Utility Work Zone Safety Guidelines and Training

State-of-the-Art Synthesis and State-of-the-Practice Synthesis

Prepared for:
United States Department of Transportation
Federal Highway Administration
Office of Acquisition Management
400 Seventh Street, SW, Room 4410
Washington, D.C. 20590

Prepared by:
Wayne State University
Transportation Research Group
Detroit, MI
and
Bradley University
Peoria, IL

Date: April 2007

U.S. Department of Transportation
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WAYNE STATE UNIVERSITY

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1.0 INTRODUCTION

Utility work zones pose unique challenges to the motorist as well as to the workers health and safety. Utility service providers such as the electric, gas, telephone and cable companies often need to work on or near public highways providing essential services to the public at large. Most of their work activities typically require less time as compared to roadway construction and maintenance activities, and are generally completed in a timely manner. It is often impractical for a utility company to create detailed, site-specific work zone plans for each and every work zone they work in. The utility companies and their contractors, therefore, must follow policies, procedures and safety standards for work zone traffic control that incorporate desirable safety and mobility guidelines and standards and follow their intent to ensure the safety of the motorists and workers alone.

The federal *Manual on Uniform Traffic Control Devices* (MUTCD) *(1)* contains the basic principles of design and the use of traffic control devices for all streets and highways. Part 6 of the MUTCD contains the standards, guidance, options, and support information related to work zones. In work zones, temporary traffic control is primarily used to enhance traffic safety and mobility. As stated in Part 6 of the MUTCD, "the primary function of temporary traffic control is to provide for the safe and efficient movement of vehicles, bicyclists, and pedestrians through or around temporary traffic control zones while reasonably protecting workers and equipment" *(1)*. The MUTCD includes 'Typical Applications' for a variety of street and highway work zone situations commonly encountered by road users. These provide detailed schematics and depict examples of recommended advanced traffic control warning signs, tapers for lane transitions, buffer space, temporary channelizing devices (such as cones drums, traffic barriers), and pavement markings. However, the MUTCD does indicate that such procedures be used for establishing traffic control devices to satisfy actual field conditions, as they may vary drastically from the condition illustrated in the 'typicals' with such conditions as: road configuration, location of work, work activity, duration of work, traffic volumes, and traffic speeds. In such cases, MUTCD recommends that the 'typicals'/guidelines be applied/adjusted to actual situations and field conditions using proper judgment *(1)*. Many professionals and regulatory agencies misinterpret the MUTCD's 'typicals' and think that they must be used in all circumstances.

The MUTCD (Part 6) provides comprehensive information related to roadway construction-related traffic control. The research that provides the background for the MUTCD rarely involves utility work zones. The manual, however, recognizes the transient nature of utility work and differentiates between the shorter duration of work by providing a certain amount of flexibility for the typical temporary traffic control for a given situation. Work duration is a major factor in determining the number and types of devices used in temporary traffic control zones *(1)*.

Work zones often contain a sign at the beginning of the work zone informing drivers that a work zone is beginning and another sign at the end letting drivers know that the work zone has ended. Utility work zones may not always contain these signs since they are shorter in duration and may be mobile. The MUTCD gives a definition of construction, maintenance and utility work zones stating that they may be defined by signs at the beginning and end of the work zones, but they may also be defined by providing rotating lights or strobe lights. According to the MUTCD, "A work zone is an area of a highway with construction, maintenance, or utility work activities. A work zone is typically marked by signs, channelizing devices, barriers, pavement markings, and/or work vehicles. It extends from the first warning sign or high-intensity rotating, flashing, oscillating, or strobe lights on a vehicle to the END ROAD WORK sign or the last TTC device." *(1)*

