MAXIMIZING INVESTMENTS IN WORK ZONE SAFETY IN OREGON

Final Report

SR 500-380

Oregon Department of Transportation

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by

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16. Abstract

Due to the federal stimulus program and the 2009 Jobs and Transportation Act, the Oregon Department of Transportation (ODOT) anticipates that a large increase in highway construction will occur. There is the expectation that, since transportation safety grant funds may not increase and due to the lack of police enforcement resources, ODOT will need to be more strategic in planning how the available funds will be used. Questions regarding the allocation of safety grants among enforcement, equipment, and public education, and the optimal use of funds within each category, are being asked.

Thus, a research project was initiated to investigate methods for maximizing work zone safety investments. The goal of this research project is to:

- provide guidance for maximizing ODOT's investments in work zone enforcement;
- determine if additional coordination between the work zone enforcement program and the traffic control planning and work zone management efforts would enhance the programs; and
- review the effectiveness of the work zone safety public education program both in terms of message and media and determine if other approaches should be considered.

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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	millimeters squared	mm^2
ft^2	square feet	0.093	meters squared	m^2
yd^2	square yards	0.836	meters squared	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	kilometers squared	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	ml
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	meters cubed	m^3
yd^3	cubic yards	0.765	meters cubed	m^3
NOTE: Volumes greater than 1000 L shall be shown in m^3.				
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams	Mg
		TEMPERATURE (exact)		
°F	Fahrenheit	(F-32)/1.8	Celsius	°C

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	millimeters squared	0.0016	square inches	in^2
m^2	meters squared	10.764	square feet	ft^2
m^2	meters squared	1.196	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	kilometers squared	0.386	square miles	mi^2
		VOLUME		
ml	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	meters cubed	35.315	cubic feet	ft^3
m^3	meters cubed	1.308	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.205	pounds	lb
Mg	megagrams	1.102	short tons (2000 lb)	T
		TEMPERATURE (exact)		
°C	Celsius	1.8C+32	Fahrenheit	°F

*SI is the symbol for the International System of Measurement

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DISCLAIMER

MAXIMIZING INVESTMENTS IN WORK ZONE SAFETY IN OREGON

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1.0 INTRODUCTION

Due to the federal stimulus program and the 2009 Jobs and Transportation Act, the Oregon Department of Transportation (ODOT) is anticipating a large increase in highway construction. Since transportation safety grant funds may not increase and due to the lack of police enforcement resources, ODOT will need to be more strategic in planning how the available funds will be used. Questions regarding the allocation of safety grants among enforcement, equipment, and public education, and the optimal use of funds within each category, are being asked.

Thus, a research project was initiated to investigate methods for maximizing work zone safety investments. The goal of the research project was to:

- provide guidance for maximizing ODOT's investments in work zone enforcement;
- determine if additional coordination between the work zone enforcement program and the traffic control planning and work zone management efforts would enhance the programs; and
- review the effectiveness of the work zone safety public education program both in terms of message and media and determine if other approaches should be considered.

Section 2.0 is a literature review that provides general background information about work zone safety, traffic control, enforcement, and public information with a focus on identifying approaches taken by other states to improve both safety and mobility in work zones that could be considered for adoption in Oregon.

Section 3.0 focuses on Oregon and includes an analysis of crashes occurring in work zones and summarizes the results of surveys completed to gauge the public's perception of work zone safety. It also summarizes information about Oregon's work zone traffic management and enforcement efforts.

Section 4.0 draws conclusions and makes recommendations.

2.0 LITERATURE REVIEW

The following section summarizes the results of research completed on countermeasures to safety problems occurring in work zones. While safety is an issue in all types of work zones, the emphasis of this literature review was on long term construction work zones, as they present particular challenges for safety as well as mobility. Some of the findings however may be applicable to short term work zones established for maintenance activities and minor projects.

This literature review is organized to provide general background information on the following topics:

- Safety problems that occur in work zones.
- Basic principles for the design of work zones and requirements for traffic control devices as described in the Manual on Uniform Traffic Control Devices (MUTCD) (*FHWA 2009a*)
- Enhanced traffic control devices.
- Federal Highway Administration's (FHWA) Work Zone Safety and Mobility Rule.

More detailed information is provided on the optimal deployment of enforcement resources and efforts that have been taken to enhance their effectiveness. Specific topics covered are:

- Effectiveness of enforcement by uniformed police officers.
- When to use uniformed police officers.
- Enhancing the impact of enforcement.
- Approaches for coordinating work zone traffic enforcement and work zone management.

Additional information is provided on approaches for increasing motorist awareness about work zone safety in general and about specific construction sites.

2.1 SAFETY PROBLEMS THAT OCCUR IN WORK ZONES

Work zone safety is a growing roadway safety concern. In 2008, nationally there were 720 fatalities in work zones; this figure represents two percent of all roadway fatalities for the year (*ARTBA 2009*).

Understanding the risk factors of work zone crashes is critical to improving the effectiveness of work zone safety efforts. Recently published research by Li and Bai (*2009*) provided insight on the risk factors of crashes. The study included an investigation of work zone crashes in Kansas and reviewed relevant studies, finding that risk factors in freeway work zones included: roadway geometry, weather conditions, the age and gender of drivers, and lighting conditions. Their study revealed that driver errors included: disregard of traffic control, following too closely, alcohol and drug impairment, and driving too fast for conditions, which all contributed to the severity of

crashes. The research indicated that the chance of fatalities in severe crashes is significantly greater when speeds are over 60 MPH when the driver disregarded traffic control, and when a heavy truck was involved. The authors suggested that these findings indicate "there is room for improving the effectiveness of the traffic controls currently used in…high risk work zones" (*Li and Bai 2009, p. 701)* where speeds are above 60 miles per hour and the roadway geometry is unfavorable.

Another research study looked at high volume, high speed work zones in Texas. The research found that motorists perceive that the established speed limit was inappropriate and that the likelihood of receiving a citation for exceeding the speed was low (*Ullman et al. 2001*). In addition to some motorists traveling at excessive speeds there was the related problem of significant speed differentials. Especially when there was a lane closure, drivers often changed lanes erratically trying to protect their position in the queue. Figure 2.1 below, which was developed as part of a Texas Transportation Institute Research project (*Ullman et al. 2001*), summarizes the most prevalent safety problems occurring in work zones and shows the types of behaviors that cause the problem along with other contributing factors.

Problem Category	Types of Behaviors	Causes/Contributing Factors
Excessive speeds upstream and within the work zone	• Motorists traveling faster than speed limit • Motorists traveling significantly faster than others in the traffic stream	• Perception of inappropriate speed limits, that lower speeds not necessary (i.e., workers not present) • Perception that apprehension of speed violation is not a significant threat
Severe braking and lane-changing upstream of queue	• Large decelerations as vehicles move into queue • Last-second lane changes as vehicle joins queue	• Driver surprised as speeds into the work zone queue reduce quicker than expected • Driver tries to protect his/her position in queue by delaying deceleration as long as possible • Driver tries to maximize his/her travel into the beginning of queue by selecting a lane at the last minute
Severe braking and lane-changing within queue	• Accelerate to move up behind lead vehicle, followed by rapid deceleration • Accelerate to quickly move into adjacent lane, sometimes aborted when another vehicle moves for the same spot	• Desire to protect position in queue (prevent someone from changing lanes in front of them) • Desire to move through the queue faster than others
Lane straddling by trucks	• Trucks straddle two lanes • Two trucks travel side by side	• Desire to reduce frequency of queue jumpers • Desire to protect area immediately in front of the truck for deceleration
Erratic exits upstream of and within the traffic queue	• Across multiple lanes and/or the painted gore • Across grassy median between freeway and frontage road	• Last-minute selection of frontage road to avoid freeway queue • Insufficient warning of queue presence • Indecision as to whether the frontage road offers a travel time benefit

Source: *Ullman et al. 2001*

Figure 2.1: Summary of identified safety problems

2.2 WORK ZONE TRAFFIC DESIGN AND TRAFFIC CONTROL DEVICES

This section covers a range of topics related to work zone traffic design and traffic control devices from the basic guidance provided in the Manual on Uniform Traffic Control Devices (MUTCD) to a full range of smart work zone devices that improve work zone management and traveler information and offer promising solutions to safety and mobility problems occurring in our work zones.

2.2.1 Manual on Traffic Control Devices (Part 6)

The MUTCD establishes "the national standard for all traffic control devices installed on any street, highway, or bicycle trail open to public travel in accordance with 23 U.S.C. 109 (d) and 402(a)" (*FHWA 2009b*). Part 6 addresses temporary traffic control and establishes standards which state that the needs of all road users shall be considered in all highway construction, utility work, maintenance operations, and when managing traffic incidents. The term "work zone" is used to refer to all of the conditions that warrant adherence to Part 6. Part 6 establishes standards and guidelines for design of the work zone, traffic control devices, pedestrian and worker safety, flagger control, temporary traffic control devices, typical applications that occur in work zones, and control of traffic through traffic incident management areas.

Warning signs in work zones are orange with black legend; regulatory signs are white with a black legend. One of these is R2-6 which is a 24-inch square sign with the legend "FINES HIGHER". The 2009 MUTCD includes some additional signing options. These include signs with the following legends:

- FINES DOUBLE
- $150 FINE
- BEGIN HIGHER FINES ZONE
- END HIGHER FINES ZONE

The MUTCD provides some latitude for the road authority to supplement the basic guidance with additional traffic control devices and measures to improve safety and mobility. Most states publish supplemental guidance documents giving exceptions to the MUTCD and providing additional guidance for setting up a work zone as well as additional sign designs. Some states, including Oregon have adopted other signs; Oregon uses the legend "TRAFFIC FINES DOUBLE" (Sign 5-77) which is shown below in Figure 2.2.

Figure 2.2: Traffic Fines Double sign

2.2.2 Enhancements to Work Zone Signing

As will be discussed below, there is significant research on the impact of traffic enforcement presence in reducing speeds in work zones and also on the results that can be achieved with enforcement enhanced with traffic control devices. In the paper, *Evaluating Speed Reduction Strategies for Highway Work Zones, Wang et al. (2003*) acknowledge that due to the limited availability and high cost of enforcement, it is essential that other strategies that can be used alone be tested and evaluated. Below is some brief information describing evaluations of innovative message signs, florescent sign sheeting, and changeable message signs with radar or speed display signs.

2.2.2.1 Portable Variable Message Signs

Portable variable message signs (PVMSs), also referred to as portable changeable message signs (PCMS), provide drivers with warnings and special instructions. Studies completed in the 1980s, when PVMSs were not so widely used, showed speed reductions of 0 to 7 miles per hour (mph) (*Ullman et al. 2009*). More recent studies have not been conducted, thus the current effect is uncertain.

2.2.2.2 Portable Regulatory Signs

Portable regulatory signs are signs mounted on trailers with flashing lights and are generally used for a speed reduction. Variable Speed Limit (VSL) systems utilize portable signs and are designed to adjust speeds under changing traffic conditions and have been effective in reducing the speed differential and increasing volumes. An evaluation of a system installed on I-494 in the Twin Cities, Minnesota showed up to a 35% reduction in the average 1-minute maximum speed variance in the work zone and a 7% increase in throughput during the morning peak period (*Kwon et al. 2007*).

2.2.2.3 Automated Flagger Assistance Devices

Automated Flagger Assistance Devices (AFFDs) are used in temporary traffic control zones to allow the flagger to be positioned out of the lane of traffic. Stop/Slow paddles supplemented by a signs that say “WAIT ON STOP” and “GO ON SLOW” or signal displays are used. These are most appropriate deployed for relatively low traffic situations for short lane closures on two-lane, two-way roads. If there is an unobstructed view, one person can operate devices controlling traffic on both sides of the closure which results in long term savings in addition to safety benefits due to the flagger not having to stand in a potentially dangerous location. (*Cottrell 2006*)

2.2.2.4 Highway Advisory Radio

To alert motorists to specific conditions occurring at major work zones, highway advisory radio (HAR) systems have been used. Generally, motorists are alerted by a static sign encouraging them to set their radio at a particular frequency when the beacon on the sign is flashing. This system should not be used alone but to supplement other signing with more explicit information.

2.2.2.5 Florescent Sign Sheeting

In an effort to make signs more conspicuous, florescent sheeting has been used. A research study by Wang et al. (*2003*) compared the use of florescent micro prismatic sheeting on standard work zone signs to use of high intensity orange sheeting. Speeds of vehicles with greater than a five-second headway were collected at locations in advance of the work zone, in the advance warning area, and within the work zone. Results showed that speeds were down 1 to 3 mph, but that there was an increase in the variation of speeds. Length of time the speed reductions were sustained varied by site.

2.2.2.6 Variable Message Signs with Radar

Variable message signs with radar are often called speed display signs. They are portable radar units that display the regulatory speed and the motorists speed. Often there is an additional message telling the driver to slow down. Use of these signs was evaluated by Wang et al. (*2003*) using the same approach as used for fluorescent sheeting and innovative signs. The message displayed to vehicles traveling five miles or more over the posted speed was "You are speeding. Slow down now". The message displayed to vehicles going below this speed or if no vehicles were present was "Active Work Zone. Reduce Speed". The results of this study indicated speed reductions of 7 to 8 mph. The research indicted that the impact did not seem to diminish over time.

Another study, conducted in a work zone on I-80 near Lincoln, Nebraska, was designed to evaluate long term effectiveness of speed display signs. In the study, three signs were displayed at different points in two adjacent work zones. The normal speed was 75 mph but the speed in the work zones was reduced to 55 mph. Speed measurements were taken before, each week during a five-week study period, and after at each location. Data were collected only during uncongested flow conditions, and only for vehicles with at least a five-second headway. The signs were found to be effective in lowering speeds and increasing the uniformity of speeds over the five-week study period. Reductions of 3 mph in mean speeds and 4 mph in 85th percentile speeds were observed for passenger cars and reductions of 2 mph were observed for both the mean and 85th percentile for other vehicles (*Pesti and McCoy 2001*).

2.2.3 Enhancements to Work Zone Traffic Control

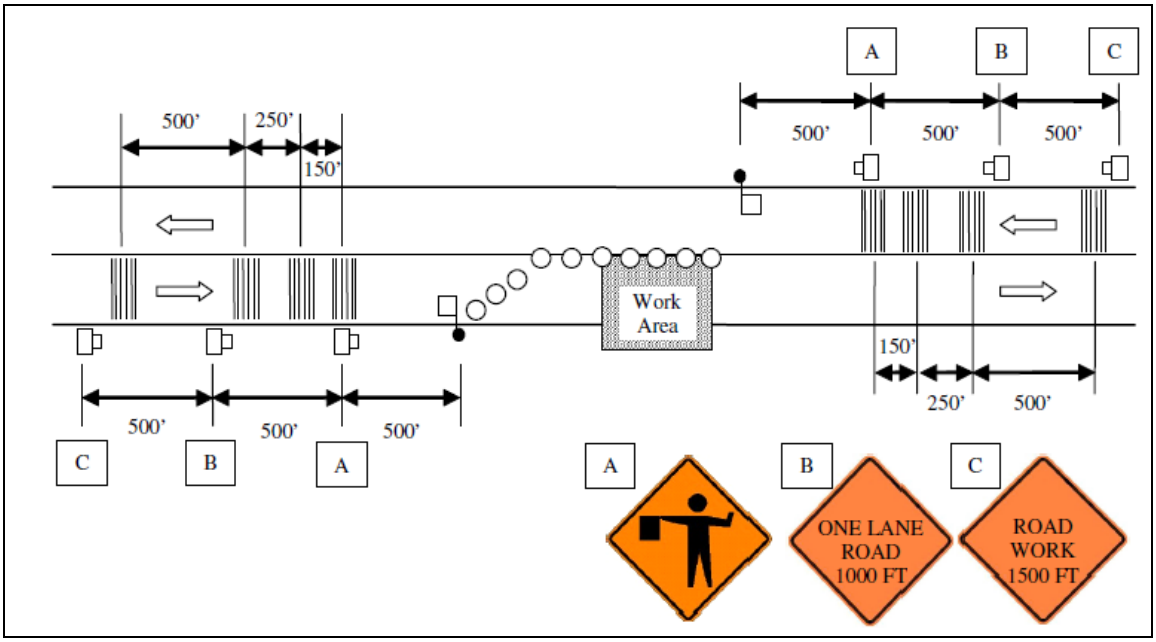
Various approaches have been used to enhance work zone safety and traffic flow. This section first discusses the use of temporary rumble strips then provides information on the general concept of using intelligent transportation systems (ITS), also known as Smart Work Zones, and provides some examples of specific smart work zone tools that have performed well.

2.2.3.1 Temporary Rumble Strips

Rumble strips are widely used on road edges of high speed facilities to alert drivers that they are leaving the road. They produce both a physical vibration and an auditory rumble sound. While traditional rumble strips are not easy to install or remove, manufacturers now produce temporary rumble strips from highly durable composite material with an adhesive backing

that allows them to be installed transversely and removed easily. An additional advantage over traditional rumble strips is that they are brightly colored so they are highly visible.

Various states have used temporary rumble strips to slow down traffic entering construction zones. A recent study evaluated their use at work zones in Florida. Sets of rumble strips were installed 5,500 feet and 600 feet upstream from a work zone and, it was found, that speeds were reduced by 8.7 mph. These results were compared to the results gained in trials in other states. The authors concluded that the most significant speed reductions could be achieved when rumble strips were placed close to the work zone and several sets were placed in succession. Site-specific characteristics should be considered prior to choosing to install temporary rumble strips (*McAvoy et al. 2009*). Figure 2.3 shows the layout of temporary rumble strips in a work zone. Additional research is needed to determine optimal rumble strip sequences.



Source: *McAvoy et al. 2009*

Figure 2.3: Layout of temporary rumble strips in a work zone

2.2.3.2 ITS Technologies

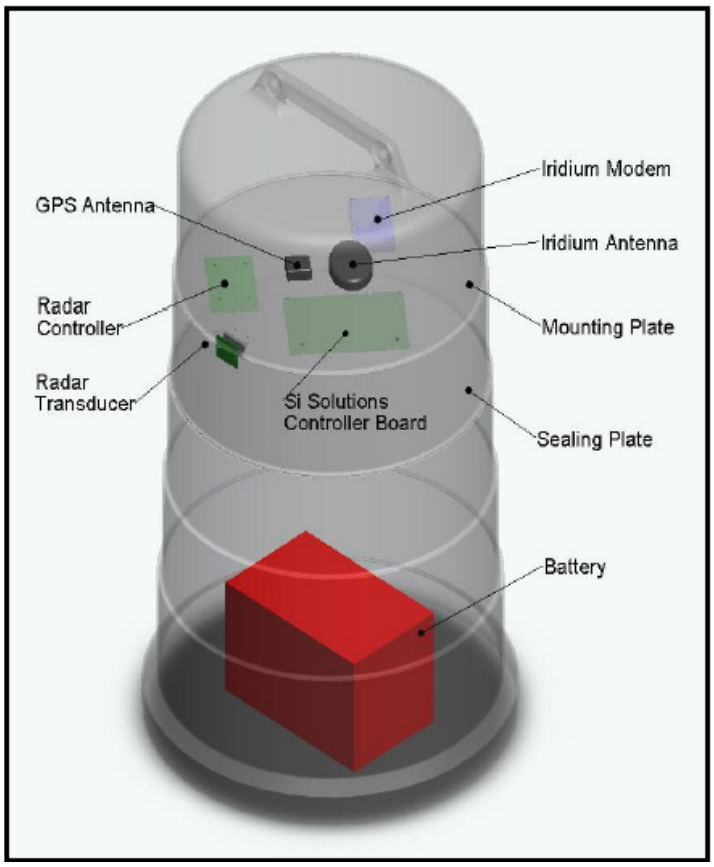
ITS technologies are increasingly being used to provide traffic monitoring and management, data collection, traveler information and to enhance enforcement activities. Some applications such as variable message signs and highway advisory radio have been utilized for many years. Others such as lane merge systems, queue detection, and real time traveler information are newer.

Washington is among the states that are active in using ITS technologies. The Washington State DOT (WSDOT) summarizes the value of ITS technologies as follows: "ITS technologies increasingly are being used to anticipate and mitigate congestion caused by highway work zones. The use of ITS technology in work zones such as portable camera

systems, highway advisory radios, variable speed limits, ramp metering, traveler information, merge guidance, and queue detection information is aimed at increasing safety for both workers and road users…Work zone ITS elements should be identified early in the strategy development process and included in the preliminary estimate so they can be designed along with other traffic control elements" (*WSDOT 2010*).

ITS designed to provide traffic monitoring and management and traveler information can deploy a range of options for collecting basic information about traffic volumes and speeds that is used to determine delays through the work zone and trigger messages to the driving public. Options include using Bluetooth devices to obtain travel time measurement samples (*Haseman et al. 2010*) temporary traffic sensors (*Chandler et al. 2010*), and more sophisticated queue detection devices that have been used widely in some states including New Hampshire (*Ferguson 2008*).

The report by Chandler et al.(*2010*) on the use of portable, temporary traffic sensors provides several examples of demonstrations done in California. Caltrans staff found that using the devices (shown in Figure 2.4) allowed them to focus on areas with the greatest problems. Caltrans identified the potential for using these devices to determine if speeds are significantly high to need law enforcement to patrol a particular construction area, stating that: "instead of immediately dispatching an officer, Caltrans staff could assess and confirm the contractor's concerns by first placing a PTMD in the work zone. When the speeds consistently register significantly higher than the speed limit, Caltrans staff can then justify contacting law enforcement to request their presence" (*Chandler et al. 2010, p. 17*).



Source: *Chandler et al. 2010*

Figure 2.4: Diagram of portable traffic monitoring device

Numerous research projects have been completed to assess the effectiveness of these devices and the systems that rely on the data collected. A review of this literature is beyond the scope of this research project, however recognizing the significant benefits that ITS technologies can offer to improve work zone safety and mobility is important.

2.2.3.3 Lane Merge Systems

Normally, when there is a lane closure in a work zone drivers do not merge at any one time. This results in disruptions in traffic flow and more delay. Aggressive drivers abruptly changing lanes increase the risk of traffic crashes which result not only in injuries but in further delay until the involved vehicles can be cleared from the roadway.

To specify a merge point, there are two approaches; one designed to have drivers merge well before a work zone, and one that sets a specific merge point just prior to the lane closure. With the early merge approach, vehicles are directed to move out of the lane that is to be closed and passing is restricted. This approach requires enforcement. The late merge system establishes a definite merge point where drivers are directed to take their turn. This approach provides for greater capacity as it limits the length of the lane closure and improves traffic flow.

