the researchers retained the same general structure for when drop-offs are present but reduced the traffic exposure thresholds at which positive protection could be justified. Such a reduction makes intuitive sense because the consideration of the additional hazards associated with simply intruding into the work space and potentially impacting work equipment, materials, and workers themselves would increase crash costs and make the use of positive protection more easily justifiable. The researchers also concluded that work zones on high-volume (40,000 vpd) roadways can justify positive protection even when drop-offs are not present. Consequently, TxDOT is currently considering adopting three levels of guidance:

1. For work spaces adjacent to travel lanes, a threshold of 40,000 vpd per project year exposure that justifies positive protection use.

2. A modification of the existing TxDOT positive protection guidance for conditions where the work space is located between travel lanes and the drop-off.

3. A second modification of the TxDOT guidance for conditions where a drop-off exists and then the work space is located beyond the drop-off.

TxDOT staff are currently working to determine how best to incorporate these findings into their processes.

In addition to the guidance developed through the research project, TxDOT is also considering including use of the recent positive protection decision tool spreadsheet being developed by Science Applications International Corporation (SAIC) through the FHWA Work Zone Safety Grant Program. This tool uses a ranking and weighting process of various factors listed under 23 CFR 620 Subpart K to achieve an objective assessment of the level of need of positive protection. TxDOT envisions recommending that this tool be used to further assess the conditions where engineering judgment is recommended to be used in making a positive protection decision. The tool is currently under beta testing, having been demonstrated to TxDOT staff and to state department of transportation personnel in Utah, Iowa, Virginia, Illinois and Minnesota.

Literature Review on Use of Positive Protection in Work Zones

The 2010 TTI report on work zone positive protection guidelines for TxDOT also includes a comprehensive review of literature regarding methods of determining when and where to use positive protection in work zones.(5) The review identified that early efforts in this area either did not consider the risks and costs of the crashes involving a worker or equipment, or placed workers and equipment in various assumed locations within the work zone for analysis. Both these approaches limit their usefulness in evaluating the potential need for positive protection in future projects that are not exactly of the type that was modeled in the assessments. The review also identified that the cost-effectiveness of the recent portable barrier technologies under various roadway and work zone situations has not been fully assessed.(6 – 18) Some examples of such technologies are shown in Appendix B.

Limited published literature was found on guidelines for the use of positive protection devices in work zones since the publication of the 2010 TTI report.(5) A 2013 Kansas study surveyed various state highway agencies and summarized current guidance or changes in guidance to comply with 23 CFR 630 Subpart K.(1) The review noted that all state DOTs had some form of basic guidelines in place for common positive protection devices (e.g., PCBs, truck/trailer-mounted attenuators, and longitudinal barrier end-treatments). However, only a few states such as Arkansas, New Hampshire, and Virginia, had extensive guidance on when to use positive protection devices and which devices to use. A decision flowchart was developed as part of the proposed guidance for Kansas, which assists an engineer to determine where positive protection is required and which existing guidance document to use for various exposures reduction/mitigation measures. In general, positive protection is recommended for

Kansas work zones with no escape for workers that are on roadways with speeds of 65 mph or more with no buffer zone between the workers and traffic, or in work areas with a drop-off of more than 4 inches or unfinished decks that remain overnight.[18]

State-of-the-Practice Review of State Highway Agency Guidance on Use of Positive Protection in Work Zones

As part of the 2010 TTI report, the research team also reviewed state department of transportation policies and procedures pertaining to positive protection use in work zones.[5] The review found that many states formulated their guidance to be very similar to the requirements stated in the federal regulations (i.e., 23 CFR 630 Subpart K), with some providing guidance on protection of pavement edge drop-offs near travel lanes. Limited guidance was found for protection against other intrusion hazards. Criteria followed by Maryland, Michigan, and Virginia include more detail on when to use positive protection and reflect consideration of work zone crashes in addition to drop-offs. Maryland and Michigan's criteria consider the minimum duration of the work zone, whereas Virginia's criterion considers crash risk, using run-off-the-road (ROR) crashes and annual average daily traffic (AADT). Also, Virginia's crash risk assessment is based on fixed objects within the work area.

A 2002 study reviewed practices and policies for addressing the safety hazard of pavement edge drop-offs in several states, and found that the most common factor considered in pavement edge treatment practices was depth, as shown in Table 1.[19] Of the 17 states listed in Table 1, 12 were found to have some guidance on use of temporary traffic barriers based on drop-off depth and location (i.e., the distance from the travel lane) (shown in Table 2). The review found that the depth of drop-off warranting a temporary barrier varied from 2 in. to 5 ft among the states reviewed. The review also identified a "Spacing Factor" formula developed by the Montana Department of Transportation to identify the most appropriate type of traffic control depending upon the AADT, degree of curvature, measured width from the drop-off to the far edge of the adjacent travel lane, posted speed limit, and drop-off depth.

Table 1. Factors Considered in Pavement Edge Treatment Practices in Various States[19]

State	Depth	Location	AADT	Highway Type	Speed	Project Duration	Time of Day
Iowa	x	x		x			
Arkansas	x	x					
California	x	x					
Florida	x	x					
Illinois	x	x			x		
Minnesota	x	x			x	x	
Missouri	x	x					x
Montana	x	x	x		x		
Nebraska	x						
New York	x	x	x		x	x	
North Dakota	x	x			x		
Ohio	x	x			x		x
Oregon	x			x			
Pennsylvania	x	x		x	x		
South Dakota	x						
Texas	x	x	x			x	

Table 2. Criteria for Consideration of Temporary Traffic Barrier Use in Various States[19]

State	Criteria				
	Drop-Off Depth, Location, and Length	**Speed**	**Project Duration/ Exposure**	**AADT**	**Project Length**
Iowa	> 10 in., located within 10 ft of travel way (informal)				
Arkansas	> 5 ft				
California	> 6 in., located within 8 ft of travel way; special engineering consideration for all drop-offs > 2.5 ft				
Florida	> 3 in., located within 12 ft		1 Day		
Minnesota	> 4 in., if no 45° wedge used to transition between the pavement height, located adjacent to travel way, length < 50 ft; if (drop-off depth) > 12 in. recommended	>30 mph	> 3 days		
Missouri	Alternative for use with lane closures when > 2 in.				
Montana	Drop-off located within 30 ft of travel way , if no wedge provided, spacing factor < 20 ft (by formula)		> 48 Hours		
New York	> 2 ft	> 45 mph	≥ 60 Days	≥ 7,500	
North Dakota	> 4 in. if no wedge, all drop-offs depth > 12 in., located adjacent to travel way	> 30 mph	> 7 Days		> 50 ft
Ohio	> 5 in. located between travel lanes; (drop-off depth) > 2 ft located within 30 ft of travel way		Overnight		
Texas	> 2 ft	> 40 mph			
West Virginia	> 3 in. located within 30 ft of travel way on multi-lane highways, located within 20 ft of travel way on undivided highways	> 45 mph	> 48 Hours		

In addition to a review of guidance documents for states discussed above, the research team sent out a request for agency practices related to the use of positive protection via the listserv membership on the National Work Zone Safety Information Clearinghouse.[18,1] The listserv maintained by the clearinghouse is comprised of approximately 1,500 state and local transportation agency personnel, private-sector contractors, safety advocacy associations (e.g., the Laborers' Health and Safety Fund of North America), and other agencies with interest in work zone safety for travelers and workers (e.g., the National Institute of Occupational Safety and Health). The survey specifically asked for agency practices and policies that were above and beyond the requirements listed in 23 CFR 630 Subpart K. Three states responded to the survey: Virginia, Montana, and Colorado. The research team included Minnesota's guidance in this review after discussions at a recent American Association of State Highway and

Transportation Officials (AASHTO) meeting. The research team reviewed all the above-mentioned states' guidance documents to gather the following information:

1. Factors and criteria that are considered in deciding whether or not to require positive protection for a given work zone situation.

2. Work zone situations where PCB use is generally always required.

3. Work zone situations (e.g., roadway types, AADTs, speeds, project types, and specific hazards) that DOTs find the most difficult in determining whether or not to specify the use of PCB or any other positive protection in the construction plans.

4. The extent to which factors other than worker or traffic safety are considered (e.g., contractor productivity and simplicity of implementation of positive protection) and how they are considered in the decision-making process for use of positive protection.

5. The existence of any decision criteria regarding the specification of other vehicle-intrusion countermeasures (e.g., reduced speed limits or the presence of enforcement) in the plans.

Colorado

The guidelines used by the Colorado Department of Transportation (CDOT) are contained in the CDOT *Guidelines for the Use of Positive Protection in Work Zones*, published in January 2010.[20] The guidelines warrant use of positive protection (based on an engineering study in conjunction with engineering judgment) when that would result in reduction in the severity of potential crashes and crash outcomes. Typical application examples include intrusion prevention and worker protection.

The primary factors listed in the guidelines to be considered when deciding on the need for positive protection are:

1. Clear Zone Distances.
2. Roadside Geometry.
3. Anticipated Traffic Volumes.
4. Work Zone Speeds.
5. Project Duration.

Consideration of positive protection is recommended in situations where there is an increased risk to workers or pedestrians, such as when a multi-lane divided facility is temporarily shifted to a two-lane two-way traffic operation. However, no decision criteria in terms of AADT, speed, etc. are provided (except in the case of pavement drop-offs and embankments).

In situations where a clear decision is not evident based on the primary factors listed above, the manual suggests consideration of crash history, impacts on project cost and duration, impacts on available lane width, roadway classification, work area restriction, and bridge construction.

Michigan

The guidelines used by the Michigan Department of Transportation (MDOT) are in Chapter 17 of its *Work Zone Safety and Mobility Manual,* revised in January 2010.[21] These guidelines cover the “may,” “should,” and “shall” conditions for positive protection use:

- May: On roadways with temporary crossovers.

- Should:
    - On bridge work where a precipitous drop-off is within 4 ft of the toe of the barrier closest to the active traffic lane.

    - Where scaffolding or other overhead structures or equipment with workers is in place for 3 days or more.

    - Where motorized and non-motorized traffic lanes (i.e., work area) are adjacent to each other with no difference in elevation or are separated by mountable curbs with vehicles operating at speeds of 45 mph or higher.

    - On all long-duration (3 days or more) projects where workers are continuously within 6 ft of an open high-speed traffic lane or lanes in 1 specific location.

- Shall: On freeway projects where opposing traffic lanes are adjacent to each other and the posted speed limit prior to construction is ≥ 50 mph.

The manual provides guidance on spacing of channelizing devices (based on posted speed limit), treatments for traffic lanes with milled edges, and treatments for land and edge drop-offs. Table 3 shows the criteria. The survey respondent indicated that the agency recently completed a process review, and as a result of that, the manual is currently (as of June 2013) under review for some minor changes.

Table 3. Lane and Edge Drop-Off Treatments[21]

Differential	Distance from the Active Traffic Lane: 0 - 3 ft for Shoulders or Between Directional Traffic Lanes	Distance from the Active Traffic Lane: 3 - 8 ft for Shoulders or Between Directional Traffic Lanes
0 - < 2 in. without Taper	Install "Shoulder Drop-Off" Signing or "Uneven Lane" Signing.	Install Striped Edge Line. Install "Low Shoulder" Signing (optional).
2 - < 4 in. with 1:3 Taper	Install "Shoulder Drop-Off" Signing or "Uneven Lane" Signing.	Install striped edge line. Install "Low Shoulder" Signing (optional).
2 - < 4 in. without Taper	Install "Shoulder Closed" Signing or "Uneven Lane" Signing. Install Channelizing Devices.	Install "Shoulder Closed" Signing. Install Channelizing Devices.
4 - < 12 in. with 1:4 Taper	Install "Shoulder Drop-Off" signing or "Uneven Lane" signing.	Install Striped Edge Line. Install "Low Shoulder" Signing (optional).
4 - < 12 in. with 1:3 Taper	Install "Shoulder Closed" Signing or "Uneven Lane" Signing. Install Channelizing Devices.	Install "Shoulder Closed" Signing. Install Channelizing Devices.
4 - < 12 in. without Taper	Install "Shoulder Closed" Signing or "Uneven Lane" Signing. Install Channelizing Devices. Install Type III Barricades at 20xS Spacing.	Install "Shoulder Closed" Signing. Install Channelizing Devices. Install Type III Barricades at 20xS Spacing.
12 in. or Greater	Install Barrier Wall or Reduce Channelizing Device Spacing.*	Install Barrier Wall or Reduce Channelizing Device Spacing.*
* Use channelizing devices at a reduced spacing if mobility requirements on the project prohibit use of barrier wall.		

Minnesota

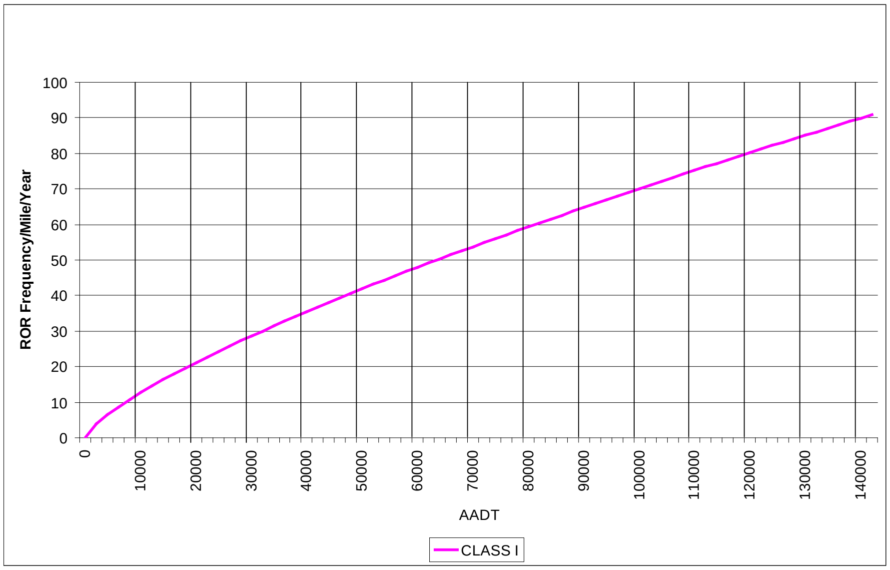
The guidelines used by the Minnesota Department of Transportation (MnDOT) are in its *Temporary Traffic Control Zone Layout* (Chapter K), published in February 2011, and *Minnesota Manual on Uniform Traffic Control Devices* (Section 6F.85, Temporary Traffic Barriers), published in 2010.[22,23] Guidance provided for drop-off situations is the same as that summarized in Table 2.

North Carolina

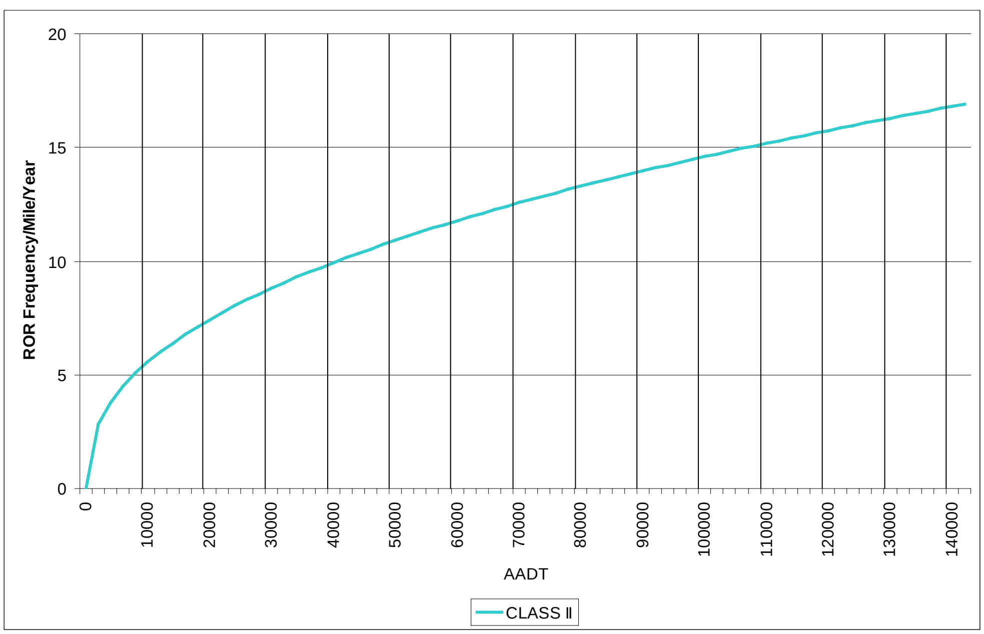
The guidelines used by the North Carolina Department of Transportation (NCDOT) are the same as those used by CDOT and are documented in the North Carolina Department of Transportation's *Guidelines for the Use of Positive Protection in Work Zones*, published in April 2009.[24]

Virginia

The guidelines used by the Virginia Department of Transportation (VDOT) are contained in Appendix A of the *Virginia Work Area Protection Manual* (revised August 2011).[25] These guidelines are currently (as of June 2013) under review for some proposed minor revisions. As noted in the 2010 TTI report, the VDOT procedure for channelizing device or barrier selection is based on the expected frequency of ROR incidents near fixed objects or work crews in close proximity to the travel lane, based on the type of roadway.[5] The ROR crash frequency chart for various roadway types is shown in Figure 1. A barrier is recommended if the potential for crash is great than 50 percent. The guidance (shown in Table 4), however, distinguishes between the use of a barrier and guardrail as a longitudinal channelizing device.



a. Run-Off-the-Road Frequency Factor Chart for Limited-Access Highways (Class I)



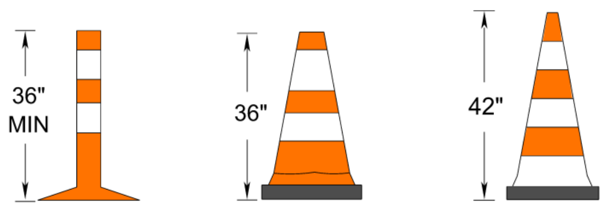
b. Run-Off-the-Road Frequency Factor Chart for All Other Highways (Class II)

Figure 1. Run-Off-the-Road Crash Frequency Chart[(23)]

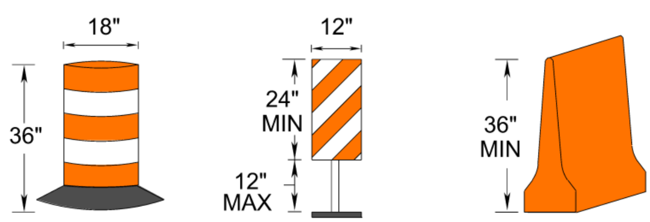
Table 4. Preliminary Channelizing Device - Barrier Chart[23]

Existing Annual Average Daily Traffic (AADT)	Posted Speed Limit (mph)				
	0 - 25	**26 - 35**	**36 – 45**	**46 - 54**	**55+**
0 - 750	1,2	1,2	1,2	1,2	1,2 / B
751 - 5,500	1,2	1,2	1,2 / B	B	B / A
5,501 - 15,000	1,2	1,2 / B	B	B / A	A
Above 15,000	1,2	1,2 / B	A	A	A

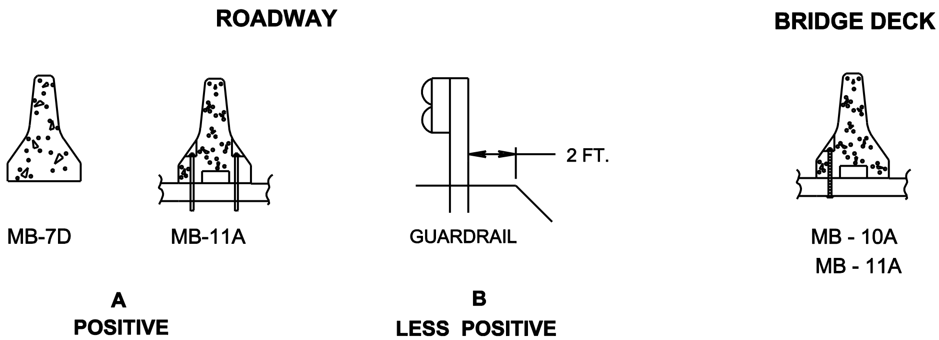
For 1 and 2 designations, refer to Group 1 and 2 devices, respectively, in the image below.
For A and B designations, refer to Type A and B barriers, respectively, in the image below.