The US Department of Transportation, Federal Highway Administration has established a 'Work Zone Safety and Mobility Rule' *(2)*, which is applicable to all state and local governments that receive highway funds. It supports a three-tiered approach to work zone mobility and safety, which includes an overall policy for management of work zone impacts, agency-level processes and procedures to implement the work zone policy, and project-level procedures to assess and manage work zone impacts. The first component of the Rule promotes the use of decision-making framework and targeted strategies to address a wide range of safety and mobility impacts in work zones throughout the project development stages. The second component requires agencies to develop an agency-level work zone safety and mobility policy utilizing the work zone safety and operational data, personnel training, and process reviews to assess and manage the impacts of all project stages based on standard procedures adopted by the agency. The third component includes the identification of ‘significant projects’ and requires that the transportation management plans consist of a Temporary Traffic Control Plan, Transportation Operational Strategies and Public Information components. *(2)*

Researchers from Wayne State University and Bradley University received a grant from the Federal Highway Administration to develop safety and mobility guidelines for utility work zone traffic control. The overall objectives of this grant are to 1) develop utility work zone safety guidelines to assist transportation agencies, utility companies and contractors in achieving reductions in injuries and fatalities while complying with FHWA’s ‘Work Zone Safety and Mobility Rule’, 2) develop a training program based on the developed utility work zone safety and mobility guidelines and 3) conduct ‘train-the-trainer’ workshops at a national level and pilot training sessions on the methods and procedures of implementing utility work zone safety guidelines developed as a part of this project.

In order to accomplish the grant objectives, a comprehensive state-of-the-art review and a current practice survey have been conducted. This document presents the findings from the state-of-the-art literature review and the current practices survey. The basic purpose of the literature review and current practices survey is to determine the current knowledge of issues pertaining to utility work zone safety and mobility, assess the current state of practice among the transportation agencies and utility companies/contractors. Establishing the current state of knowledge related to utility work zones will allow the identification of gaps that need to be addressed in the utility work zone guidelines. The guidelines developed as a part of this project will provide local transportation agencies and utility companies and contractors with the needed information and guidance to perform their work on and around roads and streets safely and efficiently and to assist road agencies in the development of local guidelines and standards that will meet the safety and mobility goals of the utility work zones.

2.0 STATE-OF-THE-ART SYNTHESIS

A comprehensive literature review was conducted in order to assess the state-of-the-art of work zone safety-related topics. This search was conducted through web-based queries, as well as queries through specific agency search engines such as the United States Department of

Transportation (USDOT), Federal Highway Administration (FHWA), the National Work Zone Safety Information Clearinghouse, Transportation Research Information Services (TRIS), the Transportation Research Board (TRB), the Institute of Transportation Engineers (ITE), American Society of Civil Engineers (ASCE) Journal of Transportation Engineering, the Texas Transportation Institute (TTI) and others.

A comprehensive search of topics in the broad area of "work zone safety and mobility" was conducted. This generated a broad list of potential papers and reports to be included in the literature review for the utility work zone program. The references cited within the papers initially obtained were reviewed for relevancy and those that seemed applicable were further reviewed in detail. This resulted in a review of a total of 329 papers and reports as listed in the Bibliography (Appendix I). This list was further reviewed to identify those papers and reports that would be relevant to the utility work zone program. All papers were given a 1 through 4 number rating, with rating 1 meaning most relevant and rating 4 meaning least relevant. The papers and reports that may have some relevance (numbers 1, 2 and 3) to the topic of utility work zones were further reviewed and summarized. This resulted in the preparation of a total of approximately 130 papers and reports. The papers and reports with the most relevance (number 1) have been included in this report as direct reference and all others with some relevance (numbers 2 and 3) are included in the form of a table in Appendix II and have been used in this report implicitly. This table includes the name of the authors, the title and the publisher of each paper or report along with a brief statement regarding the basic goal of the paper/report. Most papers and reports shown in the table (Appendix II) were not directly included in this report; however, material from these has been used in formulating the conclusions. Most utility work is short-term, conducted on local roads and streets and during the daytime hours. Long-term and/or utility construction projects on or around freeways, nighttime emergency work and planned work in high speed roads should follow normal highway work zone traffic control guidelines since they may pose greater risk.

The relevant topics for utility work zones included in this literature review are: 1) definitions of work duration, 2) crash and injury risks related to utility work zones, 3) urban issues, 4) utility work zone locations, 5) human factors in utility work zones, 6) installation/removal times for traffic control devices, 7) relevant traffic control and warning devices and 8) utility worker safety issues. In addition, existing training programs on utility/maintenance work zones were identified and have been discussed in this report.