The Dynamic Late Lane Merge System (DLLMS) was implemented on three freeways in Michigan where it was necessary to move traffic from two lanes to one due to highway construction. A conventional work zone merge system was used to compare traffic flow, merge behavior, and to estimate travel time savings. A study of the system (*Grillo et al. 2008*) concluded that the benefits of the system outweigh the costs of the system ($57,108 for one site) if the value of time is greater than $5.00 an hour. In the study, the system (which is triggered by sensors which measure volume and speed) operated only two hours a day for five days a week during an 11-week period. The test sites had relatively low volumes so use of the system in more highly congested work zones would result in greater benefits. In the study, crash rates for one test site (I-94 westbound) were compared to the control site (I-94 eastbound). While crash rates were slightly lower at the test site, the reduction was not statistically significant.

Similar systems, known as the "zipper merge system" have been used in Germany, the Netherlands and the United Kingdom. In Germany, where the zipper principle became a law in 2001, a static sign is used to display the correct merging pattern. In the Netherlands, where the system is called "zipping," advance signs warn drivers to "Zip in 300m" and "Zip Here." The late merge system was first implemented in the United States in Pennsylvania using static signs. Other states have used portable message signs that could be activated when congestion reached certain levels. Another method is to add detectors of different types and activate the system when speeds and volumes reach a certain threshold. In Texas, when a dynamic late merge system was tested in a work zone requiring traffic to go from three lanes to two, results indicated that the onset of congestion was delayed by 14 minutes and the maximum queue was reduced from 7,800 feet to 6,000 feet (*Grillo et al. 2008*).

Based on the results a Dynamic Late Lane Merge System (DLLMS) study in Michigan (*Grillo et al. 2008*), the researchers concluded that a DLLMS is effective in reducing travel time, stops, and travel time delay. A benefit cost analysis was completed as part of the research. Without considering any safety benefits that could result, it was found that the benefits in terms of reduced travel time and fuel savings resulted in a benefit cost ratio greater than 1 for values of time greater than $5.00 per hour. The researchers made recommendations about the specific design of the work zone and placement of signs. They recommended using the system on urban congested freeways where lane volumes are at least 1,800 vehicles per hour per direction for at least two hours per day and average daily traffic is at least 22,500 per direction. A media campaign to inform drivers about how the system works and its benefits was recommended (*Grillo et al. 2008*).

2.2.3.4 Variable Speed Limit Systems

Variable speed limit systems, when used in work zones, allow speeds to be changed depending on construction or maintenance activities, traffic conditions, time of day, and other factors. Some static speed limits in dynamic environments have low levels of compliance, and speed limits that are responsive to the situation should be more credible and may result in improved compliance. This may be the case especially if construction is taking place in a limited area of lengthy work zone.

After the Code of Virginia was modified to permit the posting of variable speed limits on interstates in 2006 a research project used traffic simulation and field tests at a work zone to assess the safety and mobility impact of variable speed limit signs. The non-construction posted speed at this location was 70 mph. The analysis showed that both static and variable speed reduction signs displaying 65 mph could achieve speed reductions. Variable speed signs were effective in reducing speed variances at the beginning of the work zone. At night, when VSL signs were set to 65 mph and no construction activity was taking place, VSL sign data showed average speeds that were generally lower than static speed limit signs. At night, when VSL signs were set to 65 mph, the standard deviation of speeds decreased to the 0.5- to 1.0 mph range, down from the 1.5- to 5.0 mph range for the static signs.

Providing drivers with speed restrictions that reflect actual conditions (construction underway during the day or no construction at night) builds trust in the posted work zone speed limit, thus increasing driver compliance with the posted speed limit and increasing work zone safety. (*McMurFtry et al. 2009*)

2.3 FHWA'S WORK ZONE SAFETY AND MOBILITY RULE

In 2004, Title 23, Code for Federal Regulations, Part 630, Subpart J relating to Work Zone Safety and Mobility was revised with an effective date of October 12, 2007. The new regulation placed additional requirements on states to manage the work zone impacts of all Federal-aid highway projects. States are required to perform a process review every two years to assess the effectiveness of their work zone safety and mobility practices. Highlights of the regulations are:

- "States should develop and implement systematic procedures to assess work zone impacts in project development, and to manage safety and mobility during project implementation."
- "States shall use field observations, available work zone crash data, and operational information to manage work zone impacts for specific projects during implementation."
- "States shall require that personnel involved in the development, design, implementation, operation, inspection, and enforcement of work zone related transportation management and traffic control be trained, appropriate to the job decisions each individual is required to make."
- "…States shall perform a process review at least every two years. This review may include the evaluation of work zone data at the State level, and/or review of randomly selected projects throughout their jurisdictions."
- "For significant projects (as defined in § 630.1010) the State shall develop a TMP (Transportation Management Plan) that consists of a Temporary Traffic Control (TTC) plan and address both Transportation Operations (TO) and Public Information (PI) components." (§ 630.1010 defines significant projects as projects that are anticipated to cause sustained work zone impact and all interstate system projects within the boundaries of a designated Transportation Management Area that occupy a location for more than three days with intermittent or continuous lane closures. The State is to

identify upcoming projects that are considered to be significant as early as possible in their development.)

- The TTC plan is to be consistent with the MUTCD and describe specific measures to be used to facilitate movement of road users through the work zone.
- The TO component should identify strategies to be used to improve operations and would typically include "demand management, corridor/network management, safety management and enforcement, and work zone traffic management".
- The PI component should identify strategies for communicating with road users, area residents, and the general public about the specific project and expected impacts such as closures and delays.

- "States should develop and implement the TMP in sustained consultation with stakeholders (e.g., other transportation agencies, railroad agencies/operators, transit providers, freight movers, utility suppliers, police, fire, emergency medical services, schools, business communities, and regional transportation management centers)."

To assist states with the implementation of the new rule the Federal Highway Administration has developed modeling and simulation tools for work zone analysis. Tools such as QuickZone and Construction Analysis for Pavement Rehabilitation Strategies (CA4PRS) have been designed specifically for work zone analysis (http://ops.fhwa.dot.gov/wz/traffic_analysis/index.htm).

2.4 WORK ZONE TRAFFIC ENFORCEMENT

Most states utilize uniformed police to reduce speeds and encourage safe driving in work zones. Surveys of police and state highway agencies consistently reveal widespread support for the effectiveness of police presence in terms of speed reduction (*JHK and Associates 1990; FHWA 2001; Arnold 2003; Kamyab et al. 2003*). Research has indicated that speed reductions of over 10 mph can be realized (*Ullman et al. 2006*). Only limited research has been done on the impact of enforcement on crash reduction. An exception is research on the California Construction Zone Enhanced Enforcement (COZEEP) which indicated that reductions of up to 20% are possible. To achieve a reduction of 10%, it was determined that 20 officer hours of patrol time per month per directional mile was required (*JHK & Associates 1990*).

2.4.1 Traffic Laws

The National Work Zone Safety Information Clearinghouse (NWZSIC) website provides information on enhanced fines for traffic violations occurring in work zones. See Appendix A for a summary of Oregon's statutes relating to highway work zones and Appendix B for work zone legislation for all states. All 50 states have increased fines in work zones. Thirty-four states apply higher penalties only to speed violations, while increased fines can be issued for all traffic violations in 11 of the states. Four states describe specific traffic violations where higher fines can be applied, such as reckless driving, driving under the influence, improper passing/overtaking, and following too closely.

Some states actively enforce more than just moving violations in work zones. The states of Michigan, Montana, Oregon, and Washington have enacted legislation allowing a driver to be charged with reckless endangerment of highway workers in a work zone. The state of Oregon also permits drivers to be cited for refusing to obey a flagger. Similarly, Utah allows tickets to be issued for failure to obey a police officer or other traffic controllers in construction or maintenance zones. Increased fine amounts vary from state to state; most commonly, standard fine rates are doubled for work zone violations. Fifteen states with increased fines in work zones use fixed amounts for violations.

Approximately half of the states apply increased fines only if workers are present in the work zone. In addition to requiring workers to be present for higher fine application, Illinois, Tennessee, and Pennsylvania require flashing lights to indicate that workers are actually present (*Ullman et al. 2009*)

It is not known whether increased fines in work zones results in improvements to safety. The results of a survey of 245 Oregon construction zone workers conducted as part of a research project (*Jones and Christianson 1996*) suggest this might be the case. The question "Apart from speed enforcement, which of any of the following has helped to improve highway work zone safety?" was asked of ODOT and contractor employees. Doubling fines in work zones was viewed as the top countermeasure contributing to safety (70.4% reported that it "has helped"). Responses are shown in Table 2.1.

Table 2.1: Responses to employee survey on contribution to safety of various countermeasures

Countermeasure	Has Helped	Not Sure	Has Not Helped	Don't Know / No Answer
Signing	59.3 %	19.0 %	11.1 %	10.7 %
Work Scheduling	35.6 %	36.4 %	13.0 %	15.0 %
Public Information/Education	48.6 %	32.0 %	7.5 %	11.8 %
Double Fines	70.4 %	16.2 %	6.7 %	6.7 %
Project Planning and Design	28.5 %	39.1 %	12.6 %	19.8 %

Source: *Jones and Christianson 1996*

2.4.2 Effectiveness of Enforcement by Uniformed Police

There has been considerable research on the effectiveness of enforcement by uniformed police. The results of several studies are presented here.

2.4.2.1 Stationary Marked Police Car

Use of a stationary marked police car is the most commonly used approach. This technique has been thoroughly researched starting in the late 1970s, and since that time, results have been consistently positive. The approach is very widely used. Results indicate that stationary patrols can result in reductions in speeds of up to 13 mph with many studies indicating reductions in the range of 6 to 8 mph (*Ullman et al. 2006*).

2.4.2.2 Circulating Marked Police Car Experiment

Research was completed in 1992 at the University of Illinois that was designed to identify the effect of a marked police car circulating in a highway work zone (*Benekohal et al. 1992*).

There were two objectives in the study: 1) to determine the effect of a police officer circulating in a marked car and issuing citations, and 2) to determine how long the impact of police presence lasts. The posted speed outside the work zone was 65 mph for cars and 55 mph for trucks. The speed inside the work zone was reduced to 45 mph when flashing beacons were turned on to alert drivers that workers were present. Speeds of free flow and total traffic were collected at three different locations: one (Station 1) outside the work zone and two (Stations 2 and 3) inside the work zone where only one lane was open to traffic.

Between the hours of 11 AM and 3 PM, a marked police car patrolled in both directions of the freeway. The officer wrote 12 tickets. Data collected during this time was used to assess the effect of police presence; data collected for one hour after the patrol left the area was used to measure the longer term or "halo" effect. It was found that the average speeds of cars in the work zone were 4.3 (Station 2) to 4.4 (Station 3) mph lower when police were patrolling than when there was no police presence. Truck speeds declined by 5.0 mph (Station 2) and 4.3 mph (Station 3). These reductions were statistically significant.

The second part of the research was designed to determine how long the effect of police presence lasted after the police were no longer patrolling. After the police officer has left the work zone, the trend of traveling at a reduced speed may continue. If the reduced speed lasts, one police officer may be able to patrol adjacent work zones without diminishing their effectiveness. The results showed that during the hour immediately after the police left the area speeds increased by 2.4 miles (at Station 2) and 3.0 mph (at Station 3) for cars and these changes were considered significant. However, speeds were still lower than they had been prior to the police patrol. Speeds increased less for trucks (0.4 and 0.3 mph) and were not determined to be significant. The research concluded that the effects of police presence inside the work zone on trucks lasted for at least an hour after the police left the area.

2.4.2.3 Photo Enforcement

Numerous studies have been done to evaluate the use of photo radar in work zones. The Oregon Department of Transportation recently published the results of a pilot study that was conducted to fulfill a legislative mandate. It was found that during periods when photo radar enforcement was active, speeding was reduced by an average of 27.3% in the work zone. This reduction was temporary and did not persist after the photo radar enforcement van left the area (Joerger 2010).

2.4.2.4 Comparison of Police Presence and Automated Enforcement

Several research studies provided insight regarding the use of enforcement in work zones and enhancements to improve the impact. The Transportation Research Board (TRB) "Comparison of Effects of Automated Speed Enforcement and Police Presence on Speeding

in Work Zones" (*Hajbabie et al. 2009*) is one. Illinois was one of the first states to use a Speed Photo-Radar Enforcement (SPE) van for work zone speed enforcement. Photo speed enforcement vans are staffed by specially-trained troopers and are equipped with the latest in photo radar technology designed to record the speed of vehicles and to capture clear images of the driver and the license plate. Tickets are then sent by certified mail to drivers. Research was conducted at two work zone sites on interstate highways in Illinois with posted speeds of 55 mph. There was moderate speeding occurring at one site, and more extensive speeding at the other. Base line speed data and speed data for four different types of treatment were collected for both the shoulder and median lane for free flowing vehicles (minimum of four-second headway). Data was collected using two markers placed 200 feet apart and a camcorder. The following treatments were evaluated:

- speed display trailer
- police vehicle without lights on
- trailer and police vehicle without lights on
- speed photo-radar enforcement (SPE) van

Speed enforcement that included law enforcement reduced mean speeds from 4.2 to 8.4 mph. In the work zone where speeding was moderate, police and SPE reduced the mean speeds about the same; however the trailer plus police resulted in larger speed reductions. In the work zone where excessive speeding was occurring, SPE and speed display trailer plus police resulted in similar reductions. Speeds decreased when the police vehicle without lights on was used alone, but less than for the other treatments involving enforcement. The average reduction in mean speeds for the four treatments is shown in Table 2.2.

Table 2.2: Average reduction in mean speeds for four work zone treatments

Treatment	Average Reduction in Mean Speed (mph)
Trailer	1.3
Police	6.0
Police + Trailer	7.0
SPE Van	6.3

Source: *Hajbabaie et al. 2009*

2.4.2.5 Downstream Effects of Speed Reduction Treatments

The TRB paper "Downstream Effects of Speed Photo Enforcement and Other Speed Reduction Treatments on Work Zones" (*Medina et al. 2009*) also looked at the use of photo radar enforcement in Illinois.

This study was conducted at two seven mile long work zones on interstate highways in Illinois to determine the impact of various treatments approximately one and a half miles downstream from the work zone. The posted speed was 55 mph in both work zones. The researchers were interested in determining downstream effects of the treatments both on the average speed and degree of speeding.

The six treatments evaluated were:

- speed display trailer,
- police vehicle with emergency lights on,
- police vehicle with emergency lights off,
- trailer and police vehicle with emergency lights on,
- trailer and police vehicle with emergency lights off, and
- speed photo-radar enforcement (SPE).

Three sets of data were collected (AM and PM off-peak at one site and PM off-peak at the other site) for each of the two travel lanes. Car and truck speeds were evaluated separately.

The results indicate that the use of SPE showed greater downstream effects on free flowing cars and trucks than the other treatments. The use of a trailer and a police vehicle with emergency lights off had downstream effects on the mean speed and degree of speeding in some cases. Neither police vehicle with emergency lights off, trailer plus police vehicle with emergency lights on and trailer, or the trailer alone had any significant downstream effects on mean speed.

2.4.2.6 Augmented Speed Enforcement

Many states do not allow the use of photo-radar to identify speeding vehicles in work zones. One of these states is California where automated speed enforcement is specifically forbidden by state law. Concerned about an increase in crash rates and worker fatalities Caltrans is implementing an ITS project to evaluate Augmented Speed Enforcement (aSE) in a work zone on Highway 99 in California's San Joaquin Valley (*Skabardonis et al. 2009*).

In the proposed aSE, a sensor will detect the speed of vehicles as they approach the work zone and if a vehicle is exceeding the posted speed, the driver will get a warning displayed on a variable message sign that tells him/her that he/she is going too fast and to slow down. In the work zone there are a series of "smart cones" that are each fitted with a beacon and radar. The function of the smart cones is to track individual vehicle speed and synchronize the cone light display to "highlight" and follow any violating vehicle. This provides a warning to drivers that they are violating the speed limit and to workers to alert them to a potential speeding hazard in the work zone.

At the same time the driver is being warned, workers are receiving a message on a pager alerting them that a driver is going through the work zone traveling at an excessive speed. This pager system will also incorporate a "panic mode" that any worker can trigger in the case of an injury to automatically contact the site supervisor who can then dispatch emergency medical services (EMS) to the work zone. This panic mode may also trigger a unique and conspicuous sequence of cone lights to alert all workers to the potential injury event.

The enforcement officer also gets a message and follows through by tracking the vehicle with hand-held radar, making a stop, and giving the driver a warning.

A public education campaign is to precede implementation in order to inform drivers about this pilot program and let them know that, while radar is used to detect speeders, no tickets are being written.

2.4.3 Maximizing the Use Uniformed Traffic Enforcement

While using uniformed traffic officers is a proven countermeasure to reduce speeding in work zones, the cost of using uniformed police officers is relatively high and the availability of patrol officers is limited. When used in work zones, uniformed traffic enforcement must be deployed efficiently and enhanced with other countermeasures that raise driver awareness and encourage drivers to slow down.

2.4.3.1 Situations When Enforcement Should be Used

In 2001, the Federal Highway Administration (*2001*), in preparation for developing the new rule on the required procedures to be used to address safety and mobility issues in work zones, performed a survey to learn more about how uniformed police were used to provide enforcement in work zones. Those surveyed included state transportation agencies, law enforcement agencies, highway industry associations, law enforcement organizations, and contractors and suppliers.

Many of the survey respondents were able to cite specific circumstances when police officers were always used. Uses most often cited were night operations, lane closures, and high volume/high-speed traffic. Other conditions identified included:

- roads with heavy congestion,
- high crime areas,
- areas with above-average accident rates,
- intersection work,
- roads with bi-directional flows,
- when placing bridge beams or installing overhead signs,
- when moving heavy equipment,
- when a traffic signal is taken out of service; and
- for pacing traffic.

Of those saying that there was no specific conditions dictating use of police officers, most said that enforcement was provided on a case by case basis, sometimes determined at the time the contract is awarded and sometimes after the project is under way.

A survey of enforcement personnel in Virginia identified the following additional criteria for use of uniformed police officers in work zones: higher traffic volumes, type of road (interstates, arterials, and primary highways), road geometry, peak hour congestion, and when workers are close to the road (*Arnold 2003*).

The interim report for the NCHRP study, "Traffic Enforcement Strategies in Work Zones Project" (*Ullman et al. 2006*) suggests the following criteria be used to help determine the types of construction where enforcement should be considered:

- projects in urban areas with high traffic volumes
- major and high impact projects
- highly complex projects
- projects with lane closures, transitions, merges, or shoulder work
- projects involving geometric modifications, multiple transitions and lane shifts, loss of shoulders or reduced lane widths
- projects that incorporate key traffic decision points and intersections
- long-term projects and projects with queuing and congestion potential
- interstate projects
- projects involving night work
- projects in major high-speed, high-volume corridors
- projects that involve a large amount of truck traffic moving around within the work zone
- work zones where flaggers are used
- projects involving close proximities between workers and traffic
- projects involving special construction activities (i.e., bridge crews working directly above moving traffic)

Bryden and Mace, in an NCHRP report entitled, "Guidelines for Design and Operation of Nighttime Traffic Control for Highway Maintenance and Construction" (*2002*), included traffic control guidelines for nighttime maintenance and construction projects. The report states that the need for police services should be considered for all nighttime work activities. The following specific criteria for nighttime use of uniformed police enforcement (as well as daytime use) were suggested:

- construction activities close to traffic
- restrictions to traffic flow based on work zone features such as no shoulder, or reduction in number of travel lanes or width
- locations where an incident would result in substantial congestion and delays
- operations that require changes to the traffic pattern
- locations with a crash history

- projects with heightened public concern regarding the impacts of the traffic control plan
- areas with high traffic speeds and/or volumes

Criteria used by other states to identify the need for work zone enforcement is compiled in Appendix C.

In 23 CFR Part 630, Temporary Traffic Control Devices specifically in Part 630.1108 guidelines are provided for usage of uniformed law enforcement and is included as Appendix E.

2.4.3.2 Maximizing Results of Enforcement Investments

The same report (*Bryden and Mace 2002, pp.88-89*) lists operational requirements to help fulfill these functions for night work, as follows:

- "When a lane closure or full road closure is being set up on high-speed highways, police should be stationed upstream with flashing lights operating.
- After a lane closure has been implemented and work is underway, patrol cars should normally be stationed upstream of the work area, with flashing lights in operation.
- Patrol cars can be used to temporarily stop traffic or to create a rolling roadblock to provide full access to the roadway when installing lane and/or road closures and to shift traffic from one side of the road to the other.
- To maintain credibility of enforcement efforts, a second patrol car should occasionally be stationed downstream from the work area to issue citations for speeding or other violations. This method reduced both congestion and distraction to motorists when passing through the work area.
- Patrol cars should operate radar to activate detectors on vehicles approaching the work zone.
- Patrol cars should assist with clearing crashes or incidents such as vehicle breakdowns.
- Patrol cars should assist with controlling traffic at potential problem locations, such as ramp closures, and other possible intrusion locations."

The FHWA study (*2001*) done prior to the implementation of the mobility rule identified practices adopted by some states that could contribute to maximizing the use of enforcement personnel in work zones. These included:

- Written guidelines outlining the specific conditions where work zone enforcement should be considered.
- Written policies stating that the traffic control planning process should address the need for work zone enforcement.
- Inclusion of law enforcement expertise in the traffic control planning process.

- Requiring officers to participate work zone safety training programs to maximize the benefit of placing officers on a construction project.
- Reducing the cost of enforcement by using dedicated patrol units rather than overtime assignments.

As a result of the survey findings, FHWA (*2001*) recommended the following:

- State highway and law enforcement agencies should work together to develop written policies and guidelines on priority situations where law enforcement is needed; the work zone traffic control planning process; and officer pay, procedures, and supervision.
- Police officers assigned to work zones traffic enforcement should receive training in MUTCD requirements.
- Agencies should use data on traffic safety incidents to better assess the effectiveness of work zone traffic control techniques.
- Agencies should consider using new traffic control technologies, such as automated enforcement and intrusion alarms.

2.4.3.3 Benefits and Costs of Enforcement

The final report from the NCHRP 3-80 research study (*Ullman et al. 2010*) reported on research done on the benefits of enforcement versus cost in freeway work zones. The results are reported as the point, expressed in vehicles per day, at which the benefits exceed the cost for various enforcement costs. Table 2.3 summarizes this information.