GROUP 1
TUBULAR MARKER & CONE



GROUP 2
DRUM, VERTICAL PANEL, &
LONGITUDINAL CHANNELIZING DEVICE



Chapter 3
Analysis of Expected Crash Reduction Benefits and Costs of Portable Concrete Barrier Use in Work Zones

Background

One of the primary reasons for using positive protection in work zones is the hypothesis that the safety of both the work crews and the motoring public is enhanced. Unfortunately, good field data regarding the actual safety benefits of positive protection use in terms of reduced crash severity or crash costs are not available. For example, of the various state department of transportation positive protection guidelines discussed previously, only the Virginia guidance used any estimate of potential crash reduction as part of the decision-making process. Consequently, the encroachment-based hazard protection benefit-cost analysis approach outlined in the American Association of State Highway and Transportation Officials (AASHTO's) *Roadside Design Guide* (RDG) is the most logical choice for a safety-based analysis.(9) In this task, the research team made use of the benefit-cost tool for the 2011 edition of the RDG, the Roadside Safety Analysis Program Version 3 (RSAPv3).(26) RSAPv3 was used in conjunction with Idaho data to assess the cost-effectiveness of positive protection use under different roadway and work zone conditions through a (modified) RSAPv3 analysis.

Roadside Safety Analysis Program Version 3 Overview

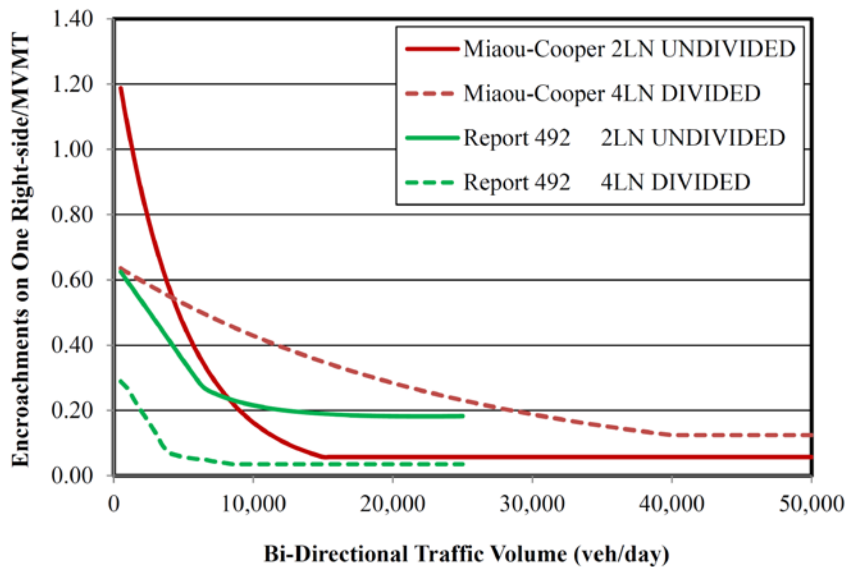
RSAPv3 uses a conditional encroachment-collision-severity approach to determine the frequency, severity, and societal cost of roadside crashes for each user-entered design alternative. RSAPv3, developed through funding administered through the National Cooperative Highway Research Program (NCHRP) project 22-27, has significant revisions when compared to its previous version (RSAPv2 NCHRP Report 492 used in the 2010 TxDOT study).(26,27) The following are the most notable changes in the RSAPv3 methodologies:

- Encroachment Probability Module:
    - For RSAPv2, lateral encroachment data used in the original version of the model were reanalyzed by excluding encroachments of 4 m or less in lateral extent, which adjusted encroachment frequency upward (by a ratio of 2.466 for two-lane undivided highways and 1.878 for multi-lane divided highways) to account for under-reporting of encroachments because of paved shoulders. For RSAPv3, these data were again reanalyzed to develop both encroachment rate and encroachment distance models using a full Bayesian approach (which took into account the uncertainty associated with the estimates of the model parameters and provided exact measures of uncertainty).
    - The adjustment factors used in RSAPv2 include horizontal curvature and vertical grade, traffic growth factor, and a user-defined adjustment factor. Some of that data were also reanalyzed to account for additional variables and normalize them to the same base

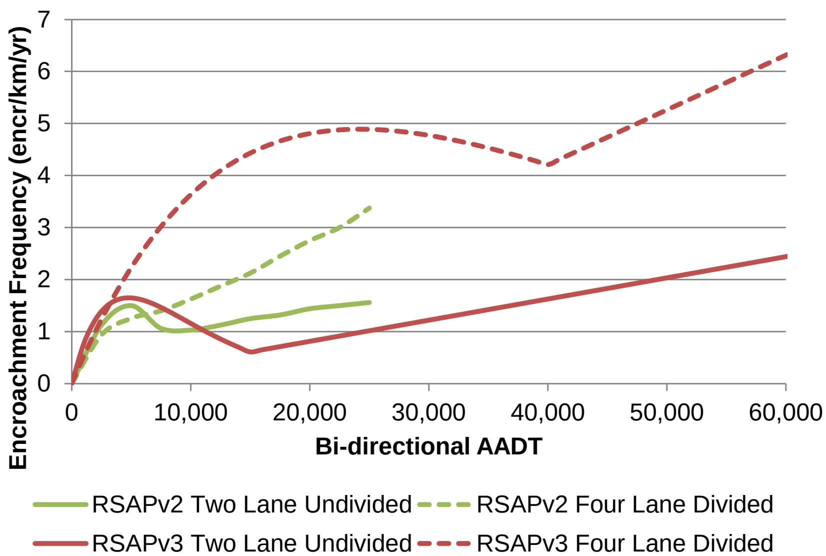
conditions for posted speed limit, terrain, number of lanes, vertical grade, horizontal curve, lane width, and access density.

  - The RSAPv2 data were limited to undivided highways with AADT of less than 13,000 and divided highways with AADT less than 45,000. RSAPv3 extrapolates to higher traffic volumes by assuming the rate remains constant at 0.0715 encroachments/million vehicle kilometers traveled (MVKT) for AADT greater than 15,000 on two-lane undivided roads and at 0.1554 encroachments/MVKT for AADT greater than 40,000 on four-lane divided roads. Figure 2 shows a comparison of the base encroachment base encroachment rate and frequency between the 2 RSAP versions.

- Crash Prediction Module:
  - RSAPv3 does not use the Monte Carlo simulation (used in RSAPv2) to calculate the probability of a collision given an encroachment. Instead, a deterministic method is used where a sample of real crash trajectories (from a database of 890 ROR crash reconstructions) are compared to the roadside and used to determine the collision and severity upon encroachment.
  - RSAPv2 estimates the crash severity of the first feature struck as well as any subsequent features in the vehicle's path. The highest severity of any feature in the vehicle's path is then used in the calculation of crash cost. In RSAPv3, instead of assigning a higher blanket severity to account for secondary collisions, each incident (after impact with the barrier and until the velocity of the vehicle goes to zero) is analyzed separately, and the total crash cost for the trajectory is computed as a sum of each incident.
  - In RSAPv2, hazard penetration was determined based solely on the mechanics of the impact event. That is, the impact conditions were calculated and compared to the known structural capacity of the hazard. If impact conditions exceeded the capacity of the hazard, then the hazard was assumed to be completely penetrated; otherwise, the vehicle was either redirected or stopped in contact with the hazard. However, there should not be such a drastic transition from a zero probability of penetration - when impact conditions are just below theoretical capacity - to a 100 percent probability of penetration - when impact conditions are exactly at capacity. The hazard penetration model (structural) in RSAPv3 deals with penetrations using a combination of both crash statistics and the mechanics of the collision event. The penetration model assumes that for very-low-impact speeds and angles, the probability of penetration would be relatively low and would increase gradually as the impact conditions approach and begin to exceed the capacity of the barrier.



a. Encroachment Rate on One Right-Side Edge by Bi-Directional AADT (Miaou-Cooper = RSAPv3, Report 492 = RSAPv2)



b. Encroachment Frequency on All Sides by Bi-Directional AADT

Figure 2. Comparison of Base Encroachment Frequency and Base Encroachment Rate Between RSAPv2 and RSAPv3[(26)]

- Severity Prediction Module:
  - The severity index (SI) used in RSAPv2 is a linear function of speed. RSAPv2 would randomly generate an impact speed that was multiplied by the slope of the SI speed curve and mapped to the generic distribution of crash severities, which is weighted by

crash costs to determine the average crash cost at a given impact speed. The slope values were primarily based on engineering judgment.

- The RSAPv3 severity model is based on observed police-reported crash data, which are adjusted to account for unreported crashes and scaled to account for speed effects. The subjective SI (used in RSAPv2) is replaced with an objective fatal crash cost ratio, the Equivalent Fatal Crash Cost Ratio (EFCCR).
- The severity model used in RSAPv3 for each type of roadside feature is composed of three items that account for the sequence of crash events that injury and its associated crash cost depend on:
    1. A measure of crash severity of that object when collision does not result in penetration of the object or rollover during redirection away from the object.
    2. The percent of total crashes with the object that will result in a penetration, rollover of the object, or vault (PRV) of the object.
    3. The percent of total crashes with the object where the vehicle rolls over after being redirected away from the object (i.e., rollover-same-side [RSS] crashes).
- Figure 3 illustrates the difference in severity estimates for a utility pole using the SI model and crash data.

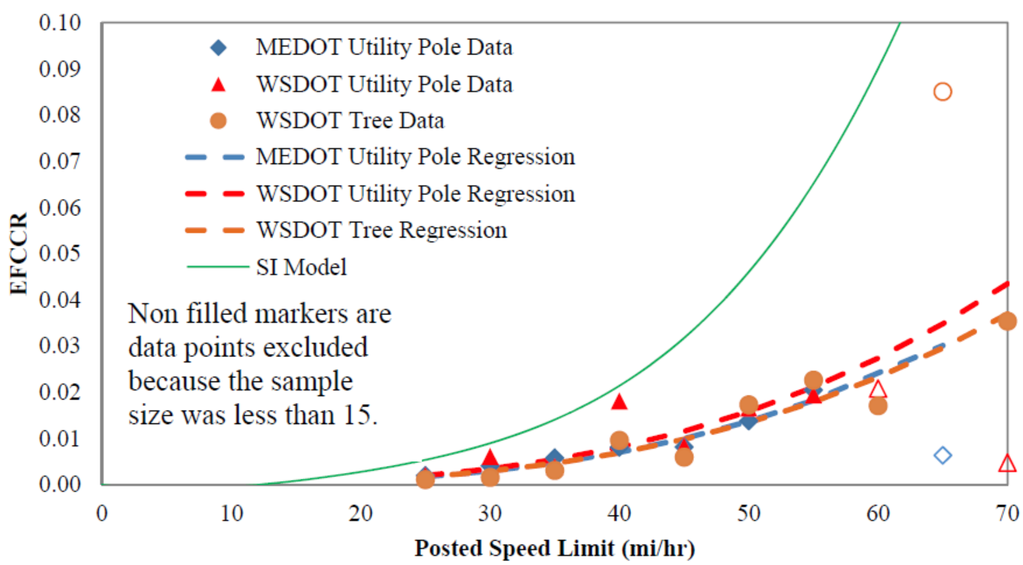


Figure 3. Comparison of Equivalent Fatal Crash Cost Ratio for a Utility Pole Using SI Model and Crash Data[26]

WSDOT = Washington State Department of Transportation
MEDOT = Maine Department of Transportation

Idaho-Specific Costs

Construction Costs

Researchers identified Idaho-specific construction costs for use in this analysis from ITDs Division of Highways bid average reports. In the 2011 report (October 1, 2010, through September 30, 2011, and available in May 2013), the average unit cost for concrete guardrail (Item Number 612-150A) was $53.76 (low average bid price). This number was quoted as $15.79 in the 2012 bid average report (October 1, 2011, through September 30, 2012, and available in September 2013). However, the 2012 report also had a few projects that bid at about $53.00; these projects had smaller quantities than those that bid at about $15.00. The cost for portable concrete guardrail (including removal and restoration costs) (Item Numbers S612-15A and S612-20A) were quoted as $42.06 in the 2011 report and as $37.91 in the 2012 report. The research team decided to use the $53.76 unit price for the concrete guardrail to make a conservative benefit-cost estimate. The accompanying spreadsheet tool has the in-built capability to let the analyst choose a specific barrier cost.

Crash Costs/Value of Statistical Life

ITD provided the research team with crash costs based on the FHWA publication from 2008, adjusted using the gross domestic product implicit price deflator.[28] FHWA published new crash costs or Value of Statistical Life (VSL) in 2013, providing a more current estimate.[29] The 2013 FHWA VSL estimates were:

- $12.9 million (High Estimate).
- $9.1 million (Median Estimate).
- $5.2 million (Low Estimate).

The research team decided to use the 2013 VSL numbers for this analysis as this range would include the 2008 numbers provided by ITD when adjusted to 2012 values. To calculate the average crash cost by severity level, the Abbreviated Injury Severity (AIS) level distribution published by FHWA (shown in Table 5) was used. AIS level was converted to the police-reported KABCO level (a scale of crash severity categories designated as fatal [K], serious [A], moderate [B], minor [C], and none [O]) using the conversion matrix provided by the National Highway Traffic Safety Administration (NHTSA), shown in Table 6.[30]

Table 5. Distribution of Value of Statistical Life by Abbreviated Injury Severity Level[29]

AIS Level		Fraction of VSL
No Injury	0	0.000
Minor	1	0.003
Moderate	2	0.047
Serious	3	0.105
Severe	4	0.266
Critical	5	0.593
Un-Survivable	6	1.000

Table 6. KABCO/Unknown to Abbreviated Injury Severity Data Conversion Matrix[30]

AIS Level	No Injury	Possible Injury	Non-Incapacitating Injury	Incapacitating Injury	Fatal	Unknown If Injured	Injured, Unknown Severity
	O	C	B	A	K	U	IUS
0	0.92534	0.23437	0.08347	0.03437	0.00000	0.21538	0.43676
1	0.07257	0.68946	0.76843	0.55449	0.00000	0.62728	0.41739
2	0.00198	0.06391	0.10898	0.20908	0.00000	0.10400	0.08872
3	0.00008	0.01071	0.03191	0.14437	0.00000	0.03858	0.04817
4	0.00000	0.00142	0.00620	0.03986	0.00000	0.00442	0.00617
5	0.00003	0.00013	0.00101	0.01783	0.00000	0.01034	0.00279
6	0.00000	0.00000	0.00000	0.00000	1.00000	0.00000	0.00000
2013 (Med.) VSL	$3,066	$60,529	$118,537	$435,208	$9,100,000	$164,966	$125,358
2013 (Low) VSL	$1,752	$34,588	$67,735	$248,690	$5,200,000	$94,266	$71,633
2013 (High) VSL	$4,347	$85,804	$168,036	$616,943	$12,900,000	$233,852	$177,705
2008 ITD Crash Costs	$6,739	$58,209	$87,814	$313,516	$6,295,406	-	-

Roadside Safety Analysis Program v3 Analysis Set-Up

The set-up used in this analysis is discussed in Table 7 and Figure 4. Researchers used zero feet as the right shoulder width to model the lack of a shoulder available to motorists. An offset of 1 ft is maintained between the worker and barrier, between the barrier and drop-off, and between the drop-off and worker.

Table 7. Highway Characteristics Used in Roadside Safety Analysis Program v3 Analysis[27]

Highway Characteristics	Unit	Highway Type	
		Divided	Undivided
Posted Speed Limit	mph	50, 70	50, 70
Terrain	F/M/R	F	F
Total Number of Lanes	-	4	2
Primary Direction Grade	%	0	0
Primary Radius of Curve	ft	T	T
Lanes in Primary Direction	Number	2	1
Median Width	ft	30	-
Median Shoulder Width	ft	10	-
Lane Width	ft	12	12
Access Density	Points/mi	0	0
Rumble Strips	True/False	False	False
Right Shoulder Width	ft	0	0

F/M/R = Flat/Mountainous/Rolling T = Tangent

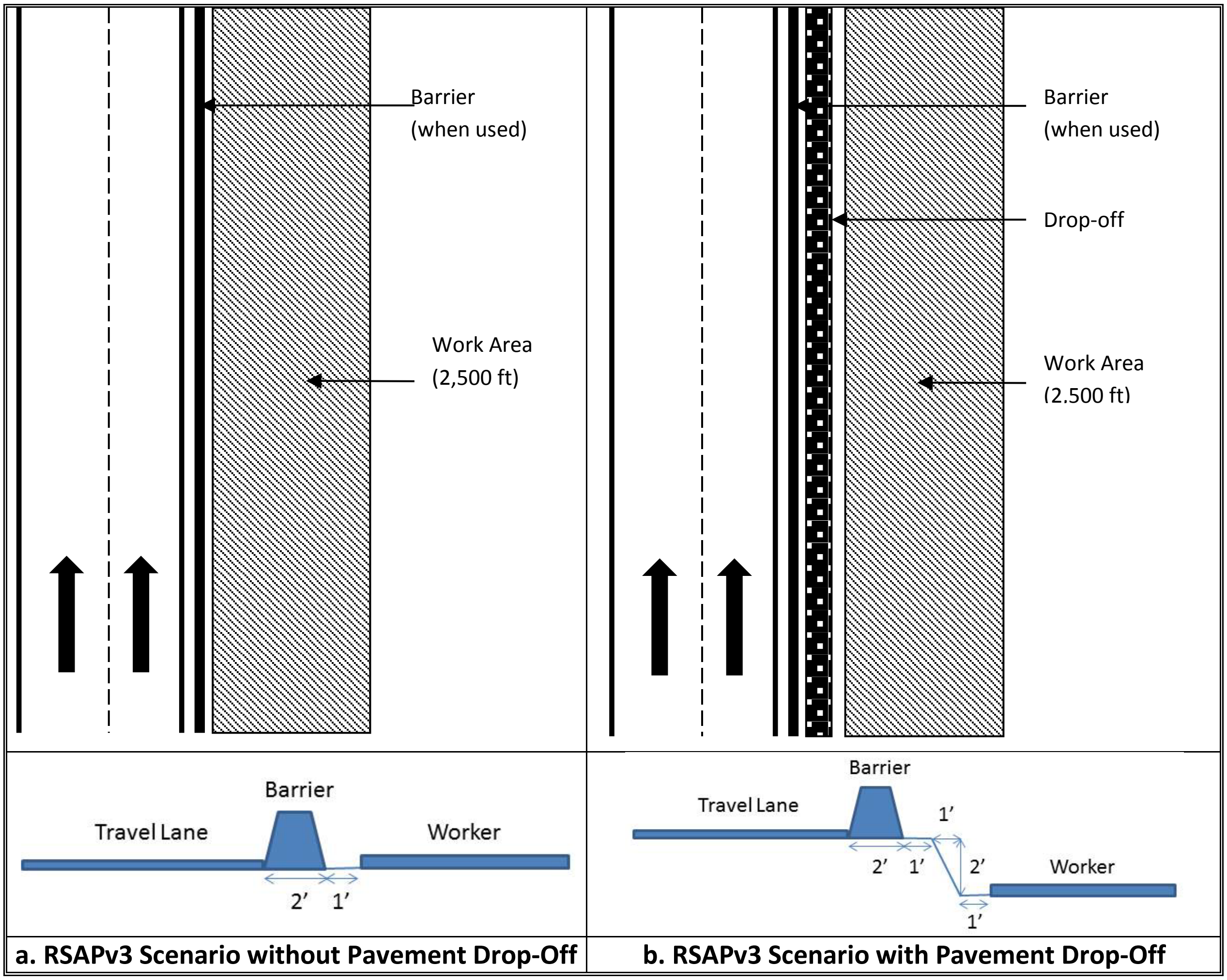


Figure 4. Roadside Safety Analysis Program Version 3 Model Setup for Intrusion Crash Analysis

Equivalent Fatal Crash Cost Ratio for Worker Area

A worker or worker area is not one of the predefined roadside hazards in RSAPv3. To develop EFCCR and other needed parameters for modeling a worker area as a roadside hazard, the research team used previously published data on intrusion crashes at highway work zones in New York.[31] The distribution of property-damage-only (PDO), injury, and fatal crashes observed from intrusion crashes (shown in Table 8) provided an indication of the overall severity of intrusion events into work zones. It was further assumed that these intrusion events represented an intrusion speed of approximately 55 mph (since most of these events were on freeways or other high-speed roadways).