2.1 Definitions

As per the MUTCD guidelines (Section 6G.02), the "five categories of work duration and their time at a location shall be:

A. **Long-term stationary** is work that occupies a location more than 3 days
B. **Intermediate-term stationary** is work that occupies a location more than one daylight period up to 3 days, or nighttime work lasting more than 1 hour
C. **Short-term stationary** is daytime work that occupies a location for more than 1 hour within a single daylight period
D. **Short duration** is work that occupies a location up to 1 hour
E. **Mobile** is work that moves intermittently or continuously" *(1)*.

The majority of utility projects are short-term stationary, short duration or mobile operations and thus, will be the focus of this initiative. However, in a situation where the utility, construction or maintenance project requires planned nighttime work, or up to or more than three days, often poses increased risks and the traffic control requirements set forth in the MUTCD and in the 'typicals' standards should be used to assure motorist and worker safety. Intermediate-term and long-term utility, construction and maintenance projects are similar to normal highway construction and maintenance work zones. Therefore it should be treated as such, and the temporary traffic control for such projects must follow the MUTCD and local standards and guidelines. Therefore, the focus of this utility work zone guideline development initiative will be directed towards short-term stationary, short duration and mobile work.

The MUTCD recognizes the nature of such work zones and states that "During short-duration work, **it often takes longer to set up and remove the TTC zone than to perform the work**. Workers face hazards in setting up and taking down the TTC zone. Also, since the work time is short, delays affecting road users are significantly increased when additional devices are installed and removed" *(1)*. It also presents that "Considering these factors, simplified control procedures may be warranted for short-duration work. A reduction in the number of devices may be offset by the use of other more dominant devices such as high-intensity rotating, flashing, oscillating, or strobe lights on work vehicles" *(1)*.

It should be noted that the "up to one hour" time for 'Short Duration' work is not an absolute increment of time. The language of MUTCD (Section 6G.02) *(1)* appears to allow for a judgment as to whether the time necessary to set up and remove the traffic control zone is justified under the circumstances. It should also be noted that the next category 'Short Term Stationary' has a time period of greater than one hour and within one daylight period. There could certainly be situations in which work extends past one hour, perhaps three hours, but does not approach the entire daylight period. The procedures in the 'Short Term Stationary' category are applicable to work lasting an entire day and, therefore, may not be appropriate for a three hour job.

The traffic control plan for utility work should be determined based on the type of work being conducted rather than the time it will take to complete. In a study conducted in Michigan *(3)*, field observations were performed to determine the various types of work conducted by utility companies and the amount of time needed to complete each job. It was found that the same type of utility work done at one location took a different amount of time to complete as compared to another location. If a traffic control plan is set-up for a 30 minute work zone but the work ends up taking say 90 minutes to complete, the workers are not going to adjust the traffic control plan halfway through the job. The plan should have been set-up for the type of work being performed so that when the work takes longer than expected, the proper traffic control will have already been set-up. *(3)*

Brooke, Ullman, Finley & Trout *(4)* conducted a current practice survey of 17 state transportation agencies and also sought the opinions of a focus group of Texas DOT employees to identify variations in the definitions of mobile and short duration highway construction/maintenance operations among state DOTs and assess their procedures and plans used in short duration and mobile operations. The authors obtained responses for the current practice survey from 17 state DOTs. It was found from the survey that the definition of mobile operations did not vary dramatically among state DOTs who responded to the survey, which was ‘work that moves intermittently or continuously’. The short duration operation definitions varied from work performed in less than 15 minutes (Oregon DOT) to work that lasts up to 12 hours (Maryland DOT). The Nevada DOT indicated that although their definition reads “work that occupies a location up to one hour”, they acknowledge that the actual work categorized as ‘short duration’ could take several hours. The authors stated that “one interesting note made by several states is that the work encompassed by the definition of short duration maintenance can frequently take a shorter amount of time to complete than to set up and remove the appropriate traffic control devices” *(4)*. As per the state DOT responses, the type of work performed under the short duration category generally include guardrail work, lighting maintenance, paving operations, pothole patching, sign repair/installation and signal work.