Table 2.3: Comparison of enforcement benefits and costs at freeway work zones

Enforcement Costs	AADT Where Enforcement Benefits are Approximately Equal to Enforcement Costs	
	Favorable-Benefit Scenario	Conservative-Benefit Scenario
$25 per hour		
Daytime work zone	5000 vpd	20,000 vpd
Nighttime work zone	20,000 vpd	45,000 vpd
$50 per hour		
Daytime work zone	10,000 vpd	35,000 vpd
Nighttime work zone	35,000 vpd	100,000 vpd
$75 per hour		
Daytime work zone	15,000 vpd	50,000 vpd
Nighttime work zone	50,000 vpd	150,000 vpd
$100 per hour		
Daytime work zone	20,000 vpd	70,000 vpd
Nighttime work zone	65,000 vpd	200,000 vpd

Source: *Ullman et al. 2010*

2.4.4 Approaches for Coordinating Enforcement with Work Zone Management

Surveys conducted for NCHRP 3-80 showed that states take different approaches to administering work zone enforcement. In some cases enforcement activities were identified for the entire program, in others an enforcement component was included in the contract for each project identifying the need. In some states the enforcement agency participated in pre-construction meetings and responsibilities were enumerated specifically; in others the arrangements were less formal.

Generally the roles and responsibilities of the enforcement agency and the transportation agency were identified in a memorandum of understanding (MOU). The information included in the MOUs of twelve states, including Oregon, is summarized in Figure 2.5 (*Ullman et al. 2006*).

Component	FL[a]	LA	MD	MI	NC	ND	NJ	NY	OR[a]	PA	WA	WI
Estimated amount of support to be provided under the agreement	✓				✓	✓	✓	✓	✓	✓	✓	✓
Required law enforcement participation in pre-construction meetings	✓	✓	✓				✓	✓				
Minimum notification time to schedule a shift			✓					✓		✓		
Minimum notification time to cancel a shift			✓					✓				
Types of costs to be charged	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Law enforcement agency right of first refusal for the enforcement activity			✓				✓	✓	✓			
Billing information requirements	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	
Payment schedule	✓		✓				✓				✓	
Specific officer responsibilities during shift	✓	✓	✓				✓	✓		✓		✓
Right to terminate agreement	✓		✓	✓			✓	✓		✓	✓	

[a] Information reviewed concerning the agreement was not complete: additional information may be contained in the actual agreement

Figure 2.5: Summary of MOU/operating agreement contents for work zone enforcement

Funding approaches vary. Federal regulations allowed for the cost of work zone enforcement to be administered through the federal-aid program either on a project-by-project basis or as part of the overall construction budget. Some states had legislation that allowed for a portion of the fines received from work zone enforcement to fund additional work zone enforcement (*Ullman et al. 2006*).

2.5 WORK ZONE SAFETY PUBLIC AWARENESS PROGRAMS

Several programs exist which were designed to educate the public about and/or emphasize work zone safety. At the national level, one of the more widely recognized safety programs was the work zone awareness week. National programs such as these are described below, as are examples of programs in various states. The programs described below are those designed to inform the public generally, as opposed to provide traveler information, which is described in Section 2.6.

2.5.1 Work Zone Memorials

One of the more illustrative methods of emphasizing the importance of work zone safety is through recognition of the work zone employee fatalities. Nationally, a traveling exhibit, known as the "National Work Zone Memorial – Respect and Remembrance: Reflections of Life on the Road" (http://www.atssa.com/cs/work-zone-memorial) has been developed. The program includes a traveling memorial which pays tribute to the individuals who have died in work zones. The exhibit is intended to raise public awareness of safety in work zones.

Many states have some form of work zone memorial, such as: memorial services, displays, commemorative plaques, and/or websites. As an example, in 2008 the California Department of Transportation (Caltrans) created a temporary memorial display, featuring 170 orange safety cones (for each fallen worker), a jumbo-screen showing pictures of individuals who died in 2007, a ceremonial dove release, and musical tribute performances. The use of cones to represent fallen workers was also meant to reinforce Caltrans work zone safety theme of "slow for the cone zone." In addition to displays such as these, Caltrans has placed a memorial plaque in the lobby of their headquarters building, as well as maintains a website listing the names of workers killed since 1993. (http://www.dot.ca.gov/hq/paffairs/about/safety.htm).

2.5.2 National Work Zone Awareness Week

Another public awareness campaign is the annual "National Work Zone Awareness Week" (http://www.ops.fhwa.dot.gov/wz/outreach/wz_awareness.htm). The event takes place in April and is held to promote motorist and worker safety and mobility in work zones. The theme of the event varies from year to year; past themes have included:

- 2010: Work Zones Need Your Undivided Attention
- 2009: Drive to Survive – Our Future is Riding On It!
- 2008: Slow for the Cone Zone
- 2007: Signs of Change
- 2006: Working at the Speed of Night
- 2005: Slow Down or Pay Up

Many states host their own awareness events in addition to the theme of the National Work Zone Awareness Week. For example, the Missouri DOT has attempted to raise work zone safety awareness by holding an art contest for children, where school kids compete for recognition of the

best work zone safety scene. Similar events have been conducted in various states and other efforts have been initiated to help publicize the Awareness Week.

2.5.2.1 Orange Campaigns

Mostly associated with the National Awareness Week, but becoming more broadly used, "orange campaigns" have been initiated in several states. The Missouri DOT, for example, has launched "Operation Orange," a campaign where State landmarks are colored orange (http://www.modot.org/operationorange/). Several other states, such as Ohio and Washington, have developed versions of the orange campaign.

Washington's version, referred to as the "Go Orange Work Zone Safety" program, is promoted by the Washington Department of Transportation (WSDOT). It is described in Washington's 2010 Highway Safety Performance Plan as "…a low-cost, high impact campaign to engage drivers, the community and workers to make work zones safer. The funding will contribute to the education and publicity portion of high visibility enforcement" (*Washington Traffic Safety Commission 2009*). For 2010, the program was budgeted at $35,000. As part of Go Orange, WSDOT invites the public to participate in the program by posting photos of themselves on agency feeds to social networking sites such as Facebook and Flickr®. Businesses are also encouraged to participate and are publicized on the WSDOT webpage under "Who's In?"

2.5.3 Other Public Events

In addition to events associated with the National Work Zone Awareness Week, some transportation agencies have made efforts to emphasize work zone safety at occasions such as parades, fairs, community events, school functions, and at conferences. As an example, the North Carolina DOT sends mascots, Buddy Barrel and Connie Cone, to various public events. Pens, key chains, and other promotional gear feature pictures of the mascots. The use of a mascot in general is common in multiple states, such as Arizona's Highway Hawk, for educating school children.

Similar to the art contests mentioned for the Awareness Week, states such as Maine and Illinois hold children's art contests for calendar competitions.

2.5.4 Work Zone Safety Curriculum in Driver Education Programs

The FHWA, among other organizations, has worked to develop materials for driver education. Some of these materials, specifically targeting younger drivers, have been incorporated into state driver education programs. FHWAs widely distributed interactive CD-ROM "Moving Safely Across America," includes tips and information for teens on how to safely drive through work zones (http://safety.fhwa.dot.gov/training/training/train_msaa.cfm).

Additional materials have been prepared as part of the "Turning Point: Roadway Work Zone Safety for New Drivers" Campaign (http://workzonedriver.org/index.htm). The program was initiated by FHWA at the direction of Congress. The Turning Point Campaign is designed for young drivers and to supplement existing driver education courses. Supplemental materials include interactive CD-

ROMs, video, informational documents and promotional materials, such as bumper stickers and posters. The campaign emphasizes the following messages:

- Know the work zone signs.
- Pay attention to other drivers.
- Stay focused. Avoid distractions.
- Expect the unexpected.
- Keep your cool. Be patient.

Washington is an example of one state who has adopted materials from "Turning Point" for their driver education program. In addition to the program materials, the Washington Department of Transportation (WSDOT) has developed several documents designed to teach new drivers about safe driving in Washington work zones. Documents include: a list of common work zone offenses, examples of traffic control devices, tips for driving safely in a work zone (e.g. merging as early as possible, and turning on headlights), and a PowerPoint presentation on "Give 'Em a Break" (*WSDOT 2010*). Also developed was an informational video titled "Driver's Education: Learning Work Zone Safety."

More individualized programs, such as the one put together by the Indiana DOT and Indiana State Police, have been developed to supplement youth driver education in many states. Indiana's program focuses on educating students on traffic control devices. Personnel from the DOT are involved in the curriculum (*INDOT 2010*).

To target drivers of all experiences and ages, the "Work Zone Traffic Violator Awareness Program" was developed by the American Traffic Safety Services Association (ATSSA) and the Virginia Department of Transportation (VDOT). The program uses a CD-ROM and other instructional material to educate motorists about work zone hazards and safety (http://www.atssa.com/page.ww?name=Work+ZoneTraffic+Violator+Awareness+Program&section=Course+Information).

Ullman et al. (*2010*) acknowledged that, while it is generally thought that public awareness campaigns can enhance work zone enforcement activities, there have been "no formal evaluations of work zone enforcement public information efforts or their effectiveness."

2.5.5 Education and Promotion of Work Zone Safety through Advertising

Disseminating information to the general public on work zone safety can be done through a variety of media. The media most commonly mentioned by DOT safety programs included: television, radio, websites, newspapers, and billboards.

While most advertising was developed at and for the state or local level, national advertising can take the form of websites and information clearinghouses. One such example is the National Work Zone Safety Information Clearinghouse website (www.workzonesafety.org). The website is used as a public outreach tool; and a repository of information for highway professionals.

Another example of national advertising is US DOT's campaign, "Get the Picture. Listen to the Signs." As with many campaigns developed at the state level, the US DOT worked with consultants to develop and disseminate the message. The protagonist of the campaign is a three-dimensional computer generated male construction worker named "Jack Hammer." The stated goal of the campaign is to "generate awareness and educate drivers of the dangers faced while driving through a work zone, in order to change behavior" (*S & C Advertising 2007*).

Although most state DOTs were unique in their advertising slogans and campaigns, some common variations included: "Give 'Em a Break," "My Dad Works Out There," and "Expect the Unexpected."

North Carolina, has developed a state specific campaign with slogans designed to: emphasize the need for drivers to take responsibility in work zones by paying attention and slowing down ("Drive Smart. Do Your Part"), educate drivers that distraction could lead to a crash ("Pay Attention or Pay the Price"), and raise awareness that speeding in a work zone could lead to significant fines ("Speed a Little, Lose a Lot"). In 2009, North Carolina accompanied the campaign "Drive Smart. Do Your Part" with "Operation Drive Smart," a joint program by the North Carolina DOT and the North Carolina State Highway Patrol. As part of the program, efforts were made to combine advertising with enforcement and to crack down on excessive speeding in work zones (*NCDOT 2010*).

Campaigns focusing on driver attentiveness and awareness appeared to be widespread and tied to the acknowledgement that driver inattention is a cited cause of many work zone accidents. Two of the slogans mentioned above for North Carolina speak to the driver's responsibilities. Similar slogans include Nebraska's "When You're in the Driver's Seat, You Make the Difference!" and Wisconsin's "One Distraction. One Second. One Life."

In an effort to recognize effective awareness campaigns, many awards have been created to honor innovators in the field. Awarding organizations include the American Road and Transportation Builders Association -Transportation Development Association, the American Road and Transportation Builders Association and National Safety Council, among others. An example of an award winning campaign is Nevada's "The Flagger Moms of Orange Cone Hell". The campaign was initiated by a local laborers' union and focuses on moms informing the public about the dangers of working in construction zones. Another example of an advertising effort receiving recognition is the conferring of the Telly Award to the "Get the Picture. Listen to the Signs" campaign by the US DOT described above.

2.6 WORK ZONE TRAVELER INFORMATION

Most state work zone safety programs include methods for providing motorists with traveler information about specific construction projects. Work zone information may be disseminated as part of traveler information systems that are designed to provide information on incidents and weather conditions. Traveler information can be disseminated through a variety of media including printed materials, email, websites, phone, and variable message signs and highway advisory radio. The messages include details about work zone location and detours, characteristics about the work site, as well as information on travel time and expected delays. Technological advances allow states to provide motorists with real time information.

The provision of "public information" is emphasized throughout the Work Zone Safety and Mobility Rule (*Federal Register 2004*) and is an important consideration in the development of a Traffic Control Plan (TCP). In Washington, the importance of public information is specified in their *Work Zone Traffic Control Guidelines*, which state that "information to the public is a valuable element in the overall traffic control strategy. The use of public information resources, such as project web pages, newspapers, radio, and television can greatly improve the public's perception and acceptance of the necessary delays and other inconveniences caused by the project's construction" (*WSDOT 2009*).

For real-time traveler information, FHWA recommends the following state-of-the-art approaches (*FHWA 2010*):

- Monitor work zone traffic conditions on all NHS projects on a statewide/area-wide basis through fixed traffic management systems, portable traffic management systems, and/or cameras tied into a statewide/area-wide communications system.
- Display real-time work zone traffic conditions on the Internet, large screens at rest areas, welcome centers, weigh stations, truck stops, major tourist attractions, large parking garages, large office buildings, employment centers, and/or other large traffic generators.
- Use variable message signs, traffic advisory radio, and early warning systems to warn motorists approaching congested work zones.
- Use ITS hardware to safely guide motorists through the work zone.
- Develop media and private sector partnerships that provide real-time work zone information to the public.

An evaluation was completed by Savolainen et al. (*2009*) on a motorist awareness system implemented experimentally in Florida on highways I-10 and I-95 to provide motorists with information about construction work. The system was an enhancement to what is known as "a maintenance of traffic (MOT) plan" which consists of five warning signs and channelizing devices leading up to the work area. The enhanced motorist awareness system (MAS) provided more specific information such as lane closures and reduced speed limits using portable VMSs, regulatory signs, and radar speed display units. The traditional MOT and the MAS were evaluated with and without the addition of law enforcement. The MAS resulted in reduction in mean speeds, 85^{th} percentile speeds, speed variance, and the proportion of speeding vehicles. Combining the system with enforcement produced average speed reductions of 4 to 5 miles per hour.

2.6.1 Newsletters, Flyers, and Brochures

Work zone-related newsletters/flyers/brochures can be used to provide general updates on construction zones and can give advanced warning of planned activities; they do not, however, provide real-time travel information. Overall, a newsletter/flyer/brochure may be designed for a single project, for a corridor, for a region, or statewide.

Unlike flyers and brochures, which are typically openly distributed, newsletters tend to be sent to specific individuals, businesses, and/or groups. Newsletters may be distributed by hard-copy in the mail, or electronically through email. As cited by the FHWA under work zone safety and mobility

best practices (*2010*), Arizona effectively uses newsletters to communicate construction and project information to the public and to stakeholders. The newsletters are distributed weekly to local businesses and residents, as well as to the media. Typically, information is provided on the status of the project, lane or ramp closures, suggested detour routes, and other notices about access and restrictions.

Flyers can be developed and distributed in a variety of ways. One example is Illinois's use of fact sheets as a way to distribute work zone traveler information to various media sources. Another example is Wyoming, which uses flyers to give notice to the freight industry about work zones on major routes. The flyers are distributed through the Wyoming trucking association and posted at ports of entry and truck stops. Similar to flyers, are posters and other publicly visible print, such as coasters and placemats. As an example, Pennsylvania has printed and distributed placemats to various restaurants through their district offices. The placemats have included a map of the state's major roads under construction as well as tips for driving safely (*FHWA 2010*).

The Pennsylvania DOT was also recognized for their creation of a work zone advisory brochure (*FHWA 2010*). The content of the brochure was identical to the placemat but received wider distribution, including rest areas, welcome centers, and DMV offices. Caltrans has developed project-level brochures for major construction projects expected to significantly impact travel. The Caltrans brochures typically include a map showing the impacted areas and describe the improvement projects.

2.6.2 Email

While email serves as a way to distribute electronic versions of newsletters, flyers, and brochures, it also can be used to send messages on work zone projects. Several states (e.g. Wisconsin and Texas) have created email distribution lists for work zone projects. The lists are comprised of customers who choose to subscribe to the service.

2.6.3 Websites

Websites are a popular way to disseminate information on work zones. Websites may be created for the entire system and/or for a single project. An example of system website is Georgia DOT's *Georgia-Navigator*, which includes information on work zone delay and other work zone details, as well as general traveler information. An example of a system-wide website devoted solely to work zone traveler information is Pennsylvania DOT's *Highway Construction Advisory Map* (*PennDOT 2010*). The site provides an interactive map showing the location of work sites. The user can click on the sites to display details including: highway route number, date range of construction activity, work zone name, and details about the work being performed (e.g. "addition of turn lane"). Some DOTs, such as Mississippi, have paid for the placement of internet kiosks (e.g. at a rest area) to display their website (*FHWA 2010*).

While project websites are common, not all include work zone traveler information. Typically sites that do are tied to "smart work zones," a term referring to integrated ITS within a construction site. Information being transmitted to and displayed on a website may include such information as: travel time, average delays, and live video feeds.

2.6.4 Phone

One of the most recognizable traveler information phone numbers is "511." In 2000, the Federal Communications Commission (FCC) designated the three-digit code "511" for traveler information. There are now systems in 35 states including Oregon (initiated in December 2003). The line is designed for motorists to call and get information about road conditions, incidents, and construction delays, including lane closures. Some locations are developing enhanced systems that include information on additional travel modes, parking, driving directions, and real time incident and travel time information (*LogicTree 2008*).

Separate from "511," some agencies, such as the Washington DOT, provide the public with the phone number of the project engineer or other employee.

2.6.5 Variable Message Signs (VMSs)

Within and just prior to work zone areas, the use of portable VMSs is common. Some areas have also utilized stationary VMSs to provide detour or other information on near-by work zones. VMSs provide versatility in traveler information because the messages can be programmed with specific information or updated in real-time.

VMSs can be used in a variety of ways, such as to display cautionary messages. The technology has been used to display public service messages such as "fines double," and "stay alert." An evaluation of innovative messages (such as "My Dad Works Here; Drive Slowly" written in a font designed to resemble hand writing) found that the messages resulted in a speed reduction of 0.2 to 1.8 mph during the day, but had little impact at night (*Wang et al. 2003*).

For purposes of traveler information, VMSs have been commonly used to display details about alternative routes or detours, as well as travel time and delay data. A few studies have been completed which have evaluated the impact of detour and travel time VMS information on route choice. Within work zones in Texas and the District of Columbia (DC), information on detours was found to significantly divert traffic. Diversion rates of 10 percent and 52 percent were observed, respectively (*FHWA 2008*). A compilation of survey findings from the use of VMS detour and delay information in four states (Ohio, North Carolina, California, and Minnesota) found that between 50 and 85 percent of drivers surveyed said that they changed their route because of the messages provided on the work zone VMS (*FHWA 2007*).

In many states Highway Advisory Radio is used to supplement variable message signs. Signs are used to alert motorists to tune to a specific radio station if a beacon is flashing to hear detailed information about the work occurring at the specific site that might involve delays or detours.

2.6.6 Use of Traveler Information

Several methods for disseminating traveler information were described above. The best method for communication is dependent on the context and the profile of travelers. These methods may be used in combination with one another and in combination with other safety programs such as public awareness campaigns, and with site traffic control and enforcement.

2.7 CONCLUSION

Extensive research on engineering, enforcement, and education efforts to address work zone safety has been completed. This literature review was not meant to be exhaustive but was designed to focus on those topics of potential interest to ODOT program managers looking for new approaches. The literature revealed the following:

1. Traffic enforcement is very expensive. To maximize the investment, it is critical to be selective in choosing the projects and specific construction activities that can make the biggest contribution. This means ongoing evaluation of what is accomplished and willingness to modify deployment. Impact of enforcement can be improved in some situations with use of ITS technologies.

2. FHWA's Work Zone Safety and Mobility Rule is providing direction to states. If the component requiring annual assessments and the development and tracking of performance measures is conscientiously carried out it has the potential to encourage states to select the most effective approaches and improve their results.

3. Using technology, whether it is to enhance traffic control, enforcement, or communication with travelers, offers significant potential.

4. Some states have made providing travelers with real time information a priority. Travelers can use up-to-date information to choose alternative modes, routes, travel times, and avoid areas of extreme congestion. The bottom-line safety and mobility results are likely to be positive.

5. Significant resources are spent on public awareness campaigns related to work zone safety and, while they are thought to enhance traffic safety, there are no formal evaluations of their effectiveness.

Chapter 3.0 provides a summary of the work zone safety programs in place in ODOT. This provides the background for the final chapter which draws conclusions and makes recommendations.

3.0 OREGON WORK ZONE SAFETY

This chapter provides a picture of Oregon's work zone traffic crashes in terms of overall numbers and crash causation. This serves as a backdrop for separate sections on work zone safety and mobility policies and performance measures, public perception of work zone safety, traffic management, work zone enforcement, public information, and traveler information.

Conducting an exhaustive inventory of work zone safety programs and activities in Oregon is beyond the scope of this research effort. Instead, the researchers focused on and have summarized public attitudes about work zone safety, public information activities and their effectiveness, the impact of doubling fines in work zones, work zone traffic management, and work zone enforcement.

It is also worth noting that there have been two research projects completed in Oregon recently that relate to work zone safety. One related to traffic control plan (TCP) design and implementation (*Gambatese and Johnson 2010*) and one related to the use of photo radar in work zones (*Joerger 2010*).

3.1 CRASHES IN OREGON WORK ZONES

Table 3.1 summarizes crashes, by severity, occurring in work zones each year from 2005 to 2009 and provides an average for each category. The data is from the Crash Analysis and Reporting System (CARS). It provides information on all crashes and shows the percentage of all crashes that occurred in work zones. The table reveals that while crashes occurring in work zones account for only about 1.2 % of all crashes, they account for a far higher percentage of fatal crashes (2.6% average) and a slightly higher percent of injury crashes (1.5% average). In 2005 there were 19 fatal work zone crashes which was 4.3% of total fatal crashes and then, after several years where the number declined, in 2009 there were 17 fatal work zone crashes which was slightly over five percent of all fatal crashes.