Table 8. Severity of Work Zone Intrusion Crashes in New York[31]

Crash Severity	Daytime Work Zones (n = 133) (percent)	Nighttime Work Zones (n = 39) (percent)	Both Types Combined (n = 172) (percent)
Fatal	2.3	7.7	3.5
Injury	36.8	53.8	40.7
Property Damage Only	60.9	38.5	55.8

The cost of injury crashes is assumed to be an average value of A, B, and C crash severities (shown in Table 6). Total intrusion cost for the worker area was calculated by multiplying the crash cost for each severity level with its percentage and summing. $EFCCR_{55}$ is calculated by dividing the intrusion crash cost by the fatal crash cost. To reformulate the $EFCCR_{55}$ in terms of a single baseline speed of 65 mph, the relationship in Figure 5 is used.[26] The data used to generate the $EFCCR_{55}$ and $EFCCR_{65}$ values are shown in Table 9.

$$\boldsymbol{EFCCR_{65} = \frac{EFCCR_{55} \times 65^3}{55^3}}$$

Figure 5. $EFCCR_{65}$

Table 9. Calculation of Equivalent Fatal Crash Cost Ratio Based on 2013 Medium Value of Statistical Life

Proportion of Crashes by Crash Severity (percent)				Total Intrusion Crash Cost (Using $9.1 Million VSL)	$EFCCR_{55}$	$EFCCR_{65}$
No Impact	**Fatal**	**Injury**	**Property Damage Only**			
0.0	3.50	40.7	55.8	$403,547	0.04435	0.07320
25.0	2.63	30.5	41.9	$302,661	0.03326	0.05490
50.0	1.75	20.4	27.9	$201,774	0.02217	0.03660

Since EFCCR involves dividing the average crash cost calculated in any particular year by the cost of a fatal crash in that same year, it can be used irrespective of the change in VSL. The worker area is added to the hazard worksheet of RSAPv3 along with the parameters shown in Table 10.

Table 10. Worker Area Parameters Used in Analysis

Parameter	Value
Name	Worker
Type of Hazard (Line or Point)	Line
Typical Annual Maintenance Cost	$0
Typical Repair Cost	$0
$EFCCR_{65}$	0% No Impact Model = 0.07320 25% No Impact Model = 0.05490 50% No Impact Model = 0.03660
Percentage of Penetration, Rollover or Vault of the Object (PRV) Crashes	0%
Percentage of Rollover-Same-Side (RSS) Crashes	0%
Height of the Barrier	N/A
Speed Adjustment Flag (True/False)	T
Hazard Category	Special Edge

Equivalent Fatal Crash Cost Ratio for Pavement Edge Drop-Off

Pavement edge drop-off is also not one of the predefined roadside hazards in RSAPv3. The *RSAPv3 User's Manual* states that "Unlike earlier versions of RSAP, it is not necessary to identify an embankment, ditch or slope hazard since RSAPv3 assumes that whenever there is a change in cross-section slope, there is a chance of rollover."(26) Although RSAPv3 automatically includes a terrain rollover hazard and bases the probability of a rollover occurring on the cross-sectional information, it does not have a cross-section for pavement edge drop-off. The research team determined that one option for modeling drop-off was as a "Special Edge" roadside hazard, defined as a line hazard category that, when crossed, has consequences on the total crashes (i.e., trajectory path intersections). Within this hazard category, "Low Bridge Edge" hazard indicates a low-hazard environment below the bridge (e.g., water bodies not used for transportation, low-volume transportation facilities, or areas without buildings or houses). The Low Bridge Edge hazard indicates no possibility of non-motor-vehicle-related victims of a rail penetration. In other words, the vehicle occupants and the vehicle itself are the only cost components considered. The EFCCR suggested for this hazard (0.0584) is similar to that for an on-road rollover (0.0220), making it a reasonable choice for modeling a pavement drop-off. The parameters used to model a pavement edge drop-off are shown in Table 11. The energy capacity is changed from 10^9 ft-lb to blank to ensure the trajectory path continues once it crosses the pavement drop-off hazard. This condition reflects a drop-off of 6 inches or more (i.e., the height at which the ability for a driver to recover is very low).(32) Undoubtedly, safety is compromised at smaller drop-off heights, but we were trying to err on the side of increased severity so as to provide a factor of safety in our analyses.

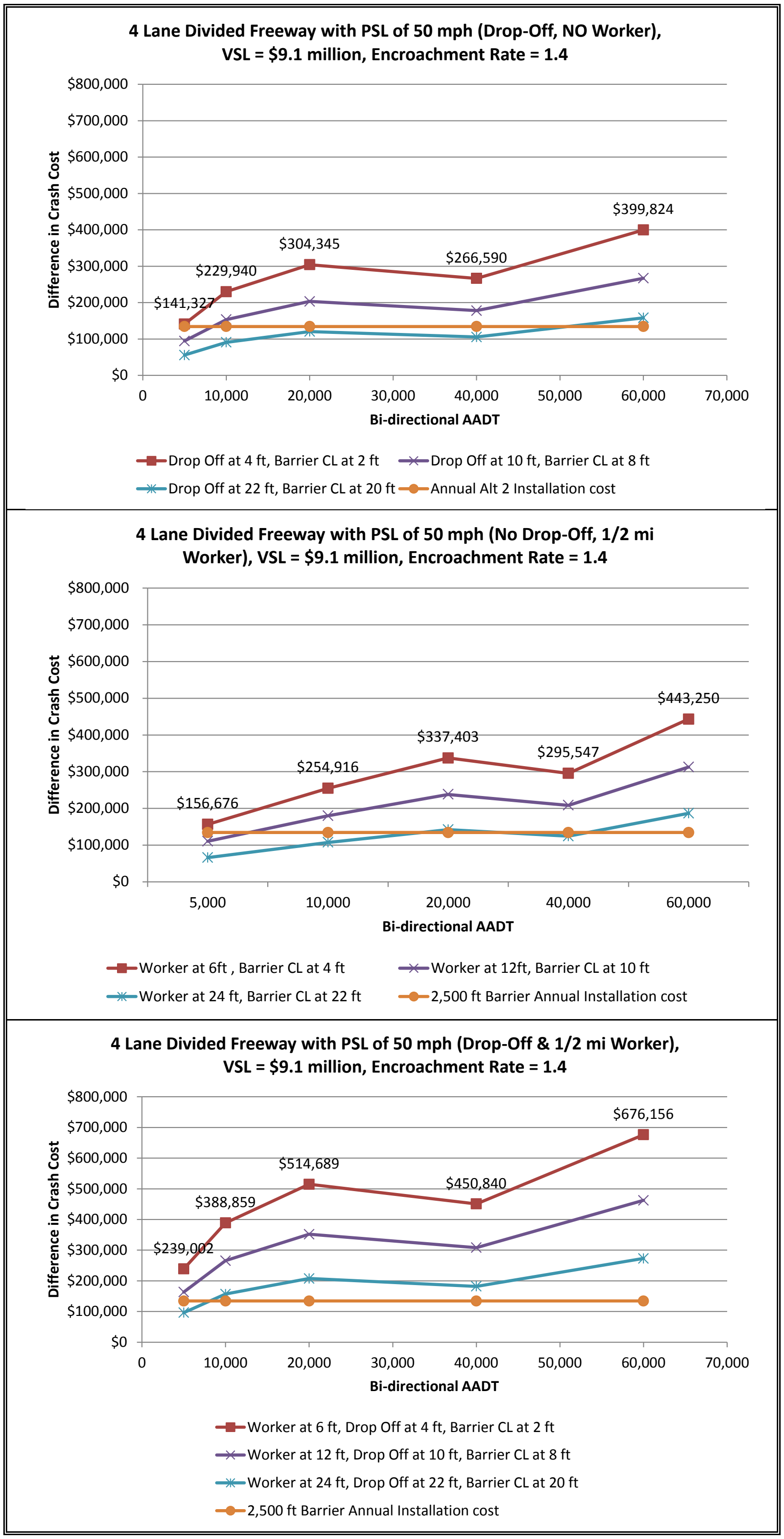
Table 11. Pavement Edge Drop-Off Parameters Used in Analysis

Parameter	Value
Name	Mod_BE_Low
Type of Hazard (Line or Point)	Line
Typical Annual Maintenance Cost	$-
Typical Repair Cost	$-
$EFCCR_{65}$	0.0584
Percentage of PRV Crashes	100%
Percentage of RSS Crashes	0%
Height of the Barrier	-
Speed Adjustment Flag (True/False)	F
Hazard Category	Special Edge

Benefit-Cost Analysis of Portable Concrete Barrier Use

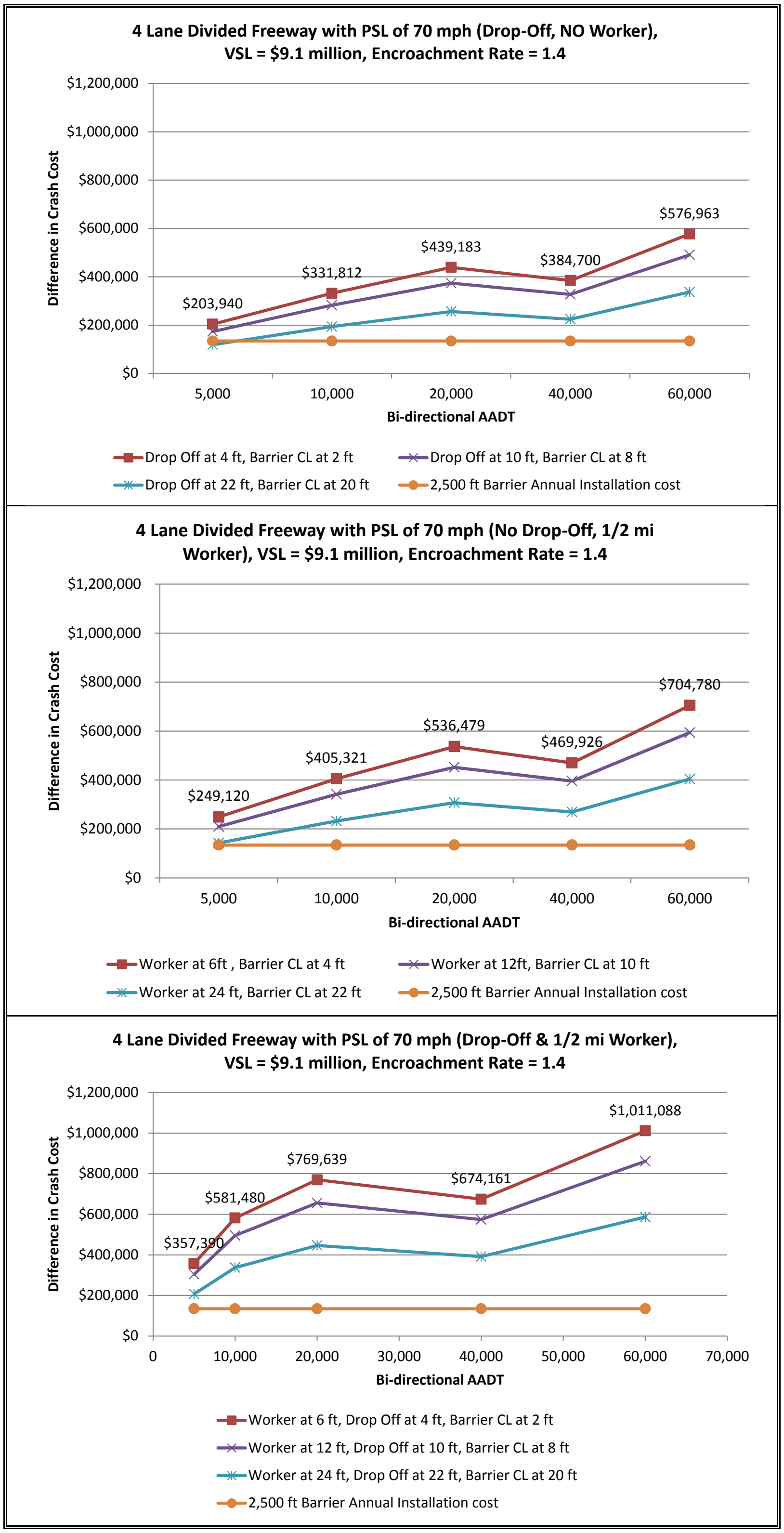
Work zone scenarios were modeled to include an approximate half-mile (2,500 ft) work area with and without a pavement edge drop-off. The work area and drop-off (when present) were modeled for varying offsets from the travel lane (3 - 24 ft) and AADT (5,000 - 60,000). To account for the fact that the RSAPv3 encroachment frequency model is developed using data from non-work zone conditions, whereas work zone crashes (assumed to be correlated to encroachments = encroachments in work zones) typically increase relative to non-work-zone conditions, researchers applied a 40 percent increase adjustment to the encroachment frequency relationship in RSAPv3. A review of literature cited elsewhere as well as research findings themselves indicate that this increase is reasonable.[28] Sensitivity analyses with low and medium VSL ($5.2 million and $9.1 million, respectively) were also conducted to assess VSL assumptions on the benefit-cost. The results of the analysis are shown in Figure 6 through Figure 9. The results show positive benefit in protecting drop-offs and work areas at higher volumes and when they are present closer to the travel lanes at lower volumes. In all cases, the analysis represents a work zone condition where work activity is occurring at all times through the entire work area. In the guidelines that were subsequently developed based on this analysis, researchers use a series of exposure adjustment factors to account for periods in which work is not occurring and/or only a portion of the area being considered for positive protection actually has work activity occurring.

The rather strange results for the two-lane highway analysis are the result of the non-linear encroachment function used in RSAPv3. The same trend, albeit less pronounced, is also evident in the four-lane roadway analyses.



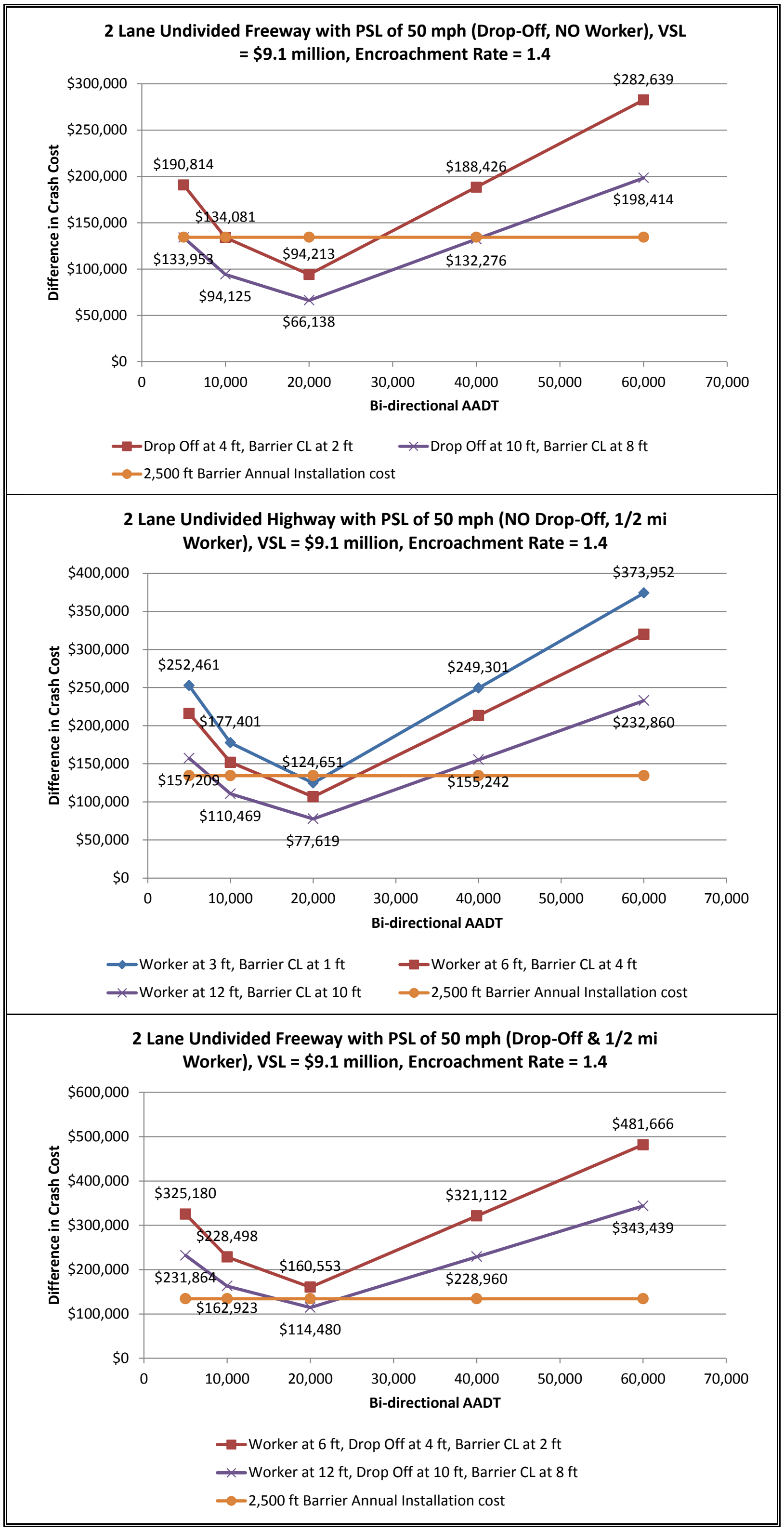
PSL = Posted Speed Limit; VSL = Value of Statistical Life; CL = Centerline; LF = Linear Foot