In terms of defined procedures and plans for short duration and mobile operations, all the responding states indicated that they have standard traffic control plans for mobile operations and all but one state (Connecticut) indicated that they have standard plans for **short duration operations** *(4)*.

Twelve of the responding states have safety manuals that address short duration and mobile operations and worker safety, and typically include general guidelines on taper lengths, buffer zones, traffic control devices, flagger instructions and work zone temporary traffic control plans. The work zone temporary traffic control plans are typically categorized based on roadway type, and location of work, as opposed to duration *(4)*.

Several states address issues pertaining to short duration work, as it relates to the trade-offs between the time it takes to install and remove traffic control devices for the temporary traffic control versus the time needed to complete the work. Direct quotes from state DOT manuals are as follows *(4)*:

Oregon DOT

Traffic Control on State Highways for Short Term Work Zones, revised 1998.

> "There are safety concerns for the crew in setting up and taking down traffic control zones. Since the work time is short, the time during which road users are affected is significantly increased when additional devices are installed and removed. Considering these factors, it is generally held that simplified control procedures are warranted for short duration activities. Such shortcomings may be offset by the use of other more dominant devices such as special lighting units on work vehicles"

Washington DOT

Work Zone Traffic Control Guidelines, May 2000.

> "Remember, short duration work is not a 'short-cut'; it's a traffic control method that reduces worker exposure to traffic hazards by using larger, more mobile equipment instead of many smaller devices"

The authors *(4)* conducted seven focus group meetings comprised of Texas DOT field personnel and supervisory personnel/engineers. Issues discussed at the focus group meetings were related to short duration and mobile operation definitions, hazards encountered, and worker safety issues. In terms of definitions of short duration and mobile operations, there was not much consistency amongst Texas DOT personnel. "These variations make it difficult for field personnel to select the proper traffic control for maintenance operations. In addition, participants indicated a desire to have guidelines concerning the use of optional devices based on traffic volume and/or roadway speed" *(4)*.

The authors concluded that there is a need for: a clearer distinction between mobile and short duration operations, guidance in applying standards to specific types of operations, and enhancement of guidelines to provide direction related to roadway conditions *(4)*.

2.2 Crashes, Injuries and Fatalities in Work Zones

The number of fatalities that occurred in work zones throughout the USA were obtained from the National Work Zone Safety Information Clearinghouse website *(5)*. The data posted on this site was extracted from the Fatality Analysis Reporting System (FARS) database and categorized the number of fatalities by type of work zone. The nationwide fatalities by work zone type for a twelve year period (1994 – 2005) are shown in Table 1 and Figure 1.

Table 1. Fatalities in Motor Vehicle Crashes by Work Zone Type in the USA (1994-2005)

Year	Type of Work Zone				
	Construction	Maintenance	Utility	Unknown Work Zone Type	Total
1994	644	96	16	72	**828**
1995	657	58	8	66	**789**
1996	575	64	19	59	**717**
1997	549	81	11	52	**693**
1998	652	52	15	53	**772**
1999	740	72	10	50	**872**
2000	873	92	12	49	**1,026**
2001	808	96	8	77	**989**
2002	1028	84	12	62	**1,186**
2003	862	79	21	66	**1,028**
2004	836	99	16	112	**1,063**
2005	872	98	17	87	**1,074**

Table 1 indicates that the majority of work zone fatalities over the twelve year period occurred in construction zones (75 to 85 percent each year). Maintenance zone fatalities represent 7 to 11 percent of all work zone fatalities, while fatalities in utility zones represent a very small portion of all work zone fatalities, approximately 1 to 2 percent annually. There is also a substantial portion of work zone fatalities that were not categorized by work zone type (5 to 10 percent each year). This is most likely attributable to the differences in the level of detail of work zone crash reporting among the states and may also be such due to coding inconsistencies.