Table 3.1 Work zone and all crashes, 2005-2009

	Total Crashes			Fatal Crashes			Injury Crashes			PDO Crashes		
Year	**All**	**Work Zone**	**% of All**	**All**	**Work Zone**	**% of All**	**All**	**Work Zone**	**% of All**	**All**	**Work Zone**	**% of All**
2005	44,878	512	1.1%	444	19	4.3%	19,446	274	1.4%	24,988	219	0.9%
2006	45,017	533	1.2%	417	5	1.2%	19,749	262	1.3%	24,851	266	1.1%
2007	44,162	591	1.3%	411	6	1.5%	18,500	311	1.7%	25,251	274	1.1%
2008	41,815	505	1.2%	369	5	1.4%	18,040	261	1.4%	23,406	239	1.0%
2009	41,271	508	1.2%	331	17	5.1%	19,053	286	1.5%	21,887	205	0.9%
Avg.	43,429	530	1.2%	394	10	2.6%	18,958	279	1.5%	24,077	241	1.0%

Source: CARS

During the same five-year period (2005-2009) there were a total of 58 fatalities in work zones which accounted for 2.6% of total fatalities.

Reviewing data on construction expenditures and using construction dollars spent to develop a rate of work zone-involved fatalities and crashes provides additional insight on whether Oregon's work zones are becoming more or less safe. Table 3.2 presents a 10-year summary of construction dollars spent and the work zone crashes and resulting fatalities occurring each year. While the number of crashes has increased, the construction dollars have increased as well. In this chart, construction dollars are used as a measure of construction activity. The construction dollars invested each year are recalculated in equivalent 2009 dollars so that a comparison can be made for the entire 10-year period.

Table 3.2: Work zone-involved fatalities and crashes on state highways and construction expenditures, 2000-2009

Year	Fatalities	Crashes	Construction $ in millions	Construction $ in millions (2009)	Crashes/million Construction $
2000	4	217	$273.3	340	0.64
2001	6	200	$241.7	293	0.68
2002	4	234	$250.7	299	0.78
2003	1	305	$342.0	399	0.76
2004	9	341	$421.4	479	0.71
2005	17	353	$411.4	452	0.78
2006	3	346	$452.2	481	0.72
2007	9	411	$519.9	538	0.76
2008	5	336	$541.0	539	0.62
2009	17	383	$601.2	601	0.64

Sources: Fatality Analysis Reporting System, CARS, Construction payments made to Contractors per calendar year (Construction Contract Administration)

When looking at work zone crashes per million dollars spent on construction projects there is a reduction in the two most recent years from the prior seven years, Figure 3.1 shows this graphically.

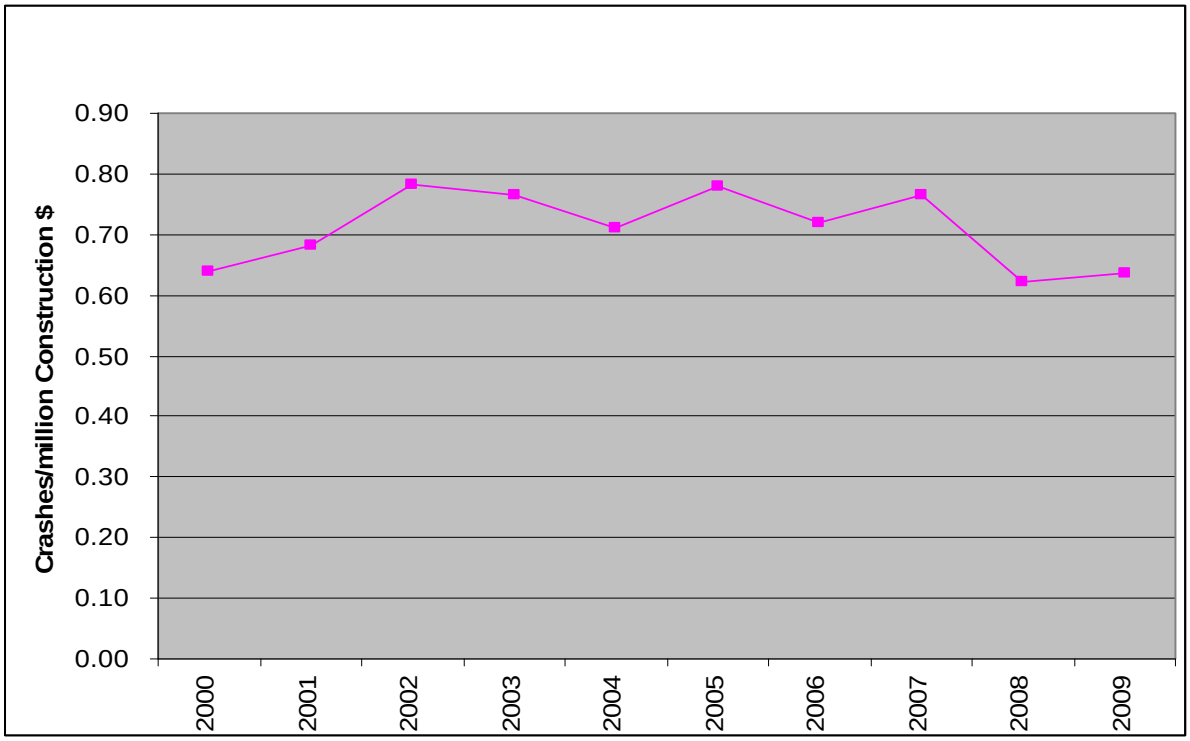


Figure 3.1: Work zone crashes on state highways per $million construction expenditures, 1999-2008

To gain a better understanding of the characteristics of work zone crashes occurring in Oregon an analysis was undertaken that compared the characteristics of work zone crashes to those of all other crashes. Data used for the analysis was pulled from the Crash Analysis and Reporting System (CARS) and was for the years 2001 through 2008. This yielded a total of 2,528 work zone crashes and 154,495 other crashes.

Some of the results were anticipated. As would be expected, work zone crashes were overrepresented between May and October, the construction season, and underrepresented between November and April. Work zone crashes were overrepresented between the hours of 11AM and 3PM and between 8PM and 3AM and underrepresented between 3PM and 8 PM. This is a reflection of work often being suspended during the peak afternoon travel hours and nighttime construction activity increasing.

It was also found that proportionally more of the work zone crashes involved fatalities and injuries than other crashes. Over half (55%) were considered to be a “rear end” collision, compared to 40% of the crashes not in work zones. Work zone crashes involved vehicles stopped or traveling straight ahead more frequently than crashes not in work zones which were more likely to involve vehicles turning or colliding at an angle.

Crash causation data for the most frequently mentioned causes of work zone crashes is summarized in Table 3.3 below. The information is useful in that it identifies the top six causes of work zone crashes and whether or not the factor is more or less significant for a work zone crash than for all other crashes. Note that while “speed too fast for conditions” is a leading cause of work zone crashes, “driving in excess of posted speed” is not.

Table 3.3: Most frequent causes of work zone crashes in Oregon, 2001-2008

Crash Level Cause	% of Crashes with Cause		Over or Under Representation
	Work Zone Crashes	All Other Crashes	
Followed too closely	35.8	26.6	9.2%
Speed too fast for conditions	27.8	27.8	0.0%
Other improper driving	12.2	10.4	1.8%
Inattention	9.5	5.3	4.1%
Did not yield right-of-way	7.0	14.7	-7.7%
Improper lane change*	6.1	3.3	2.9%

*data is for 2004-2008
Source: CARS

3.2 WORK ZONE SAFETY AND MOBILITY POLICIES AND PERFORMANCE MEASURES

ODOT's work zone safety program is influenced by long established safety-related polices and performance goals as well as mobility and safety requirements resulting from FHWA's Work Zone Safety and Mobility Rule. Additionally comprehensive performance measures have been established by the Oregon Bridge Delivery Partners and through an ODOT Highway Division-wide performance management system and include measures related to both safety and mobility.

3.2.1 Oregon Transportation Safety Action Plan and Performance Plan

Oregon's strategic highway safety plan which is known as the *Oregon Transportation Safety Action Plan*, was last updated in 2004 under the leadership of the Oregon Transportation Safety Division, and includes the following actions that specifically address work zone safety (*ODOT 2004, p. 19*):

- "Continue and expand efforts to reduce traffic-related deaths and injuries in roadway work zones.
- Continue the work zone enforcement program and enhance public information programs such as Give 'Em a Brake.
- Review ODOT practices and procedures relating to crew activity in work zones.
- Review road construction contract specifications dealing with placement and condition of traffic control devices.
- Consider legislation to implement photo radar in work zones."

The Oregon Traffic Safety Performance Plan, Fiscal Year 2010, also developed by the Oregon Transportation Safety Division (*2009*), provides further direction to achieving the above action. The 2009 plan, which was developed and will be monitored using data from CARS establishes the following target:

- Reduce work zone fatalities from 12, the average for 2005-2007, to 10 or below each year through 2015.

The Performance Plan also establishes the following targets:

- Maintain work zone injuries at 456, the average for 2005-2007, by December 31, 2010.
- Maintain work zone crashes at 545, the average for 2005-2007, by December 31, 2010.

Additional performance measures are program oriented and relate to providing overtime work zone enforcements funds, a public information campaign, and training. The 2009-2011biennial budget was $3.6 million. The program has been funded at approximately this level since the 2005-07 biennium. This is an increase from the 2003-05 biennium when the budget was $1.2 million.

3.2.2 Highway Mobility Operations Manual

The Highway Mobility Operations Manual (*ODOT 2005*) provides direction to the mobility program. It describes the committee and organization structure and the roles of the Statewide Mobility Manager, the five ODOT regions, the OBDP Delivery Partners (OBDP), various other units within ODOT, and freight-related associations. Among the policies formalized in the manual is the following related to delay: "All construction projects will be evaluated for delay impacts to mobility and staging options will be carefully reviewed to minimize the duration and severity of necessary delay impacts" (*ODOT 2005, p.37).*

Corridor delay thresholds have been established for four high volume corridors (I-5 North, I-5 South, I-84, and US 26/97/20). These values are published in corridor level traffic management plans. Table 3.4 provides an example of the delay thresholds established for the I-84 corridor.

Table 3.4: Delay thresholds for the I-84 corridor

Segment	Segment Boundaries	Area Type	Segment Length (Miles)	Assumed Travel Speed (MPH)	Est. Off-Peak Travel Time (Min.)	Est. Peak Travel Time (Min.)	Calc. Delay Threshold (Min.)
3-A	I-5 to I-205	Urban	6	55	7	10	1
3-B	I-205 to OR 35	Urban	62	60	62	89	9
3-C	OR 35 to US 97	Other	40	65	37	41	5
3-D	US 97 to US 730	Other	63	65	58	64	7
3-E	US 730 to US 395	Other	43	65	40	44	5
3-F	US 395 to OR 82	Other	51	65	47	52	6
3-G	OR 82 to State Line	Other	116	65	107	118	12
						Corridor Total	45

Source: Oregon Bridge Delivery Partners 2005.

3.2.3 Oregon Bridge Delivery Partners

Oregon Bridge Delivery Partners (OBDP) has developed a performance measure framework for guiding their work. A major component is measures related to maintaining freight mobility and keeping traffic moving. Performance measures to be tracked include the following:

- total delay through corridor,
- number of crashes in work zones; and

- work zone delays.

Collection of data on delay and queues is by field observation though it is being automated in some areas (Oregon Bridge Delivery Partners 2008). OBPD construction and safety personnel are to gather crash data for each work zone from law enforcement agencies from construction inspection staff and from logs prepared by the Traffic Control Supervisor. Crash data is to be tracked for each work zone.

3.2.4 Highway Division Performance Management System

The ODOT Highway Division Performance Management System includes performance measures related to work zone safety that are currently in use or may be used in the future. Measures relevant to this research include the following:

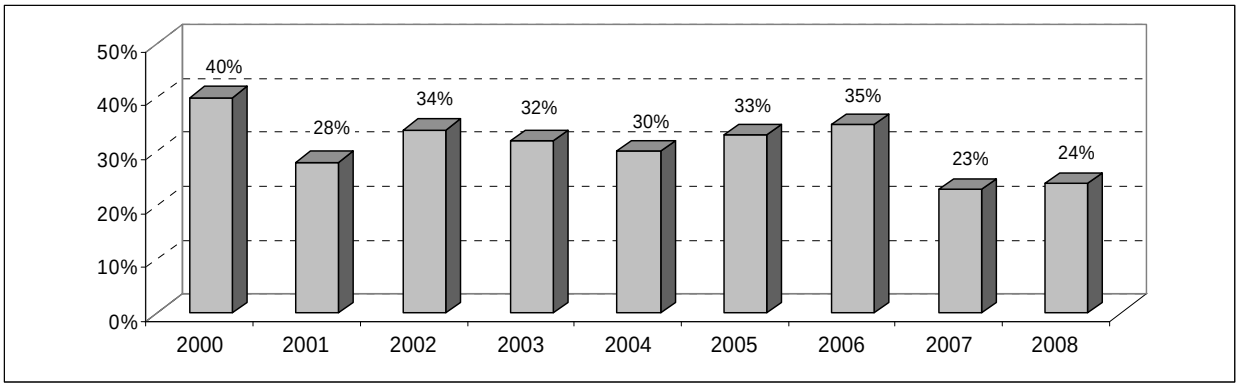
- Work zone crash rate: number of work-zone crashes, serious injuries, and fatalities, per 1,000 work zone hours. This is a future measure as neither construction nor maintenance work zone hours are currently available.
- Total hours of nonrecurring delay: total hours of delay due to nonrecurring sources (snow, incidents, construction, events, etc.). Currently this measure is limited to estimated incident-based delay in Portland, Salem, and Eugene.
- TripCheck visits: total number of TripCheck visits per quarter/calendar year. Data are currently available.

3.2.5 Conclusion

Through various publications including the Oregon Transportation Safety Action Plan and the Highway Mobility Operations Manual ODOT has established work zone safety and mobility goals and identified performance measures. Additionally the OBDP performance measure framework and the Highway Division Performance Management System identify similar safety and mobility performance measures.

3.3 PUBLIC PERCEPTION OF WORK ZONE SAFETY IN OREGON

In Oregon, a variety of surveys have been used to gauge public perception of work zone safety. One which has collected annual data on the issue is the Oregon Department of Transportation's, Transportation Safety Division Public Opinion Surveys. First conducted in 1983 and repeated annually, the survey provides insight regarding the public perception of work zone safety in Oregon. To understand how Oregonians perceive safety in the state, data from the survey were compiled and analyzed from the past nine years (2000-2008) on several questions regarding public perceptions of work zone safety. One such question asked respondents to review a list of potential work zone safety concerns and indicate which concerns/problems they experienced. The results showed that the most frequently observed problem was speeding (23%), followed by traffic delays (14%). All other problems evaluated, such as flagging, warning, and signing, had relatively low levels of concern (about 5%) (*Intercept Research 2008*). The proportion of respondents indicating no concern/no problem has varied over the years, from as high as 40 percent in 2000 to as low as 23 percent in 2007 (Figure 3.2).



Source: Data from *Intercept Research 2008*.

Figure 3.2: Survey responses indicating NO problem/concern observed while traveling through an Oregon work zone.

For overall work zone safety in Oregon, results from a separate survey, the FY 2009 Oregon Transportation Needs and Issues Survey, showed that 89 percent of Oregonians were satisfied with overall safety (warning signs, directional signs, highway markers, and other traffic control) of work zones on major Oregon highways (*Pietz and Sperley 2009*).

3.3.1 Public Perception of Work Zone Enforcement

Another factor of work zone safety is enforcement of posted speeds and other laws. Results from the Transportation Safety Division's public opinion surveys for 2005-2008 showed that respondents perceived Oregon's work zone laws were being enforced. About 10 percent of respondents felt that they were strictly enforced (*Intercept Research 2008*).

In the FY 2009 Oregon Transportation Needs and Issues Survey, results showed that 81 percent of respondents were satisfied with enforcement of reduced speeds and other traffic laws in work zones on major Oregon highways (*Pietz and Sperley 2009*).

The Transportation Safety Division's public opinion survey in 2008 and 2009 included a question to assess whether the public favored or opposed the use of photo radar in work zone traffic enforcement. The results showed that nearly three-quarters (74% in 2008 and 73% in 2009) favored the use of photo radar in work zones (*Intercept Research 2009*).

3.3.2 Self-Reported Speeding in Oregon Work Zones

Speeding in work zones is the most frequently cited problem (20% in 2008) observed by Oregon drivers (*Intercept Research 2008*).

A separate survey, completed in 2002, found a large difference between self-reported speed obedience in work zones and drivers' perception of others' speed obedience. Table 3.5 presents the survey results.

Table 3.5: Speed compliance in work zones (How often does self/others obey signs to reduce speed?) (2002)

	Always	Most of the Time	Sometimes	Hardly Ever
Self	65%	29%	5%	1%
Others	9%	48%	30%	13%

Source: Data from *Jones, Griffith and Haas 2002*.

While nearly all of the respondents (94%) reported that they *always*, or *most of the time* obeyed speeds in work zones, they thought that just over half (57%) of other drivers did the same (*Jones, Griffith and Haas 2002*). In comparison to other contexts (school zones, urban areas, congested rural areas, and safety corridors), self-reported speed obedience in work zones was second highest (65% *always*), behind that reported for school zones (82% *always*) (*Jones, Griffith and Haas 2002*).

The 2002 survey also evaluated the influence of certain risks (accidents, traffic citations, traffic fines, and cost of auto insurance) on speed obedience. Table 3.6 presents these results.

Table 3.6: Influence of risk assessment on obedience of posted speed in various contexts (2002)

Question: How often does the risk of _____ influence you to obey posted speeds?		School Zone	Work Zone	Safety Corridor
Accident	Always	78%	61%	41%
	Most of time	13%	27%	33%
Traffic Citation	Always	55%	43%	33%
	Most of time	21%	25%	28%
Traffic Fine	Always	27%	37%	30%
	Most of time	10%	19%	21%
Cost of Insurance	Always	47%	21%	22%
	Most of time	15%	11%	14%

Source: Data from *Jones, Griffith and Haas 2002*.

The data shows that, regardless of the context, the risk of getting in an accident was consistently the predominant factor in speed obedience, followed by the risk of receiving a traffic citation. While traffic fines were the third most influential factor for all contexts, a greater risk was perceived for work zones than for school zones or safety corridors.

3.3.3 Evaluation of Oregon's Double Fine

Double fines have applied to violations occurring in work zones in Oregon since 1995 when a law was passed by the Oregon Legislature. The public has been informed about the law through public service announcement, the media and posting of signs in work zones.

In 2005 and 2006, respondents to the Transportation Safety Division's public opinion survey were asked if they were aware of what automatically happens to the fine when a driver is cited for a traffic violation while traveling through a work zone or an area of road construction. In 2005 69% were aware the fine is doubled; in 2006, 73% said the fine doubled. (*Intercept Research 2008*). These were unaided responses.

3.4 WORK ZONE TRAFFIC MANAGEMENT

ODOT's Traffic/Roadway Section has overall responsibility for implementing federal and state requirements regarding work zone traffic management with consideration to safety and mobility. The primary tool for work zone management is the development and implementation of effective Traffic Control Plans (TCPs). Traffic Control Plans for all projects on state highways are completed by ODOT and by consultants under contract to ODOT. ODOT staff provides general oversight through the development of design policies and guidance materials which are delivered through regular training classes.

Implementation and maintenance of Traffic Control Plans in active work zones on Oregon highways is the responsibility of ODOT Construction Project Managers and contractors. To aide in quality assurance and provide recommendations for improvements within ODOT's temporary traffic control practices, interdisciplinary teams conduct work zone tours of many active construction projects. Projects are evaluated for quality, consistency and overall compliance with project TCPs.

The overall work zone management program is evaluated through a process set up by the Federal Highway Administration (FHWA). States complete a self-assessment each year which is evaluated by the local FHWA technical staff. The results for Oregon are presented in the 2009 *Work Zone Mobility and Safety Self Assessment, Oregon Summary Report* (*FHWA 2009b*). The results from all states are combined and presented in a national report, *Work Zone Mobility and Safety Self Assessment 2009 National Report* (*FHWA 2009c*) which includes data for the current and previous years.

This section provides a summary of ODOT work zone practices including the guidelines developed in Oregon to supplement the Manual on Uniform Traffic Control Devices (MUTCD) previously mentioned in Section 2.0. It also includes a summary of the most recent work zone tours and the *2009 Work Zone Mobility and Safety Self Assessment, Oregon Summary Report* (*FHWA 2009b*). Additionally, *Work Zone Design and Operation Enhancements* (*Gambatese and Johnson 2010*) are presented. The recommendations that are relevant to enhancing safety in Oregon work zones are summarized.

3.4.1 Standards Guiding Work Zone Traffic Management

As part of the literature review for a recent research project, "Work Zone Design and Operation Enhancements" (*Gambatese and Johnson 2010*), standards published by the State of Oregon and national agencies were reviewed for content applicable to the design and implementation of Traffic Control Plans (TCPs). This section is a summary taken from that report (*Gambatese and Johnson 2010, p. 112).*

Oregon Standard Specifications for Construction describes the terms and conditions under which projects are to be constructed and the contractual obligations of the construction contracting parties. *Section 00220 – Accommodations for Public Traffic* focuses on contractor responsibilities for maintaining facilities to accommodate public traffic through the project for the life of the contract. *Section 00225 – Work Zone Traffic Control* focuses specifically on controlling and protecting

workers and traffic in the work zone; and, providing traffic control measures and specific devices in accordance with the TCP.

The *Oregon Temporary Traffic Control Handbook for Operations of Three Days or Less*, which is based on the *MUTCD*, provides guidance for setting up temporary traffic control zones which are in place for three days or less on public roads in Oregon.

The *Traffic Control Plans Design Manual* includes traffic control plan design standards, guidelines, policies, and procedures. It is to be utilized by designers within ODOT as well as designers working for cities, counties, and private consulting engineering firms.

The *Project-Level Transportation Management Plan (TMP) Guidance Document*, developed jointly by ODOT and Oregon Bridge Delivery Partners (OBDP), outlines the intended content and purpose of TMPs which is to minimize disruptions to motorists, the freight industry, and communities without compromising public or worker safety, or the quality of work being performed.

The *Work Zone Traffic Analysis Manual* compiles ODOT's work zone analysis methodologies, guidelines, policies, and procedures to be considered in determining lane closures and restrictions. The manual is intended to be utilized by analysts within ODOT, as well as analysts for local authorities and private consultants.