Figure 6. Analysis Results for Four-Lane Divided Freeway with 50 mph Speed Limit



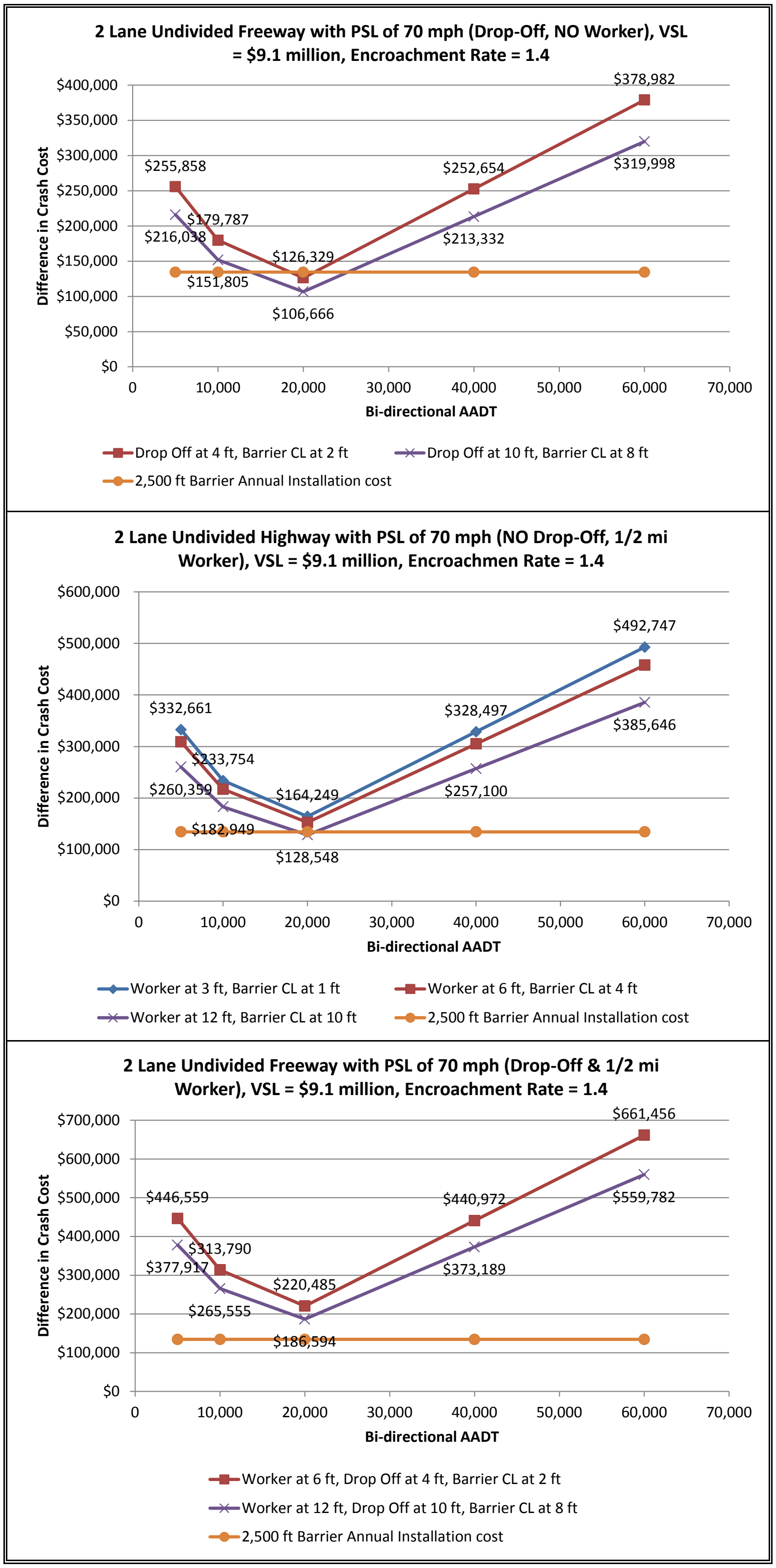
PSL = Posted Speed Limit; VSL = Value of Statistical Life; CL = Centerline; LF = Linear Foot

Figure 7. Analysis Results for Four-Lane Divided Freeway with 70 mph Speed Limit



PSL = Posted Speed Limit; VSL = Value of Statistical Life; CL = Centerline; LF = Linear Foot

Figure 8. Analysis Results for Two-Lane Undivided Roadway with 50 mph Speed Limit

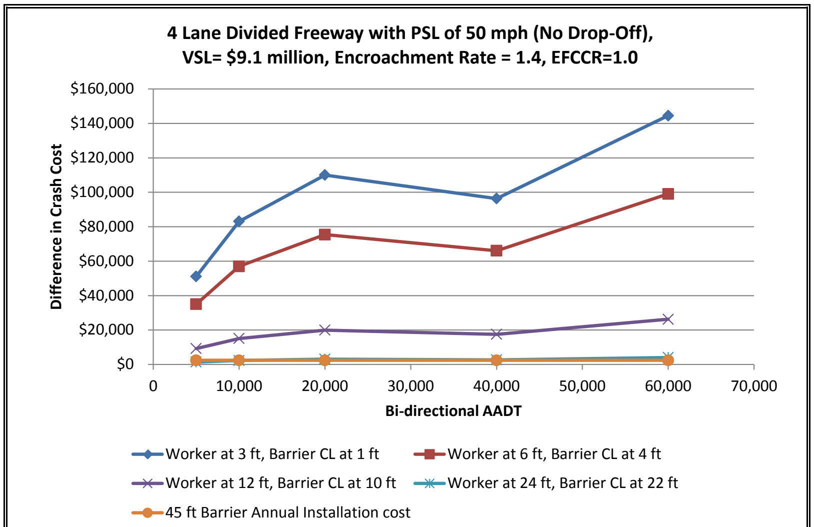


PSL = Posted Speed Limit; VSL = Value of Statistical Life; CL = Centerline; LF = Linear Foot

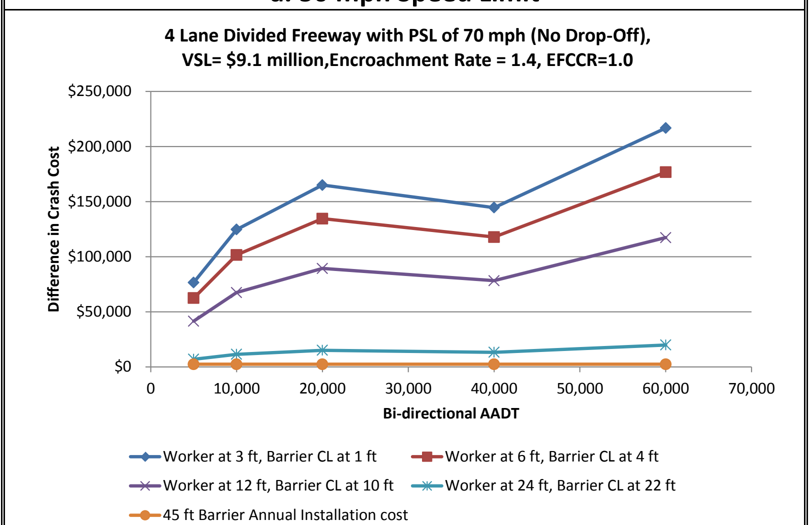
Figure 9. Analysis Results for Two-Lane Undivided Roadway with 70 mph Speed Limit

Benefit-Cost Analysis of Portable Concrete Barrier Use at High-Risk Locations

Next, work areas in high-risk locations such as tunnels were modeled as a small hazard area of 45 ft at varying offsets from the travel lane (3 - 24 ft) and AADT (5,000 - 60,000). This length was selected as a reasonable estimate of a roadway segment where workers would be congregated working on a single task. Any intrusions into this limited work space were modeled as always resulting in a worker fatality. This length approximates the work area needed for many maintenance work activities, based on a review of various work tasks performed by workers on foot.(29) Figure 10 shows the result from this analysis. As expected, the analysis shows positive benefit in protecting workers in a high-risk situation.



a. 50 mph Speed Limit



b. 70 mph Speed Limit

PSL = Posted Speed Limit; VSL = Value of Statistical Life; EFCCR = Equivalent Fatal Crash Cost Ratio ; LF = Linear Foot

Figure 10. Cost Benefit for a 45-Foot High-Risk Worker Area

Discussion of Analysis Results

The results of benefit-cost analysis of PCB use in the previous section did show a somewhat counterintuitive trend. For four-lane divided highways, crash cost reductions are higher at lower AADT values, drop at intermediate AADTs, and then increase again at higher AADTs. These observations are a reflection of the encroachment model used in RSAPv3, as shown again in Figure 11. Since it is impractical to suggest that positive protection be used at lower AADTs, not used in an intermediate range, and then again used at a higher range, the results were fitted to nonlinear regression curves to develop a consistent positive protection assessment methodology across the entire range of potential AADTs. These are discussed in detail in the next chapter.

In general, the results observed in this analysis show a higher positive benefit of worker and drop-off protection than did the 2010 Texas study.[5] The unprotected (without barrier) and protected (with barrier) worker crash costs are similar between the two analyses. However, crash costs with barrier differ by a factor of 10 (crash costs were much higher for the Texas analysis). This difference is due to the change in encroachment models and severity models between the RSAP versions used for the two analyses. Figure 12 shows the difference in severity estimate for the worker area and concrete barrier between the two RSAP versions. The SI curve used in RSAPv2 is subjective, whereas the EFCCR used in RSAPv3 is based on crash data. Given that many of the crashes in the scenario would be sideswipe and should redirect vehicles back onto the roadway, the average crash cost predicted by RSAPv2 seems too high, and that predicted by RSAPv3 seems more reasonable. In other words, the benefit-cost analysis results from RSAPv3 are more reasonable.

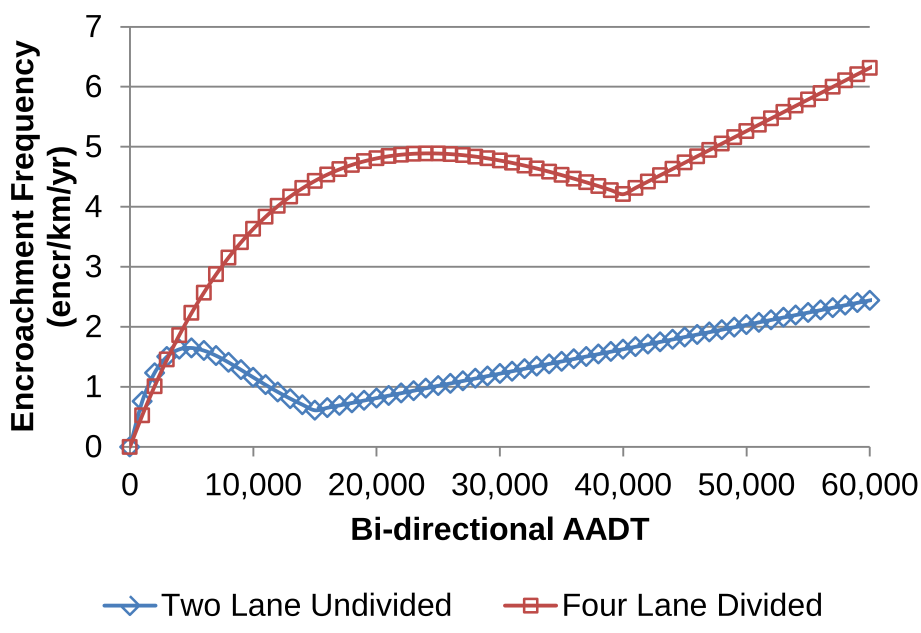
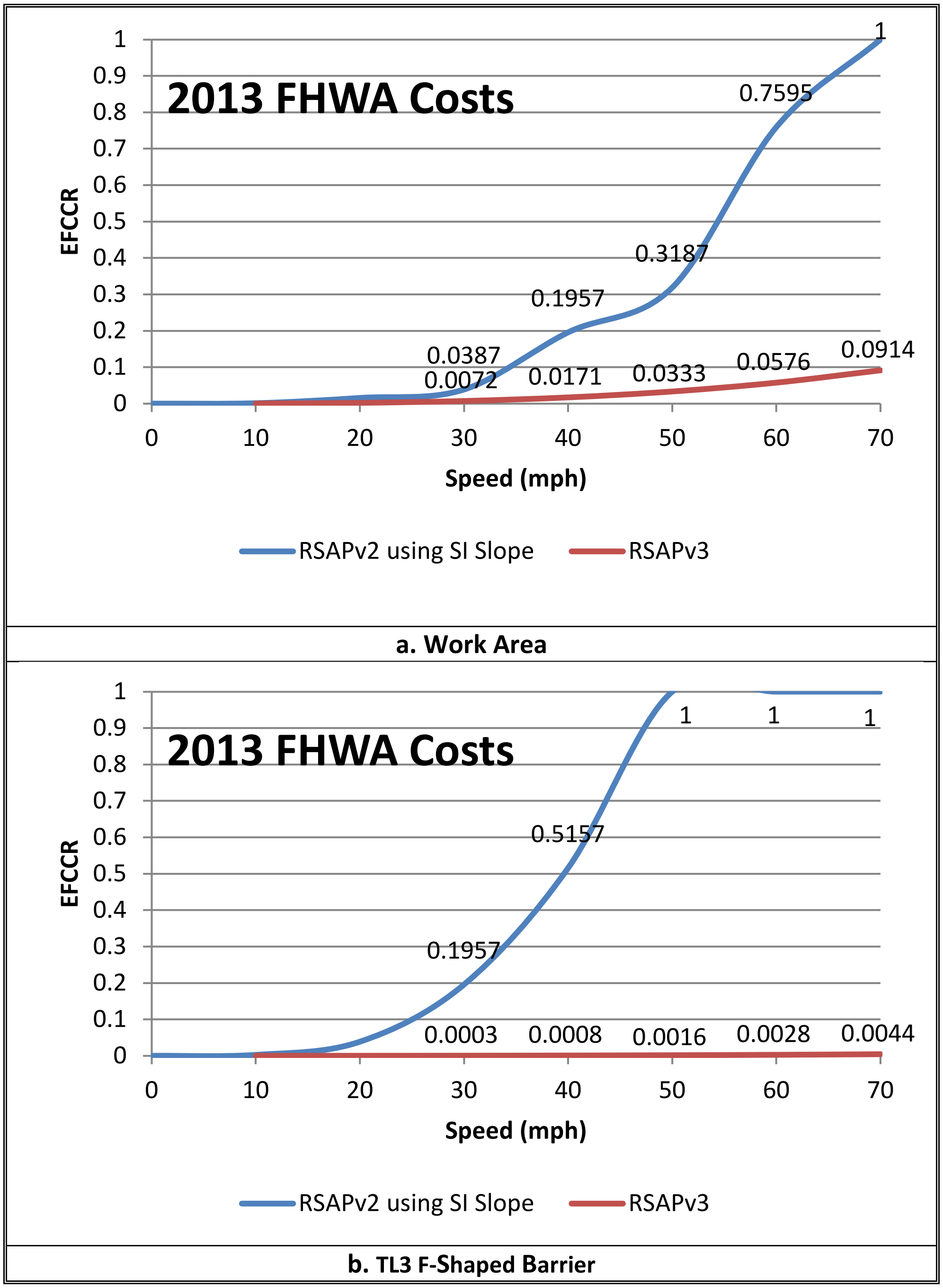


Figure 11. Encroachment Frequency Model Used in Roadside Safety Analysis Program v3[27]



a. Work Area

b. TL3 F-Shaped Barrier

Figure 12. Severity Estimate Comparison Between Roadside Safety Analysis Program v2 and Roadside Safety Analysis Program v3

Chapter 4
Development of Work Zone Positive Protection Guidelines

Overview

Since the expected encroachment frequency at a given AADT level is lower for two-lane highways than four-lane highways, the crash cost reduction benefits are also significantly lower at each AADT level for two-lane highways in Figure 9 and Figure 10 than for the four-lane highways in Figure 7 and Figure 8. As will be seen later in this chapter, even the more liberal analyses for the four-lane highways often fails to lead to a recommendation to use positive protection. Therefore, researchers concluded that the four-lane analysis results could be used to evaluate work zones on all roadway types, effectively providing a higher factor of safety with regards to the positive protection decision when using the analysis for two-lane highway work zones. This simplifies the analysis and reduces the potential for the work zone designer to use incorrect graphs in the assessment. The results obtained in the benefit-cost analysis of PCB use showed positive benefit in protecting drop-offs and workers at higher volumes and when they are present closer to the travel lanes at lower volumes.

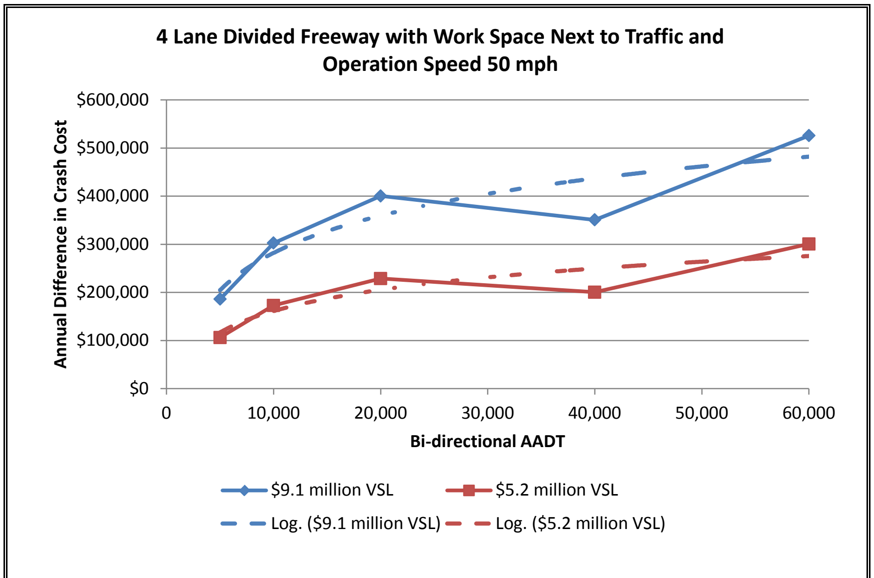
The RSAPv3 results show that the crash cost benefits are related to the work space's distance from travel lanes. This relationship can be expressed in the form of a "Work Activity Location Factor" shown in Table 12, which is the ratio of crash cost reductions achieved with barrier protecting work activities at various distances from the travel lanes to the crash cost reductions achieved when the work activity is immediately adjacent to those lanes.

