VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY

Work Zone Safety

In the Highway Construction Industry

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1.0 Abstract

This study introduces the many problems associated with the safety of highway workers in the work zone. Unfortunately each year many people lose their lives and are severely injured due to highway work zone incidents. Work zone safety among road workers in highway infrastructure is essential in the construction industry. Highway construction is very hazardous as many road workers are struck by other vehicles within the work zone. Practicing the most effective safety practices is highly prioritized in the highway construction industry. Examples of safety in the work zone among workers in the highway construction industry is greatly researched among highway state departments and organizations such as the National Institute of Safety and Health (NIOSH), the Washington State Department of Transportation (WSDOT), and the Kansas Department of Transportation (KDOT). The state of Washington implements the use of robotic technology for directing traffic that has proven to be a success due to its non human capabilities. NIOSH provides practical and effective traffic control measures for highway work zones to prevent worker injuries from vehicles and equipment. KDOT practices logistic regression to evaluate the effectiveness of safety measures in the work zone. Each of these departments and organizations have contributed greatly to finding the most effective traffic control measures to prevent the rising fatality rates in highway construction. To prove that more effective traffic control standards need to be implemented in the highway construction industry, a detailed investigation and review of the Virginia, Washington, Kansas, and Iowa department of transportation traffic control are being evaluated to find the most practical and effective solution for safer work zones in the highway construction industry. Effective traffic control standards are very descriptive which implement necessary safety measures to benefit construction workers and the general public. In depth analysis of each state's traffic control procedures and guidelines will determine the most effective traffic control measures and methods among the highway industry which will reduce the fatality and injury rate among the workplace in the construction industry.

2.0 Introduction

Highway work zones present a major safety concern for the highway industry and the general public. A highway work zone refers to a road section undergoing a construction maintenance project typically marked by signs, channelizing devices, barriers, pavement markings, and work vehicles (Bai and Li 2007). Highway workers are at great measures of risk when working on heavy civil projects in the work zone. In any sector in construction, work zone safety is of extreme importance. Accidents in the work zone occur due to workers getting struck by oncoming traffic in the work zone. Approximately 40,000 people are injured each year due to motor vehicle crashes in highway work zones (FHWA 2007). Heavy highway construction endangers and risks the lives of its workers, and more effective safety practices are needed.

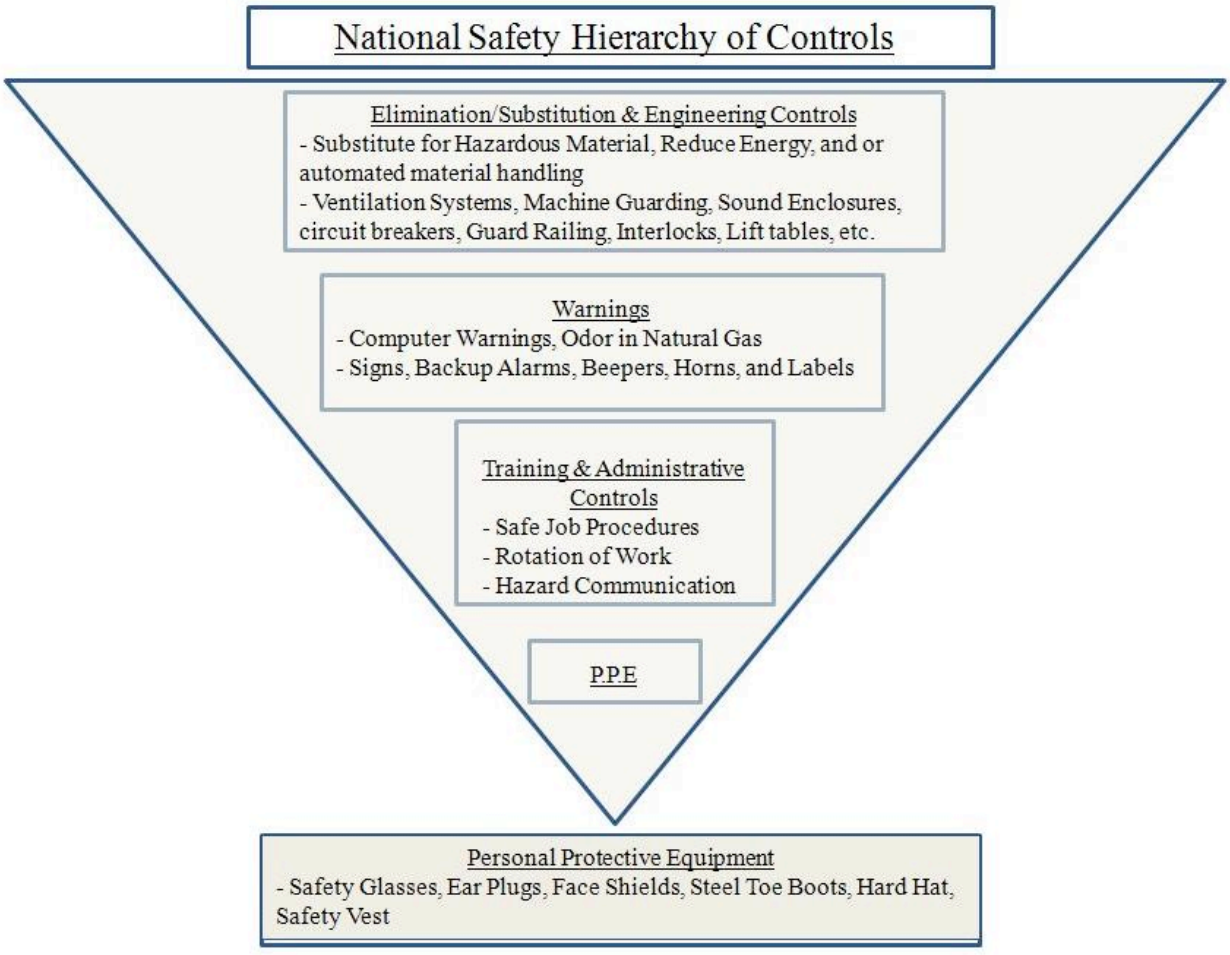
Highway infrastructure is a major contributor in the construction industry, and it is important that work zone safety is strictly enforced by highway infrastructure companies. Transportation incidents account for two-fifths of all workplace fatalities (BLS 2007). Heavy highway construction is the most hazardous nationwide, and many workers on the job-site are injured by struck-by traffic. Infrastructure companies suffer yearly due to the highway fatality rates the highway construction industry presents. Over the last five years, the number of people killed in motor vehicle crashes in work zones has risen from 989 in 2001 to 1,074 in 2005 resulting in a yearly average of 1,068 fatalities (FHWA 2007). Although the number of fatalities per mile traveled continues to decline, the total number of fatalities is on the rise.

More effective and efficient safety programs need to be adopted and implemented in order to decrease injuries and fatalities in the workplace in highway infrastructure. Data has proven that the rate of work zone deaths on highways is estimated at least four times the fatality rate for construction in general (Gautam and Mohan 2000). Fatalities and transportation incidents are not only damaging to the construction worker, but also negatively impact the construction company involved due to the financial problems transportation incidents create. Safely utilizing and implementing a highway safety plan in order to reduce the fatality rate should be the primary goal for construction companies involved in highway construction and maintenance.

The effectiveness of traffic control is very important in highway infrastructure, and current workers need the proper training and experience in order to decrease fatality rates in the work zone. The Federal Highway Administration (FHWA) has introduced a safety guide known as the *Manual on Uniform Traffic Control Devices (MUTCD)* which gives pointers on the necessary safety measures to use at construction sites, and also provides tips for motorists on traveling safely through road construction sites (Pegula 2004). The *MUTCD* is a helpful document which addresses certain topics related to safety in the work zone such as training, personal protective equipment, speed reduction, barriers, and lighting.

The fatality rate in the construction industry is heavily influenced by poor safety practices among the transportation contracting company and its workers. The contractor is solely responsible for implementing the proper safety measures on highway work zones. The theory of safety controls is a method which redesigns the workplace to fit the needs of workers (Dupont 2005). Contractors need to design workplaces which cause less harm to workers which make the health and safety of the workplace and the environment the main concern in the work zone. Fatality reduction is the responsibility of the contractor as they are managing the work zone. Contractors should enforce and educate their workers on the most effective and efficient measures for traffic control, and implement them accordingly to their tasks in highway construction. Figure 1 below shows the hierarchy of Safety and Health Controls as it relates to the fatality rate in the construction industry. The hierarchy of Safety and Health Controls can be implemented by highway contractors and workers present in the work zone. Safely maintaining a work zone is of utmost importance, and the hierarchy can help establish a safe and secure work zone for the general public and highway workers. Training and Administrative Controls is the main focus for work zone safety, and how fatality and accident rates need to be reduced across the country. Training and administrative controls are very vital in the highway construction process which contractors need to implement among their workers in order to reduce the fatality rate in the construction industry. Contractors are held solely responsible for the safety of their workers, and it is important that safety is top priority in the construction industry.

Figure 1. National Hierarchy of Controls



*(Dupontsafetyrevealed.org)

The hierarchy shown in Figure 1 labeled as the National Safety Council Hierarchy of Controls represents the safety procedures and administrative controls each contractor should follow in order to properly and successfully train their workers for the safest environment in the highway work zone. Safe job procedures, rotation of workers, equipment inspections, and worker training are all part of the hierarchy listed in the training and procedures section. Proper training and administrative control is very important in the highway construction industry, and if implemented properly the highway fatality and accident rate could possibly decline.

This study primarily focuses on the most effective traffic control measures, and how they could help reduce the notable fatality and accident rates in the construction industry. The problem that is being introduced is what are the most effective traffic control measures and methods among

the highway construction industry which effectively and efficiently reduce the noticeable fatality rate among the workplace in highway construction? In order to find the most effective traffic control measures and guidelines, this study explores the work zone safety content from four select states based on specific criteria. Another question investigated in this study relevant to work zone safety is: Is there any correlation between the contents and quality of the guidebooks and the fatalities experienced in each state?

3.0 Background

Multiple measures have been taken in order to prevent the increasing number of work zone incidents in the highway construction industry. Transportation organizations and departments have been researching the reason and results of work zone crashes on highways. Each year, more than 100 workers are killed and over 20,000 are injured in the highway and street construction industry (NIOSH 2008). For decades the injury and fatality rates of those injured within highway work zones has been a major issue in the United States. Work Zone related accidents effect the cost of production in highway construction. The total cost of construction related highway work zone accidents is calculated to be $1.09 billion (Gautam and Mohan 2000). The majority of construction related highway work zone accident costs are incurred by specific crash types. The specific crash types are rear-end collisions, hit objects, side-impact, and overturning of vehicles which incrementally affect the cost of production in highway construction (Gautam and Mohan 2000). These specific crash types drive the cost of highway accidents up, thus increasing the need for more capital in the highway construction industry.

The National Institute for Occupational Safety and Health (NIOSH) has developed a document known as *Building Safer Highway Work Zones: Measures to prevent Worker Injuries from Vehicles and Equipment.* The document lists and explains certain prevention measures to protect workers from hazards caused by construction vehicles, construction equipment, and traffic vehicles. NIOSH lays out specific safety measures which any company can use when highway construction is underway. Properly laying out the highway work zone, temporary traffic control devices, motorist education and speed enforcement, flagging, the use of high-visibility apparel, and developing traffic control plans are all necessary components of effective traffic control measures NIOSH recommends in its document.

NIOSH provides many control measures which should be greatly stressed among the highway construction industry and the work zone. Traffic control plans should be utilized in order to protect the safety of the workers on the highway work zone. A traffic control plan is a tool that project managers can use to coordinate the flow of construction vehicles, equipment, and

workers operating in close proximity within the activity area, so the safety of the workers can be ensured (NIOSH 2008). In order for proper traffic control, NIOSH suggests:

- Using traffic control devices, such as signage, warning devices, paddles, and concrete barriers, in a consistent manner throughout the work zone.
- Set up temporary traffic control within a reasonable time prior to construction so that motorists do not become complacent and ignore warning signs and devices when work begins.
- Assign a traffic control supervisor who is knowledgeable in traffic control principles overall responsibility for the safety of the work zone setup.
- Carefully review the Traffic Control Plan (TCP) and, during contract negotiations, negotiate with the contracting agency as to revisions to the TCP that are needed to ensure worker's safety.
- Provide flaggers with devices that increase their visibility to passing motorists and construction vehicles.
- Keep channelizing devices clean and properly maintained to reserve their reflective intensity and visibility.
- Ensure that all traffic control devices are operating properly and in place at all times.
- Increase the size of traffic control devices, reflective material, and lettering to improve driver recognition.
- For night work:
    - Reduce spacing between channelizing devices to compensate for reduced driver visibility.
    - Ensure arrow panels are set at nighttime levels; daytime settings used at night produce blinding light.

*(NIOSH 2008)

All of these standards for traffic control are very helpful, but do not specify the exact measures that need to be taken for the safest and most effective work zone. The suggestions listed are not very descriptive and do not explain exactly what an effective traffic control standard is. An effective traffic control standard is very descriptive and implements the most necessary safety measures for the benefit of the construction worker in the work zone which considers safely

utilizing a construction site and its layout. NIOSH makes necessary steps to decrease the fatality rate in work zones, but they do not represent the best method for proper traffic control standards.

NIOSH shows that the majority of fatalities in the highway industry occur in work zones. Table 1 displays the fatalities in the highway and street construction industry according to NIOSH:

Table 1. Fatalities in the Highway and Street Construction Industry

	Number	Percent
Occurred in a highway or street construction work zone:	**492**	**58.5**
Vehicle or equipment-related	465	55.3
Other event	27	3.2
Occurred outside a work zone:	**349**	**41.5**
Vehicle or equipment-related	198	23.5
Other event	151	18
Total	**841**	**100**

*NIOSH (2008)

Washington State's department of transportation used a technological approach to make smarter and safer work zones on highways. Approaches have been considered in order to reduce the fatality rate in highway work zones. Technology is shaping highway work zones, making them safer, more navigable, and in some instances removing traffic control personnel such as flaggers out of the path of danger. The use of robots in Washington other than flaggers is an effective way to reduce the fatality rate in highway construction.

Highway workers work in very risky conditions in which they are extremely close to construction vehicles and motor vehicle traffic. Flaggers and other pedestrians are exposed to the risk of being hit by traffic vehicles or construction equipment if they are not visible to motorist or workers who operate equipment. Current technology practices in highway construction are an ongoing process, such as robots being used as flaggers in the state of Washington.

The state of Washington has been using what is known as the Roboflagger. The Roboflagger is a 12-foot-tall steel device with automatic arms and lights remotely operated at a safe distance by a human flagger behind safety barriers (Kuennen 2007). The Roboflagger provided enhanced

visibility under nighttime conditions, and proved to be a success in the safety of highway construction workers. The use of the Roboflagger reduces workers exposure to the road which provides them with added protection. Although the Roboflagger is a great step towards traffic control standards, it was ineffective in hazardous weather situations such as heavy rain, continuous snow, and icy conditions.

Kansas is another state which is studying the necessary traffic control measures that are being implemented among the construction industry. The Kansas Department of Transportation (KDOT) accident database presented a total of 655 severe crashes, including 29 fatal crashes and 629 injury crashes, in Kansas highway work zones between January 2003 and December 2004 (Bai and Li 2003). This study focused on logistic regression in order to evaluate the effectiveness of the safety measures in work zones.

The effectiveness of flaggers, traffic signs, channeling devices, temporary pavement markings, lighting devices, and temporary traffic control signals were all assessed during this study. According to the logistic regression analyses, the presence of a flagger directing traffic could reduce the odds of having fatalities in a severe crash by 56%; having flashers or center/edge lines in work zones could reduce the odds by more than 50% as well (Bai and Li 2003). Based on the available crash information, the statistics presented in the study could not establish a relationship between the usage of stop signs/signals and no passing zones in work zones and the involvement of fatalities in severe crashes. The Kansas Department of Transportation is continuously making a great effort at implementing more effective traffic control standards in order to decrease the consistent transportation incidents nationwide.

The Kansas Department of Transportation believes the study is highly effective in providing guidance for controlling highway work zones and implementing the best safety practices for the construction worker in the state of Kansas. Control measures are very important in the highway construction industry, and they need to be properly utilized. Although the Kansas Department of Transportation did an extensive study on the safety of construction workers in the highway work zone, there still needs to be more effective traffic control measures. The study was only based on data and information from the state of Kansas. KDOT could have contributed more to their study on effective traffic control measures if they collected work zone data from other states.

This study shows there is a developing need in the construction industry for new and innovative safety countermeasures on highway work zones.

NIOSH, Washington State, and The Kansas Department of Transportation have completed extensive research on the safety of highway workers in the work zone. Each organization has made a great effort in determining the most effective traffic control measures in order to decrease the fatality rate in the construction industry, but there are still opportunities for the most effective and efficient traffic control measures nationwide. Although there has been much research towards this area in highway construction, work zone safety and the high fatality rate in highway construction is still present and can be better addressed through extensive research and documentation.