3.4.2 Work Zone Tours

To monitor and evaluate work zone practices, and to ensure proper traffic control plan implementation, formal work zone tours have been conducted since 2000. The purposes of the tours are (*McCanna 2009)*:

- To confirm ODOT's work zone standards and practices are being implemented in the field consistently.
- To confirm that the standards and practices are providing a satisfactory level of safety for the traveling public and construction workers.
- To reveal if additional techniques or technologies are needed to improve safety, traffic flow, and construction efficiency.
- To strengthen communication among ODOT design and construction staff, consultants, and contractors

In 2009, 22 persons representing a range of technical backgrounds participated in several multi-day construction work zone tours that visited 60 projects. The reviewers scored the performance on 30 different areas including signing, channelization devices, pavement markers and markings, and bicycle and pedestrian facilities. Scores from 1-10 were given by each participant who also provided clarifying comments. Overall, the scores were good (average score was 75.6 out of 100) but there were areas needing additional attention.

A primary weakness was in the accommodation of bicyclists and pedestrians through or around the work zone. Another identified deficiency was temporary signing, including the use of portable changeable message signs (PCMSs). Designers are asked to include recommended messages in the traffic control plans. According to Scott McCanna, Traffic Control Plans Engineer, coordinator of the work zone tours, and author of the report: "the messages should be providing additional warnings, guidance, or work zone details, that rigid signing in the vicinity does not already provide" (*2009, p. 26).* It was found that PCMS were used for generic, "Road Work Ahead" and "Please Use Caution" messages. On occasion, other messages were displayed using a two panel message that could not be understood unless the driver had sufficient time to read both panels. Each panel should display a stand alone message.

The summary report has been distributed widely and has been useful in providing feedback to Traffic Control Plan Designers, ODOT engineering consultants and the Region Construction Project Management offices.

3.4.3 Work Zone Mobility and Safety Self Assessment

Since 2003, FHWA Division Offices have worked in partnership with states to assess work zone practices. With the federal Work Zone Safety and Mobility rule going into effect in 2008 the assessment has been expanded. The assessment tool is designed to help states identify how well they are doing in terms of safety and mobility and identify areas needing improvement. The assessment consists of 46 questions that relate to leadership and policy, project planning and programming, project design, project construction and operations, communications and education, and program evaluation. Each question is scored from 0-15 points with scores determined in a meeting involving FHWA and ODOT staff. While this is somewhat subjective, the process does allow an opportunity to review the program and identify areas showing improvement and areas needing more attention. Oregon's score for 2009 was 10.9 which was above the national average of 9.7 (*FHWA 2009c*).

In the area of policy development, Oregon scored relatively high having established strategic goals to reduce congestion and delays and reduce crashes in work zones. In this area, the agency scored itself lowest on having established measures to track work zone congestion and delay. ODOT also scored itself high on project design and project construction and operation.

Specific areas where the agency scored low were the performance of constructability reviews that included strategies to reduce congestion and delays; evaluating ITS technologies to minimize congestion; designing projects to mitigate congestion impacts of repair and maintenance projects; and using computer modeling in traffic control plan development. ODOT also scored itself low on using performance-based selection of contractors to eliminate contractors who have not performed high quality, on-time work. Of interest is that the assessment shows significant improvement in the area of providing training to law enforcement personnel on work zone devices with the score increasing from "2" in 2008 to "14" in 2009.

In the area of communications and education the agency gave itself high scores (14 out of 15) for having a website that provides timely traveler impact information, sponsoring National Work Zone Awareness Week, and having a public education plan for providing information to the public. The exception in this area was that the agency scored itself low on making use of ITS technologies to

collect and disseminate information to motorists and agency personnel regarding work zone condition (6 out of 14).

ODOT scored itself proportionately lower in the areas of project planning and programming and program evaluation. The lowest score was given to the collection of data to track work zone congestion and delay performance. Average scores were given to activities relating to the integration of the planning process with the project development process to better assess and manage work zone impacts. (*FHWA 2009b*)

3.4.4 Smart Work Zones

Oregon is beginning to move ahead with the use of ITS technologies to manage work zones and provide real time travel time information to motorists traveling through work zones and to persons planning trips. In 2010, two demonstrations of traffic monitoring systems were carried out on interstate highways in Oregon. In both demonstrations, equipment placed on the highway collected data about vehicles traveling through the work zone and used this information to determine messages to be displayed to vehicles entering the work zone. Neither location (I-84 near Hood River and I-5 south of Salem) experienced high volumes or excessive delays during the period of the demonstration so it was difficult to assess the contribution the systems may have made to improved traveler information. It was also not possible to provide information from either system to the public as part of ODOT's *TripCheck* website, however both systems offer this potential. To facilitate these demonstrations and to encourage additional use of portable traffic management systems (PTMS) ODOT has developed Standard Guidelines for Product Review for PTMS Manufacturers.

3.4.5 Recent Research

ODOT recently completed research to assess how effective traffic control plans (TCPs) are in minimizing work zone safety hazards the optimizing mobility (*Gambatese and Johnson 2010*). The conclusions and recommendations were comprehensive. Those most relevant to the current research project are summarized below (*Gambatese and Johnson 2010, pp113-114, 120*):

- "…(T)he quality of TCP design, review, implementation, and inspection is high. There is …agreement that motorist safety and worker safety are of higher priority to project success than other project objectives such as cost, schedule, and productivity."

- The expectation on what is sufficient to provide a safe work zone differs between those involved in TCP design and those involved in TCP implementation. "This can affect the importance placed on specific aspects of a TCP design and the ultimate level of safety in a work zone."

- "There is a need to communicate more clearly with and educate the traveling public about work zones on a project by project basis."

- Using only standard TCP design drawings can be detrimental and "may result in inappropriate traffic control measures and less safe work zones. One example is over-

signing, which was noted by both designers and implementers because it desensitizes drivers to important traffic control information."

- "The research study revealed that when certain project characteristics are present, providing safety and effective traffic control is particularly challenging. Those features which had a significant impact on traffic control, in order of decreasing impact, were:
  - Numerous or frequent stage changes
  - High speeds through the work zone
  - Multiple lane closures
  - Dense existing signage
  - Unique site features (i.e. horizontal or vertical curves in/before work zone)
  - Traffic entering/leaving the work zone (intersections/ramps)
  - Urban or night setting
  - Flagging and/or pilot car operation
  - Use of temporary striping
  - Multi-lane highways"

3.5 OREGON WORK ZONE TRAFFIC ENFORCEMENT

Traffic enforcement is provided by Oregon State Police and local police in work zones throughout the state. Law enforcement agencies carryout enforcement in work zones as part of their routine traffic enforcement responsibilities and receive supplemental resources from ODOT's Transportation Safety Division in the form of grants. Officers providing work zone enforcement services are typically working on an overtime hourly basis on ODOT construction projects.

State and local law enforcement agencies provide services in specified work zones on state highways in compliance with guidance given in the provisions of local cooperative policing agreements. As stated in the 2009-2011 work zone enforcement project work plan, the objectives of the work zone enforcement program are to (*ODOT 2009, p.2*):

- "Increase driver attentiveness.
- Reduce traffic related deaths and injuries in roadway work zones by reducing average speeds through these zones.
- Concentrate on reducing vehicle speeds within the transition zone prior to the work area and throughout the work zone.
- Provide information to local media sources."

The statewide work zone enforcement program is paid for with Federal Highway Administration Funds and has an approximate biennial budget of $3.6 million for education, enforcement, and equipment. This budget includes some of the program match.

Approximately six months prior to the start of the biennium, Region Transportation Safety Coordinators and a coordinator at OBDP work with construction project managers to identify the construction projects that will benefit from enforcement resources. Basic guidance for the process is provided in the Transportation Safety Division publication, *Work Zone Enforcement Guidelines* (Appendix D), which is updated each biennium. This document includes contact information for ODOT, OBDP, and Oregon State Police (OSP), and local enforcement agency personnel involved in the work zone enforcement program; budget allocations by region; responsibilities of all parties; reimbursable activities; the Work Zone Enforcement Request (WZER) form; and the ODOT Monthly Construction Work Zone Enforcement Report Form. Also included are the federal regulations regarding Temporary Traffic Control Devices (23 CFR Part 630). These rules help construction project managers and region transportation safety coordinators identify projects that need overtime work zone enforcement (Appendix E)

Using slightly different approaches, each region identifies the number of hours needed each month that the project will be under construction. Factors considered in determining the number of hours needed include high ADT, disruption of traffic, detours, nighttime construction activity, higher speeds, crash data, and worker exposure to live traffic. Generally enforcement needs are not considered as part of the traffic control planning process. Throughout the biennium the allocation of enforcement hours among projects is updated.

For each project a Work Zone Enforcement Request (WZER) (Appendix D) is prepared and submitted to either Oregon State Police or a local enforcement agency that has signed an agreement with ODOT to provide work zone enforcement services. The form includes the following information:

- Project Name, ODOT Key # Project Manager
- Highway/Mileposts/Description
- Anticipated dates enforcement is needed
- Total number of overtime enforcement hours requested
- Enforcement needs, e.g. days of the week, number of hours per week or month, time of day.

Once the construction project is underway, the ODOT construction project manager may contact the enforcement agency about providing enforcement to assist staging traffic control changes such as detours, lane closures, and lane shifts as needed. The rest of the hours the police agency spends on the project are determined by the enforcement agency using the guidelines on the WZER which may note the days of week and times of day for enforcement to be provided. Some enforcement personnel check regularly with the project managers or, if it is in the metropolitan area, with the Traffic Operations Center, to determine the expected construction activity and enforcement needs. Police sometimes give feedback on the way a traffic change is set up. In the past, the Region 2 transportation safety coordinator hosted quarterly meetings during the year for enforcement personnel and ODOT project managers to discuss construction projects that were going to need enforcement resources. Most Regions have email lists which include police agencies to which construction project status information is sent out weekly or as often as information changes.

Each enforcement agency is required to submit a Monthly Construction Work Zone Enforcement Report Form (Appendix D) for each project where enforcement was performed. This form includes the name of the officer who worked and for each shift the date, time, number of stops, number of citations and warnings issued. This information is transferred to excel work sheets so that enforcement activity and resources spent on a specific project can be tracked, but provides only limited guidance for the overall management of the work zone traffic enforcement program.

In meetings with OSP and ODOT the importance of good communication between the construction project manager and the enforcement agency was stressed. In the past the sergeant responsible for work zone enforcement stopped by the ODOT region office to have work zone enforcement forms signed. This practice provided an opportunity to communicate about upcoming enforcement needs. Currently, forms are transmitted for signature electronically so there is less opportunity for informal communication. The option of restoring the quarterly meetings including enforcement personnel, ODOT project managers, and the region safety coordinator was suggested.

3.6 OREGON WORK ZONE SAFETY AWARENESS PROGRAM

The ODOT Work Zone Safety Program manages funding for public awareness through the Work Zone Education and Equipment Program. In 2008, for example, these funds ($170,021) were used for development and statewide distribution of messages via billboards, transit ads, radio, television, and print media. Funds were also used to provide education to state and local public works agencies, consultants and contractors on the seriousness of work zone crashes (*ODOT 2008b*). In 2009, the program was expanded to include messages in both English and Spanish, and to publicize the start to the construction season with a highly visible kick-off event at Portland's Pioneer Courthouse Square.

The work zone safety slogans used in recent years include "Give 'Em A Brake," and "Slow Down, Better Roads Ahead." These messages are disseminated using various media, such as television, radio and billboards. Public service messages can be displayed on permanent variable message signs if they are supplementary to a local or statewide transportation safety media campaign. Messages must be approved by the State Traffic Engineer and have the lowest priority (*ODOT 2008a*).

Oregon's public service announcements often focus on personalizing injuries and fatalities by statistics (such as fatalities are higher among motorists than construction workers) or by slogans, such as "Drive Safely – My Dad/Mom Works Out There." This particular slogan received national attention by the American Road and Transportation Builders Association, Transportation Development Association when ODOT was awarded first place in outreach programs at the state and regional level (*Solsby and Sant 2009*). In particular, the message was praised for its unique approach of "humanizing" work crews and featuring images of actual workers and their families.

In addition to campaigns designed to warn drivers, educational public awareness campaigns have been used in Oregon. One example is the 2008 audio announcement, "Three Things," which emphasized three reasons why motorists should slow down in work zones, these included: 1) double fines; 2) greater number of work zones; and 3) people who die most often are not working on roads, they are riding in cars.

For work zones, educational materials were developed on the "4E" approach to work zone safety. The "4E" approach to traffic safety is a comprehensive approach to safety emphasized by the U.S. Department of Transportation and supported in Oregon that recognizes that a combination of efforts that include enforcement, engineering, education, and emergency medical services will make a more significant safety impact than a program that is focused on just one discipline.

Oregon typically uses May, Transportation Safety Awareness Month, as the kick off to the construction season. Different events are done each year as part of the construction kick off. An Orange campaign was used in 2010. The following is an excerpt from a press release:

"We're asking Oregonians to show their support for work zone safety by driving slowly and carefully through work zones and to help us raise awareness by "going orange" for Work Zone Awareness Week. Washington, Missouri and other states participate in the Go Orange program during Work Zone Awareness Week and we thought it would be a good way for Oregonians to show their support for this important issue.

Going orange can be as simple as wearing something orange during the week of April 19-23, 2010. We know Oregon State University fans probably have something orange in their closets, but regardless of which team you support we can all support safety in Oregon's work zones!

Share a picture of yourself or your friends, family or coworkers "going orange" on the 'Go Orange for Work Zone Safety'…website (*ODOT April 13, 2010*)."

Oregon promotes work zone safety statewide at fairs, schools, and in driver education classes. Work Zone educational presentations are conducted at conferences held for driver education instructors.

Each construction season ODOT publishes a foldout map identifying major road projects and the expected impact on motorists. Tips for safe driving and details about website and telephone numbers to call for specific information about a construction project or highway are included (*ODOT 2010*).

Several other cautionary slogans and educational campaigns have been initiated over the years, some of which are listed in the subsection below on effectiveness.

3.6.1 Effectiveness of Oregon's Work Zone Safety Public Awareness Program

The effectiveness of ODOT's public awareness and education program is difficult to measure, however, one available method is to assess public awareness and retention of messages. The Transportation Safety Division's annual public opinion survey includes questions to assess the effectiveness of the safety awareness program. In 2008, 34 percent of survey respondents had seen or heard advertising or public service announcements aimed at making the public aware of Oregon's laws regarding driving through work zones or areas of road construction. Of the individuals who recalled the announcements, the top reported media source was television (61%), followed by radio (31%) (*Intercept Research 2008*).

The most frequently recalled message was “slow down for workers in construction zones,” followed by “traffic fines double in work zones” (Table 3.7). The percentage of respondents who did not recall a specific message has declined slightly since 2005, from 29 percent in 2005 to 16 percent in 2008 (*Intercept Research 2008*).

Table 3.7: Recollection of Primary Oregon Work Zone Safety/Law Public Service Announcements

	2005	2006	2007	2008
slow down for workers in construction zones/reduce speed limit	25%	25%	30%	34%
traffic fines double in work zones	20%	27%	26%	20%
"give 'em a brake"	13%	13%	18%	14%
be aware, watch out for workers/flaggers/their safety	7%	12%	15%	15%
be safe/cautious/aware in general	6%	6%	15%	8%
my dad/mom is a worker/be careful/watch out for them/they have families	1%	1%	4%	10%

Source: *Intercept Research 2008*

3.7 WORK ZONE TRAVELER INFORMATION

In addition to public service announcements, ODOT promotes the use of traveler information resources for work zones. Resources include the traveler information webpage, ODOT TripCheck (http://www.tripcheck.com), and the “511” telephone line.

ODOT’s website provides direct access to TripCheck and to the summer road construction map for the Portland Area. The map is a PDF file that must be downloaded to be read so it is not possible to readily identify construction locations. Along with the map on the same webpage is a listing of major highways in the Portland area and each has a listing of construction projects. Mile point range, construction dates, and a description of the construction activities are included.

On ODOT’s home page there is a listing entitled “Highway Regions/Projects.” The user can filter by geographical area and is taken to the respective region website. Each region’s website is organized differently. Some provide more complete and more up-to-date information about construction projects than others.

As mentioned in section 3.4.4, Oregon is beginning to move ahead with the use of ITS technologies to provide real time travel time information to motorists traveling through work zones and to persons planning trips. In 2010, two demonstrations of traffic monitoring systems were carried out on interstate highways in Oregon. In both demonstrations, equipment placed on the highway collected data about vehicles traveling through the work zone and used this information to determine messages to be displayed to vehicles entering the work zone. It was not possible to provide information from either system to the public as part of ODOT’s TripCheck website, however both systems offer this potential.

3.8 SUMMARY

When looking at work zone crashes per million dollars spent on construction projects there was a reduction in 2008 and 2009 compared to the previous seven years. Following too closely, speed too fast for conditions, and other improper driving are the most frequently given crash causes. The

public is satisfied with the overall safety of work zones and with the enforcement of reduced speeds and other traffic laws in work zones. Information about crash causation and public attitudes is helpful in planning work zone safety public information activities. This information could be used in the development of messages to effectively inform the public about work zone safety.

ODOT has established work zone safety and mobility goals and identified performance measures to be tracked.

ODOT's Traffic/Roadway Section has overall responsibility for implementing federal and state requirements regarding work zone traffic management with consideration to safety and mobility.

The primary tool for work zone management is the development and implementation of effective Traffic Control Plans (TCPs). Interdisciplinary teams conduct work zone tours of many active construction projects to monitor plan compliance. Oregon and other states complete a self-assessment which can be used to identify areas needing improvement. Areas for potential improvement include having constructability reviews include strategies to reduce congestion and delays, establishing measures to track work zone congestion and delay, and making better use of ITS technologies to collect and disseminate information to motorists and agency personnel regarding work zone condition. A research project confirmed the need to "communicate more clearly with and educate the traveling public about work zones on a project by project basis." (*Gambatese and Johnson, 2010, p. 113*.)

Traffic enforcement is provided by Oregon State Police and local police in work zones throughout the state, mostly on an overtime basis with reimbursement from ODOT's Transportation Safety Division in the form of grants. Region Transportation Safety Coordinators and a coordinator at OBDP work with construction project managers to identify the construction projects that will benefit from enforcement resources. Factors considered in determining the number of hours needed include high ADT, disruption of traffic, detours, nighttime construction activity, higher speeds, crash data, and worker exposure to live traffic. Once the construction project is underway, the ODOT construction project manager may contact the enforcement agency about providing enforcement to assist staging traffic control changes such as detours, lane closures, and lane shifts.

ODOT's Transportation Safety Division manages the Work Zone Education and Equipment Program. The program includes the development and distribution of messages via billboards, transit ads, radio, television, and print media as well as providing education to state and local public works agencies, consultants and contractors.

The effectiveness of ODOT's public awareness and education program is difficult to measure. The Transportation Safety Division's annual public opinion survey includes questions to assess the effectiveness of the safety awareness program. In 2008, 34 percent of survey respondents had seen or heard advertising or public service announcements aimed at making the public aware of Oregon's laws regarding driving through work zones or areas of road construction. The most frequently recalled message was "slow down for workers in construction zones," followed by "traffic fines double in work zones."

In addition to public service announcements, ODOT promotes the use of traveler information resources for work zones. Resources include the traveler information webpage, ODOT *TripCheck*

(http://www.tripcheck.com), and the “511” telephone line. Each region’s website is organized differently. Some provide more complete and more up-to-date information about construction projects than others.

Oregon is beginning to move ahead with the use of ITS technologies to provide real time travel time information to motorists traveling through work zones and to persons planning trips. It also has the ability to provide information for work zone management.

4.0 CONCLUSIONS AND RECOMMENDATIONS

This research effort has revealed that Oregon has a comprehensive program that involves engineering, enforcement, and education components to improve work zone safety and that the efforts seem to be paying off in terms of somewhat lower crash rates and high public confidence in the safety of our work zones. The review of Oregon's programs, research on work zone design and operation enhancements on Oregon's traffic control planning process, and a literature review shown strengths and opportunities for improvement. This section includes a summary of conclusions and presents recommendations regarding program enhancements.

4.1 CONCLUSIONS

4.1.1 Work Zone Safety and Mobility Goals and Performance Measures

While ODOT has established work zone safety and mobility goals and identified performance measures to be tracked, the responsibility for collecting the data and analyzing the results is shared by several different sections of the department.

4.1.2 Crash Analysis and Public Attitudes

Crashes occurring in work zones accounted for 1.2 % of all crashes occurring between 2005 and 2009, however crashes in work zones tend to be more serious than other crashes. They accounted for 2.6% of all fatal crashes during those years. Following too closely, driving too fast for conditions, and other improper driving were the most frequently reported causes of traffic crashes in Oregon's work zones.

The public is very satisfied with the overall safety of work zones and with the enforcement of reduced speeds and other traffic laws in work zones. Respondents to public attitude surveys cite "speeding" as the most frequently observed problem in work zones followed by traffic delays.

Information about crash causation and public attitudes is valuable when developing work zone safety public information activities.

4.1.3 Traffic Management and Traffic Control Planning

ODOT's Traffic/Roadway Section has overall responsibility for implementing federal and state requirements regarding work zone traffic management with consideration to safety and mobility.

FHWA's Work Zone Safety and Mobility Rule is providing direction to Oregon and other states. The component requiring annual assessments and the development and tracking of performance measures should provide useful guidance. In the assessment done in 2009, Oregon scored relatively high for having established strategic goals to reduce congestion and delays and reduce crashes in work zones. ODOT also scored itself high on project design and project construction and

operation. ODOT rated its communications and education efforts high due to its website that provides travel information, sponsorship of National Work Zone Awareness Week, and public education efforts.

The 2009 assessment showed ODOT can improve in several areas. Oregon can improve by including strategies to reduce congestion and delays in its constructability reviews and establishing measures to track performance of congestion and delays in construction projects. ODOT acknowledged that it has made limited use of ITS technologies to collect and disseminate information to motorists and agency personnel regarding work zone conditions. In 2010 two demonstrations of traffic monitoring systems were carried out on interstate highways in Oregon. In both demonstrations, equipment placed on the highway collected data about vehicles traveling through the work zone and used this information to determine messages to be displayed to vehicles entering the work zone.

ODOT recently completed research to assess how effective traffic control plans (TCPs) are in minimizing work zone safety hazards and optimizing mobility. The results showed that high priority is given to motorist and worker safety, however there is a need to communicate with the public about work zones on a project by project basis. The research study revealed that when certain project characteristics are present, providing safety and effective traffic control is particularly challenging. These features include numerous or frequent stage changes, high speeds, multiple lane closures, and unique site characteristics.