Table 12. Work Activity Location Factor

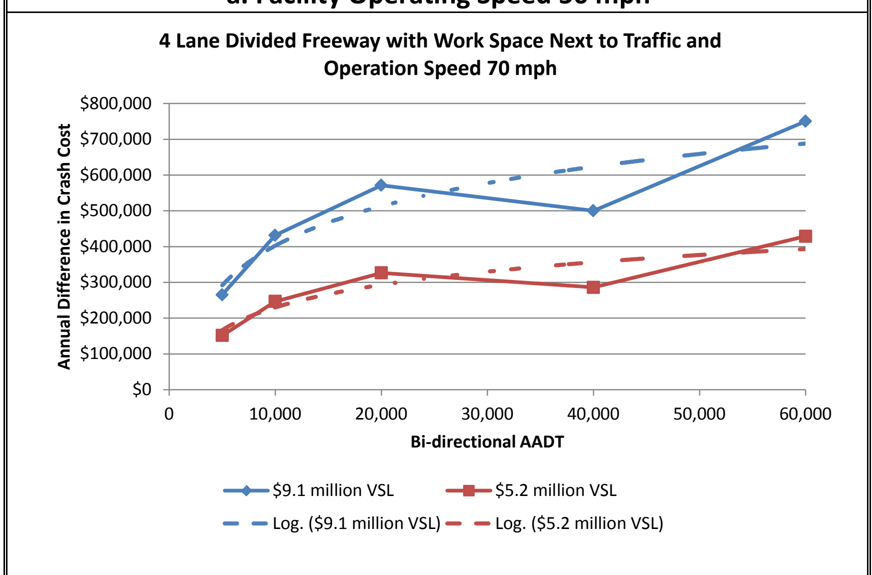
Work Activity Distance from Travel Lanes	Work Activity Location Factor
Adjacent (< 6 ft)	1.00
6 ft	0.94
12 ft	0.79
24 ft	0.54

Curve Fitting and Conversion to an Equivalent Exposure

RSAPv3 results for a four-lane divided highway show a dip in crash cost savings at 40,000 AADT, which is a reflection of the encroachment model used in RSAPv3. Since it is impractical to suggest that positive protection is beneficial at lower AADTs, then is not beneficial in an intermediate range, and then is beneficial again at a higher range, the RSAPv3 results were fitted with nonlinear regression curves for guidance development. The lower limit for positive protection use is identified using RSAPv3 results that used the FHWA medium VSL value of $9.1 million, whereas the upper limit is identified using RSAPv3 results that used the FHWA low VSL value of $5.2 million. Figure 13 shows the regression curves for RSAPv3 analysis results for a four-lane divided freeway per 2,500 ft of work zone. Equivalent AADT and exposure time in weeks that would result in a positive benefit from barrier use were calculated using these regression curves. The benefit-cost ratio obtained from the regression curves for an equivalent AADT was divided by 52 to obtain the equivalent exposure in weeks that would result in a positive benefit from barrier use for when only work activities are of concern (shown in Figure 14). The regression curves for the no-drop off condition (i.e., work space intrusion costs) and the drop-off condition were similar enough and justified using the same curves for both (for an equivalent AADT and exposure time). Thus, the guidance is based around estimating equivalent exposures for the work space intrusion costs and for any drop-off exposure costs.

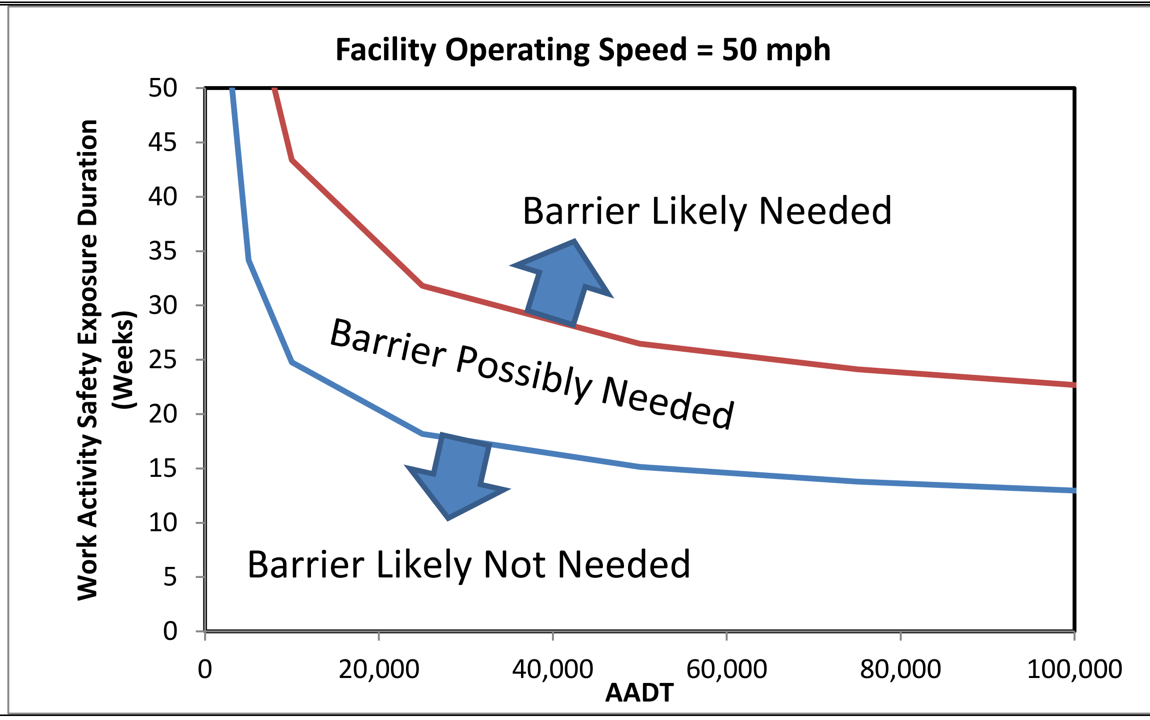


a. Facility Operating Speed 50 mph

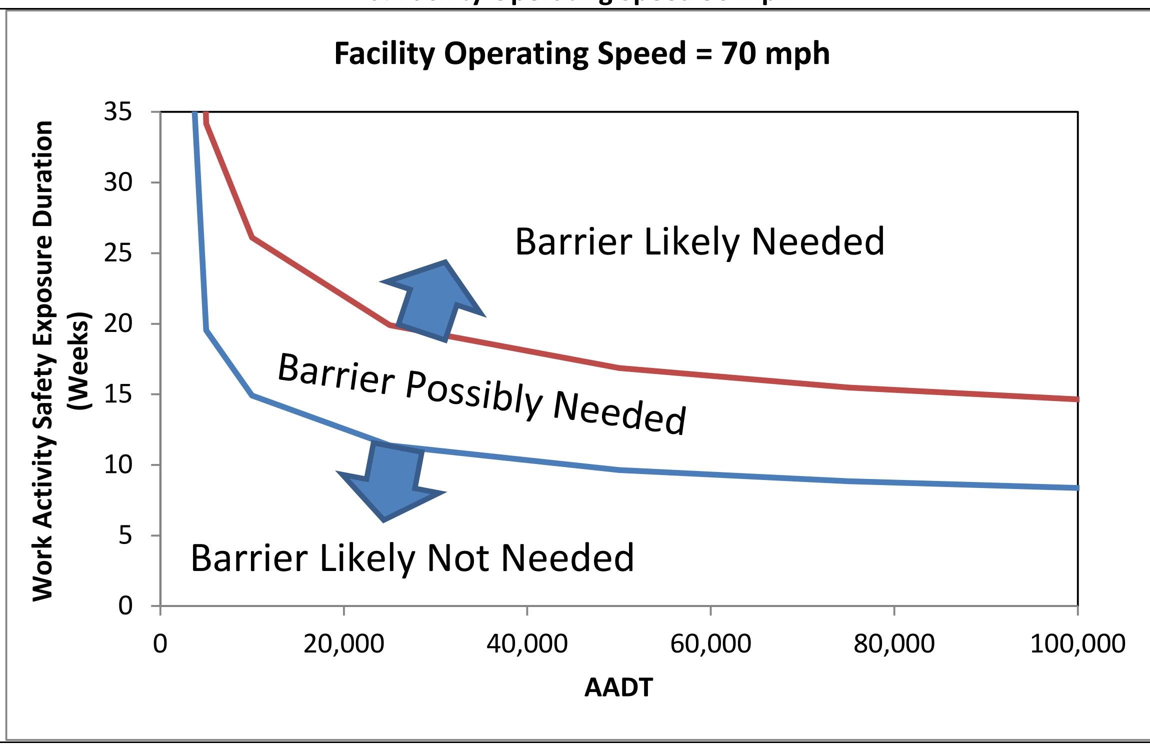


b. Facility Operating Speed 70 mph

Figure 13. Regression Curve Fitting on Roadside Safety Analysis Program v3 Analysis Results for Four-Lane Divided Freeway per 2,500 Feet of Work Zone



a. Facility Operating Speed 50 mph



b. Facility Operating Speed 70 mph

Figure 14. Barrier Use Guidance Based on Equivalent AADT and Exposure Time When Only Work Activity Hazards Are of Concern

The annual crash cost reduction benefits for positive protection use at high-risk locations generated using the RSAPv3 analysis were also converted to crash cost reduction benefits per 8-hour shift. These results were also fitted with nonlinear regression curves (shown in Figure 15). As would be expected, lower operating speeds yield a lower expected crash cost per work shift at any given AADT and lateral distance value. To provide additional consideration to mitigation of worker crash risks, researchers recommend using only the high-speed (70 mph) graph for assessing positive protection justification in the guidelines. The reason for this is again to provide a factor of safety with regards to protecting the work space from errant vehicles. Whereas a work zone speed limit might be set lower to encourage safer behavior and slower speeds, research shows that lower speed limits typically result in little, if any, actual speed reductions. It should be noted that the researchers do propose that the difference between 50 and 70 mph crash costs can be used in justifying whether to use methods of reducing vehicle speeds (use of enforcement, use of speed display trailers, etc.) in an attempt to reduce crash risks where positive protection is not used.

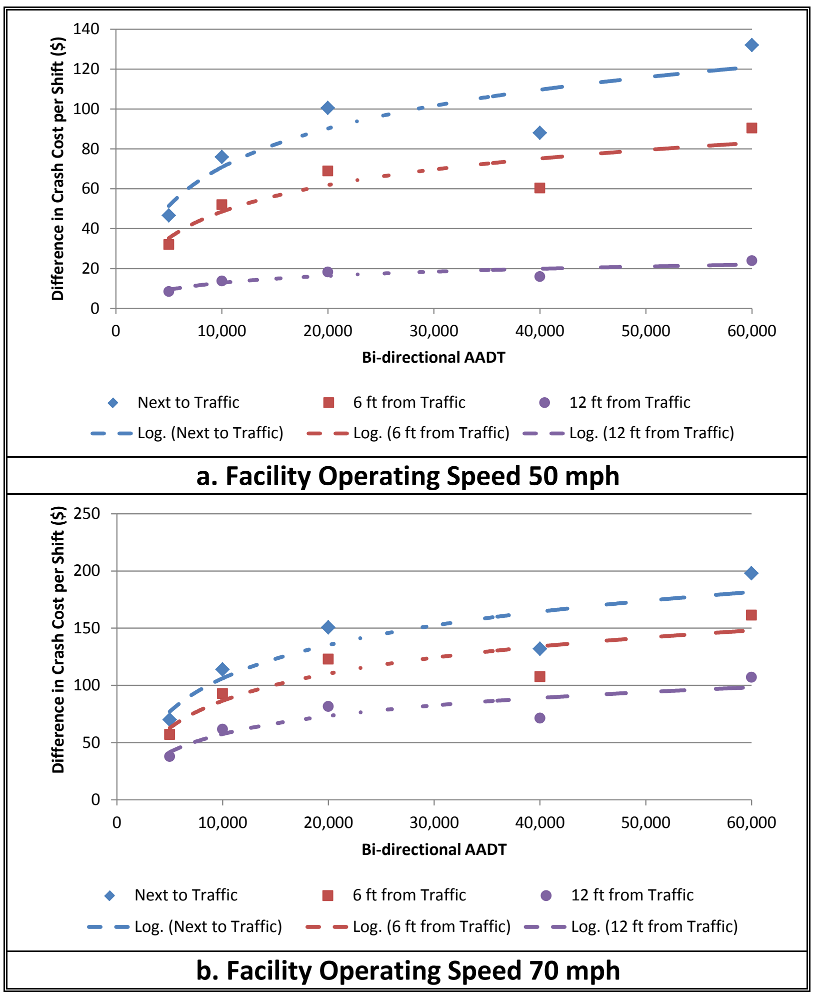


Figure 15. Regression Curve Fitted to Analysis Results v3 Analysis Results for High-Risk Locations on Four-Lane Divided Freeway (45 Foot Work Space Protection)

A Decision-Making Procedure for Assessing Work Zone Positive Protection Needs

Based on the RSAPv3 analyses and fitted regression curves to the analyses results, the researchers created a positive protection needs assessment to aid in the determination of whether positive protection use can be economically recommended at a location based on a reduction of expected crash costs during the work zone. Of course, not all work zones will require consideration of positive protection needs by means of this assessment tool. The Code of Federal Regulations 23 CFR 630 Subpart-K suggests that the following questions be used to determine whether positive projection should be considered for a particular project:

1. Does the work zone require workers to operate next to moving traffic where there is no escape (tunnels, bridges, etc.)?
2. Will the work zone last two weeks or longer?
3. Will operating speeds in the work zone likely exceed 45 mph?
4. Will work operations place workers within 12 feet of travel lanes open to traffic?
5. Will there be temporary roadside hazards close to the travel lanes that will remain in place overnight or longer within the project?

The analysis procedure presented below (a two-step process) provides a systematic process for determining whether positive protection should be considered for a particular project. The process is based on an engineering assessment of the costs of providing positive protection versus the crash cost reduction benefits that may be achieved by providing the positive protection. If the expected benefits approach exceeds the costs of providing protection, use of such protection is recommended. The process should be considered as guidance and not a standard or warrant. Rather, engineering judgment should still be applied when making positive protection decisions. Unique situations and conditions may exist at a site that are not considered in these guidelines and that could justify the use of positive protection even if the results of this process indicate otherwise.

Step 1: Determine and Categorize Hazard Locations and Types Present in Each Phase of the Project

The work zone designer should perform a systematic check of the entire project length for each phase to determine conditions where and when positive protection might be needed. Analysis procedures have been developed for three hazard types that may need some type of positive protection.

Hazard Type 1: Operations and Locations Where No Worker Escape Options Exist

This condition category includes areas where workers are performing duties in or next to open travel lanes on high-speed (i.e., 55 mph and higher) facilities in locations where are “No Escape” options are available in the event of an errant vehicle intruding into the work space. An estimate of the number and time periods (day, night, and weekend) of such operations will be required. If the traffic volumes expected and frequency of work periods are high enough, portable barrier (concrete or steel) may be recommended. If not, other techniques, such as providing shadow vehicles with truck-mounted attenuators immediately upstream and downstream of the work crew, may be recommended.

Hazard Type 2: Other Worker Activities near Traffic With or Without Temporary Roadside Hazards Near Traffic

Conditions where workers are in or within 12 ft of open travel lanes but where the potential for escape from an errant vehicle exists may also warrant positive protection in some instances. An estimate of the number of work periods required and total time to accomplish the work will be required, as will the time period(s) in which the work will be performed. If the project will involve multiple work crews, an estimate of the number of work crews likely to be present each work period will also be needed.

Pavement edge drop-offs, unfinished bridge railings, culverts, material and equipment storage, etc. may be present in a temporary condition within the permanent clear zone for the facility (as defined in Figure 5 - 7 of the *Idaho Department of Transportation Design Manual*) for more than a 1 work period.[34] When combined with consideration of other worker activities, work zone positive protection may be recommended at traffic volume levels lower than would otherwise be recommended by considering worker activities only. The expected duration of the roadside hazard and relative proximity to the open travel lanes will be needed to assess this condition.

Step 2: Select Appropriate Worksheet(s) and Perform Analyses

Simple-to-use worksheets, provided in the appendix, were developed to assist in determining whether the provision of positive protection would be recommended on the basis of the safety benefits (reduced crash costs) expected. Worksheets are provided for each hazard type defined above. Many projects will require the analyst to consider only one of the hazard types described. However, other projects that result in some work periods where workers have no escape may require consideration of both the hazard types listed.

Worksheet 1: Operations and Locations Where No Worker Escape Options Exist

The first work zone hazard type considered for positive protection consideration is the situation where the work crew must be out near moving traffic with no escape options available in the event that an errant vehicle enters the work space. Basic project information is first collected on the following:

- Project Number.
- Project Location (and Description).
- Roadway AADT.
- Lateral Distance that Traffic will be from the Workers.
- Approximate Number of Work Shifts that Will Require Workers to Be Out Next to Traffic in this “No Escape” Condition.

For this hazard situation, the guidelines assist the analyst in determining how much crash cost risk is estimated for each work shift that workers are out next to traffic. As noted above, it is assumed that any encroachment into the work space will result in a fatality. The analyst uses the estimated AADT value and the lateral distance that workers will be from traffic during the work shift to find the estimated crash cost potential without barrier for the 70 mph graph in Figure 17. Then, multiplying this per-shift crash cost without barrier by the number of such shifts expected to occur provides the total expected crash cost risk for the project or project phase of interest.

Next, the cost of providing positive protection that would be used for the work crew must be estimated. If PCB is being considered, the price per linear foot times the total length of protection is computed (along with the costs of typical crash cushion end treatments). If the work space will remain stationary over the course of the project, a fairly small length of barrier may be needed (at the very least, the minimum length needed for protection must be provided). However, if the work space moves over the length and duration of the project, it may be necessary to put barrier (if used) along the entire length of the project (certainly, some projects may allow for a shorter section of barrier to be used, and moved along the project as work progresses, but for other projects, frequent movement of barrier becomes cost and manpower prohibitive). If other highly portable techniques are being considered, such as a mobile barrier or a shadow vehicle with a truck-mounted attenuator, the per-shift amortized cost of the protection would be multiplied by the number of work shifts it would be employed. The computed costs of providing barrier are divided into the estimated crash costs/risk of not providing barrier. If the ratio exceeds one, providing barrier is recommended for this situation.

This analysis is very liberal (and so provides a large factor of safety) in terms of recommending positive protection usage since opportunities for workers to avoid an intruding vehicle and escaping unharmed are limited. Specifically, the analysis ignores the additional crash costs to vehicles that may impact the barrier if present and also is based on a high operating speed (70 mph) in the event that the intruding vehicle speed is that high. Even with these built-in factors of safety, however, conditions may also exist for which the analyst still believes positive protection is needed even if this analysis does not indicate that it can be economically justified. Factors such as working at night (when more drivers are impaired) or working where sight distances are limited may be examples of site-specific factors where engineering judgment may indicate that positive protection use is justified.

Worksheet 2: Other Worker Activities near Traffic With or Without Temporary Roadside Hazards Near Traffic

If the work space/activity area does provide some opportunities for workers to potentially avoid errant vehicles (i.e., some escape opportunities do exist), the analyst uses either Part 1 or both Part 1 and 2 of Worksheet 2 depending on whether there will be long-term roadside hazards (e.g., an edge drop-off, temporary embankment slopes that exceed ITD thresholds for unprotected permanent facilities, or materials and equipment left within the clear zone even when work activities are not occurring). Once again, the analysis begins with the collection of key project and roadway data:

- Project Number.
- Project Location (and Description).
- Roadway AADT.
- Expected Operating Speeds Approaching and Passing Through the Work Zone.
- Expected Duration of the Project or Project Phase Being Analyzed.