4.0 Problem Statement and Objectives

The highway industry will always have complications with work zone safety and the numerous injuries and fatalities that periodically occur. As stated in the previous section, many organizations and departments such as NIOSH, The Washington Department of Transportation, and The Kansas Department of Transportation provide great examples which contribute important supplemental research to reduce the injury and fatality rate in the highway construction industry.

The problem that is being studied is what are the most effective traffic control measures and methods among the highway construction industry which effectively and efficiently reduce the n fatality rate among workers in highway construction? The fatal occupational injuries by state and event or exposure in Table 2 presented below shows all 50 states in the United States and their job-related fatality count. Table 2 compares the fatality rates in the transportation industry in the work zone provided by The Bureau of Labor Statistics. The fatal occupation injuries assessed by each state help determine the parameters for this study on highway work zone safety and its assumed hypothesis. It is important that highway workers and pedestrians are protected from the risk of severe injuries and fatalities relevant to highway work zone safety.

Table 2. State Transportation Fatalities Per Capita

State of Injury	State Population	Total Fatalities (2008)	# of Fatalities Per Capita (E^-3)
Alabama	4,627,851	97	2.10
Alaska	683,478	33	4.83
Arizona	6,338,755	86	1.36
Arkansas	2,834,797	85	3.00
California	36,553,215	404	1.11
Colorado	4,861,515	102	2.10
Connecticut	3,502,309	28	0.80
Delaware	864,764	11	1.27
District of Columbia	588,292	9	1.53
Florida	18,251,243	290	1.59
Georgia	9,544,750	171	1.79
Hawaii	1,283,388	18	1.40
Idaho	1,499,402	31	2.07
Illinois	12,852,548	185	1.44
Indiana	6,345,289	127	2.00
Iowa	2,988,046	89	2.98
Kansas	2,775,997	73	2.63
Kentucky	4,241,474	105	2.48
Louisiana	4,293,204	134	3.12
Maine	1,317,207	24	1.82
Maryland	5,618,344	59	1.05
Massachusetts	6,449,755	61	0.95
Michigan	10,071,822	123	1.22
Minnesota	5,197,621	65	1.25
Mississippi	2,918,785	80	2.74
Missouri	5,878,415	147	2.50
Montana	957,861	39	4.07
Nebraska	1,774,571	53	2.99
Nevada	2,565,382	40	1.56
New Hampshire	1,315,828	7	0.53
New Jersey	8,685,920	491	5.65
New Mexico	1,969,915	31	1.57
New York	19,297,729	212	1.10
North Carolina	9,061,032	160	1.77
North Dakota	639,715	27	4.22
Ohio	11,466,917	167	1.46
Oklahoma	3,617,316	102	2.82
Oregon	3,747,455	54	1.44
Pennsylvania	12,432,792	240	1.93
Rhode Island	1,057,832	6	0.57
South Carolina	4,407,709	85	1.93
South Dakota	796,214	30	3.77
Tennessee	6,156,719	134	2.18
Texas	23,904,380	457	1.91
Utah	2,645,330	65	2.46
Vermont	621,254	10	1.61
Virginia	7,712,091	134	1.74
Washington	6,468,424	83	1.28
West Virginia	1,812,035	53	2.92
Wisconsin	5,601,640	77	1.37
Wyoming	522,830	33	6.31

*USBOL (2008)

The number of fatalities per capita is a good measure of determining the fatality rate for each individual state. To determine the number of fatalities per capita the total fatalities of each

individual state are divided by that particular state's population. The per capita calculation in essence provides a small percentage reflecting the fatality rate which helps the reader determine which states are more risk oriented in relation to fatalities in highway work zones.

The statistical data presented helps the reader get an idea of which states have higher fatality rates compared to others. Assessing fatality rates on an occupational basis for each state helps determine which states may possibly need new and improved highway work zone safety standards and procedures. Studying the highway safety standards and methods for Virginia, Washington, Kansas, and Iowa departments of transportations will help determine the most effective traffic control measures in order to help lower the fatality rate in the construction industry. These select four states have been chosen based on their different locations in the country, comparable populations, and fatality percentage rate.

Virginia and Washington are two very comparable states in relation to their population and fatality rates per capita. Virginia is approximately composed of 7.7 million people with 134 fatalities, while Washington is composed of approximately 6.5 million people with 83 fatalities. According to the fatality percent per capita calculation, Virginia is 1.74, while Washington is 1.28. These numbers are considerably lower than the two states of Iowa and Kansas. Due to their lower rates, it is hypothesized that Virginia and Washington provide their contractors and employees with clearer and more detailed content of quality and guidelines and procedures which would result in fewer fatalities and accidents.

Iowa and Kansas are two very similar states in relation to their population and fatality percentage rates. Iowa's approximate calculation is 2.9 million with 89 fatalities, while Kansas is 2.7 million with 73 fatalities. Iowa has a fatality number per capita of 2.98, while Kansas has a number of 2.63. Their percentages are relatively high compared to the states of Virginia and Washington. If the stated hypothesis is supported, it should be concluded that the states of Iowa and Kansas should adopt the safety measures which Virginia and Washington practice. It would be hypothesized that Iowa and Kansas do not practice the same safety measures as Virginia and Washington.

5.0 Methodology

This project and report focuses on data collection through literature review, published materials, and specific department of transportation web pages. Primary areas of focus and research are through Virginia, Washington, Kansas, and Iowa traffic control standards and highway work zone guidelines. This paper attempts to cover and compare selected state's traffic control guidelines and procedures to ensure a safe working environment in the highway construction industry.

The research objective of collecting data to explain the reasons why traffic control needs to be measured among the highway industry is best implemented through meticulous observation of each state's department traffic control standards and methods. Each state's traffic control standards are located online at their certain department of transportation database. The individual state's traffic control manuals are easy to find, and specifically lay out their safety procedures for traffic control on highway work zones. Each department of transportation has a specific layout of their traffic manuals in relation to work zone safety. Effectively studying and comparing each state's department's traffic manuals will provide possible explanations for the differences in fatality rates and therefore support the need for more effective traffic control measures in the highway construction industry. Iowa and Kansas are smaller states in terms of population, but have higher fatality rates than Kansas and Virginia. If the hypothesized differences in traffic control practice are determined through inspection of the traffic manuals, then these findings would support a conclusion that Iowa and Kansas need to adopt the safety measures which Virginia and Washington practice when constructing highways in the work zone.

In order to determine each state's traffic control guidelines and procedures, particular documents were selected. Document selection was based on the level of information and detail each state department considered to effectively control and secure highway work zones. Table 3 is a description of the data collected to determine the problem of accident rates in highway work zones.

Table 3. Manual Selection

Abbreviation/Title	Author/Publisher
Work Zone Safety: Guidelines for Temporary Traffic Control	Virginia Department of Transportation (VDOT)
Virginia Work Area Protection Manual: Standards and Guidelines for Temporary Traffic Control	
Work Zone Traffic Control Guidelines	Washington Department of Transportation (WSDOT)
Design Manual Chapter 9 Traffic Control	
Kansas Work Zone Safety and Mobility Processes and Procedures	Kansas Department of Transportation (KDOT)
Procedures and Standard Specifications for Construction Section 805	
Design Manual Chapter 9 Traffic Control	Iowa Department of Transportation (Iowa DOT)
Work Zone Safety Workshops 2002	

When reviewing and observing all of the literature relevant to highway work zone safety and traffic control, it is important to remain unbiased. Each state department of transportation observed has their own way of performing and practicing highway work zone safety. This paper addresses the importance of highway work zone safety, and attempts to address the most effective traffic control measures in highway work zone areas relevant to the content provided by each state. Refer to the appendices A through E to understand the countermeasures and procedures each state contains relevant to highway work zone safety and traffic control.

7.0 Comparative Analysis

Each department of transportation has developed its own way of enforcing and regulating highway work zone safety. The purpose of this study is to determine if the stated hypothesis is supported in that Virginia and Washington practice more effective and efficient safety measures in highway work zones relative to their content. This study explores the differences and similarities of each department of transportation relative to highway work zone safety. All of the states contained very similar material in relation to highway work zone safety and traffic control. The guidebooks and standards developed by each state department of transportation are examples of material regarding highway work zone safety and its importance on personal safety and security.

Table 4. Work Zone Safety Information

Department of Transportation Work Zone Safety Information				
	VDOT	WSDOT	KDOT	Iowa DOT
National Work Zone Awareness Week Participation	X	X	X	X
Complies with MUTCD part VI	X	X	X	X
Easily Accessible Traffic Control Standards	X	X	X	X
Continual Training	X	X	X	X
Video Documentation	X	X	X	X
Educational Materials	X	X	X	X
Law Enforcement/Work Zone fines	X	X	X	X
Safety Enforcement (PPE)	X	X	X	X
Safety Committee	X	X	X	X
Additional Work Zone Considerations	X	X	X	X

It is very interesting to find that Virginia, Washington, Kansas, and Iowa contain very similar information and material regarding highway work zone safety. Table 4 is a representation of the work zone safety information that each state contains. It is apparent that each state is committed to highway work zone safety and awareness. However, each state department has its own way of presenting its guidelines and procedures regarding highway work zone safety.

Virginia, Washington, and Iowa provide very detailed information through the implementation of guidelines and procedural manuals. Most of the manuals identified present the reader with great visuals and real life situations which the contractor can apply during the construction process. On the other hand, KDOT presents its highway work zone information in a very difficult format. KDOT does not have very thorough information regarding work zone safety, and this could lead to more accidents within the work zone. Although the necessary material is covered by KDOT, it is not the best way of describing and explaining highway work zone safety. The only accessible material found on the KDOT website was very basic and did not pay attention to detail. Unlike the other three states, Kansas had limited material through its *Procedures and Standard Specifications for Construction Section 805*and *Kansas Work Zone Safety and Mobility Processes and Procedures.* The standards provided by Kansas are a great source of information, but do not stress the importance of highway work zone safety. KDOT has very minimal information regarding work zone safety for contractors and employees. In order to successfully enforce highway work zone safety, Kansas could emulate a lot of the information

provided by VDOT, WSDOT, and Iowa DOT in order to decrease the fatality rate in highway construction work zones.

Table 5. Work Zone Safety Content

Work Zone Safety Content				
	VDOT	WSDOT	KDOT	Iowa DOT
Fundamental Principles of Temporary Traffic Control	X	X		X
Component Parts of a Temporary Traffic Control Zone	X	X		X
Type of Tapers and Buffer Spaces	X	X		X
Taper Length Criteria for Temporary Traffic Control Zones	X	X		X
Pedestrian and Worker Safety	X	X		
Flagger Control	X	X	X	X
Temporary Traffic Control Zone Devices	X	X		X
Advance Warning Arrow Display Specifications	X	X		X
Channeling Devices	X	X	X	X
Typical Traffic Control Figures	X	X	X	
Work Zone Safety Checklists	X	X		
Signs	X	X	X	X
Work Zone Speed Limits	X	X	X	X
Worker Protection	X	X		
Lane Closure Setup/Takedown	X	X	X	X
Automated Flagger Assistance	X	X	X	
Portable Changeable Message Signs	X	X		X
Temporary Traffic Control Guidelines and Procedures	X	X	X	X
Traffic Control Planning	X	X	X	X
Adequate Visuals	X			X
Pavement Marking and Delineators	X	X	X	X

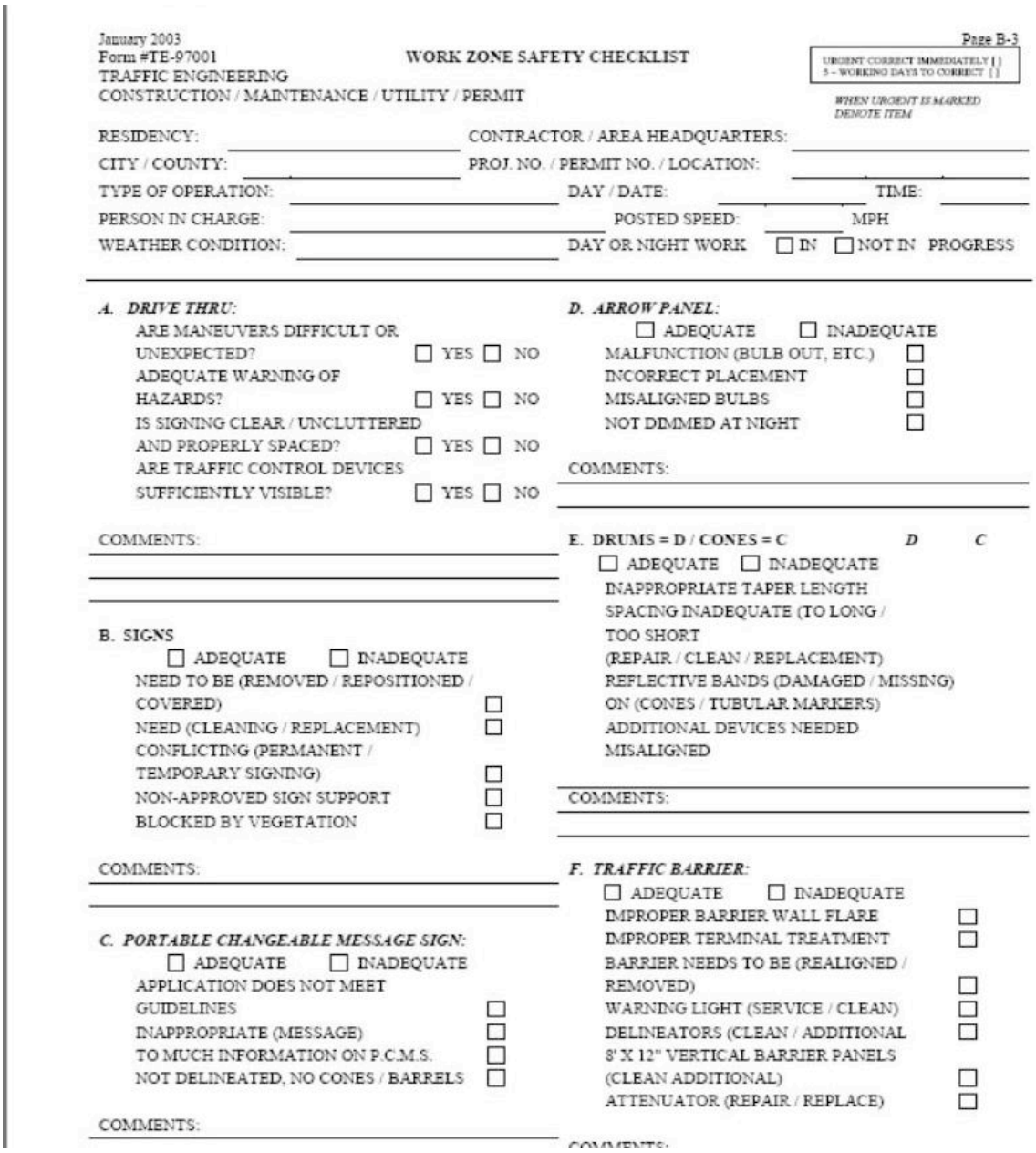
Table 5 displays the criteria evaluated by each state to ensure a safe highway work zone. Virginia, Washington, and Iowa are very comparable in relation to highway work zone safety considering the content noted in the table above. KDOT contains very minimal information necessary to ensure that highway workers and pedestrians are safe within the work zone compared to the other three states. Contractors need to be aware of the fundamental principles and components of a highway work zone in order to operate and maintain a work zone. Compared to the other three states, Kansas is putting their contractors at higher levels of risk. The table depicted above shows the criteria evaluated by each state to ensure a safe highway work zone. If KDOT does not decide to change its traffic control methods and procedures, the

fatality rate can possibly continually increase. The state of Kansas is in need of improvement, and should adopt the procedures and guidelines provided VDOT, WSDOT, and Iowa DOT.

VDOT and WSDOT contain adequate information to ensure that their highways are being operated and maintained in a fashionably safe manner. To make highways safer and more mobile for pedestrians and travelers in the state of Kansas, KDOT could implement many procedures and guidelines that VDOT and WSDOT practice such as detailed and descriptive documentation. VDOT and WSDOT provide their employees and contractors with descriptive documentation and detailed drawings that could greatly reduce accident rates on highways. The Virginia *Work Area Protection Manual* and the *WSDOT Design Manual* provided by the state of Washington are resources which Kansas could gather much information regarding work zone safety and awareness. Virginia and Washington practice many preventative measures to make certain that their work zones are secure for pedestrians and workers.

Two beneficial resources that separate Virginia and Washington from Kansas are VDOT's Work Zone Safety Checklist and WSDOT's extensive training courses. VDOT's Work Zone Safety Checklist was developed to provide a consistent way to review temporary traffic control in construction, maintenance and utility operations (*Virginia Work Area Protection Manual* 2003). The safety checklist is form intended to prevent the presence of accidents or delays in work zones. Figure 2 is a snapshot of the safety checklist provided below for further reference.