Many of these factors are important to consider when identifying the potential for using enhanced traffic control measures as well as the need for enforcement resources.

4.1.4 Traffic Enforcement

Traffic enforcement in Oregon work zones is provided by Oregon State Police and local police. Law enforcement agencies conduct enforcement in work zones as part of their routine traffic enforcement responsibilities and also receive grants from ODOT's Transportation Safety Division for additional enforcement, typically on an overtime hourly basis on ODOT construction projects on state highways.

Generally enforcement needs are not considered as part of the traffic control planning process. Region Transportation Safety Coordinators meet with construction project managers and Oregon Bridge Delivery Partners (OBDB) to identify the construction projects that will benefit the most from enhanced traffic enforcement. Using slightly different approaches, each region identifies the number of enforcement hours needed each month for each project. Factors considered in determining the number of hours needed include high ADT, disruption of traffic, detours, nighttime construction activity, higher speeds, crash data, and worker exposure to traffic.

Once the construction project is underway, the ODOT construction project manager may contact the enforcement agency about providing enforcement to assist staging traffic control changes such as detours, lane closures, and lane shifts. OSP and ODOT personnel involved in the work zone enforcement program stressed the importance of good communication between the construction project manager and the enforcement agency.

In an effort to maximize their investment in traffic enforcement, some states have developed checklists for choosing projects and determining the enforcement approach. Conscientious tracking of enforcement activities, evaluation of results, and willingness to modify deployment of resources can help to maximize resources. Impact of enforcement can be improved in some situations with use of ITS technologies.

The study on photo radar in a Portland area work zone showed that photo radar was effective while it is in place so it is an appropriate countermeasure to consider.

4.1.5 Public Information

The ODOT Transportation Safety Division manages the Work Zone Education and Equipment Program. The program includes the development and statewide distribution of messages via billboards, transit ads, radio, television, and print media as well as providing education to state and local public works agencies, consultants and contractors.

A finding of the literature review was that significant resources are spent by most states on public awareness campaigns related to work zone safety but there are no formal evaluations of their effectiveness. In some respects Oregon is an exception to this since annual surveys completed by Intercept Research for ODOT help determine public attitudes and provide some guidance for the development of public information materials; however, the effectiveness of ODOT's public awareness program has not been assessed.

As mentioned above, information about crash causation and public attitudes is valuable when developing work zone safety public information activities.

4.1.6 Traveler Information

Each construction season ODOT publishes a foldout map identifying major road projects and the expected impact on motorists. Tips for safe driving and details about website and telephone numbers to call for specific information about a construction project or highway are included (*ODOT 2010*).

ODOT promotes the use of traveler information resources for work zones. Resources include the traveler information webpage, ODOT *TripCheck* (http://www.tripcheck.com), and the "511" telephone line.

On ODOT's home page there is a listing entitled "Highway Regions/Projects." The user can choose by geographical area and is taken to the respective region website. Each region's website is organized differently. Some provide more complete and more up-to-date information about construction projects than others.

Some states have made providing travelers with real time information a priority. Travelers can use up-to-date information to choose alternative modes, routes, travel times and avoid areas of extreme congestion. The bottom-line safety and mobility results are likely to be positive. Oregon has done less than many states but is beginning to move ahead with the use of ITS technologies to provide

real time travel time information to motorists traveling through work zones and to persons planning trips.

4.2 RECOMMENDATIONS

These conclusions suggest opportunities for program enhancements which are presented as recommendations.

ODOT should review its current activities related to monitoring work zone safety and mobility. These are currently carried out by several different units within the department. A focal point for collecting and analyzing data on crashes, construction expenditures and, work zone enforcement, incidents, congestion, and delays is needed. The option of the Work Zone Safety Program Manager in ODOT's Transportation Safety Division assuming this role should be considered. It is desirable to track activity and performance on a project by project basis as well as by region and statewide. Once established this information will provide program managers with the information they need to maximize the allocation resources.

ODOT should work with enforcement agencies to enhance the process used to identify enforcement resources needed for each construction project. The process ODTO uses to identify projects most likely to need enforcement considers factors within the Temporary Traffic Control Devices 23 CFR Part 630 considers high AADT, traffic control changes, nighttime work, crash history, and worker exposure to traffic. There may be advantages to formalizing this process to include a checklist. Use of a procedure to more specifically identify dates or construction stages that can benefit the most from enforcement should be considered.

The Traffic Control Plans Engineer should be involved in the process for identifying the need for enforcement to reinforce traffic control changes due to construction projects. Opportunities for those involved in traffic control plan development and implementation to communicate regularly with enforcement agencies throughout the life of the project should be sought. Prior to and during the construction season, regional meetings with police agencies and construction project managers or their designees should be held at least quarterly to assess results and identify revisions in construction schedules and enforcement requests.

Other states may have developed management systems for work zone enforcement tracking that could be adapted for use it Oregon. The currently used practice of updating a series of excel worksheets periodically does not provide adequate information to TSD's Work Zone Program Manager, ODOT project managers, enforcement agencies, and others. Up-to-date comprehensive information on enforcement provided, future enforcement requirements, and resources available is needed. Additionally, the option of including enforcement hours spent on other types of overtime enforcement programs in place for DUII, safety belt, and speed enforcement could be considered.

Implementation of the recommendations made in the research report, Work Zone Design and Operation Enhancements (*Gambatese and Johnson 2010*) should be undertaken with careful consideration given to implications for work zone safety.

While ODOT has had annual surveys conducted to help determine public attitudes and provide guidance for the development of public information materials. To develop targeted messages, this information could be supplemented with the results of crash data analysis.

ODOT has not completed an evaluation of its work zone public information program. ODOT should consider having an evaluation of the work zone public information program completed. Since the literature review revealed that other states have not evaluated their work zone public information programs either and also that many states seem to utilize the same message and media as Oregon, the option of a pooled fund study should be considered.

ODOT could enhance the impact of its public information program by using some of its resources to provide localized work zone safety messages in areas where there are upcoming construction projects. The messages could be focused on the specific driving conditions and likely safety problems to be encountered in the area.

Websites on major construction projects should be developed and made available through ODOT's TripCheck website as well as on websites maintained by each ODOT Region. Construction information should be easy to find and consistently presented for all projects.

Use of ITS in work zones can contribute to the safety and operation of work zones by providing tools to enhance performance of work zone management as well and contribute to the quality of the information available to travelers about traffic incidents, detours, delays. ODOT should continue to explore ways ITS can be used to enhance work zone safety and mobility.

5.0 REFERENCES

Arnold, E.D., Jr. 2003.*Use of Police in Work Zones on Highways in Virginia*. Charlottesville, Virginia: Virginia Transportation Research Council.

ARTBA (American Road & Transportation Builders Association). *Roadway workzonesafety.org: The Information Resource*. ARTBA Transportation Development Foundation, TTI, and FHWA. Accessed October 2009 at: http://www.workzonesafety.org/.

Benekohal, R.F., T.V. Resende, and R.L. Orloski. 1992. *Effects of Police Presence on Speed in a Highway Work Zone: Circulating Marked Police Car Experiment*. Urbana,IL: Department of Engineering, University of Illinois at Urbana-Champaign.

Bryden, James E. and Douglas Mace. 2002. *Guidelines for Design and Operation of Nighttime Traffic Control for Highway Maintenance and Construction*. NCHRP Report 476. Washington, D.C.: National Cooperative Highway Research Program, Transportation Research Board of the National Academies.

Chandler, Brian, Kari Beasley, and Jennifer Rephlo. 2010. *National Evaluation of the Safe Trip-21 Initiative: I-95 Corridor Coalition Test Bed, Final Evaluation Report: California Deployment of Portable Traffic-Monitoring Devices*. Washington D.C.: ITS Joint Program Office, U.S. Department of Transportation.

Cottrell, Jr. B. H. 2006. Evaluation of the AutoFlagger in Virginia. FHWA/VTRC 07-R12. Virginia Department of Transportation.

Federal Register, September 9, 2004. Volume 69, No.174. pp. 54569-54572. Part 630-Preconstruction Procedures Subpart J, Work Zone Safety and Mobility.

Federal Highway Administration (FHWA). 2009b. *2009 Work Zone Mobility and Safety Self Assessment, Oregon Summary Report*.

FHWA. 2001. *A Study on the Use of Uniformed Police Officers on Federal-Aid Highway Construction Projects*. US DOT, FHWA. Accessed in August 2009 at: http://safety.fhwa.dot.gov/wz/speed/nwzaw/index.htm

FHWA. 2009a. *Manual on Uniform Traffic Control Devices*. US DOT, FHWA.

FHWA. 2007. *Intelligent Transportation Systems for Work Zones*. US DOT FHWA. FHWA-JPO-07-003. Accessed March 2010 at: http://www.its.dot.gov/jpodocs/repts_te/14320_files/14320.pdf.

FHWA. *Benefits of Using Intelligent Transportation Systems in Work Zones*. US DOT, FHWA. FHWA-HOP-09-002. October 2008. Accessed March 2010 at: http://ops.fhwa.dot.gov/wz/its/wz_comp_analysis/comp_anl_rpt_08.pdf.

FHWA. *Making Work Zones Work Better*. US DOT, FHWA. March 2010. Accessed March 2010 at: http://ops.fhwa.dot.gov/wz/publicinfostrategies/projectlevel.htm.

FHWA. 2009c. *Work Zone Mobility and Safety Self Assessment, 2009 National Report*.

Ferguson, Mary. 2008. *Traffic Delay in Smart Work Zones, Summer and Fall 2008*. New Hampshire: Transportation Management Center, New Hampshire Department of Transportation.

Gambatese, John A. and Michael Johnson. *Work Zone Design and Operation Enhancements*, SPR Report 669. Oregon Department of Transportation, 2010.

Grillo, Lia F., Tapan K. Datta, and Catherine Hartner, Dynamic Late Lane Merge System at Freeway Construction Work Zones. *Transportation Research Record*. 2055. Washington D.C.: Transportation Research Board of the National Academies. 2008.

Hajbabaie, Ali, Rahim F. Benekohal, Madhav Vijaya Chitturi, Ming-Heng Wang, and Juan C. Medina. "Comparison of Effects of Automated Speed Enforcement and Police Presence on Speeding in Work Zones." *Transportation Research Board 88th Annual Meeting*, paper 09-3651. 2009.

Haseman, Ross J., Jason S. Watson, and Darcy M. Bullock. 2009. "Real Time Measurement of Work Zone Travel Time Delay, an Evaluation Metrics Using Bluetooth Probe Tracking". *Transportation Research Board 89th Annual Meeting*, paper 10-1442.

Indiana Department of Transportation, 2010. *Highway Safety Improvement Program*. Indiana Department of Transportation (INDOT). Accessed March 2010 at: http://www.in.gov/indot/2947.htm.

Intercept Research. 2008. *Oregon Department of Transportation, Transportation Safety Division Public Opinion Survey: Historical Question Tracking*. Survey II – August. Prepared for the Oregon Department of Transportation, Transportation Safety Division.

Intercept Research. 2009. *Public Opinion Survey, Summary and Technical Report*. Prepared for the Oregon Department of Transportation, Transportation Safety Division.

JHK & Associates. 1990. *Traffic Safety in Highway Construction Zones "Enhanced Enforcement Services"*. California State Department of Transportation.

Jones, Barnie P., A. Griffith, and K. Haas. 2002. *Effectiveness of Double Fines as a Speed Control Measure in Safety Corridors*. Salem, Oregon: Research Group, Oregon Department of Transportation.

Jones, Barnie P. and Larry Christianson. 1996. *The Effectiveness of Oregon's Workzone Safety Enforcement Program*. Salem, Oregon: Oregon Department of Transportation,

Joerger, Mark. 2010. *Photo Radar Speed Enforcement in a State Highway Work Zone: Yeon Avenue Demonstration Project*. Salem, Oregon: Research Section, Oregon Department of Transportation.

Kamyab, Ali, Tom McDonald, Brandon Storm, and Mark Anderson-Wilk. 2003. *Effectiveness of Extra Enforcement in Construction and Maintenance Work Zones*. Ames, IA: Center for Transportation Research and Education, Iowa State University.

Kwon, E., D. Brannan, K. Shouman, C. Isackson, and B. Arsenneau. 2007. Development and Field Evaluation of Variable Advisory Speed Limit System for Work Zone. *Transportation Research Record* 2015:12–18.

Li, Yingfeng and Yong Bai. Highway Work Zone Risk Factors and Their Impact on Crash Severity, *Journal of Transportation Engineering* Volume 135, No. 10, October 1, 2009 p 694-701.

LogicTree. 2008. *The Voice of 511 and Transit*. LogicTree, Corporation. Accessed March 2010 at: http://www.logictree.com/content/home.htm

McAvoy, Deborah S., Peter, T. Savolainen, Vivek Reddy, Satya V. Pinapaka, Joseph Santos, Tapan K. Datta, 2009. *Evaluation of Temporary Removable Rumble Strips for Speed Reduction*. *Transportation Research Board 88th Annual Meeting*, paper 09-1970.

McCanna, Scott M. 2009. *2009 Construction Work Zone Tour Summary Report*. Salem Oregon: Traffic Control Plans Unit, Oregon Department of Transportation.

McMurtry, Thomas, Matt Riffkin, Suellen Heath, and Mitsuru Saito, 2009. *Variable Speed Limits Signs; Effects on Speed and Speed Variation*. Transportation Research Circular Number E-C135, Maintenance Management (2009 Presentations from the 12th AASHTO-TRB Maintenance Management Conference.

Medina, Juan C., Rahim F. Benekohal, Ali Hajbabaie, Ming-Heng Wang, and Madhav Vijaya Chitturi, 2009. "Downstream Effects of Speed Photo Enforcement and Other Speed Reduction Treatments on Work Zones". *Transportation Research Board 88th Annual Meeting*, paper 09-3633.

National Work Zone Safety Information Clearinghouse (NWZSIC) website. Accessed August 2009 and September 2010. at: http:// www.workzonesafety.org

NCDOT. 2010. *Work Zone Safety: Initiatives and Campaigns*. North Carolina Department of Transportation. Accessed March 2010 at: http://www.ncdot.gov/programs/workzonesafety/initiatives/default.html.

Oregon Bridge Delivery Partners. 2008. *Context Sensitive & Sustainable Solutions (CS^3) Performance Measures Framework (Version 7).* Salem, Oregon: Oregon Bridge Delivery Partners.

Oregon Bridge Delivery Partners. 2005. *Corridor-Level Traffic Management Plan (TMP): I-84 Corridor I-5 (Portland, OR) to Idaho State Line*. Accessed July 2010 at: http://intranet.odot.state.or.us/home/mobility.htm

Oregon Department of Transportation. (2008a). *Guidelines for the Operation of Variable Message Signs on State Highways*. Salem, Oregon: Traffic-Roadway Section, Oregon Department of Transportation.

Oregon Department of Transportation. 2005. *Highway Mobility Operations Manual*, Oregon Department of Transportation. Accessed July 2010 at: http://intranet.odot.state.or.us/home/mobility.htm

Oregon Department of Transportation. (2008b*), Oregon Traffic Safety Performance Plan, Fiscal Year 2008, Annual Evaluation*. Salem, Oregon: Transportation Safety Division. Oregon Department of Transportation.

Oregon Department of Transportation, 2004. *2004 Oregon Transportation Safety Action Plan.* Salem, Oregon: Oregon Department of Transportation, Transportation Safety Division.

Oregon Department of Transportation. 2009. *Oregon Traffic Safety Performance Plan: Fiscal Year 2010.* Public Version. Salem, Oregon: Transportation Safety Division. Oregon Department of Transportation. Accessed August 2010 at: http://www.oregon.gov/ODOT/TS/docs/2010_Annual_Evaluation.pdf.

Oregon Department of Transportation. 2010. *Summer 2010 Road Projects*. Accessed August 2010 at: www.Oregon.gov/ODOT/comm/20010_ConstMap.shtml.

PennDOT. *Highway Construction Advisory Map*. 2010. Pennsylvania Department of Transportation (PennDOT). Accessed March 2010 at: http://www.dot7.state.pa.us/constructionadvisory/.

Pesti, Geza and Patrick T. McCoy. 2001. "Long-Term Effectiveness of Speed Monitoring Displays in Work Zones on Rural Interstate Highways." *Transportation Research Record*, 1754. Washington D.C.: Transportation Research Board of the National Academies.

Pietz, Amanda Joy and Myra S. Sperley. 2009. *FY 2009 Oregon Transportation Needs and Issues Survey: Summary of Statewide Results*. Salem, Oregon: Research Section, Oregon Department of Transportation.

S & C Advertising. *National PSA Campaign for Federal Highway Administration "Get the Picture. Listen to the Signs." Work Zone Safety Campaign*. 2007. Accessed March 2010 at: http://www.scpr.com/jack.htm.

Savolainen, Peter T., Deborah S. McAvoy, Vivek Reddy, Satya V. Pinapaka, Joseph P. Santos, Tapan K. Datta, 2009. "Evaluation of Motorist Awareness Survey." *Transportation Research Board 88th Annual meeting*, paper 09-1968. 2009.

Skabardonis, Alexander, Ching-Yao Chan, Susan Shaheen, and Caroline Rodier. 2009. *Coordinated Speed Management Systems to Reduce Speed-Related Crashes on Rural Roadways: Augmented Speed Enforcement (aSE)Work Plan*. California Department of Transportation.

Solsby, Jeff and Sant, Brad. 2009. *2009 "Work Zone Safety Awareness Award" Winners*. American Road and Transportation Builders Association, Transportation Development Association (ARTBA-TDF). Accessed August 2009 at http://www.artba.org/article/2009-work-zone-safety-awareness-award-winners/.

Ullman, G.L., Michael D. Fontaine, Steven D. Schrock, and Poonam B. Wiles. 2001, *A Review of Traffic Management and Enforcement Problems and Improvement Options at High-Volume, High-Speed Work Zones in Texas*. College Station, Texas: Texas Transportation Institute.

Ullman, Gerald L., Steven D. Schrock, Marcus A. Brewer, Param Sankar, James E. Bryden, Mike Corkran, and CW Hubbs. 2006. *Traffic Enforcement Strategies in Work Zones.* Interim Report for NCHRP 3-80, Texas Transportation Institute.

Ullman, Gerald L., Marcus A. Brewer, James E. Bryden, Michael O. Corkran, C.W. Hubbs, Andre K. Chandra, and Krista L. Jeannotte. 2010. *Guidelines for the Use of Traffic Law Enforcement in Work Zones*, College Station, Texas: Texas Transportation Institute.

Washington Traffic Safety Commission. 2009. *Washington State Highway Safety Performance Plan*. Version 2.0. Accessed online March 2010 at: http://www.wtsc.wa.gov/documents/hsp2010.pdf.

WSDOT. 2009. *Work Zone Traffic Control Guidelines*. M 54-44.03. Washington Department of Transportation (WSDOT), Maintenance and Operations Division, Traffic Operations. Accessed March 2010 at: http://www.wsdot.wa.gov/publications/manuals/fulltext/M54-44/Workzone.pdf.

WSDOT. 2010. *Drivers Education Training*. Washington Department of Transportation (WSDOT). Accessed March 2010 at: http://www.wsdot.wa.gov/Safety/WorkZones/driversed.htm.

Wang, Chunyan, Karen K. Dixon, and David Jared. 2003. Evaluating Speed Reduction Strategies for Highway Work Zones. *Transportation Research Record*. 1824. Washington D.C.: Transportation Research Board of the National Academies.

APPENDIX A:
OREGON STATUTES RELATING TO HIGHWAY WORK ZONES

811.230 Definitions; fine; notice. (1) As used in ORS 811.230, 811.231, 811.232 and 811.233:

(a) "Flagger" means a person who controls the movement of vehicular traffic through construction projects using sign, hand or flag signals.

(b) "Highway work zone" means an area identified by advance warning where road construction, repair or maintenance work is being done by highway workers on or adjacent to a highway, regardless of whether or not highway workers are actually present. As used in this paragraph, "road construction, repair or maintenance work" includes, but is not limited to, the setting up and dismantling of advance warning systems.

(c) "Highway worker" means an employee of a government agency, private contractor or utility company working in a highway work zone.

(2)(a) The base fine amount for a person charged with an offense that is listed in subsection (3)(a) or (b) of this section and that is committed in a highway work zone shall be the amount established under ORS 153.125 to 153.145 based on the foundation amount calculated under ORS 153.131. The minimum fine for a person convicted of an offense that is listed in subsection (3)(a) or (b) of this section and that is committed in a highway work zone is the base fine amount so calculated.

(b) The minimum fine for a person convicted of a misdemeanor offense that is listed in subsection (3)(c) to (g) of this section and that is committed in a highway work zone is 20 percent of the maximum fine established for the offense.

(c) The minimum fine for a person convicted of a felony offense that is listed in subsection (3)(c) to (g) of this section and that is committed in a highway work zone is two percent of the maximum fine established for the offense.

(3) This section applies to the following offenses if committed in a highway work zone:

(a) Class A or Class B traffic violations.

(b) Class C or Class D traffic violations related to exceeding a legal speed.

(c) Reckless driving, as defined in ORS 811.140.

(d) Driving while under the influence of intoxicants, as defined in ORS 813.010.

(e) Failure to perform the duties of a driver involved in an accident or collision, as described in ORS 811.700 or 811.705.

(f) Criminal driving while suspended or revoked, as defined in ORS 811.182.

(g) Fleeing or attempting to elude a police officer, as defined in ORS 811.540.

(4) A court shall not waive, reduce or suspend the base fine amount or minimum fine required by this section.

(5) When a highway work zone is created, the agency, contractor or company responsible for the work may post signs designed to give motorists notice of the provisions of this section. [1995 c.253 §2; 1997 c.843 §3; 1999 c.1051 §292]

811.231 Reckless endangerment of highway workers; penalties. (1) A person commits the offense of reckless endangerment of highway workers if the person drives a motor vehicle in a highway work zone in such a manner as to endanger persons or property or if the person removes, evades or intentionally strikes a traffic control device in a highway work zone. (2) Reckless endangerment of highway workers is a Class A misdemeanor. In addition to any other penalty, a person convicted of reckless endangerment of highway workers is subject to suspension of driving privileges as provided in ORS 809.411 (6). [1995 c.253 §3; 1997 c.83 §4; 2001 c.176 §7; 2003 c.402 §38]

811.232 Refusing to obey flagger; penalty. (1) A person commits the offense of refusing to obey a flagger if the person intentionally and unreasonably disobeys a lawful order by a flagger relating to driving a motor vehicle in a highway work zone. (2) Refusing to obey a flagger is a Class A traffic violation. [1995 c.253 §4]

811.233 Failure to yield right of way to highway worker; penalty. (1) A person commits the offense of failure to yield the right of way to a highway worker who is a pedestrian if the person is operating a motor vehicle in a highway work zone and does not yield the right of way to a highway worker who is a pedestrian. (2) The provisions of ORS 814.040 and 814.070 regarding pedestrians do not apply to pedestrians described in subsection (1) of this section.