Information about how the project is expected to be completed must also be estimated. Questions that need to be answered are as follows:

- Will the work be performed in a typical fashion (i.e., working during daylight hours, Monday through Friday workweeks), or will it be performed in an accelerated manner or during periods of lower traffic volumes (i.e., working at nights or working on weekends)?

- How much of the activity area being considered for positive protection will have work activity occurring on a typical work period?

The objective of the analysis is to determine an equivalent exposure level (in weeks) for when work activities are occurring and thus where there would be benefits to providing positive protection. This analysis approach ignores the additional crash costs to vehicles that may occur during periods when the work zone is inactive and a barrier is used, and so is liberal in its assessment of positive protection needs (i.e., a factor of safety is applied when comparing the risks on not providing a barrier to those when a barrier is used).

The analysis involves the selection of adjustment factors that represent either traffic volume or time proportions of exposure to the work activities (Part 1). Factors include:

- **Typical Workday Factor**. If work will occur continuously both day and night, this factor will be 1.0; if work will occur predominantly during the daytime or predominantly during the nighttime, this factor will be 0.5. If the project will involve a combination of both daytime and nighttime work, the relative proportion of each can be combined. For example, if work will occur mostly during the daytime, but it is expected that the contractor will also work at night on certain time-critical tasks about 20 percent of the time, a combined workday factor of 0.5 (for daytime) + 0.5*0.2 (accounting for the 20 percent of night work effort) = 0.6 should be entered for this factor.

- **Allowable Workdays Factor**. If work activities will typically occur during a Monday through Friday workweek, a factor of 0.78 (equivalent to 0.156 per workday added together for 5 days) is used to reflect the proportion of weekly traffic volumes exposed to work activities; if work will also occur on Saturday, add 0.12; if work will also occur on Sunday, add 0.10.

- **Proportion of Workdays that Work Activities Will Occur**. On average, national data suggest this is between 0.50 and 0.60; however, specific project activities should be considered when estimating this proportion.

- **Proportion of Work Zone Activity Area that Will Have Work Operations During Each Work Shift.** If project-specific information is not available to estimate this, assume a 150 ft length per each area where work is expected on a given shift, sum over the number of simultaneous work areas, and divide by the total length of activity area being considered for positive protection.

These four factors are then multiplied together and then by the total expected duration of the project or project phase being analyzed to yield an equivalent exposure duration. Using this equivalent exposure value and roadway AADT, the intersection can be looked up in Figure 15 for the appropriate operating speed expected during the project when no temporary roadside hazards exist. For situations where long-term hazards exist within the work zone in addition to the hazards that exist during the periods of work activity at the project, Part 2 of the worksheet is also used. This first entails another adjustment of the work activity exposure to account for the times when both the work activity and the temporary roadside hazard is present:

This part of the analysis involves the selection of two additional adjustment factors:

- Work zone activity to long-term hazard interaction factor. During periods of work activity, overlap exists in the exposure to the long-term hazard and the work activity hazard. To account for the overlap, a reduction factor computed to be 0.62 from the RSAPv3 analyses is applied to the work activity equivalent exposure time.

- Work activity lateral location factor. An adjustment is made to reduce the equivalent exposure value when work activities and hazards occur farther away from the travel lanes because the risk of an errant vehicle intruding into the work space is reduced. Values are 1.0 if work and hazard are adjacent up to 6 ft from the travel lanes, 0.94 if work and hazard are 6 - 12 ft from the lanes, 0.79 if work and hazard are 12 - 24 ft from the lanes, and 0.54 if work and hazard are 24 ft or more from the lanes.

These two factors are then multiplied together and then by the duration that the hazard is expected to be present to yield the long-term hazard exposure duration. The work activity and long-term hazard exposures are then added together and used along with AADT in Figure 15 for the appropriate operating speed expected during the project.

Figure 15 is based on a barrier cost of $53.76 per foot, and sets upper and lower thresholds based on the VSL value used (higher VSL number of 9.1 million and lower VSL number of 5.2 million). The analysis can be calibrated with values other than these. The spreadsheet tool developed to support these guidelines allows for different values to be entered if desired, and modifies the graph used accordingly.

Application of the Guidelines to a Sample of ITD Projects

To evaluate whether the guidelines presented above will yield reasonable results with respect to positive protection use decisions, a sample of three projects on the ITD schedule were submitted for analysis:

- I-84 Slab Replacement near Hammett.
- US-95 Race Creek Bridge.
- Deck Life Extension Work on Pasadena Road over I-84 and I-84 over the East Bliss Railroad Overpass.

Table 13 provides an overview of the project relative to the data used in the positive protection guidelines. The two projects that involve I-84 had higher traffic volumes (AADTs in the 15,000 - 20,000 range), whereas the Race Creek Bridge project on US-95 had a lower volume (AADT 2,500 - 3,500). Also, the I-84 projects were 60 working days or less, whereas the Race Creek Bridge project was a 6 month job.

The results of the analyses of the 3 projects are provided in Table 14 through Table 19. In 2 of the 3 cases, positive protection could not be recommended on the basis of a reduction in expected crash costs over the duration of the project. Furthermore, for 2 of the 3 projects, an analysis of the 2 “No Escape” situations were performed as well as an overall assessment of the combined risk of having work activity during daytime hours and roadside hazards during both active and inactive times at the projects. The analysis could not recommend positive protection on the basis of reduced expected crash costs for these two projects when considering either the “No Escape” or the combined work activity and roadside hazard assessment. It should be noted that no-escape conditions will typically only result in barrier use recommendations under fairly high AADT values and fairly small work spaces. For example, if the Race Creek Bridge project had only required a very short work space protection area rather than the entire 1,843 ft, the analysis would have resulted in a higher benefit-cost ratio.

For the third project, the I-84 Bridge Deck Life Extension, the results of the analysis lead to a recommended consideration of positive protection based on the combined assessment of work activity and long-term roadside hazard risks during the project. It was assumed that even though the project was limited to 60 working days, it would take nearly 22 weeks to get those 60 work activity days completed.

A few caveats about the analyses deviated from the assumptions used in development of the guidelines, however. For the US-95 Race Creek Bridge project, barrier already existed at the project site that would be available for use during the project. This meant that actual barrier costs would have been significantly lower than that assumed in the development of the guidelines. Also, for the I-84 bridge deck life extension project, the location of the project relative to acceleration and deceleration lanes and ramps for an interchange appeared to create some confusion for motorists, which led to a number of crashes and then led to field changes to close those ramps and reroute the entering/exiting traffic via another interchange. Together, these caveats highlight the importance of using the guidance developed in this project as a tool rather than as a final decision. For example, the proximity of a significant drop-off between the travel lanes and work space for anything more than a few hours or days on interstate facilities may be enough of a risk to ITD to recommend positive protection regardless of the results of this analysis.

Table 13. Characteristics of Pilot Test Projects for Guidelines

Criteria	I-84 Slab Replacement—Hammett Project	Race Creek Bridge Project (US 95)	I-84 Bridge Deck Life Extension
Roadway & Project Limits	MP 90.00 - MP 114.49	MP 196.572 - MP 196.921	MP 125.16–125.33 & MP 140.01–140.13
Expected Duration of the Project	50 Working Days (moving from slab to slab as needed)	6 months	60 Working Days
Roadway AADT	2014 AADT is 19,130	Projected 2017 AADT 2,540	2014 AADT is 16,450 on I-84; much lower on Pasadena Road
Length & Location of Bridges, Tunnels, Mountainsides, etc. that Would Limit Worker Ability to Escape an Errant Vehicle	Several Areas Within Project Limits: Overpasses (No Work on the Decks) at MP 95.21 & 113.84; Culvert with Guardrail (Steep Shoulder Drop-Off) at MP 94.49; Underpasses at MP 90.32, 92.40, 94.20, & 99.58	Entire Length 0.35 miles	Pasadena Road Bridge over I-84; East Bliss & Union Pacific Railroad Grade Crossing. Bridge is 245 ft long.
Basic Description of Work to be Accomplished	The work includes replacement of joint seals, slab replacement (full or partial), installation of rumble strips, & Pavement Spall & Crack Repair.	Replace Race Creek Bridge; elevation of new bridge deck similar to old bridge deck: Phase 1: NB half of bridge built east of existing structure. Phase 2: existing bridge demolished, SB half of bridge constructed, traffic control alternating one way with signal, new structure & roadway embankment constructed above Salmon River. 20 ft MSE retaining walls in isolated areas	Pasadena Road is overlay & bridge deck rehabilitation requiring alternating one-way control; little effect on I-84. East Bliss/Union Pacific Railroad Bridge required long-term lane closures (1 or 2 depending on location relative to acceleration/deceleration lanes); edge drop-off next to open travel lane.
Project Performed on a Typical Schedule or Accelerated	Work Performed on a Typical Schedule.	Typical Schedule	Typical
Phases & Locations Where Any Temporary Roadside Hazards Might Exist	Several areas required slab replacement; the longitudinal joints of slabs located near the skip lines (a 1 - ft +/- drop-off), 10 ft outside shoulder, two 12 ft lanes, and 4 ft inside shoulder	A gabion wall is to be construction; existing concrete rail used to create a barrier between the work area & traffic	Edge Drop-Offs Where Pavement Being Repaired or Replaced.
Number of Work Crews Out On the Job During A Typical Work Shift	Up to 4 crews were working in various locations at any one time	1	1

MP = Mile Point; MSE = Mechanically-Stabilized Earth

Table 14. Results of Analysis of I-84 Hammett Project

1. Project No:	2. Project Location and Description: **I-84 Slab Replacement – Hammett**
3. Estimate Roadway AADT	19,130
4. Estimate Operating Speeds Through Work Zone	70 mph
5. Estimate the Distance from Traffic to the Work Activity (Workers) and Work Activity Location Factor *(Immediately adjacent to travel lanes = 1, separated from the travel lanes by 6 ft = 0.94, separated from the travel lanes by 12 ft = 0.79, separated from the travel lanes by 24 ft = 0.54)*	Next to travel lanes 1.0
Part 1: Worker Activity Exposure Computations	
6. Estimate Typical Time-of-Day Work Factor *(Continuous (24/7) =1.0; Mostly Daytime = 0.5; Mostly Nighttime = 0.5)*	0.50
7. Estimate Allowable Work Days Factor *(Sum of M - F = 0.78; Sat = 0.12; Sun = 0.10)*	0.78
8. Estimate Proportion of Possible Work Days with Work Activity[1]	0.60
9. Estimate Proportion of Work Zone Occupied by Active Work Space(s)[2]	0.50
10. Estimate Expected Duration of Project or Project Phase	10 weeks
11. Compute Equivalent Work Activity Exposure Duration (Item 6 x Item 7 x Item 8 x Item 9 x Item 10)	1.17 weeks
12. Multiply Item 11 with Work Activity Location Factor (Item 5)	1.17 weeks
Part 2: Temporary Roadside Hazard Exposure Computations	
13. Estimate Duration that Roadside Hazard Will Be Present	10 weeks
14. Multiply Item 13 with Work Activity Location Factor (Item 5)	10 weeks
15. Multiply Item 12 by 0.62 to Account for the Interaction of Work Activity and Roadside Hazards On Crash Costs	0.73 weeks
16. Compute the Combined Equivalent Exposure Duration by Adding Item 14 to Item 15	10.73 weeks
Part 3: Positive Protection Recommendation	
17. Higher Value of Statistical Life[3]	$ 9.1 Million
18. Lower Value of Statistical Life[3]	$ 5.2 Million
19. Cost of PCB[4]	$ 53.76 /ft
20. To determine whether positive protection can be recommended on the basis of reduced crash costs, look up on Figure B, the intersection of roadway AADT in Item 3 and weeks in Item 12 if no temporary roadside hazards exist or Item 16 if temporary roadside hazards exist[5]	**No**

Table 15. Results of Analysis of Race Creek Bridge Project: Worker Risk with No Escape Option

1. Project No:	2. Project Location and Description: **US-95 Race Creek Bridge**
3. Estimate Roadway AADT	2,540
4. Estimate the Distance From Traffic to the Work Activity (Workers)	Next to Travel Lanes
5. Value of Statistical Life[1]	$ 9.1 Million
6. Estimate the Number of Work Shifts When This Will Occur	26 * 5 = 130 shifts
7. Estimate per-Shift Potential Crash Costs of Not Providing Positive Protection (Using Values in Item 3 and Item 4 to Extract Value From Figure A)	$ 49
8. Compute Total Project Crash Cost Potential if No Protection Provided (i.e., Benefits Gained if Positive Projection Provided) (Item 6 x Item 7)	$ 49 * 130 = $6,310
9. Estimate Cost of Providing Positive Protection to Protect a Limited 45 ft-Zone for Work Crew[2] ($/ft of PCB or Steel Barrier x Total Length of Need, or $/Shift for Mobile Barrier Use x Number of Shifts, or $/Shift for Shadow Vehicle with TMA x Number of Shifts)	$ 53.76/LF * 1,843 ft = $99,080
10. Compute Ratio of Possible Crash Cost Reduction Benefits to Costs (Item 8/Item 9)	0.06

Table 16. Results of Analysis of Race Creek Bridge Project: Combined Worker and Roadside Hazard Risks

1. Project No:	2. Project Location and Description: **US-95 Race Creek Bridge**
3. Estimate Roadway AADT	2,540
4. Estimate Operating Speeds Through Work Zone	70 mph
5. Estimate the Distance From Traffic to the Work Activity (Workers) and Work Activity Location Factor *(Immediately adjacent to travel lanes = 1, separated from the travel lanes by 6 ft = 0.94, separated from the travel lanes by 12 ft = 0.79, separated from the travel lanes by 24 ft = 0.54)*	Next To Travel Lanes 1.0
Part 1: Worker Activity Exposure Computations	
6. Estimate Typical Time-of-Day Work Factor *(Continuous (24/7) =1.0; Mostly Daytime = 0.5; Mostly Nighttime = 0.5)*	0.5
7. Estimate Allowable Work Days Factor *(Sum of M - F = 0.78; Sat = 0.12; Sun = 0.10)*	0.78
8. Estimate Proportion of Possible Work Days with Work Activity[1]	0.50
9. Estimate Proportion of Work Zone Occupied by Active Work Space(s)[2]	0.50
10. Estimate Expected Duration of Project or Project Phase	26 weeks
11. Compute Equivalent Work Activity Exposure Duration (Item 6 x Item 7 x Item 8 x Item 9 x Item 10)	2.54 weeks
12. Multiply Item 11 with Work Activity Location Factor (Item 5)	2.54 weeks
Part 2: Temporary Roadside Hazard Exposure Computations	
13. Estimate Duration That Roadside Hazard Will Be Present	26 weeks
14. Multiply Item 13 with Work Activity Location Factor (Item 5)	26 weeks
15. Multiply Item 12 by 0.62 to Account for the Interaction of Work Activity and Roadside Hazards on Crash Costs	1.57 weeks
16. Compute the Combined Equivalent Exposure Duration by Adding Item 14 to Item 15	27.57 weeks
Part 3: Positive Protection Recommendation	
17. Higher Value of Statistical Life[3]	$ 9.1 Million
18. Lower Value of Statistical Life[3]	$ 5.2 Million
19. Cost of PCB[4]	$ 53.76 /ft
20. To Determine Whether Positive Protection Can Be Recommended on the Basis of Reduced Crash Costs, Look Up On Figure B, the Intersection of Roadway ADT in Item 3 and Weeks in Item 12 if No Temporary Roadside Hazards Exist or Item 16 If Temporary Roadside Hazards Exist[5]	**No**

Table 17. Results of Analysis of Pasadena Road Bridge Project: Worker Risk with No Escape Option

1. Project No:	2. Project Location and Description: **Pasadena Road Bridge Replacement**
3. Estimate Roadway AADT	2,500
4. Estimate the Distance From Traffic to the Work Activity (Workers)	Next to Travel Lanes
5. Value of Statistical Life[1]	$ 9.1 Million
6. Estimate the Number of Work Shifts When This Will Occur	60*1 = 60 shifts
7. Estimate Per-Shift Potential Crash Costs of Not Providing Positive Protection (Using Values in Item 3 and Item 4 to Extract Value from Figure A)	$ 48
8. Compute Total Project Crash Cost Potential if No Protection Provided (i.e., Benefits Gained if Positive Projection Provided) (Item 6 x Item 7)	$ 48 * 60 = $2,872
9. Estimate Cost of Providing Positive Protection to Protect a limited 45 ft-zone for Work Crew[2] ($/ft of PCB or Steel Barrier x Total Length of Need, or $/Shift for Mobile Barrier Use x Number of Shifts, or $/Shift for Shadow Vehicle with TMA x Number of Shifts)	$ 53.76/LF * 900 ft = $48,384
10. Compute Ratio of Possible Crash Cost Reduction Benefits to Costs (Item 8/Item 9)	**0.06**

Table 18. Results of Analysis of East Bliss Union Pacific Railroad Bridge: Worker Risk with No Escape Option

1. Project No:	2. Project Location and Description: **East Bliss Union Pacific Rail Road Bridge**
3. Estimate Roadway AADT	16,450
4. Estimate the Distance From Traffic to the Work Activity (Workers)	Next to Travel Lanes
5. Value of Statistical Life[1]	$ 9.1 Million
6. Estimate the Number of Work Shifts When This Will Occur	60*1 = 60 shifts
7. Estimate Per-Shift Potential Crash Costs of Not Providing Positive Protection (Using Values in Item 3 and Item 4 to Extract Value From Figure A)	$ 127
8. Compute Total Project Crash Cost Potential if No Protection Provided (i.e., Benefits Gained if Positive Projection Provided) (Item 6 x Item 7)	$ 127 * 60 = $7,627
9. Estimate Cost of Providing Positive Protection to Protect a Limited 45 ft Zone for Work Crew[2] ($/ft of PCB or Steel Barrier x Total Length of Need, or $/Shift for Mobile Barrier Use x Number of Shifts, or $/Shift for Shadow Vehicle with TMA x Number of Shifts)	$ 53.76/LF * 645 ft = $34,675
10. Compute Ratio of Possible Crash Cost Reduction Benefits to Costs (Item 8/Item 9)	**0.22**

Table 19. Results of Analysis of East Bliss Union Pacific Railroad Overpass (I-84): Combined Worker and Roadside Hazard Risks

1. Project No:	2. Project Location and Description: **East Bliss Union Pacific Railroad Overpass (I-84)**	
3. Estimate Roadway AADT		16,450
4. Estimate Operating Speeds Through Work Zone		70 mph
5. Estimate the Distance from Traffic to the Work Activity (Workers) and Work Activity Location Factor *(Immediately adjacent to travel lanes = 1, separated from the travel lanes by 6 ft = 0.94, separated from the travel lanes by 12 ft = 0.79, separated from the travel lanes by 24 ft = 0.54)*		Next to Travel Lanes 1.0
Part 1: Worker Activity Exposure Computations		
6. Estimate Typical Time-of-Day Work Factor *(Continuous (24/7) =1.0; Mostly Daytime = 0.5; Mostly Nighttime = 0.5)*		0.5
7. Estimate Allowable Work Days Factor *(Sum of M - F = 0.78; Sat = 0.12; Sun = 0.10)*		0.78
8. Estimate Proportion of Possible Work Days with Work Activity[1]		0.50
9. Estimate Proportion of Work Zone Occupied by Active Work Space(s)[2]		1.0
10. Estimate Expected Duration of Project or Project Phase		22 weeks
11. Compute Equivalent Work Activity Exposure Duration (Item 6 x Item 7 x Item 8 x Item 9 x Item 10)		4.29 weeks
12. Multiply Item 11 with Work Activity Location Factor (Item 5)		4.29 weeks
Part 2: Temporary Roadside Hazard Exposure Computations		
13. Estimate Duration that Roadside Hazard Will Be Present		22 weeks
14. Multiply Item 13 with Work Activity Location Factor (Item 5)		22 weeks
15. Multiply Item 12 by 0.62 to Account for the Interaction of Work Activity and Roadside Hazards On Crash Costs		2.66 weeks
16. Compute the Combined Equivalent Exposure Duration By Adding Item 14 to Item 15		24.66 weeks
Part 3: Positive Protection Recommendation		
17. Higher Value of Statistical Life[3]		$ 9.1 Million
18. Lower Value of Statistical Life[3]		$ 5.2 Million
19. Cost of PCB[4]		$ 53.76 /ft
20. To Determine Whether Positive Protection Can Be Recommended on the Basis of Reduced Crash Costs, Look Up On Figure B, the Intersection of Roadway AADT in Item 3 and Weeks in Item 12 if No Temporary Roadside Hazards Exist or Item 16 if Temporary Roadside Hazards Exist[5]		**Yes**

Consideration of Non–Positive Protection Measures to Improve Safety

The Code of Federal Regulations 23 CFR 630 Subpart K also requires agencies to consider the potential use of other measures to improve safety when positive protection is not justified for use on a project. A wide range of devices and strategies are listed for possible consideration to reduce the duration of a project, the amount of traffic passing by the project, and/or maximize driver awareness and safe behavior. Generally speaking, the various strategies listed are typically considered part of the normal project development process, and their effectiveness and costs depend on a large number of site-specific factors. In addition, for many of the devices intended to increase driver awareness and safe behavior, the effect of the devices on such awareness and behavior - and thus safety - is not known. Thus, the project engineer must again use judgment to determine whether strategies or devices in addition to those normally required and used on a particular type of project are justified.