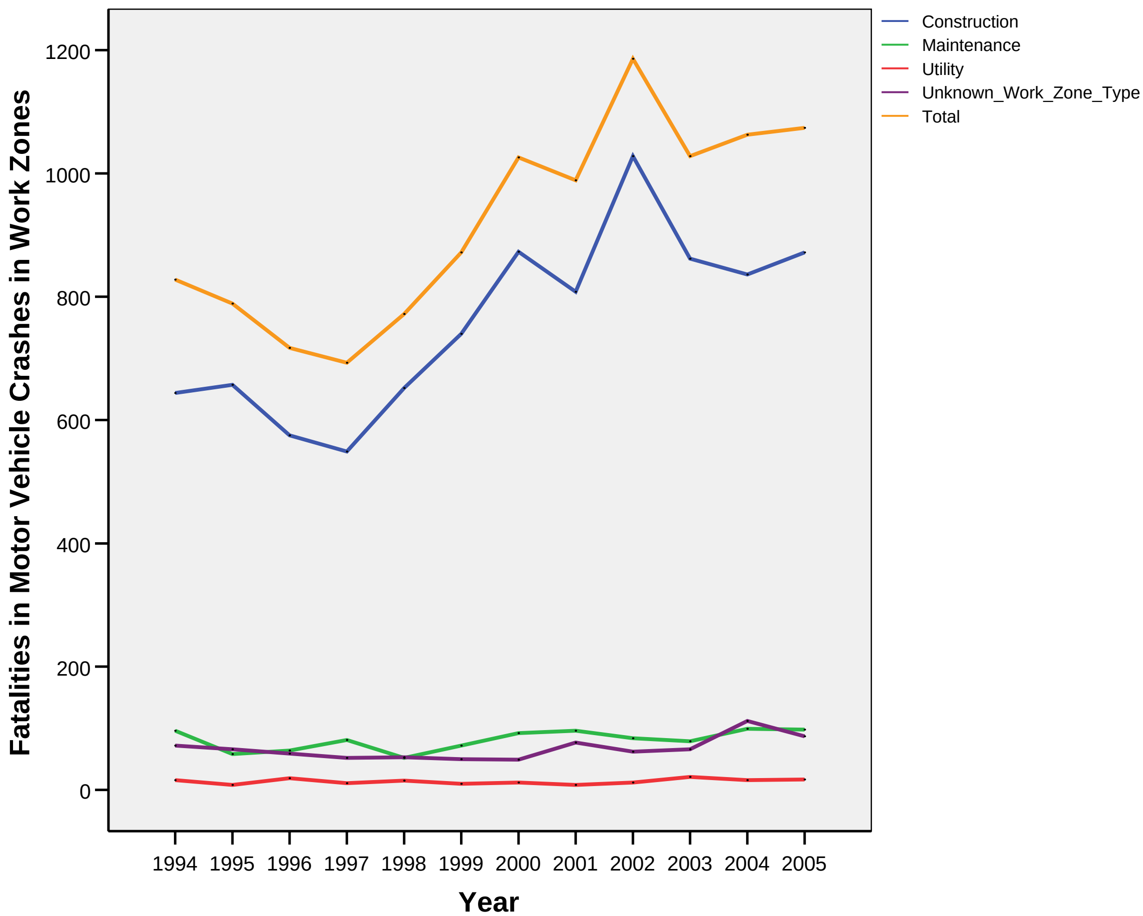

Figure 1. Trend of Motor Vehicle Fatalities by Work Zone Type in the USA (1994-2005)

For construction work zone fatalities, the trend shows that from 1994 to 1997 the annual fatalities followed a decreasing trend. Fatalities increased from 1998 to 2000, followed by a sharp decrease in 2001, then a sharp increase in 2002. Fatalities decreased again in 2003 and since then have remained essentially constant through 2005. The fatalities in maintenance work zones seem to fluctuate from year to year; however, since the magnitude of the frequencies is relatively small, no dramatic trends exist. Fatalities in utility work zones are relatively constant ranging from 8 to 21 over the twelve year period.