Figure 2. Work Zone Safety Checklist



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Form #TE-97001 — WORK ZONE SAFETY CHECKLIST
TRAFFIC ENGINEERING
CONSTRUCTION / MAINTENANCE / UTILITY / PERMIT

URGENT CORRECT IMMEDIATELY [ ]
5 – WORKING DAYS TO CORRECT [ ]
WHEN URGENT IS MARKED DENOTE ITEM

RESIDENCY: _____ CONTRACTOR / AREA HEADQUARTERS: _____
CITY / COUNTY: _____ PROJ. NO. / PERMIT NO. / LOCATION: _____
TYPE OF OPERATION: _____ DAY / DATE: _____ TIME: _____
PERSON IN CHARGE: _____ POSTED SPEED: _____ MPH
WEATHER CONDITION: _____ DAY OR NIGHT WORK ☐ IN ☐ NOT IN PROGRESS

A. DRIVE THRU:
ARE MANEUVERS DIFFICULT OR UNEXPECTED? ☐ YES ☐ NO
ADEQUATE WARNING OF HAZARDS? ☐ YES ☐ NO
IS SIGNING CLEAR / UNCLUTTERED AND PROPERLY SPACED? ☐ YES ☐ NO
ARE TRAFFIC CONTROL DEVICES SUFFICIENTLY VISIBLE? ☐ YES ☐ NO

COMMENTS:

B. SIGNS
☐ ADEQUATE ☐ INADEQUATE
NEED TO BE (REMOVED / REPOSITIONED / COVERED) ☐
NEED (CLEANING / REPLACEMENT) ☐
CONFLICTING (PERMANENT / TEMPORARY SIGNING) ☐
NON-APPROVED SIGN SUPPORT ☐
BLOCKED BY VEGETATION ☐

COMMENTS:

C. PORTABLE CHANGEABLE MESSAGE SIGN:
☐ ADEQUATE ☐ INADEQUATE
APPLICATION DOES NOT MEET GUIDELINES ☐
INAPPROPRIATE (MESSAGE) ☐
TO MUCH INFORMATION ON P.C.M.S. ☐
NOT DELINEATED, NO CONES / BARRELS ☐

COMMENTS:

D. ARROW PANEL:
☐ ADEQUATE ☐ INADEQUATE
MALFUNCTION (BULB OUT, ETC.) ☐
INCORRECT PLACEMENT ☐
MISALIGNED BULBS ☐
NOT DIMMED AT NIGHT ☐

COMMENTS:

E. DRUMS = D / CONES = C *D* *C*
☐ ADEQUATE ☐ INADEQUATE
INAPPROPRIATE TAPER LENGTH
SPACING INADEQUATE (TO LONG / TOO SHORT
(REPAIR / CLEAN / REPLACEMENT)
REFLECTIVE BANDS (DAMAGED / MISSING)
ON (CONES / TUBULAR MARKERS)
ADDITIONAL DEVICES NEEDED
MISALIGNED

COMMENTS:

F. TRAFFIC BARRIER:
☐ ADEQUATE ☐ INADEQUATE
IMPROPER BARRIER WALL FLARE ☐
IMPROPER TERMINAL TREATMENT ☐
BARRIER NEEDS TO BE (REALIGNED / REMOVED) ☐
WARNING LIGHT (SERVICE / CLEAN) ☐
DELINEATORS (CLEAN / ADDITIONAL ☐
8' X 12" VERTICAL BARRIER PANELS (CLEAN ADDITIONAL) ☐
ATTENUATOR (REPAIR / REPLACE) ☐

COMMENTS:

*Virginia Work Area Protection Manual 2003

The Work Zone Safety Checklist is a tool that can be implemented by highway contractors or employees to ensure that highway work zones are operating at a safe and efficient manner. There is no significant evidence that KDOT takes proactive measures to safely control highway work zones. KDOT contractors and employees could use this form to assess and evaluate

dangerous conditions and circumstances present in highway work zones. Another deficiency by KDOT is they do not provide the same type of training opportunities as the state of Washington. WSDOT has many training courses that are aimed to develop their employees with proficiency in work zone safety and mobility design. The WSDOT design manual mentions these training courses in greater detail. Training courses are provided below in Figure 3 as stated in the WSDOT Design Manual.

Figure 3. Training Courses

(1) Training Courses

There are many work zone-related courses available, and the HQ Staff Development Office and HQ Traffic Office's Traffic Training Program Manager can assist with the availability and scheduling of classes. Consider the following training courses to develop an overall proficiency in work zone safety and mobility design:

- **Work Zone Traffic Control Design Course:** This course, taught by the HQ Traffic Office, focuses on work zone safety and mobility through transportation management plan development and WZTC PS&E.
- **QuickZone Course:** This course, taught by McTrans, explores the QuickZone work zone traffic capacity analysis program. QuickZone is a useful tool for determining capacity needs, and it allows comparison of alternative strategies.
- **MUTCD Course:** This course, taught by Transpeed, focuses on the content and use of the MUTCD, including Part 6, Temporary Traffic Control.
- **Traffic Control Supervisor (TCS) Course:** This course, taught by the Evergreen Safety Council, NW Laborers Union, and ATSSA, is primarily for those students who intend to become a TCS or those who have TCS-related responsibilities. TCS training offers value to designers regarding how implementation issues interact with design issues. Designer attendance may be restricted to "space available" status.
- **Certified Flagger Training Course:** This course is directed at students who will become certified flaggers in Washington State and is not intended for designers. Designers may want to use the *Flagger Handbook* as a resource to learn about flagger-controlled traffic control and flagging techniques and issues. This class may be valuable for increasing the safety of designers anticipating extensive field surveying and data gathering work during the project development phase.

WSDOT Design Manual M 22-01.06
December 2009

*WSDOT Design Manual 2009

The training courses are very descriptive and offer WSDOT employees opportunities to successfully control and operate a work zone. The *Work Zone Safety and Mobility Processes and Procedures* produced by KDOT introduces the importance of training, but relevant courses are not listed compared to Washington. KDOT's document does not contain ample training information, and does not encourage employee training compared to Washington. KDOT

mentions training in a simple statement in its *Kansas Work Zone Safety and Mobility Processes and Procedures*:

- Appropriate KDOT and contractor's personnel will be trained in temporary traffic control design, set-up, maintenance, management and evaluation of work zones commensurate with their level of responsibility. Individuals may gain this training through either department provided courses of KDOT approved outside courses. KDOT provides training on basic and advanced technical principles pertaining to design, setup, maintenance, management and evaluation of work zone (*Kansas Work Zone Safety and Mobility Processes and Procedures* 2008).

The training process that KDOT mentions is very misleading compared to WSDOT, and does not clarify what courses are offered to ensure a secure safer highway work zones. Virginia's Work Zone Safety Checklist and Washington's training courses are two essential elements of highway work zone safety that Kansas could adopt for further improvement.

Iowa, unlike Virginia and Washington, has very straightforward information in relation to traffic control and work zone safety. Compared to the other three states, Iowa DOT is adapting to the measures and procedures that Virginia and Washington have developed. Iowa DOT contains very similar material compared to Virginia and Washington, but it is not as descriptive and thorough. Very similar to the state of Virginia, Iowa provides great visuals that can be beneficial to the contractor. The visuals are great learning tools that contractors can apply to real life situations. Iowa, unlike the state of Kansas, has made a considerable effort to set guidelines and procedures relevant to highway work zone control. Iowa is heading in the right direction, but could obtain very valuable information from VDOT and WSDOT.

8.0 Conclusion

The contributions of this research study were the investigation and observation of four separate states specific material relevant to highway work zone safety. Each state contained material that is beneficial to the contractor in order set up and maintain a safe workplace. Virginia, Washington, Kansas, and Iowa all set safe guidelines and procedures in order to prevent accidents in work zones.

Each state mentioned in this study has their own specific strengths and weaknesses relative to highway work zone safety. It can be argued that due to their overall clarity and detail, Virginia and Washington contain more efficient and effective safety measures regarding work zone safety. The hypothesis that clearer and more detailed content and of work zone guidelines and procedures would result in fewer fatalities is supported by every state except Kansas. Kansas contains less information such as enhanced visuals and descriptive guidelines compared to Virginia and Washington. Although their information is not as precise and direct, Iowa provides great visuals that are beneficial to the contractor. In order to help prevent fatalities and injuries in the state of Kansas, KDOT could adopt some of the procedures developed by VDOT, WSDOT, and Iowa DOT. Table 6 is a summary of the results from the stated hypothesis that clearer and more detailed content would result in fewer fatalities on a state by state basis. It is a brief explanation of the findings relevant to this study.

Table 6. Conclusions

State	% of Fatalities Per Capita	Manual Quality	Supported ?
Virginia	1.74	Precise	Yes
Washington	1.28	Precise	Yes
Iowa	2.98	Satisfactory	Yes
Kansas	2.63	Minimal	No

There could be additional explanations why accident rates are higher in other states due to various reasons. Miscommunication between workers and motorists, human error, and insufficient training could be possible explanations as to why accidents occur within work zones.

Communication is a very vital component in the construction process. Without communication the construction industry would not exist. Miscommunication between workers and pedestrians could be a possible explanation as to why accidents do occur in work zones. Motorists and workers are at fault for this phenomenon on a daily basis. Workers and motorists need to be more aware of their surroundings while in close proximity to highway work zones. Flagging techniques, radio alerts, signage, and speeding fines are current preventative measures taken to help maintain a safe work zone. In order to successfully communicate with one another, more effective practices need to be established by state transportation departments.

The difference in accident rates on a state by state basis can be further explained by the possibility of human error. Human error can be a big factor in the explanation of why accidents do occur in work zones. Examples of human error are worker fatigue and inattentive driving. Worker fatigue and inattentive driving can lead to unsafe actions and behaviors in construction work zones which can result in critical injury and death. Highway contractors are responsible for operating and maintaining work zones, and worker fatigue shall not be tolerated. If a highway worker is fatigued while operating in a work zone, it can cause serious levels of threat to crew members and surrounding motorists and pedestrians. Drivers need to be cautious while operating vehicles in work zones. In order to minimize threat to their lives, drivers should maintain a safe speed, not text message, and not make phone calls. Human error could be a leading factor as to why accidents periodically occur in work zones.

Training and educating individuals is an important process that can at times be overlooked. Highway construction professionals and employees should be consistently trained to ensure that highway work zones are safely operating. State transportation departments need to establish mandatory safety classes and educational materials focused on the importance of highway work zone safety. Proactively training and educating employees and contractors could effectively reduce accident rates in highway work zones.

9.0 Contributions and Impacts

This study can greatly benefit relevant stakeholders in the highway construction industry. Private contractors and transportation departments that predominantly work in the highway construction industry are of great interest in this study on work zone safety. The completion of this study can impact stakeholders in the highway transportation industry. Private contractors and transportation departments can become more aware of the increasing fatality and accident rates in highway work zones. Establishing an awareness of work zone fatality and injury rates can attribute to safer construction practices and methods in highway work zones. The increasing fatality and accident rates in highway work zones is a major issue that needs to be addressed by states with higher fatality rates such as Kansas. This study benefits states similar to Kansas with higher fatality rates in highway work zones. If highway work zones are operated safely and more efficient, then the general public and highway workers will be safer in the work zone thus reducing the risk of fatality or injury. Highway work zone safety greatly impacts the construction industry, and stakeholders need to become more aware of this reoccurring issue.

10.0 Future Research

Due to the present study's findings, a lot is still to be learned about highway work zone safety. Further research would greatly benefit and expand upon the understanding of the importance of highway work zone safety. Future researchers can provide further explanation as to why accidents occur in work zones through various measures and procedures.

Observing and studying state department of transportation highway material such as manuals and drawings relevant to work zone safety is proven to be fairly effective. It is a great approach to recognize the similarities and differences that each state contains. In order to understand why accidents occur in highway work zones, a more precise approach is needed. The completion of this study has yielded several topics, which require further research in order to benefit and safeguard the highway construction industry. Future research studying the following topics will provide contractors with more knowledge, safer construction practices, and minimize accidents in work zones.

- Repeat same methodology on the other 46 states to see if findings are more consistent
- Formulation of a survey study intended to explore other alternatives related to highway work zones safety
- Interviewing select state department of transportation employees and contractors
- Creating a safety handbook that states the most effective highway work zone safety practices

The further research generated from this could benefit the highway construction industry and reduce notable accident rates in many states. Protecting highway workers and motorists is very important, and better solutions can be generated through further research and investigation.

11.0 Lessons Learned

Three major lessons were learned during the present research study. First and foremost, it is important that data is collected to fulfill specific research needs. Data collection can be a strenuous and difficult process. Contacting the right personnel is very important to ensure that the data is consistent with the research objective.

Second, establishing clear and effective communication with stakeholders is extremely important. Due to the various documents regarding traffic control and work zone safety it essential that stakeholders contain relevant information. Virginia, Washington, and Iowa had consistent information which pertained to work zone safety, but Kansas did not provide similar material and documentation.

Third, time management is of utmost importance in order to complete valid research and documentation. To substantially complete this document it was essential that sufficient time and planning was considered. The information accessed relevant to traffic control and work zone safety is very detailed and much time was needed to correctly observe and describe the necessary traffic control standards in order to reduce accident rates present in highway work zones.

Appendix A. Manual Analysis/Execution

The manual analysis provides the reader with the necessary tools and guidelines to configure highway work zones for optimum safety and security. Each state department of transportation conforms to part VI of the *Manual of Uniform Traffic Control Devices (MUTCD)*, but practice their own styles and behaviors regarding highway work zone safety. Provided further in Appendices B though E are examples of each state's manuals and guidebooks used to effectively manage and prepare highway work zones. Some states contain more information regarding work zone safety than others. Virginia, Washington, Kansas, and Iowa are comparable states to analyze due to their similarities in relation to population and overall injury and fatality rate. The fundamental principles of temporary traffic control, each state's guidelines and procedures relevant to work zone safety, traffic control planning and management, and worker and pedestrian safety is the content that is described and compared to complete this study. Appendices B through E provide detailed explanations of the work zone safety content along with descriptive examples specified by the four states studied.

Appendix B. Virginia Department of Transportation (VDOT)

The Virginia Department of Transportation (VDOT) encourages the importance of work zone safety and considers it a top priority for Virginia residents and highway workers. In Virginia, seven people died in work zone crashes on state maintained roads in 2008 (VDOT Work Zone Safety 2008). Employees at VDOT believe it is important that residents of Virginia go home to their families and relatives in a safe manner on a daily basis. VDOT cares greatly about work zone safety, and its employees annually participate in work zone national awareness week which is held each year during the month of April (VDOT Work Zone Safety 2008). VDOT is committed to the overall safety of pedestrians and highway workers that are present in the construction work zone. It is important that drivers and pedestrians are aware of work zones while driving on highways. Highway workers are at great risk of injury and death while working on heavily populated highways. VDOT gives advice on what drivers should do while driving through a work zone. The advice that VDOT recommends is as follows:

- Slow Down
- Stay alert for changing conditions
- Avoid distractions, such as text messaging or talking on the phone

*VDOT 2010

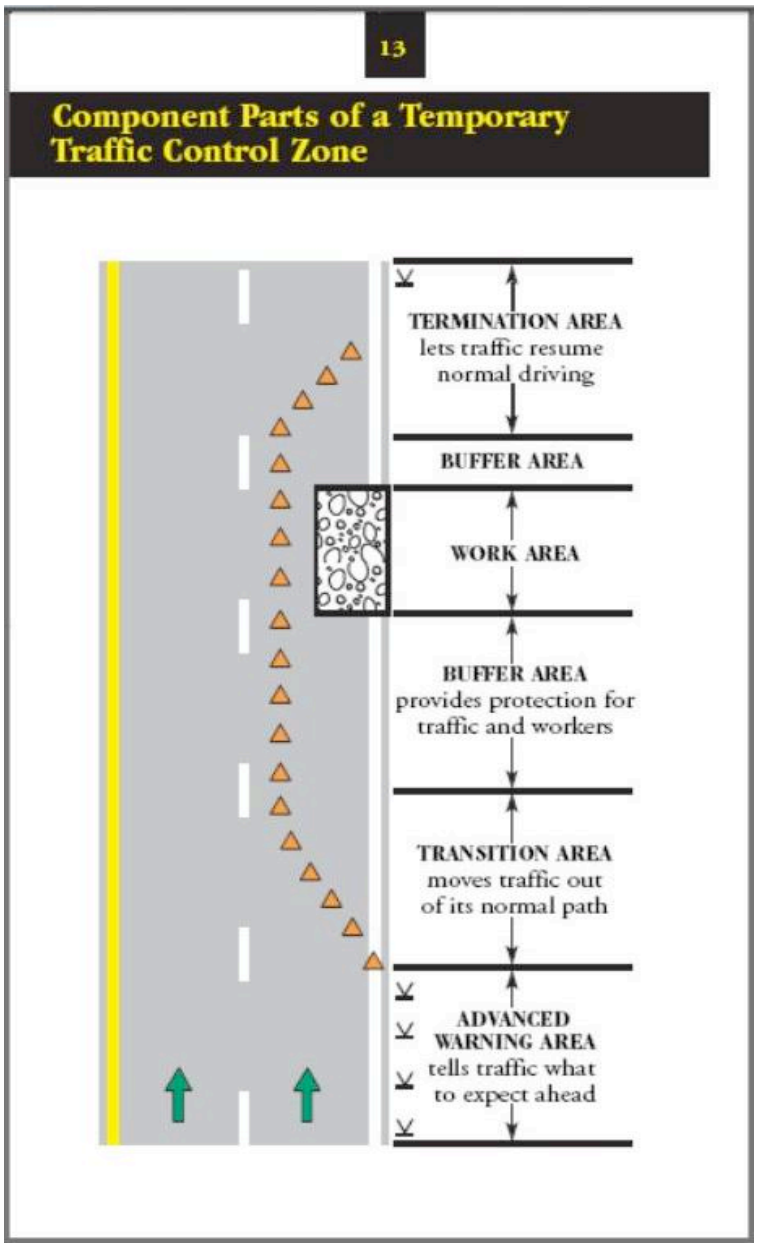
The tips that VDOT recommends are a great tool for getting drivers to become aware of work zones and their close proximity to the driver. It is important that highway contractors set up work zones that are easily avoidable to oncoming traffic and equipment in order to prevent collisions. *Work Zone Safety: Guidelines for Temporary Traffic Control* and *Virginia Work Area Protection Manual: Standards and Guidelines for Temporary Traffic Control* are two helpful manuals developed by VDOT which contractors can use to set up safe work zones to avoid injury or fatality in the work zone. Both manuals are very similar, and should be investigated and implemented thoroughly by contractors working in the state of Virginia. Each manual lays out specific rules and guidelines which contractors can use to set up a safe and efficient work zones.