One area that the analyses performed on this project may provide some insights on is techniques used to reduce driver speeds approaching and passing through work zones. Excessive speeds (i.e. speeds higher than the posted or advised speed limit) are a major contributing cause of work zone crashes nationally. ”Excessive speeds” may be of particular concern on rural facilities such as those in most parts of Idaho, where operating speeds are already relatively high. Through the years, several techniques have been suggested to reduce speeds and increase driver awareness in work zones, including:

- Enforcement.
- Speed Display Trailers.
- Transverse Rumble Strips.
- Radar Drones.
- Changeable Message Signs with Excessive Speed Messages.

Of these, enforcement is by far the most effective in reducing speeds but is typically the most expensive to implement. In addition, enforcement staff availability to obtain cooperative or dedicated enforcement, funded with overtime pay, is often limited. The other techniques listed are generally less costly and easier to control but also result in smaller speed reductions.

One of the ways to determine whether to use enforcement or one of the other techniques for speed reduction purposes at a project is to estimate what potential safety benefits might be expected by reducing operating speeds on the facility and comparing these benefits to the cost of a strategy or device. Unfortunately, the effects of speed reductions on crash costs are not well researched at this time, especially in work zone applications where speed reductions may also result in higher speed variability (which has been associated with increased crash risk in non-work zone locations).[32] Nevertheless, Figure 16 was developed from the RSAPv3 analyses performed in this research for non-positive-protected conditions. The graph represents the difference in crash costs between the 70 mph and 50 mph operating conditions at each AADT level analyzed for a four lane divided highway with no drop offs or other long term hazards. Although it is highly unlikely that any of the strategies (including enforcement) would be capable of generating speed reductions of that magnitude, the comparison does provide an order-of-magnitude liberal estimate of the benefits of reducing speeds. As would be expected, the benefits do depend heavily on the amount of traffic using the facility. A per-shift comparison of the safety benefits shown in the figure to the costs of implementing a speed reduction strategy can be used as one way to assess the potential value of that particular speed reduction strategy.

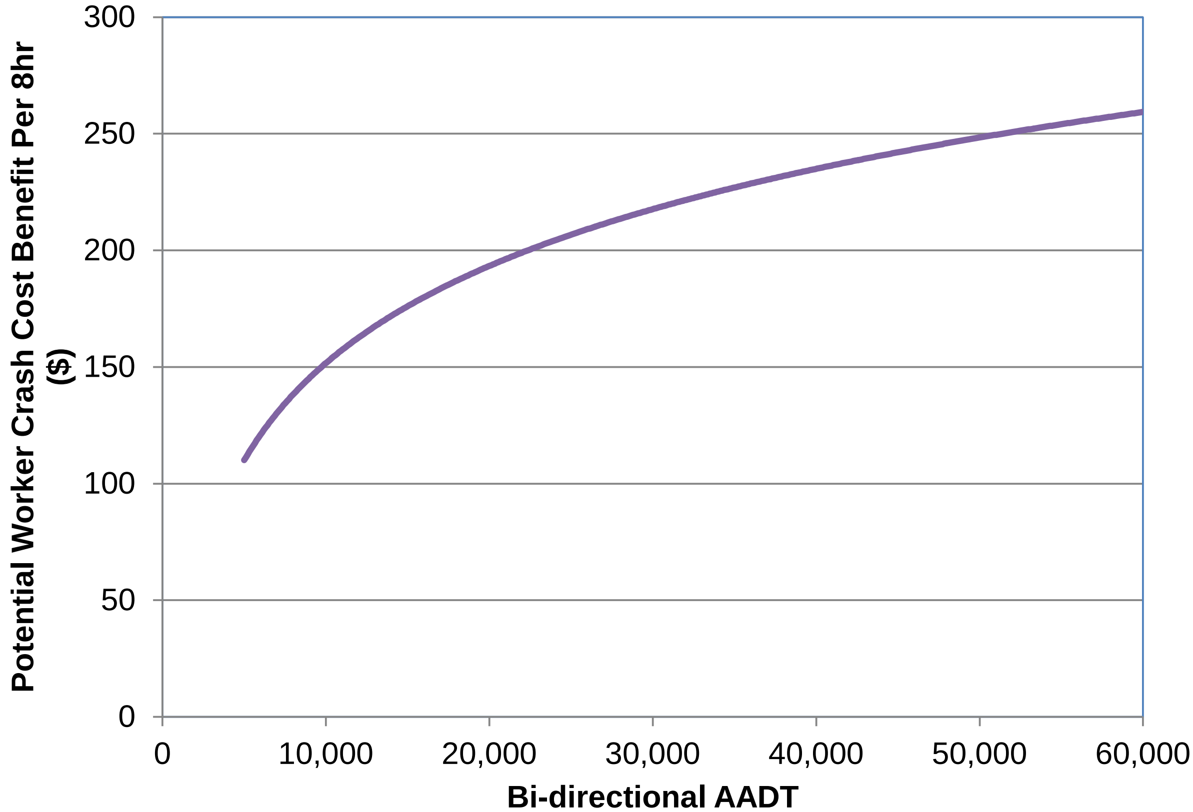


Figure 16. Potential Crash Cost Benefits for Speed Reduction Strategies per Eight-Hour Shift

Chapter 5
Summary, Conclusions, and Recommendations

Summary

Federal Regulations 23 CFR Part 630 Subpart K - Temporary Traffic Control (630.1102 - 630.1110) rule recommends that at a minimum, positive protection shall be considered where work zone conditions place workers at increased risk from motorized traffic (e.g., tunnels and bridges that limit worker escape routes, and long-duration projects on high-speed facilities that place workers in close proximity to motorized traffic) and where positive protection devices can significantly improve safety (e.g., to protect a pavement edge drop-off that will be in place overnight or longer). However, more specific requirements are not provided; states are responsible for developing general agency or project-specific decision frameworks for determining situations, locations, and types of positive protection to use (e.g., traditional PCB or one of the newer steel, water-filled, or low-profile barriers). It is also recommended that states consider techniques intended to reduce the likelihood that a vehicle intrusion into the work zone will occur at all.

A review of available literature showed that early efforts in this area either did not consider the risks and costs of the crashes involving a worker or equipment, or placed workers and equipment in various assumed locations within the work zone for analysis. Both of these approaches limit their usefulness in evaluating the potential need for positive protection in future projects that are not exactly of the type that was modeled in the assessments. A 2013 survey of state highway agencies revealed that all state highway agencies had some form of basic guidelines in place for common positive protection devices (e.g., PCBs, truck/trailer-mounted attenuators, and longitudinal barrier end treatments).(1) However, only a few states had extensive guidance on when to use positive protection devices and which devices to use.

This project developed Idaho-specific work zone positive protection guidelines that ITD staff can use when designing work zone traffic management plans. The guidelines address conditions where positive barrier application can be justified on the basis of reduced work zone crash costs. Where positive barrier justification does not exist, guidelines are provided regarding intrusion and other crash reduction countermeasures (e.g., closer channelizing device spacing and supplemental speed management devices) that could be employed.

Unfortunately, good field data regarding the actual safety benefits of positive protection use in terms of reduced crash severity or crash costs are not available. Consequently, the encroachment-based hazard protection benefit-cost analysis approach outlined in the AASHTO RDG is the most logical choice for a safety-based analysis. Thus, the research team used a modified RSAPv3 analysis - the benefit-cost tool for the 2011 edition of the RDG - in conjunction with Idaho data to assess the cost-effectiveness of positive protection use under different roadway and work zone conditions.(9)

The guidelines developed in this project are based on the theory of encroachment hazard analysis, which was conducted using RSAPv3. RSAPv3 uses a conditional encroachment-collision-severity approach to determine the frequency, severity, and societal cost of roadside crashes for each user-entered design alternative. A worker or worker area is not one of the predefined roadside hazards in RSAPv3, so the research team developed equivalent severity parameters for modeling a worker area as a roadside hazard using previously published data on intrusion crashes at highway work zones in New York.[31]

A typical work zone was modeled as a half-mile (2,500 ft) worker area with and without a pavement edge drop-off. A high-risk location (e.g., a tunnel) was modeled as a small hazard area of 45 ft, intrusions into which always resulted in a worker fatality. The results of the analysis show positive benefit in protecting drop-offs and workers at higher volumes and when they are present closer to the travel lanes at lower volumes. Although the initial analyses were performed on both four-lane divided highways and two-lane, two-way highways, the RSAPv3 results for four-lane divided highways fitted to regression curves are used in guidance development to provide a factor of safety that would err towards providing barrier protection. The guidance was based on estimating equivalent exposures for the work space intrusion costs and for any drop-off exposure costs. The work space's distance from travel lanes is incorporated into the guidance in the form of a work activity location factor. The lower limit for positive protection use is identified using RSAPv3 results that used the FHWA medium VSL estimate of $9.1 million, whereas the upper limit is identified using RSAPv3 results that used the FHWA low VSL estimate of $5.2 million. For guidance on positive protection use at high-risk locations, the RSAPv3 analysis results are also fitted to regression curves and are converted to crash cost benefits per eight-hour shift.

Conclusions and Recommendations

Longitudinal traffic barriers or other positive protection devices should be considered for use in work zone situations that place workers at increased risk from motorized traffic, and where positive protection devices offer the highest potential for increased safety for workers and road users.

A step-by-step process for performing the check is included in this report. The process is based on an engineering assessment of the costs of providing positive protection versus the crash cost reduction benefits that may be achieved by providing the positive protection. If the expected benefits approach exceeds the costs of providing protection, use of such protection is recommended. However, the guidance should still be applied using engineering judgment because unique situations and conditions may exist at sites that are not considered in these guidelines. These guidelines and worksheets could be integrated as an appendix into ITD's Work Zone Safety and Mobility Program document and referred to in the Work Zone Assessment and Impacts Management chapter.[2]

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Appendix A
Work Zone Positive Protection Guidelines Worksheets

Overview

Longitudinal traffic barriers or other positive protection devices should be considered for use in work zone situations that place workers at increased risk from motorized traffic and where positive protection devices offer a higher potential for increased safety for workers and road users. The 23 CFR 630 Subpart - K suggests using the following questions to help determine whether positive projection should be considered for a particular project:

1. Does the work zone require workers to operate next to moving traffic where there is no escape (tunnels, bridges, etc.)?
2. Will the work zone last two weeks or longer?
3. Will operating speeds in the work zone likely exceed 45 mph?
4. Will work operations place workers within 12 feet of travel lanes open to traffic?
5. Will there be temporary roadside hazards close to the travel lanes that will remain in place overnight or longer within the project?

Following is a step-by-step process for determining whether positive protection should be considered for a particular project. The process is based on an engineering assessment of the costs of providing positive protection versus the crash cost reduction benefits that may be achieved by providing the positive protection. If the expected benefits approach exceeds the costs of providing protection, use of such protection is recommended. However, the guidance should still be applied using engineering judgment because unique situations and conditions may exist at sites that are not considered in these guidelines and that could justify the use of positive protection even if the results of this process indicate otherwise.

Positive Protection Needs Assessment Process

Two steps are needed to determine the potential need for work zone positive protection.

Step 1: Determine and Categorize Hazard Locations and Types Present in Each Phase of the Project

The work zone designer should perform a systematic check of the entire project length for each phase to determine conditions where and when positive protection might be needed. Three hazard types exist that may warrant some type of positive protection:

Hazard Type 1: Operations and Locations Where "No Worker" Escape Options Exist

This condition category includes areas where workers perform duties in or next to open travel lanes on high-speed (i.e., 55 mph and higher) facilities in locations where there is no escape route available. An estimate of the number and time periods (day, night, and weekend) of such operations will be required. If the volumes and the number of work periods are high enough, portable barrier (concrete or steel) may be recommended. If not, other techniques, such as providing shadow vehicles with truck-mounted attenuators immediately upstream and downstream of the work crew, may be recommended.

Hazard Type 2: Other Worker Activities Near Traffic with or Without Temporary Roadside Hazards Near Traffic.

Conditions where workers are in or within 12 ft of open travel lanes but where the potential for escape from an errant vehicle exists may also warrant positive protection in some instances. An estimate of the number of work periods required and total time to accomplish the work will be required, as will the time period(s) in which the work will be performed. If the project will involve multiple work crews, the number of work crews likely to be present each work period will also be needed.

Pavement edge drop-offs, unfinished bridge railings, culverts, material and equipment storage, etc., may be present in a temporary condition within the permanent clear zone for the facility (as defined in Figures 5 - 7 of the *Idaho Transportation Department Design Manual*) for more than one work period.[34] When combined with consideration of other worker activities, work zone positive protection may be recommended at volume levels lower than would otherwise be recommended by only considering worker activities only. The expected duration of the roadside hazard and relative proximity to the open travel lanes will be needed.

Step 2: Select Appropriate Worksheet(s) and Perform Analyses

Simple-to-use worksheets are provided to assist in determining whether the provision of positive protection would be justified on the basis of the expected safety benefits (reduced crash costs). Worksheets are provided for each hazard type defined in Step 1 Many projects will have conditions that require the analyst to use either of the worksheets. However, projects that result in some work periods where workers have "No Escape" (Hazard Type 1), the analyst may require to consider using both worksheets.

Worksheet 1: Operations and Locations Where No Worker Escape Options Exist.

This worksheet is to be used for analyzing situations where the work crew must be out near moving traffic with no escape options available in the event that an errant vehicle enters the work space. Basic project information is first collected on the following:

- Project Number.
- Project Location (and Description).

- Roadway AADT.
- Lateral Distance That Traffic Will Be from the Workers.
- Approximate Number of Work Shifts That Will Require Workers to Be Out Next to Traffic in this “No Escape” Condition.

This worksheet assists the analyst in determining how much crash cost risk is estimated for each work shift that workers are out next to traffic. This analysis assumes that any encroachment into the work space will result in a fatality. The analyst uses the estimated AADT value and the lateral distance that workers will be from traffic during the work shift to find the estimated crash cost potential without barrier for the 70 mph graph in Figure A. Then, multiplying this per-shift crash cost without barrier by the number of such shifts expected to occur provides the total expected crash cost risk for the project or project phase of interest.

Next, the cost of providing positive protection that would be used for the work crew must be estimated. If a PCB is being considered, the price per linear foot times the total length of protection is computed (along with the costs of typical crash cushion end treatments). If the work space will remain stationary over the course of the project, a fairly small length of barrier may be needed (at the very least, the minimum length needed for protection must be provided). However, if the work space moves over the length and duration of the project, it may be necessary to put barrier (if used) along the entire length of the project (certainly, some projects may allow for a shorter section of barrier to be used, and moved along the project as work progresses, but for other projects, frequent movement of barrier becomes cost and manpower prohibitive). If other highly portable techniques are being considered, such as a mobile barrier or a shadow vehicle with a truck-mounted attenuator, the per-shift amortized cost of the protection would be multiplied by the number of work shifts it would be employed. The computed costs of providing barrier are divided into the estimated crash costs/risk of not providing barrier. If the ratio exceeds one, providing barrier is recommended for this situation.

Worksheet 2: Other Worker Activities near Traffic With or Without Temporary Roadside Hazards Near Traffic

If the work space/activity area does provide some opportunities for workers to potentially avoid errant vehicles (i.e., some escape opportunities do exist), the analyst uses either Part 1 or both Part 1 and 2 of Worksheet 2 depending on whether there will be long-term roadside hazards (e.g., an edge drop-off, temporary embankment slopes that exceed ITD thresholds for unprotected permanent facilities, or materials and equipment left within the clear zone even when work activities are not occurring).

Once again, the analysis begins with the collection of key project and roadway data:

- Project Number.
- Project location (and Description).
- Roadway AADT.

- Expected Operating Speeds Approaching and Passing Through the Work Zone.
- Expected Duration of the Project or Project Phase Being Analyzed.

Information about how the project is expected to be completed must also be estimated. Questions that need to be answered are as follows:

- Will the work be performed in a typical fashion (i.e., working during daylight hours, Monday through Friday work weeks), or will it be performed in an accelerated manner or during periods of lower traffic volumes (i.e., working at nights or working on weekends)?

- How much of the activity area being considered for positive protection will have work activity occurring on a typical work period?

The objective of the analysis is to determine an equivalent exposure level (in weeks) for when work activities are occurring and thus where there would be benefits to providing positive protection. This analysis approach ignores the additional crash costs to vehicles that may occur during periods when the work zone is inactive and a barrier is used, and so is liberal in its assessment of positive protection needs (i.e., a factor of safety is applied when comparing the risks on not providing a barrier to those when a barrier is used).

The analysis involves the selection of adjustment factors that represent either traffic volume or time proportions of exposure to the work activities (Part 1). Factors include:

- **Typical Workday Factor.** If work will occur continuously both day and night, this factor will be 1.0; if work will occur predominantly during the daytime or predominantly during the nighttime, this factor will be 0.5. If the project will involve a combination of both daytime and nighttime work, the relative proportion of each can be combined. For example, if work will occur mostly during the daytime, but it is expected that the contractor will also work at night on certain time-critical tasks about 20 percent of the time, a combined workday factor of 0.5 (for daytime) + 0.5*0.2 (accounting for the 20 percent of night work effort) = 0.6 should be entered for this factor.