The National Cooperative Highway Research Program Report 553 *(6)* used the data for 2003 from the FARS database and concluded the following:

- More than half of the fatal work zone crashes occur during the day time hours.
- Fatal work zone crashes are twice as high during the week as compared to the weekend.
- Most fatal crashes occur during the summertime.
- Over half of the fatal work zone crashes involve single motor vehicles. *(6)*

Utility/Maintenance Worker Fatalities

In the NIOSH Fatality Assessment and Control Evaluation (FACE) Program *(7)*, investigations of fatal occupational injuries are conducted throughout the USA and recommendations for mitigation of such fatalities are provided. The work zone fatalities investigated are most prevalent in highway construction projects; however, there are a few that involved utility/maintenance projects.

One report describes the fatality of a utility worker resulting from a vehicle entering into the work zone. Recommendations for future prevention of such an incident were stated as: 1) "Analyze the work site including traffic patterns and plan the work zone before you begin working", 2) "Position work vehicles to create an obstacle to prevent oncoming traffic from hitting you", 3) "Minimize exposure to moving traffic" and 4) "Drivers should not engage in activities that distract them from driving or hinder driving performance" *(7)*. These reports include isolated fatal crash investigations and didn't include any general countermeasures.

Analyses of Work Zone Crashes

Ullman and Scriba *(9)* performed an analysis of work zone fatal crashes throughout the USA using the Fatality Analysis Reporting System (FARS) to "assess possible underreporting due to differences in how information about a work zone crash is captured on standard state crash reporting forms". The authors conducted a current practice survey of crash report forms throughout the USA in 2000, which indicated that 42 percent of the states used a variable or field to signify that a crash occurred in a work zone (explicitly), 48 percent of the states had a field related to road condition, traffic control, etc. to signify a work zone (indirectly), and 10 percent of the states did not indicate whether or not a crash occurred in a work zone (not at all).

The authors *(9)* conducted an analysis of three years of fatal crash data (1998, 1999 and 2000) and assessed the extent to which work zone crashes are identified on the crash report forms. Crash frequencies were identified for each of the states in terms of work zone fatal crashes and non-work zone fatal crashes. The data was then aggregated based on work zone reporting category (explicitly, indirectly or not at all). Statistical analyses including the Pearson chi-squared test and Cochran–Armitage test were performed to "examine whether the likelihood of a fatality occurring in a work zone was related to the report form type category" *(9)*. The results of the statistical tests were highly significant at the 0.05 level. According to the authors, this implies that "those states that have an explicit field on the crash report form to note whether the fatality occurred in a work zone appear to have a significantly higher percentage of fatalities coded as occurring in a work zone," while "work zone fatalities are underreported in those states that do not have an explicit work zone field on their report forms" *(9)*.

The authors then conducted an analysis to assess the extent to which work zone fatal crashes are underreported nationwide. This was done by estimating an 'expected' percentage of work zone fatalities (using the percentage for states that explicitly identify work zone crashes on their report forms) and comparing it with the actual number of reported fatalities. **The results of this analysis indicated an underreporting rate of nearly 10 percent for national work zone fatalities between the years 1998 and 2000** *(9)*.

Garber and Zhao *(10)* conducted a study to investigate the characteristics of work-zone crashes in Virginia for a four year period (1996 through 1999) using data obtained from traffic crash report forms. This study focused on identifying the locations where crashes occurred in a work zone in one of five areas: advance warning, transition, longitudinal buffer, activity, and termination areas. In order to assess the crash characteristics relative to the location, the authors carefully examined each of the crash report forms (for a total of 1,484 work zone crashes), relying on the diagrams to provide accurate information. The results indicated that the predominant location where crashes occurred within the work zone was the activity area, which represented 70 percent of work zone crashes. In terms of roadway type (interstate, primary and secondary, rural and urban), no significant differences were found among the proportion of crashes in the activity area, or any other area. Thus, the activity area “is more susceptible to crashes regardless of the highway type” *(10)*