The purpose of *Work Zone Safety Guidelines for Temporary Traffic Control* is to present the contractor with basic guidelines for work zone traffic control and to supplement the *Virginia Work Area Protection Manual.* Information contained within the manual is intended to illustrate the principles of proper work zone traffic control, but is not a standard. The guidelines that are listed within the document are work zone activity related such as traffic control devices, component parts of a temporary traffic control zone, taper length criteria for work zones, work zone application in curves and hills, truck mounted attenuators, installing/removing lane closures, and other application diagrams that are helpful in temporary traffic control. Each of these guidelines is depicted below to express the awareness of each guideline. Highway employees must understand the important and relevance of each traffic control standard.

According to VDOT it is the responsibility of the contractor to present this information to their employees, and to understand that work zone safety is a top priority while working on site. *Work Zone Safety: Guidelines for Temporary Traffic Control* is a great handbook that lists and explains the various tools and equipment that are needed to set up an effective work zone. The manual states the four types of traffic control devices commonly used are signs, channeling devices, lighting devices, and truck mounted attenuators. Highway workers need to understand the types of traffic control devices listed and their relative importance to the highway work zone.

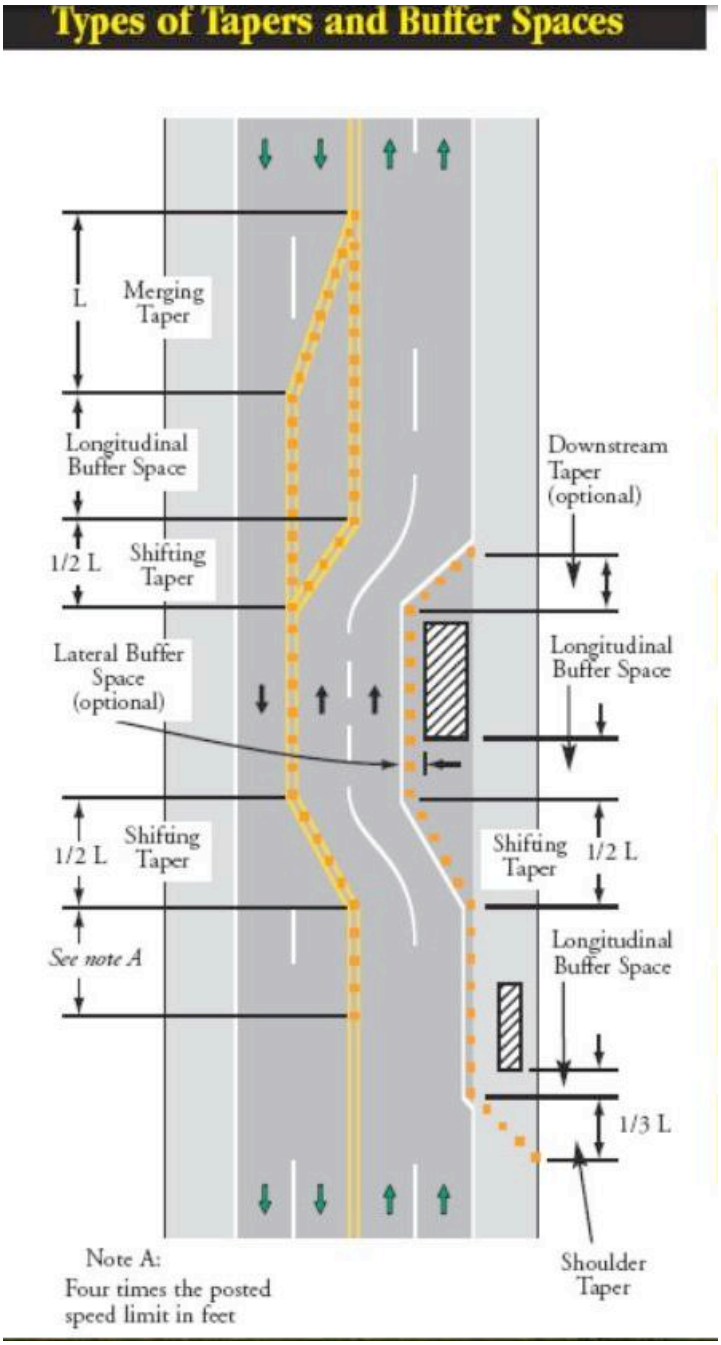
Work Zone Safety: Guidelines for Temporary Traffic Control provides examples of the components of a temporary traffic control zone. Each component interdependently relies on one another in order for the work zone to flow properly with highway traffic during working hours. The components of a temporary traffic control zone are known as the termination area, buffer area, work area, transition area and the advanced warning area. Figures 4 through 7 displayed below are representations of different work zones that are present on highways.

Figure 4. Component Parts of a Temporary Traffic Control Zone



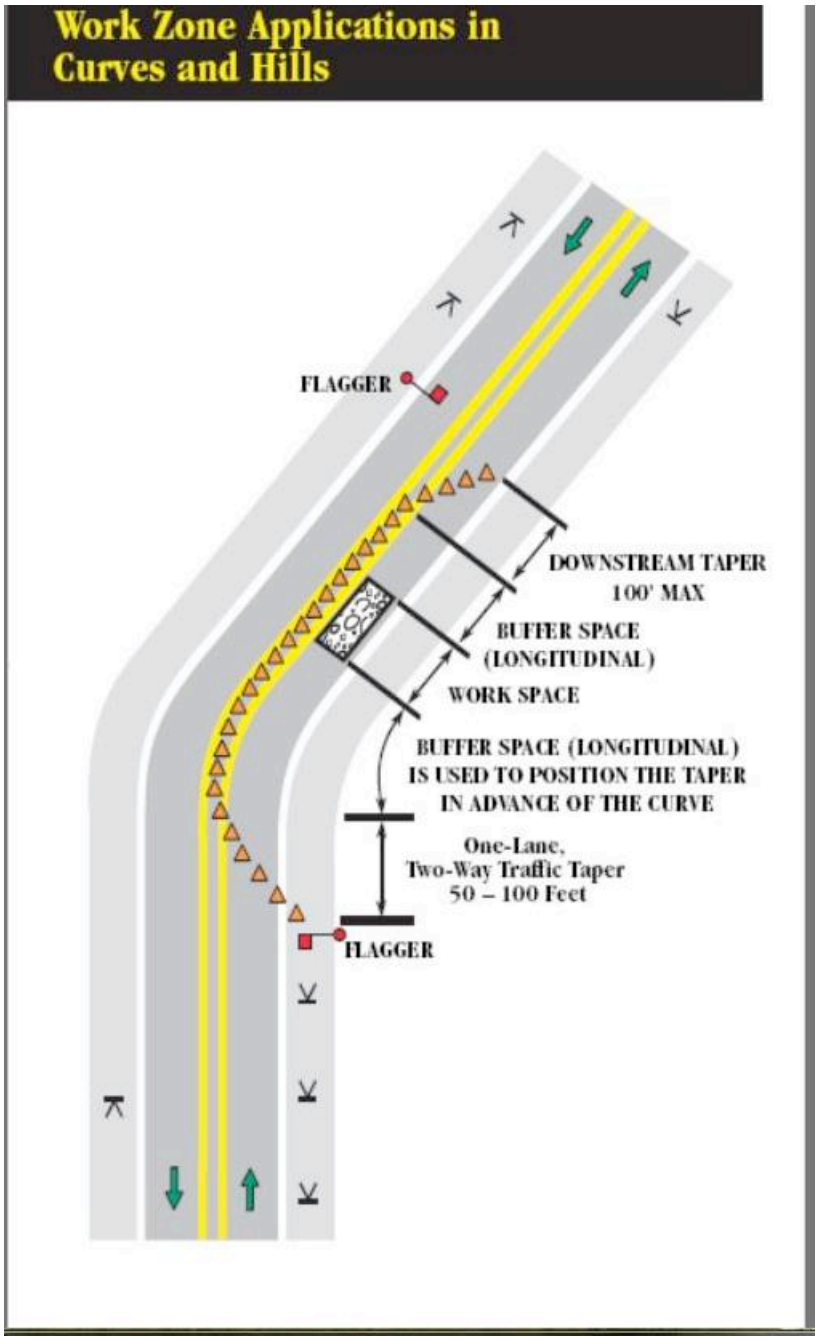
* *Work Zone Safety: Guidelines for Temporary Traffic Control 2007*

Figure 5. Types of Tapers and Buffer Spaces



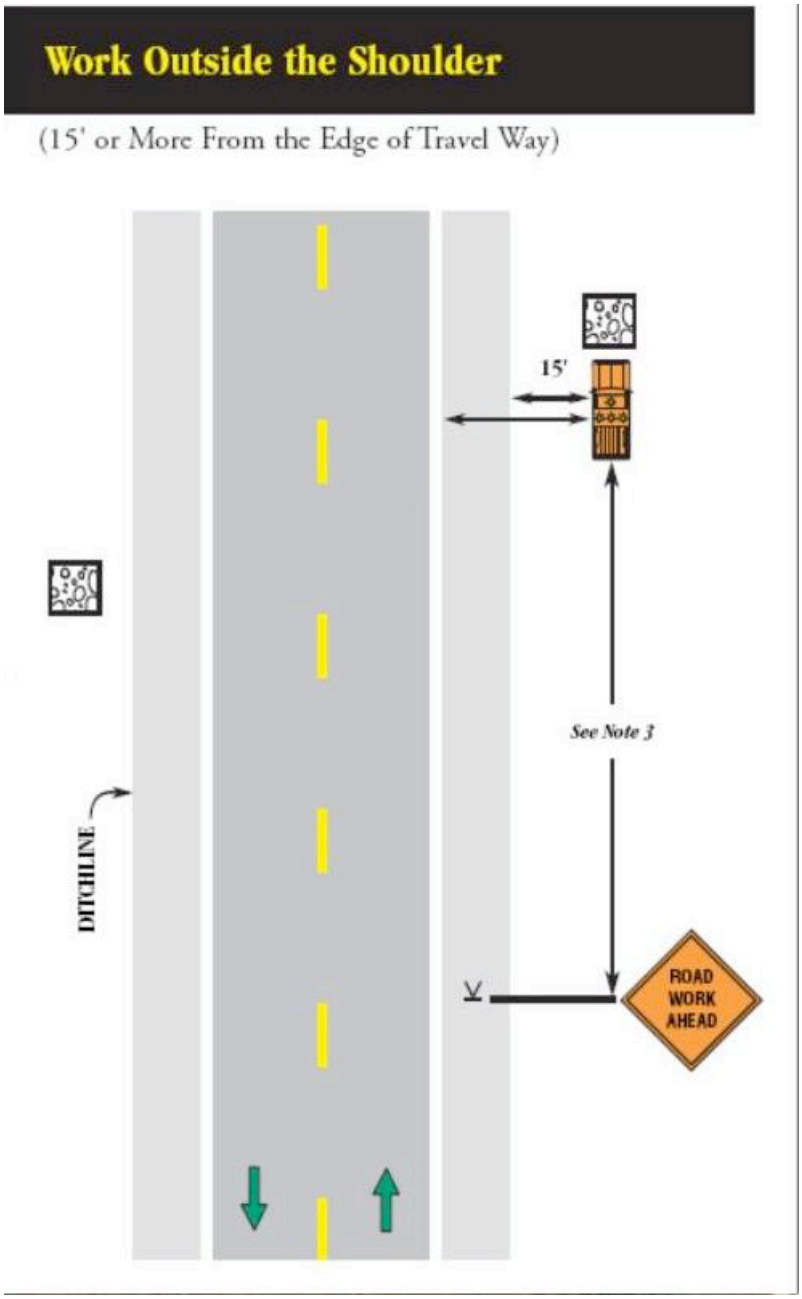
* *Work Zone Safety: Guidelines for Temporary Traffic Control 2007*

Figure 6. Work Zone Applications in Curves and Hills



* *Work Zone Safety: Guidelines for Temporary Traffic Control 2007*

Figure 7. Work Outside the Shoulder



* *Work Zone Safety: Guidelines for Temporary Traffic Control 2007*

Work Zone Safety: Guidelines for Temporary Traffic Control provides the reader with great graphics and easy to follow directions which can effectively set up a safe environment for the worker and pedestrians traveling on highways. The graphics above are a few examples of the visuals which this manual provides for contractors to rely on in order to properly set up the most

effective and efficient work zone. The documentation and explanation which *Work Zone Safety: Guidelines for Temporary Traffic Control* provides is a source that contractors can find helpful and beneficial in the highway construction industry. Companies that implement this information should have minimal problems reiterating the necessary steps provided to control traffic in the work zone.

The Virginia Department of Transportation has published the *Virginia Work Area Protection Manual: Standards and Guidelines for Temporary Traffic Control* in order to meet the needs and criteria for temporary traffic control established by the Federal Highway Administration (FHWA). The documentation provided is VDOT's version of Part VI of the *Manual on Uniform Traffic Devices (MUTCD)*. Illustrating the typical worksites and describing conditions encountered is the objective of this manual on highway work zones. This manual is a very detailed document which contains temporary traffic control measures and guidelines which highway contractors must follow in order to protect their workers and the general public. *The Virginia Work Area Protection Manual* describes the fundamental principles of traffic control, traffic control elements, pedestrian and worker safety, flagger control, traffic control zone devices, traffic control zone activities, and the typical traffic control figures. Providing safe and efficient movement of vehicles, pedestrians, and bicyclists around temporary traffic control zones while protecting workers and equipment is the main function of temporary traffic control (*Virginia Work Area Protection Manual* 2003). VDOT and this extensive manual lay out all of the necessary steps in order to control the flow of traffic in a safe and consistent manner.

Temporary traffic control zones present constantly changing conditions that are unexpected to the road user, and the objective of temporary traffic control is the efficient construction and maintenance of the highway. A temporary traffic control zone is an area of a highway where road user conditions are changed because of a work zone or incident by the use of temporary traffic control devices, flaggers, police, or other authorized personnel (*Virginia Work Area Protection Manual 2003*). Workers along with pedestrians traveling on the highway are responsible for their own safety. It is important that individuals and workers are able to interpret this document into real life situations. The *Virginia Work Area Protection Manual* has set standards that highway contractors must abide by in order to protect the general public and their employees. An example of a standard provided in the Virginia Work Area Protection Manual is:

- Temporary traffic control plans and devices shall be the responsibility of the authority of a public body or official having jurisdiction for guiding road users. There shall be adequate statutory authority for the implementation and enforcement of needed road user regulations, parking controls, speed zoning, and incident management. Such statutes shall provide sufficient flexibility in the application of temporary traffic control to meet the needs of changing conditions in the temporary traffic control zone (*Virginia Work Area Protection Manual 2003*).

According to the state of Virginia it is the sole responsibility of the contractor to control and maintain highway work zones. Overseeing a work zone is a huge obligation on the contractor and it is important that they employ the necessary responsibility and leadership skills to maintain highway work zones. The *Virginia Work Area Protection Manual* provides contractors with the necessary fundamentals vital in developing a safe and efficient highway work zone. The fundamental principles of temporary traffic control, temporary traffic control elements, and pedestrian and worker safety are three chapters in the document which help develop safe and mobile highway work zones.

Fundamental Principles of Traffic Control/ Temporary Traffic Control Elements

The Virginia Work Area Protection Manual describes the fundamental principles necessary to control traffic on highways and interstates. Controlling road users through temporary traffic zones is an essential part of highway construction, utility work, maintenance operations, and the management of traffic incidents (*Virginia Work Area Protection Manual* 2003). Various construction activities can benefit if necessary measures are taken to prevent work zone injury or fatality. Planning ahead and scheduling is very important when controlling traffic. Following and abiding by these fundamental principles will reduce the number of work zone fatalities and injuries that workers and travelers could encounter. Road user and worker safety in temporary traffic control zones should be an integral and high-priority element of every project from planning through design and construction. *The Virginia Work Area Protection Manual* is very descriptive and specific regarding the fundamental principles individuals shall follow when controlling the flow of

traffic in work areas. Although it is the responsibility of the contractor to control the work zone, it is also the responsibility of the driver to be cautious and attentive while passing through work zones.