- **Allowable Workdays Factor**. If work activities will typically occur during a Monday through Friday workweek, a factor of 0.78 (equivalent to 0.156 per workday added together for 5 days) is used to reflect the proportion of weekly traffic volumes exposed to work activities; if work will also occur on Saturday, add 0.12; if work will also occur on Sunday, add 0.10.

- **Proportion of Workdays that Work Activities Will Occur**. On average, national data suggest this is between 0.50 and 0.60; however, specific project activities should be considered when estimating this proportion.

- **Proportion of Work Zone Activity Area that Will Have Work Operations During Each Work Shift.** If project-specific information is not available to estimate this, assume a 150 ft length per each area where work is expected on a given shift, sum over the number of simultaneous work areas, and divide by the total length of activity area being considered for positive protection.

These four factors are then multiplied together and then by the total expected duration of the project or project phase being analyzed to yield an equivalent exposure duration. Using this equivalent exposure value and roadway AADT, the intersection can be looked up in Figure B for the appropriate operating speed expected during the project when no temporary roadside hazards exist.

For situations where long-term hazards exist within the work zone in addition to the hazards that exist during the periods of work activity at the project, Part 2 of the worksheet is also used. This part of the analysis involves the selection of two additional adjustment factors:

- **Work Zone Activity to Long-Term Hazard Interaction Factor**. During periods of work activity, overlap exists in the exposure to the long-term hazard and the work activity hazard. To account for the overlap, a reduction factor computed to be 0.62 from the RSAPv3 analyses is applied to the work activity equivalent exposure time.

- **Work Activity Lateral Location Factor.** An adjustment is made to reduce the equivalent exposure value when work activities and hazards occur farther away from the travel lanes because the risk of an errant vehicle intruding into the work space is reduced. Values are 1.0 if work and hazard are adjacent up to 6 ft from the travel lanes, 0.94 if work and hazard are 6 – 12 ft from the lanes, 0.79 if work and hazard are 12 - 24 ft from the lanes, and 0.54 if work and hazard are 24 ft or more from the lanes.

These two factors are then multiplied together and then by the duration that the hazard is expected to be present to yield the long-term hazard exposure duration. The work activity and long-term hazard exposures are then added together and used along with AADT in Figure B for the appropriate operating speed expected during the project.

Figure B is based on a barrier cost of $53.76 per foot, and sets upper and lower thresholds based on the VSL value used (higher VSL number of 9.1 million and lower VSL number of 5.2 million). The analysis can be calibrated using values other than these. The spreadsheet tool developed to support these guidelines allows for different values to be entered if desired, and modifies the graph used accordingly.

Worksheet 1: Workers In or Near Moving Traffic, "No Escape" From Errant Vehicles

1. Project No:	2. Project Location and Description:
3. Estimate Roadway AADT	
4. Estimate the Distance From Traffic to the Work Activity (Workers)	ft
5. Value of Statistical Life[1]	$ Million
6. Estimate the Number of Work Shifts When This Will Occur	shifts
7. Estimate Per-Shift Potential Crash Costs of Not Providing Positive Protection (Using Values In Item 3 and Item 4 to Extract Value from Figure A)	$
8. Compute Total Project Crash Cost Potential if No Protection Provided (i.e., Benefits Gained if Positive Projection Provided) (Item 6 x Item 7)	$
9. Estimate Cost of Providing Positive Protection to Protect a Limited 45 ft-Zone for Work Crew[2] ($/ft of PCB or Steel Barrier x Total Length of Need, or $/Shift for Mobile Barrier Use x Number of Shifts, or $/Shift for Shadow Vehicle with TMA x Number of Shifts)	$
10. Compute ratio of Possible Crash Cost Reduction Benefits to Costs (Item 8/Item 9)	

Notes:

[1]*Value of Statistical Life according to 2013 FHWA Guidance on Treatment of the Economic Value of Statistical Life in U.S. Department of Transportation Analyses is $9.1 million (median value).*

[2]*Shadow vehicle with TMA can be used in lieu of positive protection. However, this worksheet cannot be used to estimate crash cost benefits for TMA use*

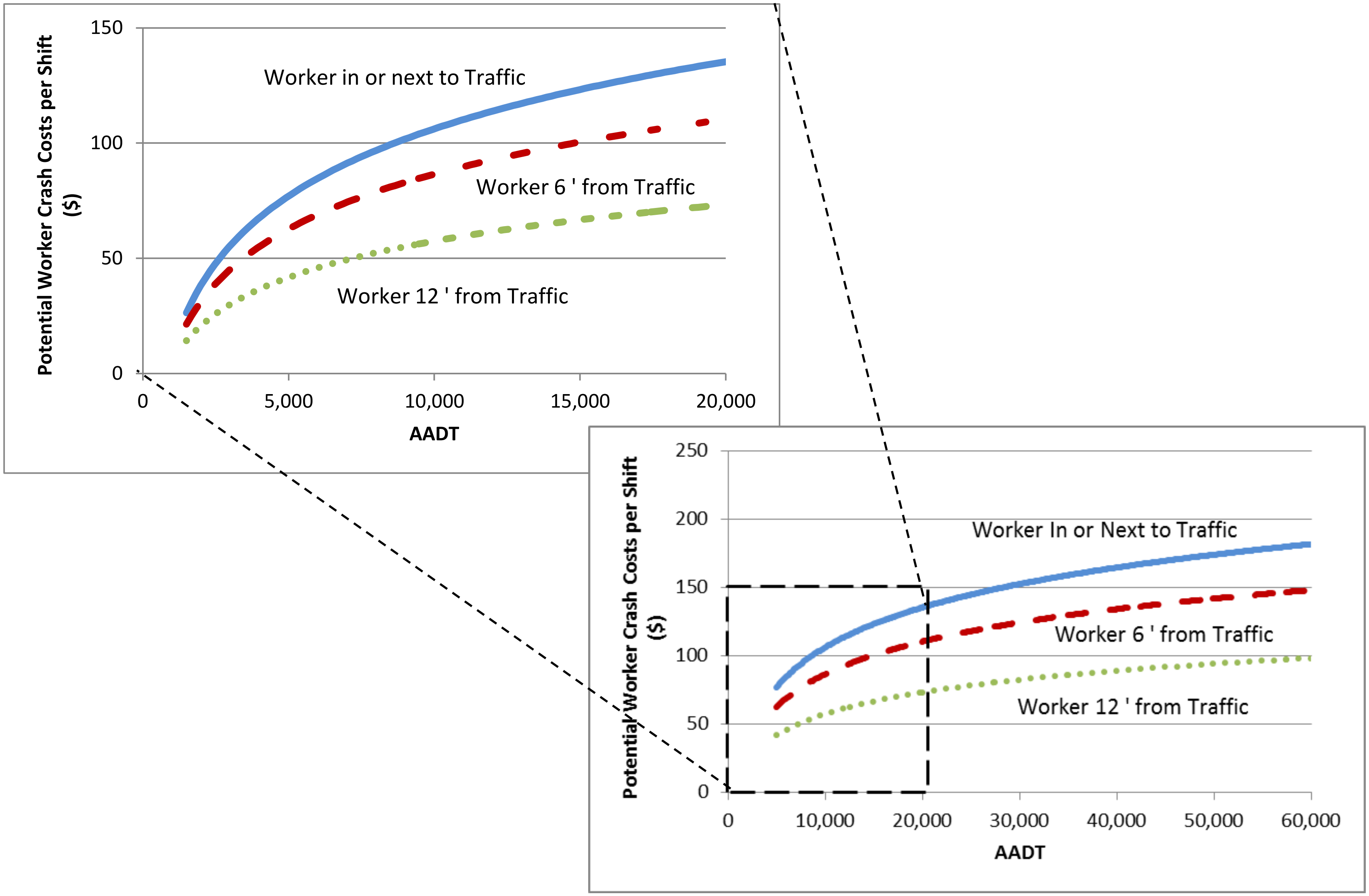

Figure A. Workers with "No Escape" From Errant Vehicles

Worksheet 2: Worker Activities and Temporary Roadside Hazards

1. Project No:	2. Project Location and Description:
3. Estimate Roadway AADT	
4. Estimate Operating Speeds Through Work Zone	mph
5. Estimate the Distance from Traffic to the Work Activity (Workers) and Work Activity Location Factor. *(Immediately adjacent to travel lanes = 1, separated from the travel lanes by 6 ft = 0.94, separated from the travel lanes by 12 ft = 0.79, separated from the travel lanes by 24 ft = 0.54)*	
Part 1: Worker Activity Exposure Computations	
6. Estimate Typical Time-of-Day Work Factor *(Continuous (24/7) = 1.0; Mostly Daytime = 0.5; Mostly Nighttime = 0.5)*	
7. Estimate Allowable Work Days Factor *(Sum of M-F = 0.78; Sat=0.12; Sun=0.10)*	
8. Estimate Proportion of Possible Work Days with Work Activity[1]	
9. Estimate Proportion of Work Zone Occupied by Active Work Space(s)[2]	
10. Estimate Expected Duration of Project or Project Phase	weeks
11. Compute Equivalent Work Activity Exposure Duration (Item 6 x Item 7 x Item 8 x Item 9 x Item 10)	weeks
12. Multiply Item 11 with Work Activity Location Factor (Item 5)	weeks
Part 2: Temporary Roadside Hazard Exposure Computations	
13. Estimate Duration that Roadside Hazard Will Be Present	weeks
14. Multiply Item 13 with Work Activity Location Factor (Item 5)	weeks
15. Multiply Item 12 by 0.62 to Account for the Interaction of Work Activity and Roadside Hazards on Crash Costs	weeks
16. Compute the Combined Equivalent Exposure Duration by Adding Item 14 to Item 15	weeks
Part 3: Positive Protection Recommendation	
17. Higher Value of Statistical Life[3]	$ Million
18. Lower Value of Statistical Life[3]	$ Million
19. Cost of PCB[4]	$ /ft
20. To Determine Whether Positive Protection Can Be Recommended on the Basis of Reduced Crash Costs, Look Up On Figure B, the Intersection of Roadway AADT in Item 3 and Weeks in Item 12 if No Temporary Roadside Hazards Exist or Item 16 if Temporary Roadside Hazards Exist[5]	Yes / Maybe / No

Notes:

[1] National work zone exposure data suggests this is typically between 50 and 60 percent due to weather and other project delays, but can be higher for accelerated construction efforts.

[2] Total of all active work spaces for each work activity period (typical work space is approximately 150 ft).

[3] Value of Statistical Life according to 2013 FHWA Guidance on Treatment of the Economic Value of Statistical Life in U.S. Department of Transportation Analyses is $9.1 million (median value) and $5.2 million (low value).

[4] Average bid cost for 2013 is assumed to be $53.76/LF.

[5] Additional site- and project-specific factors will need to be considered before making a decision. Factors such as higher anticipated barrier costs due to project location, fairly flat and straight facility, etc. might suggest that positive protection may not be needed. Conversely, large truck percentages, excessive speeds anticipated, hilly and winding terrain, etc., might suggest that positive protection should be used.

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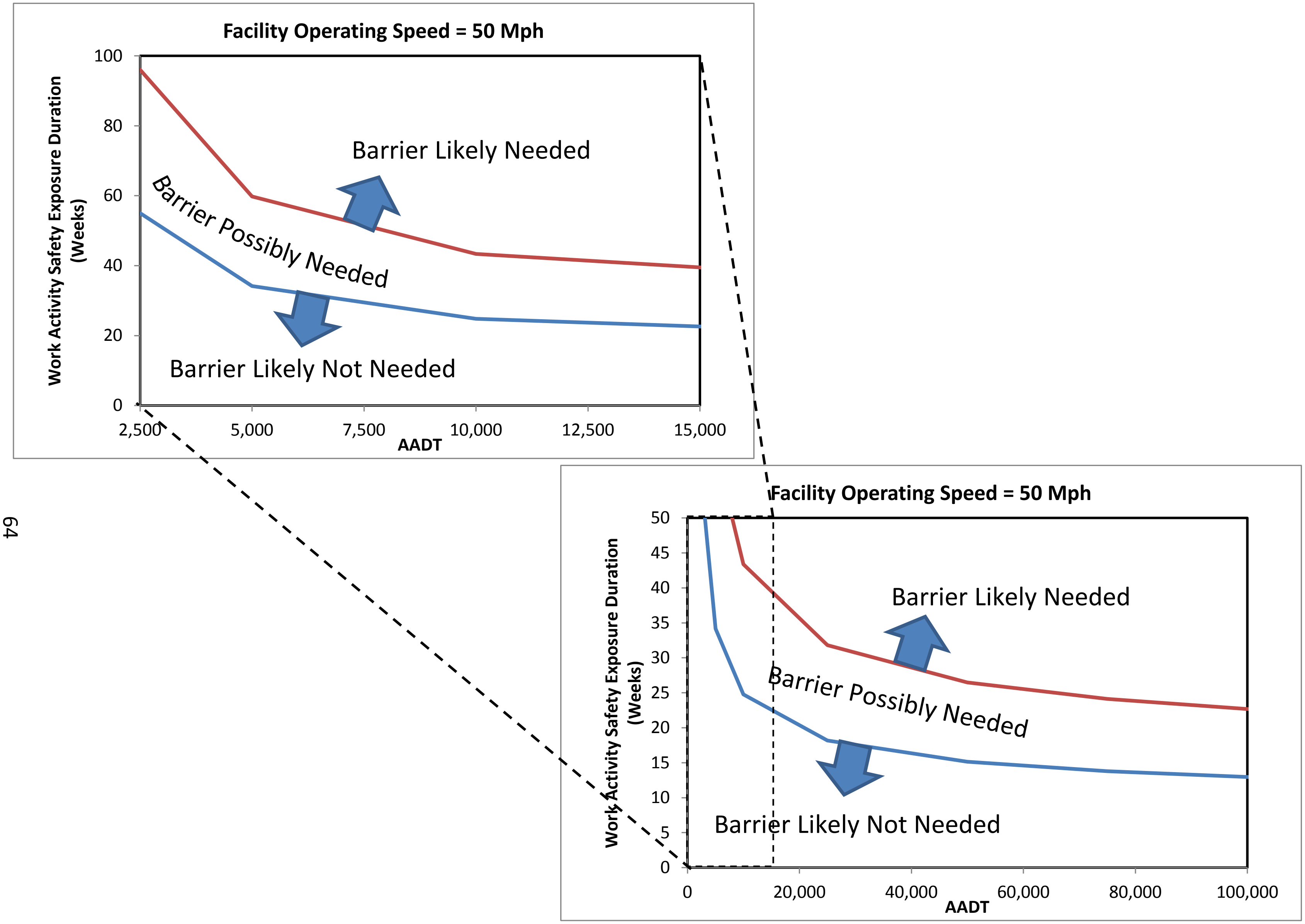

Figure B. Workers Operating Next to Moving Traffic (Roadside Hazards Exist)

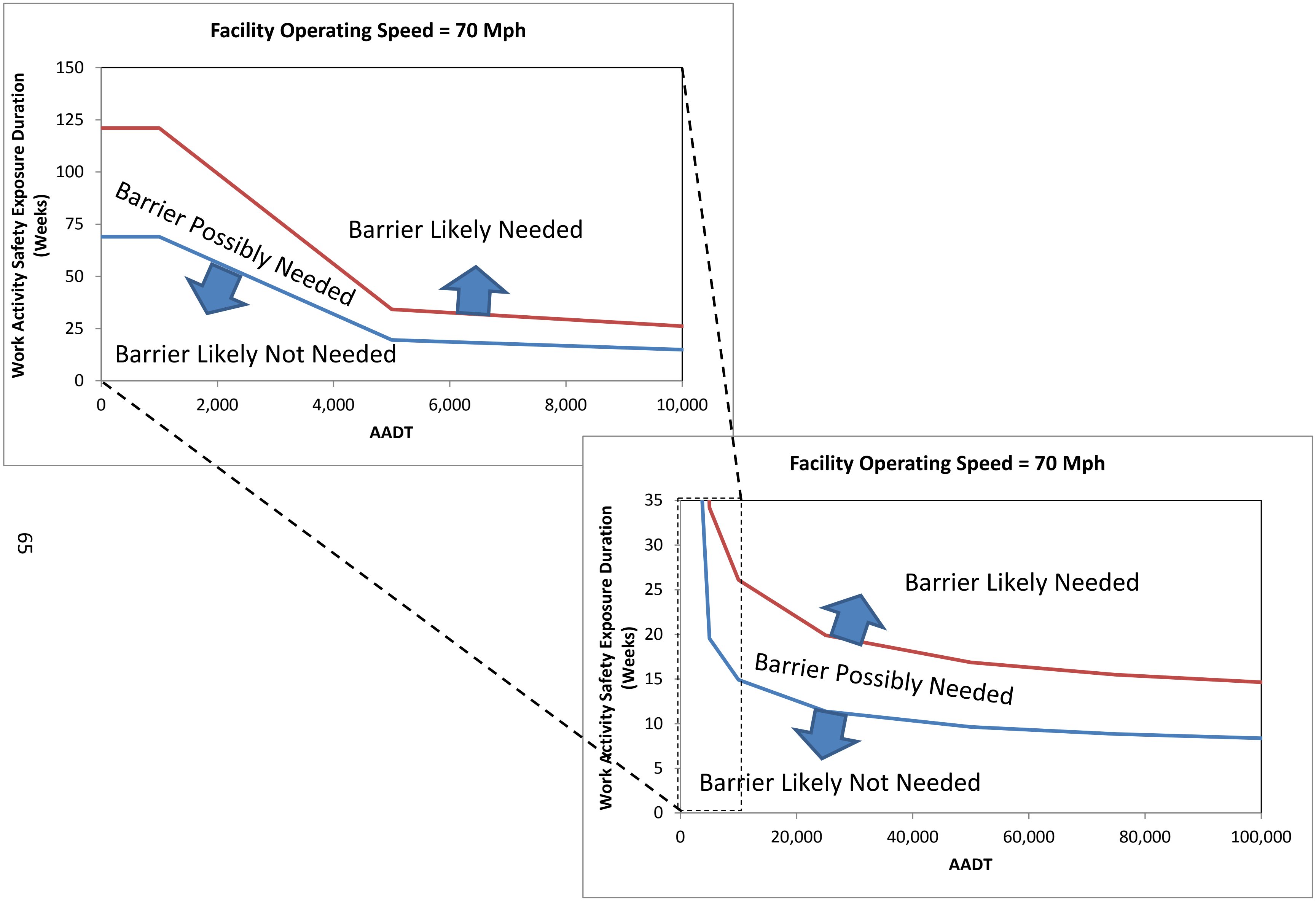

Figure B (cont.). Workers Operating Next to Moving Traffic (Roadside Hazards Exist)

Appendix B
Examples of Portable Positive Protection Devices

<table>
<tr><th>Portable Positive Protection Device</th><th>Example</th></tr>
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Deployment and Use of Steel Barrier</td><td></td></tr>
<tr><td>Mobile Barrier Technology</td><td></td></tr>
<tr><td>TMA in Use during a Mobile Operation</td><td></td></tr>
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