(3) The offense described in this section, failure to yield the right of way to a highway worker who is a pedestrian, is a Class B traffic violation. [1997 c.843 §2]

Trial program allowing use of photo radar in highway work zones

Note: Sections 4, 5 and 6, chapter 634, Oregon Laws 2007, provide:

Sec. 4. Highway work zone. (1) The Department of Transportation may operate photo radar within a highway work zone that is located on a state highway, except for a highway work zone located on an interstate highway.

(2) The department, at its own cost, may ask a jurisdiction authorized to operate photo radar under ORS 810.438 (1) or the Oregon State Police to operate a photo radar unit in a highway work zone on a state highway, except for a highway work zone located on an interstate highway.

(3) A photo radar unit operated under this section may not be used unless a sign is posted announcing that photo radar is in use. The sign posted under this subsection must be all of the following:

(a) Located on the state highway on which the photo radar unit is being used.

(b) Between 100 and 400 yards before the location of the photo radar unit.

(4) The department shall, once each biennium, conduct a process and outcome evaluation for the purposes of subsection (5) of this section that includes:

(a) The effect of the use of photo radar on traffic safety;

(b) The degree of public acceptance of the use of photo radar; and

(c) The process of administration of the use of photo radar.

(5) The department shall report to the Legislative Assembly by March 1 of each odd-numbered year.

(6) As used in this section, "highway work zone" has the meaning given that term in ORS 811.230. [2007 c.634 §4]

Sec. 5. Highway work zone; citation. (1) Notwithstanding any other provision of law, when a jurisdiction or the Oregon State Police uses photo radar in a highway work zone:

(a) A citation for speeding may be issued on the basis of photo radar if the following conditions are met:

(A) The photo radar unit is operated by a uniformed police officer.

(B) The photo radar unit is operated out of a marked police vehicle.

(C) An indication of the actual speed of the vehicle is displayed within 150 feet of the location of the photo radar unit.

(D) The citation is mailed to the registered owner of the vehicle within six business days of the alleged violation.

(E) The registered owner is given 30 days from the date the citation is mailed to respond to the citation.

(F) One or more highway workers are present. For the purposes of this subparagraph, "highway workers" has the meaning given that term in ORS 811.230.

(G) The jurisdiction operating photo radar complies with the requirements described in section 4 of this 2007 Act.

(b) A rebuttable presumption exists that the registered owner of the vehicle was the driver of the vehicle when the citation is issued and delivered as provided in this section.

(c) A person issued a citation under this subsection may respond to the citation by submitting a certificate of innocence or a certificate of nonliability under subsection (3) of this section or may make any other response allowed by law.

(2) A citation issued on the basis of photo radar may be delivered by mail or otherwise to the registered owner of the vehicle or to the driver. The citation may be prepared on a digital medium and the signature may be electronic in accordance with the provisions of ORS 84.001 to 84.061.

(3)(a) A registered owner of a vehicle may respond by mail to a citation issued under subsection (1) of this section by submitting, within 30 days from the mailing of the citation, a certificate of innocence swearing or affirming that the owner was not the driver of the vehicle and by providing a photocopy of the owner's driver license. A jurisdiction that receives a certificate of innocence under this paragraph shall dismiss the citation without requiring a court appearance by the registered owner or any other information from the registered owner other than the swearing or affirmation and the photocopy. The citation may be reissued only once, only to the registered owner and only if the jurisdiction verifies that the registered owner appears to have been the driver at the time of the violation. A registered owner may not submit a certificate of innocence in response to a reissued citation.

(b) If a business or public agency responds to a citation issued under subsection (1) of this section by submitting, within 30 days from the mailing of the citation, a certificate of nonliability stating that at the time of the alleged speeding violation the vehicle was in the custody and control of an employee, or was in the custody and control of a renter or lessee under the terms of a rental agreement or lease, and if the business or public agency provides the driver license number, name and address of the employee, renter or lessee, the citation shall be dismissed with respect to the business or public agency. The citation may then be issued and delivered by mail or otherwise to the employee, renter or lessee identified in the certificate of nonliability.

(4) If the person named as the registered owner of a vehicle in the current records of the Department of Transportation fails to respond to a citation issued under subsection (1) of this section, a default judgment under ORS 153.102 may be entered for failure to appear after notice has been given that the judgment will be entered.

(5) The penalties for and all consequences of a speeding violation initiated by the use of photo radar are the same as for a speeding violation initiated by any other means.

(6) A registered owner, employee, renter or lessee against whom a judgment for failure to appear is entered may move the court to relieve the registered owner, employee, renter or lessee from the judgment as provided in ORS 153.105 if the failure to appear was due to mistake, inadvertence, surprise or excusable neglect.

(7) As used in this section, "highway work zone" has the meaning given that term in ORS 811.230. [2007 c.634 §5]

Sec. 6. Sections 4 and 5 of this 2007 Act are repealed on December 31, 2014. [2007 c.634§6]

APPENDIX B:
WORK ZONE LEGISLATION BY STATE

Enhanced Fines

State	Citation (with link to full text)	Violations Affected	Workers Must be Present	Type of Enhanced Fine	
				Fixed ($)	Multiple of Original Fine
Alabama	Code of Ala. § 32-5A-176.1	speeding	yes	---	2X
Alaska	Alaska Stat. § 28.90.030	all traffic violations	no	---	2X
Arizona	A.R.S. § 28-710	speeding	yes	---	2X
Arkansas	A.C.A. § 27-50-408	moving traffic violations	yes	---	2X
California	Cal Veh Code § 42009	numerous violations specified	yes	---	2X
Colorado	C.R.S. 42-4-1701	all traffic violations	no	---	2X
Connecticut	Conn. Gen. Stat. § 14-212a	all moving vehicle violations	yes	---	2X
Delaware	21 Del. C. § 4105	numerous violations specified	no	---	no less than 2X for a 1st offense
Florida	Fla. Stat. § 318.18	speeding	yes	---	2X
Georgia	O.C.G.A. § 40-6-188 (Amended by HB 296)	speeding	yes	$100-$2000, up to 12 months jail, or both	---
Hawaii	HRS § 291C-104	speeding	no	$250	---
Idaho	Idaho Code § 49-657	speeding	no	$50	---
Illinois	625 ILCS 5/11-605.1	speeding	no	$375 for a first offense and $1000 for subsequent offenses	---
Indiana	IC 9-21-5-11	speeding	no	$300 for a first offense. $500 for a second offense and $1,000 for a third offense within three years.	---
Iowa	Iowa Code § 805.8A	all moving vehicle violations	no	---	Traffic violations other than speeding: 2X Speeding violations: up to $1000
Kansas	K.S.A. § 8-2004	all moving vehicle violations	no	---	2X
Kentucky	KRS § 189.394	speeding	no	---	2X
Louisiana	La. R.S. 32:57	speeding	yes	---	2X
Maine	29-A M.R.S. § 2075	speeding	no	---	2X
Maryland	Md. TRANSPORTATION Code Ann. § 27-101	speeding	no	up to $1,000	

Massachusetts	ALM GL ch. 90, § 17	speeding	no	---	2X
Michigan	MCLS § 257.601b & MCL § 257.320a	all moving vehicle violations	no	---	2X + not fewer than 3 points
Minnesota	Minn. Stat. § 169.14	speeding	yes	---	2X or X+$25 (whichever larger)
Mississippi	Miss. Code Ann. § 63-3-516	speeding	yes	---	$250 for a first offense and 2X for subsequent offenses
Missouri	§ 304.582 R.S.Mo.	speeding or passing	yes	---	$250 +X for a first offense; $300 for subsequent offenses
Montana	Mont. Code Anno., § 61-8-314(5)(a)	all traffic violations	yes	---	2X
Nebraska	R.R.S. Neb. § 60-682.01	speeding	no	---	2X
Nevada	NRS 484B.130	speeding	yes	---	2X up to a total of $1000, 6 months jail or 120 hrs. community service
New Hampshire	RSA 265:6-a	speeding	yes	$250-$500	---
New Jersey	N.J. Stat. § 39:4-203.5	all moving vehicle violations	no	---	2X
New Mexico	N.M. Stat. Ann. § 66-7-301	speeding	no	---	2X
New York	NY CLS Veh & Tr § 1180	speeding	no	---	$90-$600, up to 30 days jail, or both
North Carolina	N.C. Gen. Stat. § 20-141 (Amended by SB 649)	speeding	no	---	X+$250
North Dakota	N.D. Cent. Code. § 39-06.1-06	speeding	yes	Minimum $80	---
Ohio	ORC § 4511.21(P)(3) & ORC 4511.98	speeding	yes	---	2X
Oklahoma	47 Okl. St. § 11-806	speeding	yes	---	2X
Oregon	ORS § 811.230	numerous violations specified	no	---	minimums: misdemeanor, 20% of max. penalty; felony, 2% of max. penalty
Pennsylvania	75 Pa.C.S. § 3326	numerous violations specified	yes	---	2X
Rhode Island	R.I. Gen. Laws § 31-14-12.1	speeding	no	---	2X
South Carolina	S.C. Code Ann. § 56-5-1535	speeding	no	$75-$200, up to 30 days jail, or both	---
South Dakota	S.D. Codified Laws § 32-25-19.1 & § 22-6-2	speeding	yes	---	2X up to $500, 30 days jail, or both

Tennessee	Tenn. Code § 55-8-152(f)(2) & § 55-8-153(e)	speeding	yes	$250-$500	---
Texas	Tex. Transp. Code § 542.404	all moving vehicle violations	yes	---	2X of min. and max. applicable
Utah	Utah Code Ann. § 41-6a-209	speeding	yes	---	at least 2X
Vermont	23 V.S.A. § 1010	speeding	no	---	2X
Virginia	Va. Code Ann. § 46.2-878.1	speeding	yes	up to $500	---
Washington	Rev. Code Wash. (ARCW) § 46.61.527	speeding	no	---	2X
West Virginia	W. Va. Code § 17C-3-4b	speeding	yes	up to $200, 20 days jail, or both	---
Wisconsin	Wis. Stat. § 346.17-346.65	numerous violations specified	yes	---	2X of min. and max. applicable
Wyoming	Wyo. Stat. § 31-5-1201	speeding	---	$100[a]	---

[a] Applies to speeding violations while operating a vehicle or combination of vehicles with a gross vehicle weight or gross vehicle weight rating exceeding twenty-six thousand (26,000) pounds.

Last modified 6/17/2010
Accessed 9/21/2010

Additional Legislation

State	Type of Law	Citation (with link to full text)	Comments
Connecticut	Endangerment of a highway worker	Public Act No. 08-114	Endangerment of a highway worker - fine of up to $1,000. Aggravated endangerment of a highway worker - fine of up to $5,000 for injuring a highway worker and $10,000 for the death of a highway worker.
Illinois	Reckless homicide in a construction or maintenance zone	Public Act 095-0587	Reckless homicide of a construction worker - 3-14 years in prison. Reckless homicide of two or more construction workers - 6 to 28 years in prison.
Indiana	Aggressive driving and reckless endangerment of workers in a highway work zone	IC 9-21-8-56	Class A misdemeanor for reckless or aggressive driving: one year in prison and up to a $5,000 fine. Class D felony for injuring a worker: three years in prison and a $10,000 fine. Class C felony for killing a worker: eight years in prison and up to $10,000 in fines.
Kentucky	Reduce WZ speed limits without traffic and engineering investigation	KRS, Chapter 37, Sec. 4.189. 390 (4)(b) (HB 137)	Effective when and where signs are posted.
Maine	Reduce WZ speed limits without traffic and engineering investigation	MS Sec. 1.29-A, MRSA 2027, sub(2)	WZ speed limits can be set between 25 and 55 mph. Max. speed limit reduction allowed is 10 mph.
Michigan	Reckless endangerment of workers in a roadway construction zone	Public Acts of 2008	Penalties for causing injury - maximum fine of $1,000 or up to 1 year in prison, or both. Penalties for causing death - maximum fine of $7,500 or up to 15 years in prison, or both.

Minnesota	Reduce WZ speed limits without traffic and engineering investigation	MS 169.14 Subd. 5d	WZ speed limits can be set between 20 and 40 mph. Max. speed limit reduction allowed is 15 mph.
Montana	Set WZ speed limits without traffic and engineering investigation	MCA 61-8-314 (3)	The speed limit in a construction zone or in a work zone must be set by the DOT or the local authority based on traffic conditions or the condition of the construction, repair, maintenance, or survey project.
Montana	Reckless endangerment of highway workers	MVC 61-8-315 (definition), 61-8-715 Penalty	Misdemeanor - 90 days in jail and/or a fine of not less than $25 nor more than $300.
Nebraska	Reduce WZ speed limits without traffic and engineering investigation	Sec. 9-Sec. 60-6, 188(1)(2)(3)(4)	Statutory speed limits in WZ are 25 and 35 mph in urban and rural areas. DOT supervisors can raise limits above statutory levels (up to normal speed limits for that roadway) as they deem appropriate.
Oregon	Reckless endangerment of highway workers	MVC 811.231 (1)(2)	Class A misdemeanor - max. fine of $5,000 or 1 year jail.
Oregon	Refusing to obey a flagger	MVC 811.232 (1)(2)	Class A traffic violation
Rhode Island	Reduce WZ speed limits without traffic and engineering investigation	MVC Sec. 31-14-12.1	Effective when and where signs are posted.
South Dakota	Authorize agents of employees of DOT to issue citations for speeding violations within WZ.	Sec 1, Chap. 32-33 new section (HB 1273)	Workers must be present, and signs indicating work area required.
Utah	Obedience to peace officer or other traffic controllers in construction or maintenance zones.	To amend Chapter 138, Section 1, Sec. 41-5-13(1)	A person may not willfully fail or refuse to comply with any lawful order or direction of peace officer, fireman, flagger at a highway WZ.
Washington	Reckless endangerment of highway workers in a roadway construction zone	RCW 46.61, Sec.1 (4)(5)	Gross misdemeanor - maximum fine of $5,000 or 1 year jail, or both.

Last modified 10/20/2008.

http://www.workzonesafety.org/laws/state_laws (accessed 8/5/2009) Revised to correct ORS reference to offense of Refusing to obey a flagger.

APPENDIX C:
PROJECT SELECTION CRITERIA FOR WORK ZONE ENFORCEMENT USED BY OTHER STATES

Wisconsin Project Selection Criteria for Work Zone Enforcement

DTD - Law Enforcement Mitigation Guidelines

Projects that meet the following criteria "MAY" be considered for Law Enforcement Mitigation Funding.

A. Existing Two-Lane Non-Divided Highways.

NHS (National Highway System Highways)
AADT ≥ 4500
Reconstruction type projects and possible bridge type projects depending on type bridge improvements, Open to thru traffic.
Posted speed ≥ 45 mph
Length ≥ 5.0 miles for highway projects. (No minimum length for bridge projects)

NON-NHS(Non-National Highway System Highways)
AADT ≥ 7000
Reconstruction type projects and possible bridge type projects depending on type bridge improvements, Open to thru traffic.
Posted speed ≥ 45 mph
Length ≥ 5.0 miles for highway projects. (No minimum length for bridge projects)

B.Existing Four-Lane Non-Divided Highways.

NHS
AADT ≥ 10000
Reconstruction type projects and possible bridge type projects depending on type bridge improvements. Open to thru traffic.
Posted speed ≥ 45 mph
Length ≥ 2.5 miles for highway projects. (No minimum length for bridge projects)

C. Existing Four-Lane Divided Highways. (Expressways or Freeways)

NHS
Posted speed ≥ 50 mph
Length ≥ 5.0 miles for highway projects. (No minimum length for bridge projects)
AADT No limit – The fact that it is an expressway or freeway negates a AADT limit.
Projects have to have a total minimum capacity reduction of 50 % (e.g., Counterflow , two out of four lanes closed), or possible bridge type projects depending on type bridge improvements, or have peak hour volumes ≥ 1500 vph per lane for lanes open to traffic during the project.

D. Existing Six-Lane Divided Highways

NHS
Length ≥ 3.0 miles for highway projects. (No minimum length for bridge projects)
Posted speed ≥ 50 mph
AADT No limit – The fact that it is an expressway or freeway negates an AADT limit.
Projects have to have a total minimum capacity reduction of 33 % or more (e.g., Counterflow , two out of 6 lanes closed), or possible bridge type projects depending on type bridge improvements, or have peak hour volumes => 1500 vph per lane for lanes open to traffic during the project.

Source: Ullman et al. 2006

Maryland State Highway Administration
MARYLAND STATE POLICE
-CRITERIA FOR USE-

The use of off-duty Maryland State Police (MSP) and their vehicles may be used to enhance the safety of our employees, the contractor's employees, and/or the traveling public.

The District Engineer (or other SHA Senior Manager) or his/her designee must approve any use of MSP by affixing their signature to this criteria indicating the reason for their use.

Additionally, the use of MSP must be reported to the Chief Engineer's office as well as the Office of Traffic and Safety upon approval of the District Engineer.

Justification for Request:

- ☐ Major construction projects.
- ☐ Full roadway or major ramp closures on expressways/freeways required for temporary maintenance.
- ☐ Closure of two or more lanes on urban freeways or expressways.
- ☐ To complement reduced speed signs where reduced speed is desired.
- ☐ Work zone situations involving short term or momentary traffic flow disruptions such as those caused by the erection of overhead structures, the moving of large construction equipment, and signal swap-overs along busy arterials.
- ☐ Work areas in which driver error and/or inattentiveness may result in erratic maneuvers, such as those involving temporary median crossover, temporary bypass roads, areas with new and / or unusual traffic patterns.
- ☐ Other: _____

_____

Approval

Date of Request: _____

Job Date: _____ Number of Troopers Requested: _____

Beginning Time: _____ AM PM Ending Time: _____ AM PM

Project Location: _____

Recommended by: _____ Approval by: _____
(District Engineer)

Title: _____

Date: _____ Date: _____

For Office Use Only

SHA FMIS Number: _____ MSP Z-Number: _____

MSP Barrack Contacted: _____ MSP Contact Person: _____

MSP Available: Yes ____ No ____ If no, Department of Local Police Contacted: _____

cc: Chief Engineer for Operations
Director, Office of Traffic and Safety

Source: Ullman et al 2006

WSDOT Form 421-045 EF, "WSP Field Check List"

Washington State Department of Transportation

WSP Field Check List

Today's Date:

To be Completed by WSDOT Inspector

Contract No.	SR

	Begin WSP Shift	End WSP Shift
Date		
Time	○ AM ○ PM	○ AM ○ PM

Milepost From To

Title

Project Engineer	WSP Task Order No.
WSDOT Onsite Contact	Field Phone (include area code)
Traffic Control Strategy Meeting Location	Attended By

Traffic Control Strategy (*review with WSP officer*)

To be Completed by WSP Officer - ***Return Completed Form to WSDOT Inspector***

Percent of Time	Duties
_____	Assistance in traffic control setup and takedown (blue lights)
_____	Passive presence (yellow lights)
_____	Proactive patrol in work zone (blue lights)
_____	Ramp closures (yellow lights)
_____	Lane closure (yellow lights)
_____	Road closure (yellow lights)
_____	Detours (yellow lights)
_____	Other duties as outlined in Strategy Session (above)

Is a second officer needed for similar work in the future? ☐ Yes ☐ No

Suggestions For Traffic Control Improvements (mandatory):

Total Violators Contacted	No. of Accidents Within Work Zone

WSP Officer Name	WSP Badge No.

Source: Ullman et al 2006

APPENDIX D
SELECTIONS FROM OREGON WORK ZONE ENFORCEMENT GUIDELINES

WORK ZONE ENFORCEMENT PROJECT WORK PLAN

In 2008, work zone related traffic fatalities on Oregon roadways were responsible for the loss of 6 lives however; one year earlier in 2007 the number of lives lost equaled 11. Fatalities in work zones fluctuates annually, however work zone related crashes are on the rise and the majority occur on state highways. Work zone related crashes were at 532 in 2006 and have risen to 591 in 2007. Roadway construction continues to be on the rise and will continue at this increased rate for at least the next couple years.

Oregon 2009 Work Zone Safety Stat Sheet				
Year	**Work Zone Involved Fatalities * & ** **	**Work Zone Involved Crashes****	**Construction $$*** In Millions**	**% Change in $**
1985	3	N/A	149.7	N/A
1986	3	389	166.2	11%
1987	3	417	158.9	-4%
1988	8	446	240.8	52%
1989	6	492	230.6	-4%
1990	2	504	283.3	23%
1991	9	371	209.6	-26%
1992	2	429	195.1	-7%
1993	12	416	278	42%
1994	19	447	230.7	-17%
1995	5	488	225.7	-2%
1996	10	549	243	8%
1997	21	376	264.7	9%
1998	14	492	276.5	4%
1999	9	417	304.5	10%
2000	6	351	273.3	-10%
2001	5	324	241.7	-12%
2002	5	421	250.7	4%
2003	2	514	342	36%
2004	12	493	421.4	23%
2005	20	512	411.4	-2%
2006	5	532	452.2	10%
2007	11	591	519.9	15%
2008 Prelim.	6	unknown		
Total to Date Prelim.	**198**	**9,951**		

** FARS (Fatality Analysis Reporting System) 1994 to 2006*

***CARS (ODOT Crash Analysis and Reporting Section) 1985 to 1993*

****1985-1993 Original Construction Authorization awarded per calendar year, 1994-2006 Construction payments made to Contractors per calendar year (Construction Contract Administration)*

It's important to remember that since there's still an increase in construction projects and most of today's construction work is performed "under traffic" the risk of exposure is still on the rise for drivers, their passengers, construction workers and enforcement personnel. Federal studies show that work zone crashes tend to be more severe than other types of crashes. It's also important to note that over 40 percent of work zone crashes occur in the transition zone prior to the work area. Thus, it's a priority to get the vehicles slowed down as early as possible when entering the work zone.