VDOT Guidelines and Procedures

Contractors can find it very difficult to plan temporary traffic control plans in certain traffic situations because of the variety of incidents that can arise. VDOT has established some parameters that can be helpful for unknown incidents that can happen while controlling traffic. The guidelines provided are helpful reminders that highway contractors and their colleagues can use to control traffic effectively and efficiently within the work zone. The guidelines in the Virginia Work Area Protection Manual are listed below for further viewing.

Guidance:
General plans or guidelines should be developed to provide safety for drivers, bicyclists, pedestrians, workers, enforcement/emergency officials, and equipment, with the following factors being considered:
A. The basic safety principles governing the design of permanent roadways and roadsides should also govern the design of temporary traffic control zones. The goal should be to route road users through such zones using roadway geometrics, roadside features, and temporary traffic control devices as nearly as possible comparable to those for normal highway situations.
B. A temporary traffic control plan, in detail appropriate to the complexity of the work project or incident, should be prepared and understood by all responsible parties before the site is occupied. Any changes in the temporary traffic control plan should be approved by an official knowledgeable (for example, trained and/or certified) in proper temporary traffic control practices and documented.

Road user movement should be inhibited as little as practical, based on the following considerations:

A. Temporary traffic control at work and incident sites should be designed on the assumption that drivers will only reduce their speeds if they clearly perceive a need to do so (see Section 6C.01 for speed control).

B. Frequent and abrupt changes in geometrics such as lane narrowing, dropped lanes, or main roadway transitions that require rapid maneuvers, should be avoided.

C. Provisions should be made for the reasonably safe operation of work, particularly on high-speed, high-volume roadways.

D. Road users should be encouraged to use alternative routes that do not include temporary traffic control zones.

E. Bicyclists and pedestrians, including those with disabilities, should be provided with access and reasonably safe passage through the temporary traffic control zone.

F. Roadway occupancy should be scheduled during off-peak hours and, if necessary, night work should be considered.

G. Early coordination with officials having jurisdiction over the affected cross streets and providing emergency services should occur before roadway or ramp closings.

Drivers, bicyclists, and pedestrians should be guided in a clear and positive manner while approaching and traversing temporary traffic control zones and incident sites. The following principles should be applied:

A. Adequate warning, delineation, and channelization should be provided to assist in guiding road users in advance of and through the temporary traffic control zone or incident site by using proper pavement marking, signing, or other devices that are January 2003 Page 6B-3 effective under varying conditions. Providing information that is in usable formats by pedestrians with visual disabilities should also be considered.

B. Temporary traffic control devices inconsistent with intended travel paths through temporary traffic control zones should be removed or covered. However, in short duration and mobile operations, where visible permanent devices are inconsistent with intended travel paths, devices that highlight or emphasize the appropriate path should be used.

C. Flagging procedures, when used, should provide positive guidance to road users traversing the temporary traffic control zone.

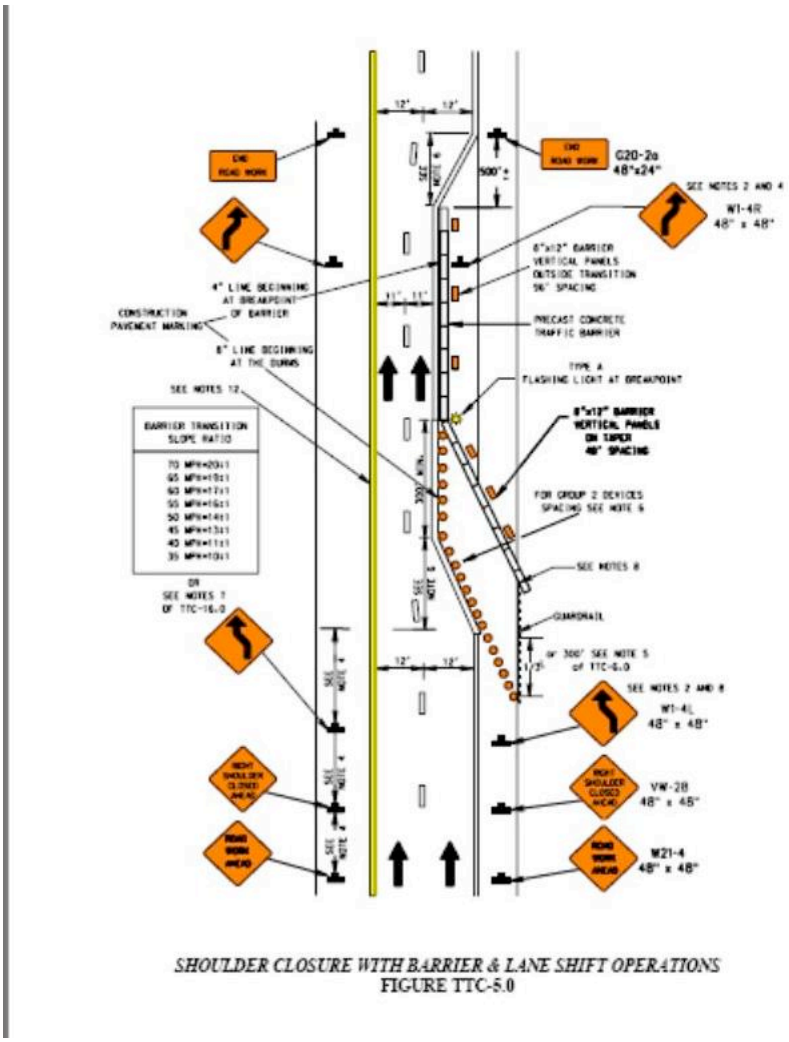
*Virginia Work Area Protection Manual (2003)

The guidelines listed above are very beneficial to the contractor in order to establish the most effective and safely operating highway work zone. Contractors need to be aware of the helpful information and documentation that is available when setting up and maintaining highway work zones. VDOT has established great measures and applications which can be introduced to contractors that are fairly new to highway construction. This section of the *Virginia Work Area Protection Manual* is great in determining what to expect when setting up a highway work zone. It is important that contractors take advantage of the readily available information relevant to highway work zone safety.

Temporary Traffic Control Planning (TTCP)

A Temporary Traffic Control Plan (TTCP) provides relevant guidance to contractors in order to set up a safe and secure highway work zone. A temporary traffic control plan describes the necessary temporary traffic control measures to be used for guiding drivers and pedestrians through a work zone. Temporary traffic control plans can be very complex or simple depending on the various situations that are present on highway work zones. This section of the *Virginia Work Area Protection Manual* is very similar to *Work Zone Safety: Guidelines for Temporary Traffic Control.* The figures presented above such as the component parts of a temporary traffic control zone, types of tapers and buffer spaces, work zone applications in curves and hills, and work outside the shoulder are mentioned in the same manner as *Work Zone Safety: Guidelines for Temporary Traffic Control*. The *Virginia Work Area Protection Manual* provides more detailed and descriptive graphics relevant to highway work zone safety as displayed in Figure 8. Common applications such as shoulder closures and signs used in highway work zones are supplied in this manual. Contractors can use worker protection manual for great reference and application when setting up and maintaining highway work zones.

Figure 8. Shoulder Closure



*Virginia Worker Protection Manual 2003

Highway contractors and workers need to understand the different work zones that can be present at any given time. In order to properly set up a work zone, temporary traffic control plans need to be prepared by individuals that are certified and trained with expertise in traffic control. Traffic control planning should be completed for all highway construction, utility work,

maintenance operations, and incident management (*Virginia Work Area Protection Manual* 2003). Productivity is reduced without a set and precise plan in the construction industry. Planning and scheduling are two key elements in construction which cannot be avoided at any circumstance. The temporary traffic control elements portion of *The Virginia Work Area Protection Manual* provides great insight and instruction for highway contractors and workers. Highway contractors are held at great risk when operating a work zone and it is important that they apply the necessary steps and principles when preparing and operating under risky circumstances.

The overall safety of the general public and the workers within the work zone is the main priority for contractors in the highway construction industry. It is imperative that contractors implement and apply the necessary safety measures on highway work zones to ensure pedestrian and worker safety. Every pedestrian needs a safe and efficient travel path that clearly separates the work zone from the traveling public. The importance of pedestrian and worker safety and how it needs to be recognized as the main priority when setting up and preparing work zones. Pointers provided within the document are provided below which notify the importance of pedestrian safety within the work zone. When planning for pedestrians in temporary traffic control zones, there are three considerations:

A. Pedestrians should not be led into conflicts with work site vehicles, equipment, and operations.

B. Pedestrians should not be led into conflicts with vehicles moving through or around the work site.

C. Pedestrians should be provided with a safe, convenient path that replicates as nearly as practical the most desirable characteristics of the existing sidewalk(s) or a footpath(s).

*Virginia Work Area Protection Manual (2003)

Worker and Pedestrian Safety

Respecting pedestrian safety is highlighted incrementally in this portion of the Virginia Work Area Protection Manual, and contractors need to be aware of the importance of the surrounding environment of highway work zones. Although pedestrian safety is of severe importance, the

safety of the worker is another important factor. Equally as important as the safety of the road users traveling through the temporary traffic control zone is the safety of workers (*Virginia Work Area Protection Manual* 2003). Traffic controls zones not only are unexpected to the road user, but can cause inconsistency with the worker. It can be a complicated process for workers when controlling a work zone due to heavy traffic, weather conditions, and in some instances miscommunication.

Temporary Traffic Control Management

Highway workers need to use the most effective traffic control devices that gain pedestrians attention while operating a highway work zone. Some key elements of temporary traffic control management that can be considered to improve worker safety suggested within this section of the manual are:

A. Training - all workers should be trained on how to work next to motor vehicle traffic in a way that minimizes their vulnerability. Workers having specific temporary traffic control responsibilities should be trained in temporary traffic control techniques, device usage, and placement. Training should be conducted on a continual basis.

B. Worker Clothing - all workers should be adequately clothed for the type of operations they will be performing (see standard below for clothing requirement when working near traffic.)

C. Temporary Traffic Barriers - temporary traffic barriers should be placed along the work space based on an engineering study considering factors such as lateral clearance of workers from adjacent traffic, speed of traffic, duration and type of operations, time of day, and volume of traffic.

D. Speed Reduction - reducing the speed of motor vehicle traffic, mainly through regulatory speed zoning, funneling, use of law enforcement officials, lane reduction, or flaggers, should be considered.

E. Activity Area – planning the internal work activity area to minimize backing-up maneuvers of construction vehicles should be considered to minimize the inherent risk to workers on foot.

*Virginia Work Area Protection Manual (2003)

If properly applied and considered, these guidelines and procedures can improve the overall safety of the pedestrians within highway work zones. Workers need to be proactive and plan ahead when working within the highway work zone. Any circumstance or situation that is risky within the work zone needs to be addressed in the safest and most efficient manner by the worker. It is important that workers and contractors maintain control of the highway work zone to ensure worker and pedestrian safety.

The Virginia Department of Transportation (VDOT) provides reliable and detailed information regarding the concept of temporary traffic control within highway work zones. *Work Zone Safety: Guidelines for Temporary Traffic Control* and the *Virginia Work Area Protection Manual: Standards and Guidelines for Temporary Traffic Control* are two very reliable documents which set the necessary standards for optimum highway work zone safety. If implemented properly, the risk of injury and fatality present in highway work zones could be decreased. Highway workers need to effectively communicate with pedestrians while working within in the work zone in order to ensure that individuals are safe while traveling on highways. VDOT provides highway contractors with the necessary guidelines and procedures to set up a safe and efficient work zones in the highway construction industry.

Appendix C. Washington State Department of Transportation

The Washington State Department of Transportation (WSDOT) is committed to provide the safest construction practices on highway work zones. According to WSDOT, 54 work zone deaths have been reported from January 2000 to March 2008 (WSDOT Work Zone Safety 2009). Similar to Virginia, Washington participates in National Work Zone Awareness Week on an annual basis to prevent the occurrence of accidents. To ensure that workers and pedestrians are secure in the work zone, WSDOT has established a Work Zone Safety Task Force in 1993 that enforces pedestrians and workers to be aware of the hazards that are present in the work zone (WSDOT Work Zone Safety 2009). The task force is committed to provide work zone training, standards, new products, and innovative practices that can mitigate the hazards present in the work zone. The Work Zone Safety Task Force has established team objectives:

1. Decrease the need and use of work zones through the design effort.
2. Reduce the traffic/worker interface through positive separation.
3. Maintain traffic flow through work zones.
4. Review products and practices to encourage state of the art best practices.
5. Continue to learn from active work zones through successes and near misses.
6. Bring to resolution work zone issues of statewide interest.
7. Communicate and educate both WSDOT staff and industry on work zone safety.

*WSDOT Work Zone Safety Task Force (2010)

The Work Zone Safety Task Force is committed to ensure that workers are properly trained and certified to operate work zones in the safest manner possible. Workers in work zones must always be attentive and make smart decisions. Developing a Work Zone Safety Task Force is a great way to ensure that Washington residents and employees are practicing the necessary safety practices and applications in the highway work zone.

WSDOT formulated a document known as *Work Zone Traffic Control Guidelines* that provides guidance for the most effective traffic control measures. The manual is intended to comply with

part VI of the *Manual on Uniform Traffic Control Devices (MUTCD)*. WSDOT adopted the *MUTCD* as the legal standard for temporary traffic control for common work operations. Effective traffic control is essential, not only for the safety of the traveling public, but also for WSDOT employees whose jobs often require them to be in close proximity to high speed traffic (*Work Zone Traffic Control Guidelines 2009)*. WSDOT cares greatly about its employees and the pedestrians traveling through highway work zones. *Work Zone Traffic Control Guidelines* is a booklet that provides extensive guidelines about highway traffic control and the need for proper planning when preparing highway work zones.

Work Zone Guidelines and Procedures

Work Zone Traffic Control Guidelines designates specific considerations relevant to the work zone. The considerations are provided to assist highway contractors and their employees when planning and coordinating for work zone preparation. It is highly recommended that highway contractors in the state of Washington take full advantage of the information that is provided for them through WSDOT. The considerations present within the manual are listed as follows:

1. Provide substantial protection and minimize worker exposure to traffic by applying positive protection and devices in practical ways. Long-term projects may warrant the use of concrete barrier, while short-term projects may be better served by a truck-mounted attenuator (TMA). Always consider the use of positive protection whenever practical.

2. Prior to the beginning of work operations, evaluate all aspects of the work area, including sight distance, traffic speed, volume, road approaches, work duration, and the type of work activity, before deciding on a traffic control plan.

3. After the traffic control plan is implemented, the supervisor (i.e., the person(s) supervising the actual work task(s) for which the TCP was implemented should drive through the work area, at the anticipated speed of the motorists, to determine the effectiveness of the plan. Additional reviews throughout the work shift are recommended to ensure that traffic control devices remain in place. It is important for work occurring during nighttime hours that the devices be reviewed to ensure proper visibility

4. Whenever the temporary traffic control zone extends more than 2 miles from the first advance warning signs the devices need to be moved forward in order to maintain appropriate advance warning to drivers.

5. Contact the region traffic management center (TMC) prior to starting work when appropriate, based on region polices to notify them of your work operation. Also coordinate with the region public information officer (PIO) for public notification and to be included in the weekly region construction activity report.

6. Plan ahead for manpower, equipment, and materials (such as signs, channelizing devices, pavement marking materials, etc.) needed for traffic control and whenever possible look for opportunities to combine multiple work operations within a temporary traffic control zone to minimize impact to drivers and for maximum efficiency.

7. The distances shown on the traffic control plans are desirable minimum requirements. Device spacing, buffer space, and sign spacing might require adjustments to provide for site conditions.

8. The Washington State Patrol (WSP) is generally available to assist WSDOT by enforcing excessive speed and impaired driver laws in critical work zone traffic control situations. These may include nighttime lane closures on high volume/high speed freeways or road closures. Contact the Region Traffic Office staff for specific information regarding procedures to utilize the WSP and the *Traffic Manual* M 51-02, Chapter 5, for guidance.

9. Traffic control devices are used to visually guide drivers through work zones. Signing, channelizing devices, arrow panels, and warning beacons all provide a message to the driver. Work zone credibility is established through the proper use of these devices to send correct messages to drivers. Poor work zone credibility has a direct, negative impact on work zone safety by causing driver confusion, frustration, and disrespect.

10. During paving operations, temporary pavement markings shall be maintained throughout the project. Temporary pavement markings shall be installed on the roadway that was paved that day. Temporary pavement markings shall be in accordance with TCD 9 (Temporary Pavement Marking Details) and *Standard Specification* 8-23.

11. Traffic delays due to work zone operations must be anticipated and addressed appropriately. Excessive delays contribute to work zone incidents of road rage or crashes. Traffic capacity issues must be addressed with the Region Traffic Office prior to starting work. Traffic should not be allowed to back up past the advance warning signs. Sign locations may need to be adjusted to fit actual site conditions or additional signs added to the sequence. Use of advance warning signs such as portable changeable message signs (PCMS) and highway advisory radio (HAR) are recommended.