Under the work zone enforcement grants ODOT will enlist the forces of state and local law enforcement agencies as authorized by ODOT and in compliance with the provisions of local cooperative policing agreements to patrol specified work zones on State highways. Grantees will operate according to processes and procedures outlined in the 2009-2011 Work Zone Enforcement Guidelines and its modifications as necessary.

Project Objectives

- Increase driver attentiveness.
- Reduce traffic related deaths and injuries in roadway work zones by reducing average speeds through these zones.
- Concentrate on reducing vehicle speeds within the transition zone prior to the work area and throughout the work zone.
- Provide information to local media sources.

Project Operation

Law enforcement is hired typically on an overtime hourly basis to patrol ODOT road construction projects. These projects must meet federal design and construction standards to be eligible for federal participation and reimbursement for enforcement. The projects may be state or federally funded projects. Maintenance projects are not eligible.

The program is paid for with Federal Highway Administration Funds. It's a statewide program operated on a biennial budget authorization though the Oregon Transportation Commission. Funds are not tied to specific projects. The entire work zone budget for the 2009-2011 biennium is approximately $3.6M for education, enforcement, and equipment. This budget includes some of the program match. Funds are split out to ODOT Regions and the Oregon Bridge Development Unit (OBDU) based on work zone enforcement needs identified by Region/OBDU staff, consultants and state/local enforcement agencies.

Work zone enforcement construction project identification and coordination for ODOT's Region managed construction projects are the responsibility of the Region Transportation Safety Coordinator or within Region 1 the Region 1 Work Zone Coordinator.

Work zone enforcement project identification and coordination for ODOT's OBDU and their consultant Oregon Bridge Delivery Partners (OBDP) construction projects are the responsibility of the OBDU Senior Construction Engineer, OBDU Designee, OBDP's Construction Manager, and OBDP's Construction Coordinators.

This agreement is primarily with the Oregon State Police, although funds may be used to fund other local police agencies within the provisions of local cooperative policing agreements. As stewards of the state highway system, OSP will have the first opportunity to cover the enforcement need in work zones on state highways up to the amount of their budget limitation. If the work zone is on a state highway, located within a City or County, OSP may be notified that patrol hours are available as long as OSP budget limitation exists. If OSP indicates they will not be able to cover the identified enforcement or they do not typically enforce in this area the enforcement hours may be offered to the local police department (PD) or sheriff's office (SO).

Reimbursable work zone activities:

- Reimbursement will be available at various percentages based on the individual OSP or local police agency grant negotiations and will be identified within the Grant Agreement.
- The total reimbursable grant amount must be matched with a non reimbursable match amount of 16.27 percent.
- Direct travel from police station headquarters to a project, or in-between projects, shall ideally not be more than a maximum of 20 percent of the total hours of patrol efforts provided for that shift. *Thus, an 8 hour patrol effort ideally will not have more than an additional 1.6 hours of associated travel time.* Travel claimed separately on a Monthly Construction Zone Project Report form (MCZPR) will be reimbursable at the same rate incurred (regular or overtime.) The final decision regarding the amount of travel time allowed on a per project basis will be at the discretion of the ODOT Region Transportation Safety Coordinator, ODOT Region 1 Work Zone Coordinator, or the OBDU Designee.
- Reimbursable patrol under this grant is to be within 1-5 miles either side of the official work zone.
- Traffic stops resulting from these dedicated work zone patrols.

- Response to crashes, obstructions, incidents, or disabled vehicles that adversely affect traffic through the work zone.
- Administrative time spent by the enforcement agency in relation to the projects and program as long as the administrative time is not already loaded into the enforcement agency billing rates. Administrative costs shall not exceed ten percent of total costs for a Monthly Construction Zone Project Report (MCZPR) form and will be reimbursable at the same rate as incurred by the enforcement agency (regular/overtime). Administrative activities eligible for reimbursement include:
    - Supervisory documentation of grant hours and activities.
    - Program level enforcement consultation with ODOT/OBDU/OBDP personnel.
    - Scheduling and coordinating enforcement patrols, billings etc.
    - Coordination of public safety announcements with news media.

Non-reimbursable work zone enforcement activities shall include

- Enforcement at work sites not approved by ODOT/OBDU/OBDP.
- Time spent on unrelated service calls.
- Match at 16.27 percent of the total grant amount.

Responsibilities

Program responsibilities have been divided into four sections:

- ODOT Transportation Safety Division.
- ODOT Region Transportation Safety Coordinator, ODOT Region 1 Work Zone Coordinator, OBDU Senior Construction Engineer, OBDU Designee, and OBDP Construction Manager.
- ODOT Construction Project Manager or Consultant Project Manager and OBDU/P Construction Manager or Construction Coordinators.
- Enforcement Agency.

ODOT Transportation Safety Division:

- Develop grant documents as necessary.
- Monitor program and budget at statewide level.
- Revise program scope as necessary.
- Adjust Region and OBDU budget allocations as needed.

- Track total program expenditures and budgets.
- Partner with FHWA.
- Develop and administer Work Zone Public Information and Education Program statewide.
- Work with ODOT Headquarters and Region, OBDU/P, OSP and local police agency public information representative(s) to provide information to statewide media.
- Work with statewide media to promote work zone enforcement, education, and EMS awareness.
- Process and authorize various program documents in a timely manner.
- Operate according to project guidelines outlined in official grant document including the 2009-2011 Work Zone Enforcement Guidelines and its modifications as necessary.
- Raise safety concerns in work zones up the ODOT chain of command if issues are not dealt with in a timely, appropriate and safe manner.

ODOT Region Transportation Safety Coordinator (RTSC), ODOT Region 1 Work Zone Coordinator, OBDU Senior Construction Engineer, OBDU Designee, and OBDP Construction Manager:

- Develop annual and biennial enforcement plan/project lists and budget in coordination and partnership with ODOT Construction Project Managers, Consultant Project Managers, OBDP Construction Manager/Coordinators and state/local law enforcement or their designees.
- Allocate enforcement hours and update project list and allocations as needed.
- Monitor work zone enforcement program status at Region/OBDU/P level
- Work with ODOT Region, OBDU/P, OSP and local police agency public information representative(s) to provide information to local media.
- Work with local media as possible to promote work zone enforcement, education, and EMS awareness.
- Process and authorize various program documents in a timely manner.
- Operate according to project guidelines outlined in official grant document including the 2009-2011 Work Zone Enforcement Guidelines and its modifications as necessary.
- Track expenditure of enforcement hours by project.
- Meet regularly with project and enforcement staff to assess program and project progress and needs.

- Maintain the various processes and forms identified within the 2009-2011 Work Zone Enforcement Guidelines to provide consistency throughout the state.
- Raise safety concerns in work zones up the ODOT or OBDP chain of command if issues are not dealt with in a timely, appropriate and safe manner.

ODOT Construction Project Manager or Consultant Project Manager and OBDP Construction Manager or OBDP Construction Coordinators:

- Coordinate individual project work schedules with enforcement agency(s), Region Transportation Safety Coordinators, Region 1 Work Zone Coordinator and OBDU Designee.
- Schedule specific overtime enforcement needs through a completed Work Zone Enforcement Request (WZER) form ideally 3 months prior to construction start date. Two weeks prior to construction start date, at a minimum, police should be contacted to start the development of the overtime shift schedule development.
- Consider provision of safe enforcement areas such as "launch pads" and pull-outs when possible within specific work zones. Encourage the use of Class III safety apparel at all times.
- Monitor roadway and shoulder areas for debris including gravel which could be hazardous to police motorcycle patrols.
- Process and authorize various program documents in a timely manner.
- Encourage notation of presence of patrols on construction Daily Progress Reports or similar logs when possible.
- Encourage cooperative working relationship between Contractor, Inspector, Work Zone Traffic Control Supervisor and police agencies in order to perform construction and enforcement functions in the safest manner possible.
- Operate according to project guidelines outlined in official grant document including the 2009-2011 Work Zone Enforcement Guidelines and its modifications as necessary.
- Work with ODOT Region, OBDU/P, OSP and local police agency public information representative(s) to provide information to local media.
- Work with local media as possible to promote work zone enforcement, education, and EMS awareness.
- Raise safety concerns in work zones up the ODOT or OBDP chain of command if issues are not dealt with in a timely, appropriate and safe manner.

Enforcement Agency

- Provide for staffing per agreed Enforcement Plan and/or finalized WZER forms.
- Provide 16.27 percent match.
- Provide high visibility/high contact enforcement effort while patrolling under this grant and while performing match patrol hours under this grant.
- Work with ODOT and OBDU/P to identify alternative law enforcement resources if OSP is unable to provide services.
- Contact ODOT Construction Project Manager/Consultant Project Manager; or OBDP Construction Manager/Construction Coordinators to alert of work zone safety issues. In emergencies contact the Region Dispatch Office or in Region 1 the Traffic Management Operations Center as noted in the 2009-2011 Work Zone Enforcement Guidelines.
- Raise safety concerns in work zones up the ODOT or OBDU/P chain of command if issues are not dealt with in a timely, appropriate and safe manner.
- Document information requested on the MCZPR forms and submits MCZPR forms per work zone project for approval monthly to the contact noted on the WZER forms. These forms may be modified as deemed necessary by TSD.

The 16.27 percent Match may be provided in various forms as agreed upon and documented within the Grant Agreement. Examples include but are not limited to:

Option A: Provide 16.27 percent match in documented straight time enforcement ideally on a monthly basis and based on the amount of overtime funds provided on each work zone.

Option B: provide the overtime billings for enforcement to ODOT with a requested reimbursement of 83.73 percent. No straight time reporting is necessary with this option.

Option C: Provide 16.27 percent match in documented straight/overtime court appearances on work zone citations directly related from this grant.

Required documentation for reimbursable grant funds and/or the 10.27 percent “hard match” if the match is provided as enforcement hours:

Officer name,

Calendar day,

# of overtime or match hours provided,

Hourly shift worked or similar notation,

# of citations,

# of warnings,

Significant issues occurring during the shift or Other activities, and,

At what hourly rate e.g. OT, Straight Time and if Travel Time or Administrative Time,

Required documentation for the 6 percent "soft match" requirement is as follows if the match is provided as enforcement hours:

Officer name,

Calendar day,

# of match hours provided,

# of citations,

# of warnings,

Significant issues occurring during the shift or Other activities,

Note the hourly rate is Match, and,

At what hourly rate e.g. OT, Straight Time and if Travel Time or Administrative Time.

- Working with other parts of the enforcement agency regarding resource needs, if applicable.
- Maintaining project files for federal and state audit purposes.
- Processing and authorizing various program documents in a timely manner.
- Participating in project design or work zone evaluation meetings as requested, pending availability.
- Working with ODOT Region, OBDU/P, OSP and local police agency public information representative(s) to provide information to local media.
- Working with local media as possible to promote work zone enforcement, education, and EMS awareness.
- Operating according to project guidelines outlined in official grant document including the 2009-2011 Work Zone Enforcement Guidelines and its modifications as necessary.

WORK ZONE ENFORCEMENT REQUEST (WZER)

DATE: _____

TO: **POLICE AGENCY (Check One and add name/title)**

☐ OSP Field Office Patrol Sgt: _____

OR,

☐ Local Police Agency Patrol Sgt: _____

Police Agency Contact Name/Title: _____
Address: _____
Telephone Numbers: _____
Electronic Mail Address: _____
Facsimile Numbers: _____

FROM: ☐ RTSC or Region 1 Work Zone Enforcement Coordinator, Don Bergmann
(*Manages the Region Work Zone Enforcement Budget.)*
(Check One and add name/title)

_____

OR,

☐ Oregon Bridge Delivery Program (OBDP)
(*Manages the OBDU/P Work Zone Enforcement Budget via OBDU approval.)*

_____

Bill Barnhart, OBDP Construction Mgr. (*ODOT's Consultant Management Firm)*

RTSC/R1 Work Zone Enforcement Coordinator or OBDU Financial Contact = *Manages the Region/OBDU Work Zone Enforcement Budget.*

RTSC/R1 Work Zone Enforcement Coordinator/OBDU Financial Contact:

Contact Name/Title: _____
Address: _____
Telephone numbers: _____
Electronic Mail Address: _____
Facsimile numbers: _____

RE: _____
ODOT Key # and Official ODOT STIP Project Name

ROLES, AND CONTACT/PROJECT INFORMATION

ODOT PM/CPM *or their designee or* ***OBDP Construction Manager*** *= Manages the work zone construction project. If no* ***Billing Contact*** *is noted within this form then the person herein is also responsible for review and approval of the* ***Monthly Construction Zone Project Report(s) (MCZPR's).***

ODOT/OBDP PM/CPM or Construction Manager

Name/Title: _____
Address: _____
Telephone numbers: _____
Electronic Mail Address: _____
Facsimile numbers: _____

Billing Contact for Project *= If there's a* ***Billing Contact*** *for this project other than the* ***PM/CPM*** *noted above than complete the information below. Role = Develop* ***WZER*** *and provide review/approval of* ***Monthly Construction Zone Project Report(s) (MCZPR's)*** *instead of the* ***PM/CPM.*** *Otherwise in some Regions this may routinely be their* ***RTSC, R1 Work Zone Enforcement Coordinator****, or* ***Inspector****.*

Billing Contact

Name/Title: _____
Address: _____
Telephone numbers: _____
Electronic Mail Address: _____
Facsimile numbers: _____

Work Zone Project Information and Enforcement Needs:

Official STIP Project Name: _____
ODOT Key #: _____
Project Manager/Consultant Project Manager if not already noted herein: _____
Highway/Mileposts: _____
Landmark Description: _____
Enforcement anticipated start date & end date: _____
Total # of OT enforcement hours requested: _____
Enforcement needs e.g. days of week, # of hours/ week or month, time of day, night construction etc.
(*If there is not a set enforcement schedule identified the Patrol Sgt. will develop their own based on their knowledge of the traffic patters at the project location.)* _____

APPROVALS VIA ELECTRONIC SIGNATURE AND DATE

Please provide your electronic signature/date via a unique font below. Do not remove other approvals that have already been provided below. Please provide any additional information to identify yourself in addition to your electronic signature/date e.g. title, organization if it doesn't exist elsewhere within this document.

RTSC/R1 Work Zone Enforcement Coordinator, OR **OBDU Financial Contact**

___
Approval of Region or OBDU/P Budget.

OSP Field Office Patrol Sgt. or **Local Agency Patrol Sgt**.

___
Approval of ability to provide hours/needs for the project negotiated with ODOT or OBDU/P.

IMPORTANT: Your e-mailed electronic signature and date approval of this electronic request provided via unique font is equivalent to your signature approval on a hardcopy version of this same request. By e-mailing your approval via electronic signature and date, you are certifying that (1) you are the responsible party named in the document, (2) you have responsibility/authority to approve this transaction, and (3) you approve the transaction through your electronic signature and date.

ODOT, OR BRIDGE DELIVERY UNIT (OBDU) Monthly Construction Work Zone Enforcement Report Form

Official Project Name:	*Enforcement, Engineering, Education - The "3-Es" Working Together for Safety*	OBDP Construction Coordinator (Official Contact):
HWY/MP's:		
Key #/Bundle #		
Police Agency/Field Office:		
ODOT Region/County:		
Billing Month/Year:		Page 1 of 1

Officer	Date	Time	Cites	Warn	Other Significant Activity	Grant Hours	Match Hours	Reg Hours	Admin Hours	Travel Hours	Total Vehicles Stopped
	Totals:	0	0			0	0	0	0		0

Police Agency Patrol Supervisor:	Date:	Comments:	Bill Barnhart
OBDP Construction Coordinator:	Date:		Office (503) 587-3653
OBDU Designee:	Date:		Cell (503) 602-9963
SFY 2009 Rates = OT $90.00; OT w/Match Reduction = $75.36; Match per hour = $14.64			Fax (503) 587-2929

Match provided by reduction of billable rate from $90.00 to $75.36; Admin Hrs=billable at OT rate not more than 10% of total Form.
Travel Hrs=billable at OT rate not more than 20% of total shift.

ODOT, OR BRIDGE DELIVERY UNIT (OBDU) Monthly Construction Work Zone Enforcement Report Form

Official Project Name: I84 Fifteen Mile Cr - US 97 Spanish Hollow Cr
HWY/MP's: I84 MP 88.04 US 97 MP 2.48
Key #14029/Bundle #207
Police Agency/Field Office: The Dalles
ODOT Region/County: Region 4
Billing Month/Year: November 2010

Enforcement, Engineering, Education - The "3-Es" Working Together for Safety

OBDP Construction Coordinator (Official Contact):

Officer	Date	Time	Cites	Warn	Other Significant Activity	Grant Hours	Match Hours	Reg Hours	Admin Hours	Travel Hours	Total Vehicles Stopped
Holloran, Mike	11/16/2010	900-1400	18	8		5.00	0.00	0			16
Pearson, Swede	11/24/2010	1400-1600	2	1		2.00	0.00	0			2
Pearson, Swede	11/30/2010	830-1130	1	11		3.00	0.00	0			8
Preston, Elijah	11/30/2010	1300-1800	3	4	PCS Interdiction/3 Assists	5.00	0.00	0			0
Raiser, Kaipo	11/4/2010	800-1300	1	5	TI/Consent Search	5.00	0.00	0			6
Shortt, Patrick	11/29/2010	2020-2120	1	2		1.00	0.00	0			3
Shortt, Patrick	11/30/2010	930-1300	3	12	Assist	4.00	0.00	0			8
	Totals:		29	43		25	0	0			43

Police Agency Patrol Supervisor: Sgt. Julie Wilcox — **Date:** 12/21/2010
OBDP Construction Coordinator: Bob Fitzner — **Date:** 12/22/10
OBDU Designee: Andrea McCausland — **Date:** 12/22/10

Comments:

Bill Barnhart
Office (503) 587-3653
Cell (503) 602-9963
Fax (503) 587-2929

SFY 2009 Rates = OT $63.44; Match $48.49

Match provided by reduction of billable rate from $90.00 to $75.36; Admin Hrs=billable at OT rate not more than 10% of total Form. Travel Hrs=billable at OT rate not more than 20% of total shift.

Revised 4/8/2005

APPENDIX E

TITLE 23: HIGHWAYS PART 630—PRECONSTRUCTION PROCEDURES

Title 23: Highways

PART 630—PRECONSTRUCTION PROCEDURES
Subpart K—Temporary Traffic Control Devices

§ 630.1108 Work zone safety management measures and strategies.

(a) *Positive Protection Devices.* The need for longitudinal traffic barrier and other positive protection devices shall be based on an engineering study. The engineering study may be used to develop positive protection guidelines for the agency, or to determine the measures to be applied on an individual project. The engineering study should be based on consideration of the factors and characteristics described in section 630.1106(b). At a minimum, positive protection devices shall be considered 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, such as:

(1) Work zones that provide workers no means of escape from motorized traffic (e.g., tunnels, bridges, etc.);

(2) Long duration work zones (e.g., two weeks or more) resulting in substantial worker exposure to motorized traffic;

(3) Projects with high anticipated operating speeds (e.g., 45 mph or greater), especially when combined with high traffic volumes;

(4) Work operations that place workers close to travel lanes open to traffic; and

(5) Roadside hazards, such as drop-offs or unfinished bridge decks, that will remain in place overnight or longer.

(b) *Exposure Control Measures.* Exposure Control Measures should be considered where appropriate to avoid or minimize worker exposure to motorized traffic and exposure of road users to work activities, while also providing adequate consideration to the potential impacts on mobility. A wide range of measures may be appropriate for use on individual projects, such as:

(1) Full road closures;

(2) Ramp closures;

(3) Median crossovers;

(4) Full or partial detours or diversions;

(5) Protection of work zone setup and removal operations using rolling road blocks;

(6) Performing work at night or during off-peak periods when traffic volumes are lower; and

(7) Accelerated construction techniques.

(c) *Other Traffic Control Measures.* Other Traffic Control Measures should be given appropriate consideration for use in work zones to reduce work zone crashes and risks and consequences of motorized traffic intrusion into the work space. These measures, which are not mutually exclusive and should be considered in combination as appropriate, include a wide range of other traffic control measures such as:

(1) Effective, credible signing;

(2) Changeable message signs;

(3) Arrow panels;

(4) Warning flags and lights on signs;

(5) Longitudinal and lateral buffer space;

(6) Trained flaggers and spotters;

(7) Enhanced flagger station setups;

(8) Intrusion alarms;

(9) Rumble strips;

(10) Pace or pilot vehicle;

(11) High quality work zone pavement markings and removal of misleading markings;

(12) Channelizing device spacing reduction;

(13) Longitudinal channelizing barricades;

(14) Work zone speed management (including changes to the regulatory speed and/or variable speed limits);

(15) Law enforcement;

(16) Automated speed enforcement (where permitted by State/local laws);

(17) Drone radar;

(18) Worker and work vehicle/equipment visibility;

(19) Worker training;

(20) Public information and traveler information; and

(21) Temporary traffic signals.

(d) *Uniformed Law Enforcement Officers.* (1) A number of conditions may indicate the need for or benefit of uniformed law enforcement in work zones. The presence of a uniformed law enforcement officer and marked law enforcement vehicle in view of motorized traffic on a highway project can affect driver behavior, helping to maintain appropriate speeds and improve driver alertness through the work zone. However, such law enforcement presence is not a substitute for the temporary traffic control devices required by Part 6 of the MUTCD. In general, the need for law enforcement is greatest on projects with high traffic speeds and volumes, and where the work zone is expected to result in substantial disruption to or changes in normal traffic flow patterns. Specific project conditions should be examined to determine the need for or potential benefit of law enforcement, such as the following:

(i) Frequent worker presence adjacent to high-speed traffic without positive protection devices;

(ii) Traffic control setup or removal that presents significant risks to workers and road users;

(iii) Complex or very short term changes in traffic patterns with significant potential for road user confusion or worker risk from traffic exposure;

(iv) Night work operations that create substantial traffic safety risks for workers and road users;

(v) Existing traffic conditions and crash histories that indicate a potential for substantial safety and congestion impacts related to the work zone activity, and that may be mitigated by improved driver behavior and awareness of the work zone;

(vi) Work zone operations that require brief stoppage of all traffic in one or both directions;

(vii) High-speed roadways where unexpected or sudden traffic queuing is anticipated, especially if the queue forms a considerable distance in advance of the work zone or immediately adjacent to the work space; and

(viii) Other work site conditions where traffic presents a high risk for workers and road users, such that the risk may be reduced by improving road user behavior and awareness.