*WSDOT Work Zone Traffic Control Guidelines (2009)

The recommendations that WSDOT's document provides is essential when planning and preparing a highway work zone. The *WSDOT Design Manual* is an additional manual provided by WSDOT that focuses on Work Zone Safety and Mobility. The Washington state department of transportation incorporates the concept of highway work zone safety, and has dedicated a great amount time and effort in developing this design manual regarding Work Zone Safety and Mobility.

Worker and Pedestrian Safety

The Work Zone Safety and Mobility portion of the design manual provides specific information relevant to highway work zones. Work zones generate levels of traffic impacts and require necessary safety measures. A systematic process for addressing work zone impacts is required by state and federal law (*WSDOT Design Manual* 2009*)*. The Work Zone Safety and Mobility section provides the contractor with assistance to develop comprehensive work zone strategies and plans to address a project's safety, mobility, and constructability issues.

Temporary Traffic Control Planning (TTCP)/Transportation Management

It is important that the concept of a transportation management plan (TMP) is introduced when planning and coordinating work zone awareness and safety. A transportation management plan is a set of strategies for managing the work zone impacts of a project, and is required for all projects as it is a key element in addressing all work zone safety and mobility impacts (*WSDOT Design Manual 2009)*. The *WSDOT Design Manual* specifies three major components of a transportation management plan. The three major components of a transportation management

plan are temporary traffic control (TTC), transportation operations (TO), and public information (PI). The temporary traffic control plan, transportation operations plan, and public information are explained in greater detail below as noted in the *WSDOT Design Manual*.

(a)Temporary Traffic Control (TTC)

• Control Strategies: Could include staged construction, full road closures, lane shifts or closures, night work, or one-lane two-way operations (flagging and or pilot car).

• Traffic Control Devices: Temporary signing, channelizing devices (cones, drums), changeable message signs, arrow panels, temporary signals, and temporary pavement markings.

• Project Coordination, Contracting Strategies, and Innovative Construction Strategies: A+B bidding, incentives/disincentives, and precast members or rapid cure materials.

These strategies are to be included in the Plans, Specifications, and Estimates (PS&E) as traffic control plans (TCPs) and contract provisions.

(b) Transportation Operations (TO)

• Demand Management Strategies: Transit service improvements, transit incentives, and park & ride promotion.

• Corridor/Network Management (traffic operations) Strategies: Signal timing/coordination improvements, temporary signals, bus pullouts, reversible lanes, and truck/heavy-vehicle restrictions.

• Work Zone Safety Management Strategies: Speed limit reductions, barrier and attenuators, and automated flagger assistance devices.

• Traffic/Incident Management and Enforcement Strategies: Work Zone Intelligent Transportation Systems (ITS), Washington State Patrol, town service, WSDOT Incident Management vehicle(s), and traffic screens.

Some of these strategies may be included in the PS&E, but could also be WSDOT-managed elements outside the contract.

(c) Public Information (PI)

• Public Awareness Strategies: Brochures or mailers, press releases, paid advertisements, and project website (consider providing information in other languages if appropriate).

• Motorist Information Strategies: Highway advisory radio (HAR), changeable message signs, and transportation management center (TMC).

Public awareness strategies may be developed and implemented by WSDOT through the region or Headquarters (HQ) Communications offices and implemented before and during construction. Motorist information strategies may be WSDOT-managed elements with state equipment outside the contract or identified on plans in the PS&E.

*WSDOT Design Manual (2009)

The three major components of a transportation management plan are heavily important in securing the work zone for pedestrians and workers. These components are interdependently related, and one cannot exist without the other. Traffic control plans, transportation operation plans, and public information plans are required by the contractor to properly mitigate the safety and mobility of pedestrians and workers in the work zone. Contractors must be aware that traffic management plans be modified in accordance with the development of specific highway projects. Innovative and creative practices are sometimes necessary in order to develop the most effective and practical transportation management plan. Open communication with other designers and contractors is greatly stressed when developing a transportation management plan. WSDOT wants to ensure they have construction professionals that contain the necessary leadership skills and abilities to create the safest and efficient work zones in the highway industry.

In developing and designing a work zone there are mandatory considerations set by federal and state law. This WSDOT design manual addresses these considerations regarding work zone safety and mobility. WSDOT provides designers with the mandatory considerations when planning and preparing work zones.

- Minimize, mitigate, and manage work zone impacts.
- Integrate work zone impacts strategies early, during planning, programming, and design.
- Develop an accurate scoping estimate based on the work zone strategies.
- Utilize the Work Zone TMP Checklist/TMP document required for significant projects.
- Hold a Work Zone Design Strategy Conference early in the design process.
- Emphasize flagger safety.
- Address work zone mobility through a capacity analysis.
- Determine work zone impacts through an impact assessment process.

- Integrate project constructability into the work zone design strategy.
- Attend required work zone training.
- Address state of Washington traffic and safety regulations as provided for by state law
- Use the legally adopted *Manual on Uniform Traffic Control Devices* (MUTCD), with Washington State modifications as the minimum standard.
- Provide an appropriate level of traffic control plans (TCPs).
- Consider work zone ITS elements.
- Use established design criteria in work zone roadway and roadside design.
- Accommodate pedestrian (including ADA requirements) and bicycle traffic.
- Consider maintenance of existing transit stops.
- Consider school zone impacts.
- Consider risk management and tort liability exposure.
- Consider work efficiency and cost containment.
- Approach the work zone design from the road user's perspective.
- Incorporate worker and other roadway user needs in your work zone designs.
- Account for all needed work areas and operations.
- Address work vehicle ingress and egress to each work area.

*WSDOT Design Manual 2009

The items addressed above must be planned for appropriately when designing a work zone. Washington wants to ensure that work zone safety and mobility is addressed appropriately. Contractors and designers have very reliable sources of information regarding work zone safety and mobility in the state of Washington. WSDOT provides its employees and state contractors with substantial information regarding work zone safety and traffic control. This chapter aids the contractor by reducing the overall liability and responsibility that is present on highway work zones. Safety will always be an important factor in the construction industry, but it is the sole responsibility of the contractor to provide its employees with the necessary resources and training to operate at a safe and productive manner according to the state of Washington.

Temporary Traffic Control Management

The *WSDOT Design Manual* describes transportation management plans in great depth relative to the importance of traffic control. In order to successfully implement a Transportation Management Plan, temporary traffic control devices are needed. Channeling devices, portable and temporary signing, fixed signing, warning lights, arrow panels, portable changeable message signs, truck-mounted attenuators, portable temporary traffic control signs, portable highway advisory radios, and automated flagger assistance devices are examples of temporary traffic control devices necessary for traffic control in the work zone. The *WSDOT Design Manual* provides a more descriptive version of each traffic control device. Each traffic control device is provided below in greater detail.

(1)Channelizing Devices

Channelizing devices are used to alert and guide road users through the work zone.
They are a supplement to signing, pavement markings, and other work zone devices.
Typical channelizing devices include the following:

(a) Cones

Traffic safety cones are the most commonly used devices for traffic control and are very effective in providing delineation to the work zone. Cones are orange in color and are constructed of a material that will not cause injury to the occupants of a vehicle when impacted. For daytime operations on lower-speed (40 mph or lower) roadways, 18-inch-high cones can be used. For nighttime operations and high-speed roadways, reflector zed 28-inch-high cones are necessary. Traffic cones are used to channelize traffic, divide opposing traffic lanes, and delineate short-duration work zones.

(b) Traffic Safety Drums

Drums are fluorescent orange in color, constructed of lightweight, flexible materials, and are a minimum of 3 feet in height and 18 inches in diameter.
They are highly visible and appear to be formidable obstacles. They are also less likely to be displaced by the wind generated by moving traffic. For these reasons, drums are preferred on high-speed roadways. Type-C steady-burn warning lights may be installed atop drums to improve visibility.

(c) Tall Channelizing Devices

Tall channelizing devices are 42 inches tall, fluorescent orange in color, and are constructed of lightweight, flexible material that may be less likely to cause injury in an impact. Tall channelizing devices are used to channelize traffic, divide opposing traffic lanes, and delineate short-duration work zones. These devices provide a larger target value in terms of retro reflectivity than cones, but less than that of drums. They do have a smaller footprint than drums, so they are a good alternative in narrow shoulder conditions.

(d) Tubular Markers

Tubular markers are not a recommended device unless they are being used to separate traffic on low-volume low-speed roadways. For descriptions and restrictions on use, refer to the MUTCD and the Channelization Device Application Matrix in the *Work Zone Traffic Control Guidelines*.

(e) Barricades

The barricades used in work zone applications are portable devices. They are used to control traffic by closing, restricting, or delineating all or a portion of the roadway. There are four barricade types:

1. Type 1 Barricade: Used on lower-speed roads and streets to mark a specific object.
2. Type 2 Barricade: Used on higher-speed roadways; it has more reflective area for nighttime use to mark a specific object.
3. Type 3 Barricade: Used for lane and road closures.
4. Directional Indicator Barricade: A special-use device not commonly used.

The device is used to define the route of travel on low-speed streets or in urban areas where tight turns are required. In lane reductions, the directional arrow on this barrier can be used in the transition taper to indicate the direction of the merge.

(f) Longitudinal Channelizing Devices

Longitudinal channelizing devices such as lightweight water-filled barriers are an improvement over the traffic cones and drums used to channelize traffic through a work zone. These types of barriers are not intended as a replacement for concrete barrier.

(g) Barrier Drums

Barrier drums are low-density polyethylene fabricated devices placed on and along temporary concrete barriers. They are fluorescent orange with retro reflective bands and are designed to straddle a concrete barrier. They can be used in place of barrier reflectors for barrier delineation.

(2) Portable and Temporary Signing

Portable and temporary signs (Class B Construction Signs) are generally used in short-term work zones. They are set up and removed daily or frequently repositioned as the work moves along the highway. These signs are mounted on crashworthy, collapsible sign supports. They need to be placed such that they do not obstruct pedestrian facilities. Warning signs in place longer than three days at one location must be post-mounted.

(3) Fixed Signing

Fixed signing (Class A Construction Signs) are the signs mounted on conventional sign supports along or over the roadway. This signing is used for long-term stationary work zones. Ground-mounted sign supports are usually wood; details for their design are in Chapter 1020 and the *Standard Plans*. Sign messages, color, configuration, and usage are shown in the MUTCD and the *Sign Fabrication Manual.* Existing signs may need to be covered, removed, or modified during construction.

(4) Warning Lights

Warning lights are either flashing or steady burn (Types A, B, or C) and are mounted on channelizing devices, barriers, and signs. Secure warning lights to the channelizing device or sign so they will not come loose and become a flying object if impacted by a vehicle. (See the MUTCD for additional information.)

• Type A: Low-intensity flashing warning light used to warn road users during nighttime hours that they are approaching a work zone.

• Type B: High-intensity flashing warning light used to warn road users during both daytime and nighttime hours.

• Type C and Type D 360 degree: Steady-burn warning lights designed to operate 24 hours a day to delineate the edge of the roadway.

(5) Arrow Panel

The arrow panel (Sequential Arrow Sign) displays either an arrow or a chevron pointing in the direction of the intended route of travel. Arrow panel displays are required for lane closures on multilane roadways. When closing more than one lane, use an arrow panel display for each lane reduction. Place the arrow panel at the beginning of the transition taper and out of the traveled way. The caution display (four corner lights) is only used for shoulder work. Arrow panels are not used on two-lane two-way roadways. (See the MUTCD for additional information.)

(6) Portable Changeable Message Signs (PCMS)

PCMS displays have electronic displays that can be modified and programmed with specific messages, and they are supplemental to other warning signs. These signs are usually mounted on trailers and use solar power and batteries to energize the electronic displays. The maximum number of message panels is two per location.

If additional information is necessary, consider using a second sign. Place the PCMS far enough in advance of the roadway condition to allow the approaching driver adequate time to read the sign's message twice. PCMS systems are typically used where:

• Traffic speed is expected to drop substantially.

• Significant queuing and delays are expected.

• There are extreme changes in alignment or surface conditions.

• Advance notice of ramp, lane, or roadway closures is necessary.

• Incident management teams are used.

(7) Truck-Mounted Attenuators

A truck-mounted attenuator (TMA) is a portable impact attenuator attached to the rear of a large truck. Ballast is added to the truck to minimize the roll-ahead distance when impacted by a vehicle. The TMA is used as a shield to prevent errant vehicles from entering the work zone. TMAs should be used on all high-speed roadways. If a TMA is not available, the use of a protective or shadow vehicle is still highly recommended.

(8) Portable Temporary Traffic Control Signals

Portable temporary traffic signals are trailer-mounted and used in work zones to control traffic. These versatile portable units allow for alternative power sources such as solar power, generators, and deep-cycle marine batteries, in addition to AC power.

(See the MUTCD for additional information). Portable traffic signals are typically used on two-lane two-way highways where one lane is closed for an extended duration and alternating traffic movements need to be maintained. Contact the region

Traffic Office and Signal Superintendent for specific guidance and advice on the use of these systems; a traffic control plan is required.

(9) Portable Highway Advisory Radio (HAR)

A HAR is a roadside radio system that provides traffic and travel-related information (typically affecting the roadway being traveled) via AM radio. The system may be a permanently located

transmitter or a portable trailer-mounted system that can be moved from location to location as necessary. Contact the region Traffic Office for specific guidance and advice on the use of these systems.

(10) Automated Flagger Assistance Device (AFAD)

The AFAD is an automated flagging machine that is operated remotely by a flagger located off the roadway and away from traffic. The device is a safety enhancement for projects that use alternating traffic control by physically placing the human flagger off the roadway while maintaining control of the traffic movements approaching the work zone. Contact the region Traffic Office for specific guidance and advice on the use of these systems. A traffic control plan is required for use of the AFAD.

*WSDOT Design Manual 2009

The *WSDOT Design Manual is* a very reliable document that provides contractors with the necessary steps and procedures to mitigate the risks that are present in the work zone. The booklet mentions and explains the components within a work zone in a very descriptive and specific manner. Due to the resources and information available for employees in Washington State, it can be assumed that highway Work Zones are designed to minimize the risk of injury or collision with pedestrians in the work zone. The preventative measures notified by WSDOT will keep travelers and workers safe.

The information provided by WSDOT is sufficient with details and materials regarding highway work zone safety and traffic control. Washington's *Work Zone Traffic Control Guidelines* and the *WSDOT Design Manual* are very specific documents regarding work zone safety, but lack visuals necessary for contractors to control the work zone. It would be very beneficial if the documentation provided had particular images contained within its descriptive information. Providing visuals is a great learning tool that can be adopted by the Washington State Department of Transportation, and could possibly decrease injury or fatality in highway work zones.

Appendix D. Kansas Department of Transportation

The Kansas Department of Transportation (KDOT) understands the importance of highway work zone safety. Highway work zones are very dangerous due to instances such as human error, miscommunication, weather conditions, and inattentive motorist. More than 130 people have been killed and more than 6,100 people have been injured in Kansas work zones in the past 10 years (Work Zone Safety is a Top Priority 2009). KDOT is determined to improve the overall safety of their employees and motorists near highway work zones. Like VDOT and WSDOT, KDOT participates in National Work Zone Safety Awareness week to provide the general public and highway employees with continuous education regarding highway work zone safety. Kansas highway patrol officers enforce strict policies when driving through highway work zones. Travelers caught speeding in work zones face double fines and other severe penalties. KDOT has created two specific booklets which relate to work zone safety on highways. *Kansas Work Zone Safety and Mobility Processes and Procedures* and *Standard Specifications for Construction Section 805* are the two documents utilized to ensure highway work zone safety in the state of Kansas.

KDOT Guidelines and Procedures

The *Kansas Work Zone Safety and Mobility Processes and Procedures* is a handbook that explains KDOT's main safety priorities regarding highway work zone safety. KDOT is committed to developing and managing work zones in a reasonable manner that provides safety and mobility for travelers and workers. KDOT has established objectives that pertain to highway work zone safety to reduce the possibility of injury or fatality. The main goals that KDOT has established are:

- Provide an environment conducive to the safety of workers and the traveling public.
- Maintain delays to below 30 minutes in work zones.
- Work "Toward Zero Deaths" in work zones.
- Incorporate current ITS technology that attempts to reduce delays and improve safety.

- Develop a training program for appropriate project staff relating to work zones.
- Develop a data base of work zone related crashes and a review process to see if improvements can be made to work zone designs.
- Attempt to reduce crashes involving the traveling public in all work zones.

*Kansas Work Zone Safety and Mobility Processes and Procedures 2008

The goals established are set to ensure that highway work zone safety is a top priority in the state of Kansas. KDOT believes that all work zone impacts should be considered in all phases of a project from start to completion. Establishing parameters for work zone safety is beneficial for all parties involved. It is important that KDOT enforce these objectives, and apply them accordingly to highway work zones and their impact on personal security and protection.

The *Kansas Work Zone Safety and Mobility Processes and Procedures* guidebook lists specific organizations and their responsibilities regarding highway work zone safety. Each organization is required to have the necessary credentials and training to participate in highway work zone procedures. Work zone data and project reviews are implemented by KDOT to make necessary modifications on a project by project basis. The most significant departments regarding traffic control and work zone safety are The Bureau of Traffic Engineering, The Bureau of Traffic Safety, The Bureau of Construction and Maintenance, and the Traffic Control Review Team (TCRT). Provided below are the responsibilities of each department specifically listed in the *Kansas Work Zone Safety and Mobility Processes and Procedures.*

The Bureau of Traffic Engineering is responsible for (in cooperation with the Bureau of Construction and Maintenance) setting work zone policies and guidelines and identifying and communicating issues related to work zones. Responsibilities of Traffic Engineering include:

- Design and review work zone traffic control plans on a project-by project basis, through typical traffic control drawings, or through the Highway Signing Manual.
- Prepare and maintain work zone typical traffic control drawings.
- Coordinate with the Bureau of Construction and Maintenance to prepare work zone traffic control specifications and special provisions.

- Pursue improvement of work zone safety and mobility processes and procedures.
- Assist District Offices with analysis of work zone alternatives upon request
- Review and comment on exception requests for significant projects.
- Aid in developing work zone training programs for appropriate personnel (designers, construction inspectors, flaggers, workers, supervisors, etc.) to the level commensurate with their responsibility. Traffic Engineering will periodically evaluate the work zone traffic control training and make updates when appropriate.

The Bureau of Traffic Safety is responsible for coordinating with the public information liaisons to implement educational and enforcement strategies aimed at increasing the public awareness of work zone safety.

The Bureau of Construction and Maintenance will be responsible for (in addition to those already listed under the Bureau of Traffic Engineering):

- Training and support to KDOT Maintenance personnel by the Field Maintenance Engineer and staff.
- Reporting accidents in construction and maintenance work zones per Standard Operating Manual (S.O.M.) 1.11.3.
- Managing work zone inspection results and providing access to this information via KDOT's intranet website.
- Training and support to KDOT Construction personnel by the Field Construction Engineer.

Traffic Control Review Team (TCRT): The Traffic Control Review Team (TCRT) shall review randomly selected construction and maintenance work areas on the State Highway System and on off-system construction projects to determine if improvements are needed to the Kansas Department of Transportation's traffic control procedures. A minimum of three Districts will be reviewed each year by the TCRT, resulting in a biennial review of each district.

*Kansas Work Zone Safety and Mobility Processes and Procedures 2008

Each organization is held accountable for their responsibilities regarding traffic control and work zone safety. KDOT takes work zone safety very serious, and wants the best and most certified personnel controlling their work zones. Training KDOT employees periodically is very important to ensure an injury free highway work zone. KDOT provides training on basic and advanced technical principles pertaining to design, setup, maintenance, management, and evaluation of work zones (*Kansas Work Zone Safety Mobility Processes and Procedures 2008).* Employees working at KDOT are required to take approved courses on highway work zone safety. Training and certification programs regarding overall safety in the work zone is greatly emphasized in the construction industry. The *Work Zone Safety Mobility Processes and Procedures* manual is a beneficial guide that provides KDOT employees with the necessary guidelines to ensure a secure highway work zone.

Temporary Traffic Control Planning/Transportation Management

Training employees is an essential process that outlined in KDOT's *Work Zone Safety Mobility Processes and Procedures* booklet. Another vital piece of information which this document contains is the concept of a Transportation Management Plan (TMP). A TMP should be developed for any project by the project manager according to KDOT. For significant projects, the TMP shall contain a Temporary Traffic Control Plan (TTCP), a Traffic Operations Component (TO), and a Public Information (PI) component (*Work Zone Safety Mobility Processes and Procedures* 2008). The descriptions of each component are very similar to the Washington Department of Transportation and their procedures. A description of each component is provided below as listed in KDOT's *Work Zone Safety Mobility Processes and Procedures* guidebook.

1. The TTCP component shall conform to the applicable portions of Section 821 Traffic Control in the Standard Specifications. Also, it may consist of any one or more of the following, but need not be limited to:

a. Work hour restrictions

b. Detours and lane closures

c. Construction phasing

d. Weekend work

e. Full roadway closures

2. The TO component may consist of any one or more of the following, but need not be limited to:

a. Signal timing

b. Temporary traffic signals

c. Turn restrictions

d. Heavy vehicle restrictions

3. The PI component may consist of any one or more of the following, but need not be limited to:

a. Newspaper ads

b. News releases

c. Public ad campaign

d. Internet sites

e. Changeable message signs (CMS)

f. Dynamic speed message sign

g. Traveler information systems (511)

* Kansas Work Zone Safety and Mobility Processes and Procedures 2008

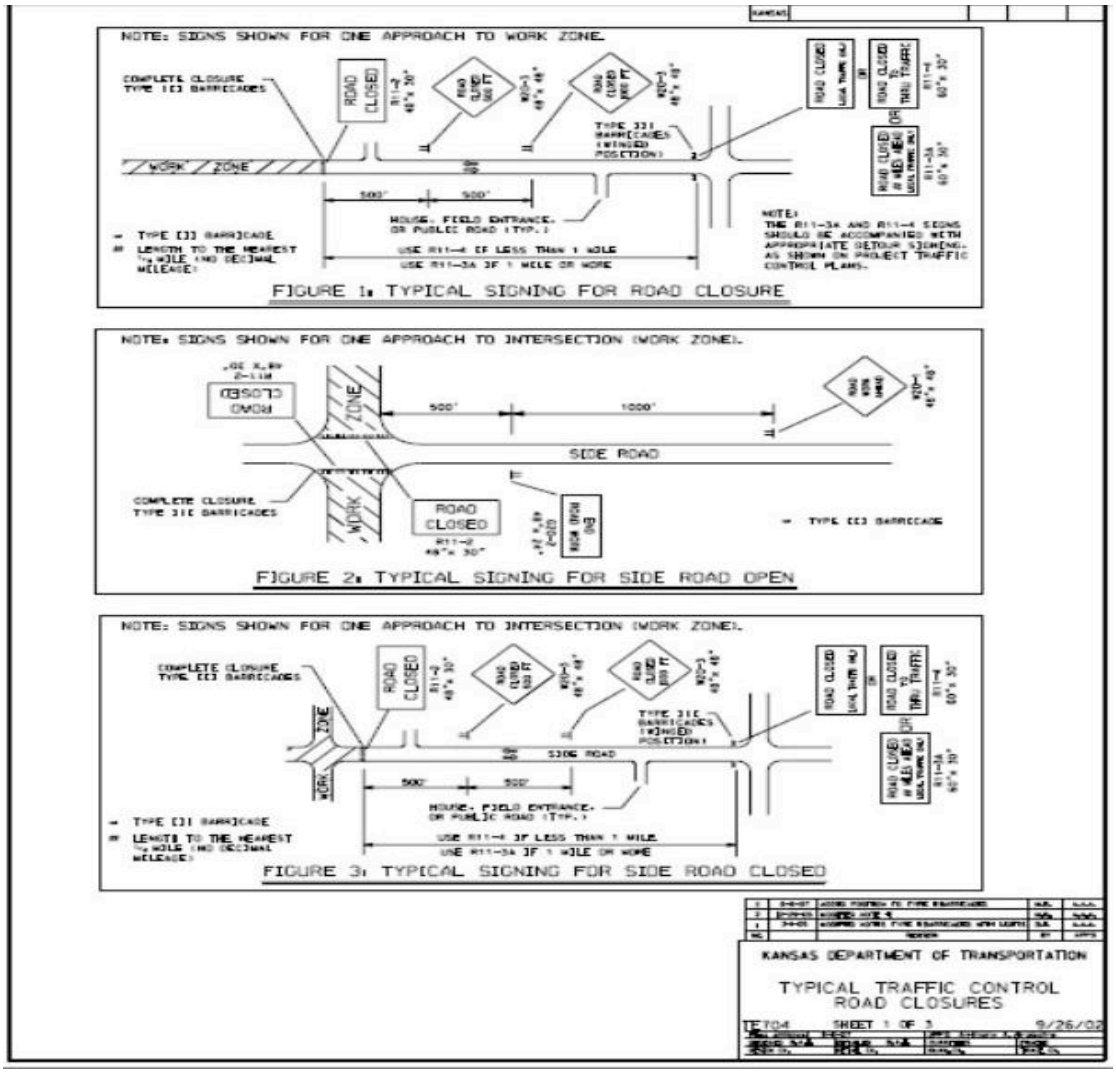
The TMP is an essential part of any project, and is required to be implemented on any project in the highway construction industry. It is important that KDOT contains the necessary clientele with the required training and expertise to maintain a work zone. Each component that makes up the TMP is critical in controlling a work zone and its surroundings. The *Kansas Work Zone Safety and Mobility Processes and Procedures* manual is intended to introduce the necessary guidelines and procedures for traffic control and work zone safety.

Unlike the states of Virginia and Washington, Kansas does not contain a descriptive document that explains traffic control guidelines and procedures in the highway work zone. Other than a traffic control handbook, KDOT has a set of standards that are developed specifically for work

zone traffic control and safety known as *Standard Specifications for Construction Section 805*. The standards are intended to guide highway contractors in setting up the safest and most efficient work zones on the highway.

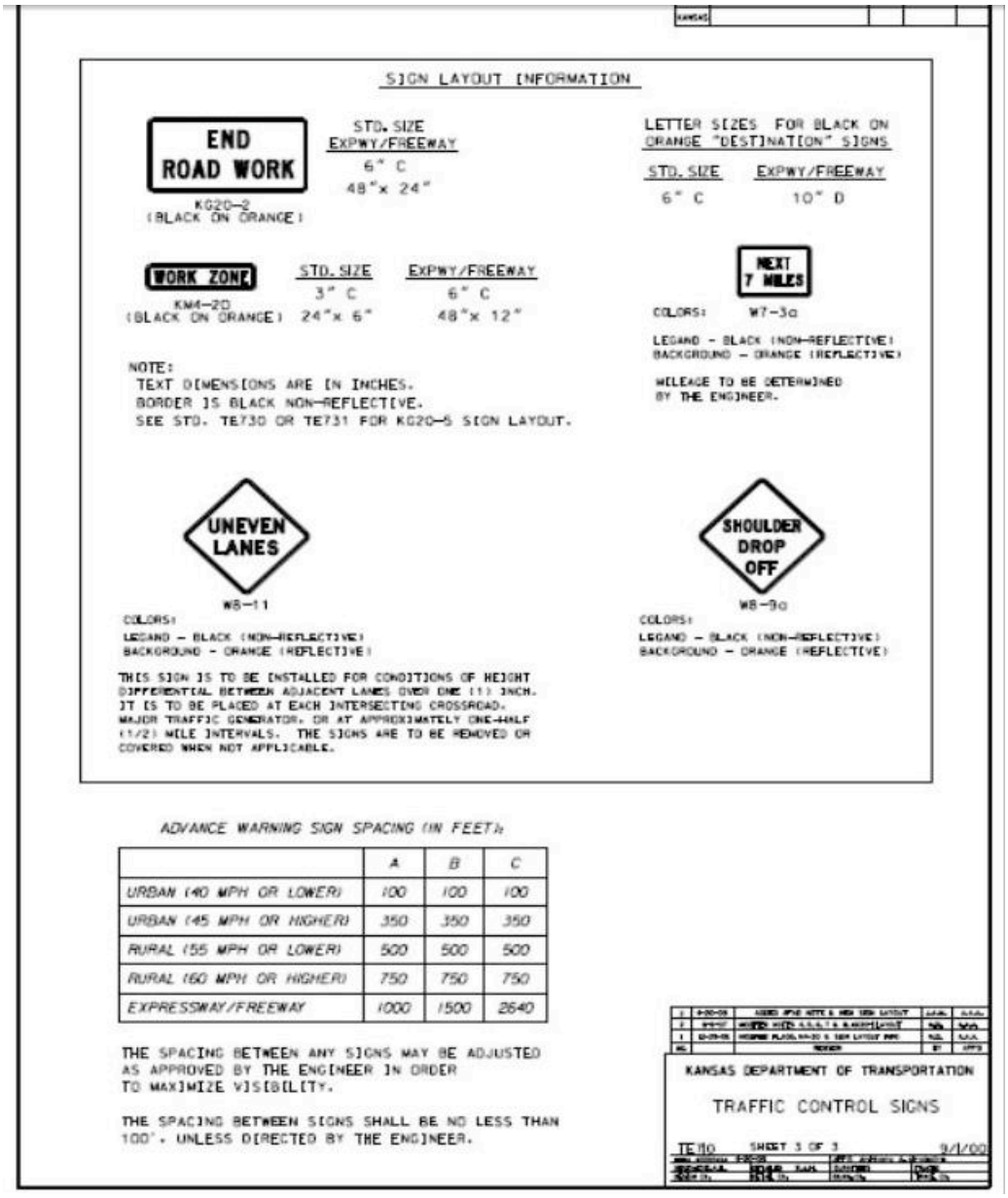
The standards implemented by the state of Kansas are to comply with part VI of the *Manual on Uniform Traffic Control Devices (MUTCD)*. Contractors are to follow the exact procedures present in the *Kansas Standard Specifications for Construction Division 800 Section 805*. The document contains drawings which display how a work zone should be set up during the construction process. Typical traffic control road closures, traffic control signs, and typical traffic control work on or near the shoulder of a divided highway are a few examples portrayed below in figures 9 through 11 of what is contained in KDOT's standards document.

Figure 9. Typical Traffic Control Road Closures



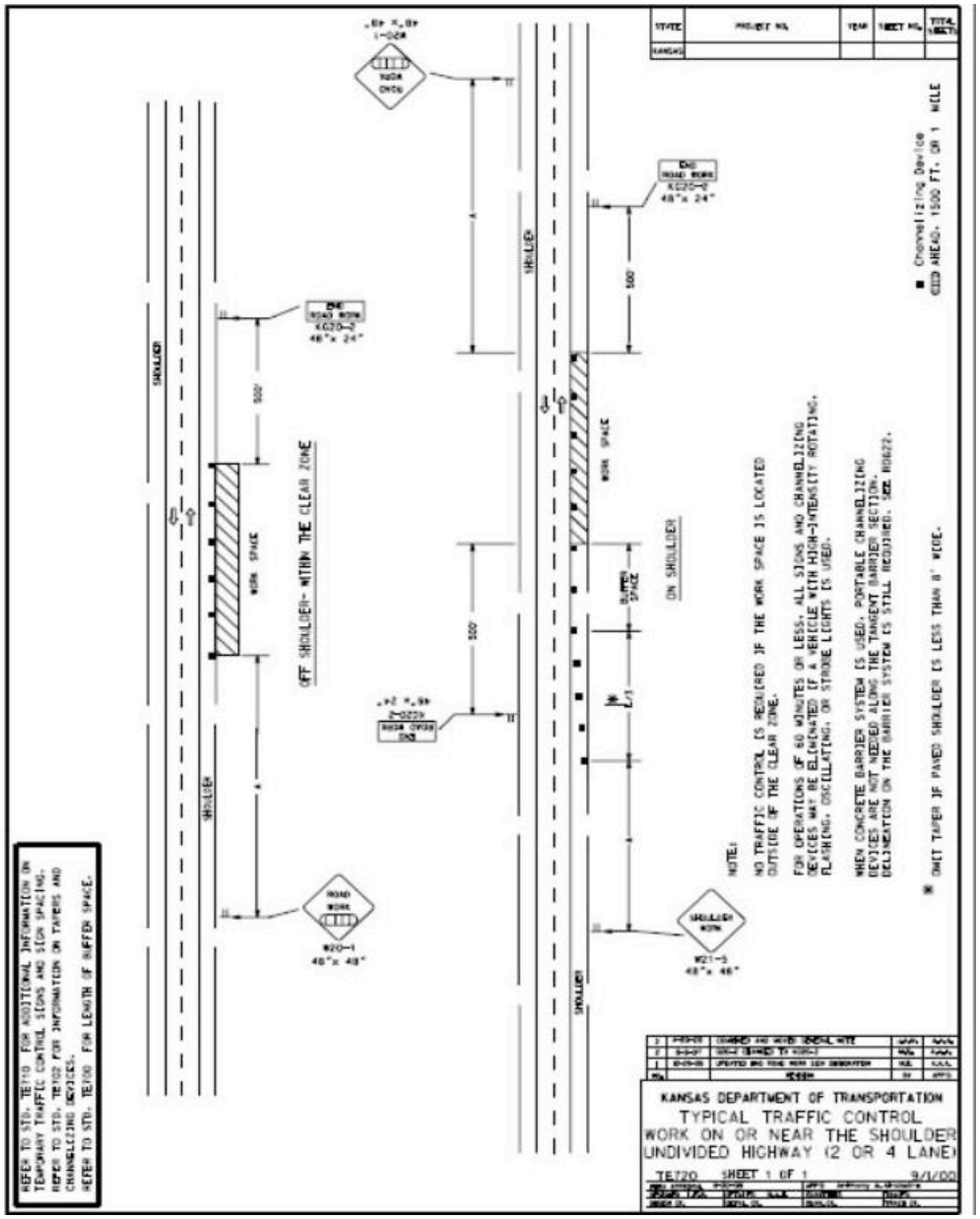
** Kansas Standard Specifications for Construction Division 800 Section 805 2009*

Figure 10. Traffic Control Signs



** Kansas Standard Specifications for Construction Division 800 Section 805 2009*

Figure 11. Typical Traffic Control Work on or Near the Shoulder Undivided Highway



** Kansas Standard Specifications for Construction Division 800 Section 805 2009*

The *Standards Specifications for Construction Section 805* provided by KDOT are very reliable for highway contractors. Although there are numerous standards defined by KDOT, minimal measures are taken to prevent the risk of injury and fatality among workers and pedestrians. KDOT needs to develop a written handbook that is detail oriented which pertains to the specifics of work zone safety on highways. The standards developed by KDOT only relate to the

contractor, and it is important that residents in Kansas understand the relevance of work zone safety.

KDOT contains minimal information regarding highway work zone safety and traffic control in the highway work zone industry. For example KDOT does not introduce the fundamental principles of temporary traffic control and worker and pedestrian safety compared to the other three states assessed in this study. Highway contractors and related personnel need as much information as possible in order to successfully set up a safe and efficient work zone. *Kansas Work Zone Safety and Mobility Processes and Procedures* and the *Standards Specifications for Construction Section 805* are two helpful documents, but do not provide sufficient information to control a safe and secure highway work zone. KDOT could adopt some procedures and guidelines from Virginia and Washington to help clarify their overall approach to work zone safety and highway traffic control.

Appendix E. Iowa Department of Transportation

The Iowa Department of Transportation takes various measures and guidelines to ensure that highway work zones are safe and secure. On average 6.3 fatalities occur on Iowa state maintained roads (Iowa Work Zone Quick Facts 2009). To prevent accidents in work zones, Iowa has established a Work Zone Safety Committee. The committee oversees work zone traffic safety issues that affect pedestrians and road workers within traffic control zones. The Work Zone Safety Committee is determined to ensure that workers and pedestrians are safe while near and around work zones. The committee members conduct field reviews during the construction season to observe traffic control installations and recommend changes for future work zones (Work Zone Safety 2010). Establishing a Work Zone Safety Committee is a great incentive to ensure that highway work zone safety is effectively practiced by highway workers. Like the states mentioned prior in this study, the Iowa Department of Transportation participates in national work zone awareness week. National work zone awareness week is heavily participated in by the state of Iowa, and Iowa believes that injuries and fatalities in the work zone can be minimized incrementally. Iowa has established new penalties for speeding which are very similar to the double fine law the state of Kansas mandated for highway work zones. As of July 2008, Iowa established a speeding law that represents the steps that Iowa is taking to protect the safety of highway workers, enforcement personnel, and motorists (Work Zone Fines 2008). If a pedestrian is caught speeding at an excess of 25 mph, that individual can be fined up to $1000. Workers and contractors that work in highway work zones will benefit from the new speeding laws that Iowa has established.

Establishing a Work Zone Safety Committee and controlling speeding pedestrians are two great incentives to establish a safer work zone for highway contractors and motorists. Iowa has various guidelines and procedures that are implemented to ensure a safe and effective work zone.

The Iowa Department of Transportation also has developed workshops for their employees to use and implement for guidance while in close proximity to work zones. Like the state of Kansas, standard drawings were developed for contractors to rely on while setting up and maintain a work zone. In order to become more aware of the importance of work zone safety,

the educational materials and guidebooks have been developed and implemented by the state of Iowa. The *Work Zone Safety Workshops 2002* and the *Design Manual Chapter 9 Traffic Control* are two documents that Iowa uses to enforce and educate highway work zone safety in the state of Iowa.

The *Work Zone Safety Workshop 2002* is an educational program sponsored by the Iowa Department of Transportation to reintroduce work zone awareness and safety to highway workers. The workshop has established a few objectives which are defined as:

- To introduce the principles and convey the importance of using proper methods for safe and efficient traffic control at work sites.

- To examine some specific applications relevant to situations normally encountered by city, county, utility, contractor, and Iowa DOT crews.

- To reduce motor vehicle traffic crashes at road work sites, resulting in greater safety for highway users and workers alike.

* Work Zone Safety Workshops 2002

The objectives established are important to ensure that highway workers practice safe construction methods and procedures in order to decrease the accident rate. A team of teachers guide the workshop to explain the importance of traffic control relevant to the *Manual on Uniform Traffic Control Devices (MUTCD)* and other common applications. Iowa encourages its state employees to attend the workshops to promote a safer work zone for highway workers in the construction industry.

Iowa has developed a chapter devoted to traffic control on highway work zones known as the *Design Manual Chapter 9 Traffic Control*. In a highway work zone, problems will always be present to control traffic and pedestrians. The Design manual was published by Iowa's Office of Design, and is used to provide guidance for contractors and designers in the highway industry. Chapter 9 of the design manual primarily focuses on traffic control and its fundamental principles. The manual consists of many drawings and explanations of important factors relevant to highway work zones. Issues addressed in this chapter that relate to the safety of highway

work zones are the fundamental principles of traffic control, traffic control zones, and traffic control plans.

Iowa DOT Guidelines and Procedures

It is important to recognize the importance of highway work zones and their fundamental principles. Iowa has formulated a set of guidelines that highway contractors can follow to ensure a safe working environment in the work zone. The Iowa DOT design manual has listed the guidelines and principles that one shall follow while controlling and maintaining a highway work zone. The guidelines are as follows:

A. Traffic safety in construction and maintenance zones should be an integral and high-priority element of every project from planning through design and construction.

- The basic principles used in the design of permanent roadways should also govern the design of traffic control in work zones.
- Appropriate traffic control, based on the complexity of the job, should be prepared by knowledgeable persons. Pertinent information should be gathered, analyzed, and used to prepare the traffic control plan.

B. Traffic movement should be inhibited as little as possible.

- Assume motorists will reduce their speed only if they perceive a need to do so. Therefore, reduced-speed zoning should be avoided as much as possible.
- Frequent and abrupt changes in geometrics (lane narrowing, dropped lanes, lane shifting) should be avoided. Proper distances between maneuvers must be maintained.
- Consideration should be given to the safe operation of work vehicles, especially on high volume, high-speed roadways.
- Construction time should be minimized to reduce driver exposure to potential risks.

C. Motorists should be given clear and positive guidance when approaching and traversing construction areas.

- Proper warning, delineation, and channelization should be provided to assure positive guidance through the work area.

- Existing traffic controls (signs, pavement markings, etc.) that are inappropriate to or conflict with temporary traffic controls should be removed or covered so that motorists will not be misled.

D. The designer should make periodic reviews of actual traffic control installations. Special attention should be given to the effectiveness of the traffic control and any problems that have been encountered. This information will be useful for designing traffic control on future projects.

* Design Manual Chapter 9 Traffic Control 2009

The guidelines that Iowa DOT has considered when safely controlling a work zone are very general, and do not specify exactly what a highway contractor can do to ensure proper work zone security. Although they are very helpful for the contractor and workers, they tend to be very wordy and not descriptive enough. It is great that Iowa has established a set of guidelines pertaining to highway work zone safety, and it is important that highway contractors take this issue very seriously.

Fundamental Principles of Temporary Traffic Control

The Iowa DOT has determined that understanding a traffic control zone and its components is very important when controlling traffic. When traffic is interrupted by construction activities, it is important that is it controlled at the most safe and effective manner. A traffic control zone is the segment of the roadway between the first advance warning sign and the point beyond the work area where the traffic is no longer effected (*Design Manual Chapter 9 Traffic Control* 2009). Iowa explains that the four main parts of a traffic control zone are the advance warning area, transition area, activity area, and the termination area. Figure 11 provided in Iowa's manual aids the contractor in understanding each component of the traffic control zone. Figure 12 is very similar to VDOT's description of the common work zone areas and is provided below for further reference.

Figure 12. Work Zone Areas

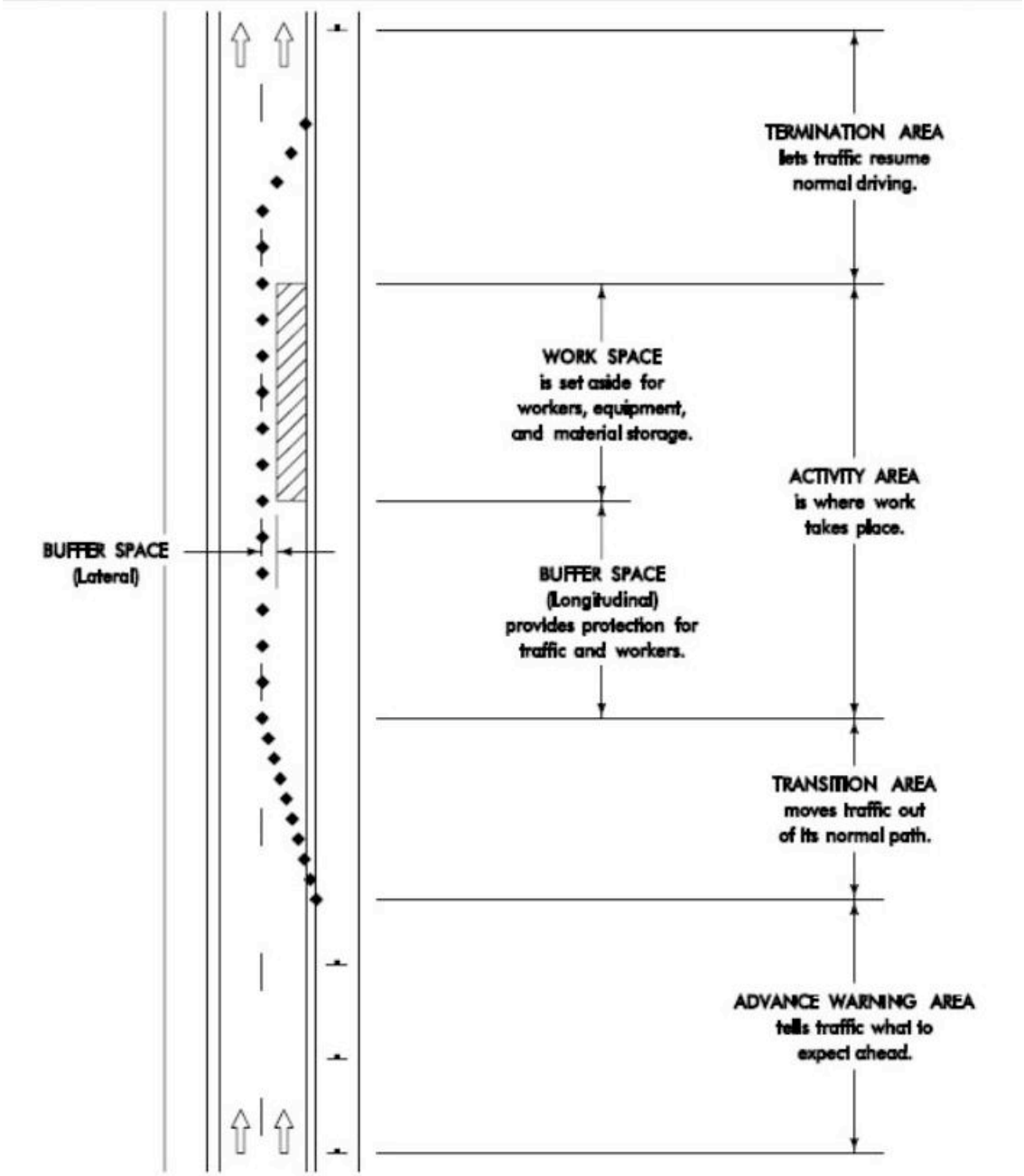


Figure 1: Work zone areas.

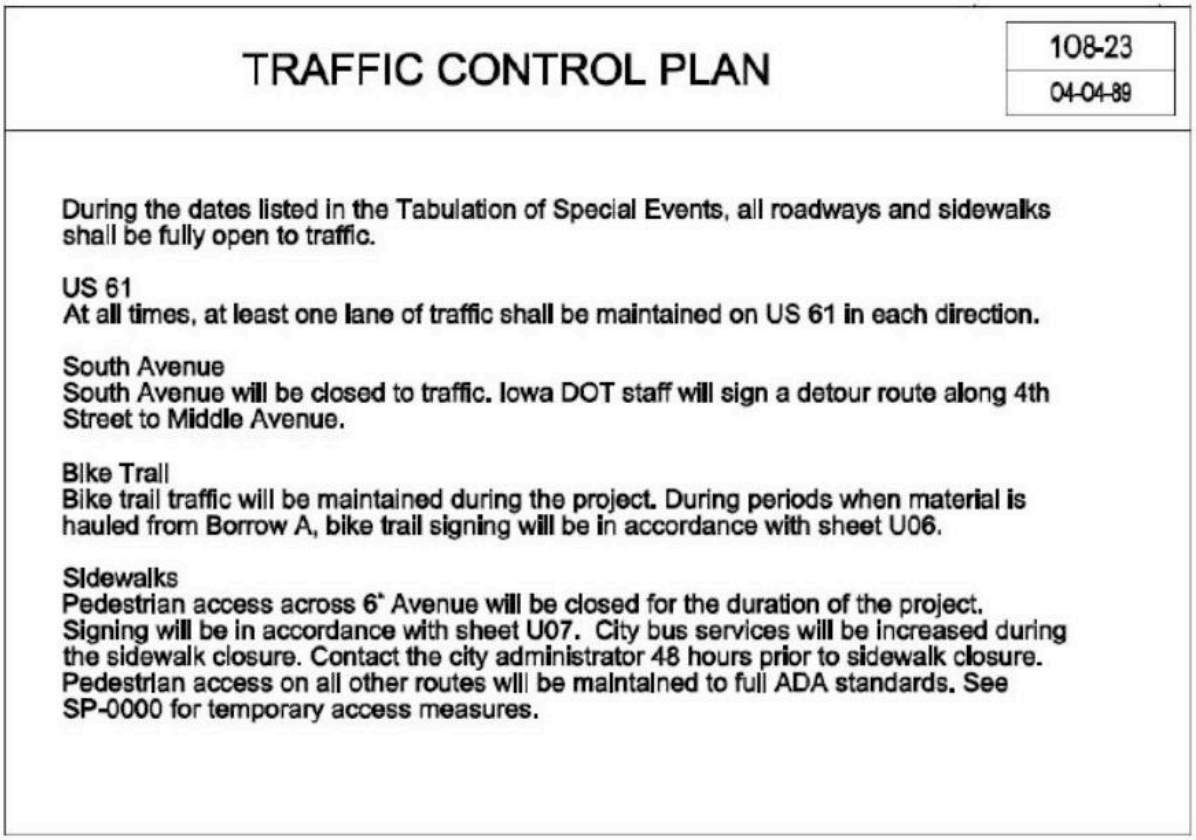
* Design Manual Chapter 9A-2 Traffic Control 2009

The graphics provided in this chapter are a great way for highway contractors and workers to envision and apply highway work zone safety to its fullest. Iowa, like the other states mentioned in this study, emphasizes the importance of traffic control planning for highway work zones.

Traffic Control Planning/Transportation Management

Traffic control planning is essential during the construction process to ensure that highway work zones are operating safely. Transportation management plans (TMP) are required by federal law, and all states must abide to this regulation. According to the Iowa DOT, a TMP includes a Temporary Traffic Control Plan (TTC), Transportation Operations Plan (TO), and a Public Information Plan (PIP) (*Design Manual Chapter 9 Traffic Control)*. The components that make up a transportation management plan are the same for each state described in this study. One difference that Iowa has provided is an example of a Traffic Control Plan Tabulation. Figure 13 below is a Traffic Control Plan Tabulation from Chapter 9 of the Design Manual of Traffic Control.

Figure 13. Traffic Control Plan



TRAFFIC CONTROL PLAN

108-23
04-04-89

During the dates listed in the Tabulation of Special Events, all roadways and sidewalks shall be fully open to traffic.

US 61
At all times, at least one lane of traffic shall be maintained on US 61 in each direction.

South Avenue
South Avenue will be closed to traffic. Iowa DOT staff will sign a detour route along 4th Street to Middle Avenue.

Bike Trail
Bike trail traffic will be maintained during the project. During periods when material is hauled from Borrow A, bike trail signing will be in accordance with sheet U06.

Sidewalks
Pedestrian access across 6th Avenue will be closed for the duration of the project. Signing will be in accordance with sheet U07. City bus services will be increased during the sidewalk closure. Contact the city administrator 48 hours prior to sidewalk closure. Pedestrian access on all other routes will be maintained to full ADA standards. See SP-0000 for temporary access measures.

*Design Manual Chapter 9A-5 Traffic Control 2009

Iowa DOT and their Traffic Control Tabulation enable highway contractors and workers to understand how to document a traffic control plan relevant to its procedures. Planning and documentation is a great way to ensure that work zones are safe and secure for workers and travelers.

The Iowa DOT has established many parameters to ensure that work zones are safe and secure on highways. Providing employees with educational courses and traffic control guidelines are important measures in determining work zone safety. The two documents provided by Iowa DOT are very helpful for the contractor to understand work zones and their common applications, but do not enforce the necessary measures that need to be taken for optimum highway work zone safety. The *Work Zone Safety Work Shop Information* and the *Design Manual Chapter 9 Traffic Control* are very insightful documents, but lack the necessary feedback to prevent injury and fatality in the work zone. Guidelines, procedures, and educational materials are incentives to control highway work zones, but there are better ways to enforce and control the safety and awareness of motorists, pedestrians, and workers.

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