Bryden, Andrew and Fortuniewicz *(11)* investigated work zone crashes in New York State Department of Transportation construction projects to examine the involvement of traffic control devices, work zone safety features and construction vehicles, equipment and workers. Traffic crash data was analyzed from 1994 to 1996. The results show that less than 5 percent of the crashes involved traffic control devices, work zone safety features including impact attenuators and arrester nets were involved in slightly more than 5 percent of the crashes, portable concrete barriers were involved in 4 percent of the crashes and 14 percent of the crashes involved construction vehicle, equipment and workers. Even though the work zone safety and traffic control features were involved in crashes, the installation of these features had prevented the crashes from resulting in more serious injuries. *(11)*

Several studies in the literature analyze work zone traffic crashes and worker injuries and the key findings from these are summarized below:

- An analysis of crashes in work zones (construction and maintenance) was performed in the urban areas of Virginia. *(13)* Some key findings indicated that crash rates are higher in urban work zones as compared to urban non-work zone locations. Urban work zones experience a higher proportion of multi-vehicle crashes and the “type and severity of crashes are not significantly affected by the installation of a work zone in an urban area” *(13)*
- A study conducted in the Chicago area *(14)* from 1980 to 1985 revealed that for short-term projects, the crash rate remained essentially constant before, during and after the maintenance work at a rate of 0.80 crashes per mile-day of work activity.
- Studies in Kentucky (1983 – 1986) *(15)*, Georgia (1995 – 1997) *(16)*, Virginia (1996 – 1999) *(10)*, and several other states (1991 – 1992) *(8)* indicated the following work zone crash patterns:
  - **Fatal crashes were more predominant in construction work zones as compared to maintenance work zones *(16)***

- **Only a small percentage of work zone crashes occurred in utility work zones *(15)***
- Most of the work zone crashes and injuries occurred on interstates and major arterials *(8,10,15)*
- High percentages of work zone crashes involved heavy trucks, as compared to non-work zone crashes *(15,16)*
- Rear end, sideswipe and fixed object crashes represent high proportions of work zone crashes *(8,10,15,16)*
- Contributing factors to work zone crashes include drivers losing control, failure to yield, inattention, following too close and driving too fast for the conditions *(15,16)*

2.3 Urban Issues

Tsyganov, et. al. *(17)* conducted a study to identify ways to improve traffic control plans and develop guidelines for urban work zones. The researchers conducted traffic crash analyses, field investigations, and a questionnaire survey of the Texas DOT personnel to identify common problems, traffic control layouts and human perceptional issues to improve traffic control plans used on urban streets. **Some of the problems identified in urban work zones included "information insufficiency due to specifics of urban environment such as frequent intersections and visual noise caused by commercial displays, as well as presence of frequent local access roadways**" *(17)*. Effectiveness evaluations were performed using a controlled laboratory environment and a driving simulator. Those traffic control strategies that were effective in the simulator were then implemented in the field. The researchers *(17)* recommended three different strategies to improve traffic control in urban work zones, which include advance information, active roadwork area, and road sign dominance.

The authors' recommendations were as follows:

- Start lane closures a block upstream of the actual roadwork location
- Enlarge and/or relocate street name signs so that drivers can see them clearly, add stop signs to driveways within the work zone, install a sign grouping the names or logos of businesses to minimize last minute maneuvers, use a minimum radius of 25 feet at

intersections with other streets and driveways located within the work zone so that they are easily recognized, place cones on the edge of curves to improve visibility and recognition.

- Sign spacing (for commercial signs, traffic signs and temporary traffic signs) along urban roadways should be 30 feet laterally and 60 feet longitudinally.

Hawkins and Kacir *(18)* also conducted a study to develop traffic control guidelines for urban arterial work zones. Urban arterial work zones have characteristics that are different than work zones on rural roadways or freeways. According to the authors, “the most important of the characteristics are higher speed variations, highly variable volumes, limited maneuvering space, frequent turning and crossing maneuvers, multiple access points, higher pedestrian volumes, frequent traffic obstructions, greater competition for driver attention, and more traffic signals.” *(18)* The authors researched the current traffic control practices of local agencies and collected data from three urban arterial work zones to help develop traffic control guidelines. The guidelines were developed for six different categories including signalized intersections, intersections and driveways, lane closures, speed control, channelization and pavement markings. The guidelines for each category are summarized below *(18)*:

- Signalized Intersections: Signal phasing and timings should be modified to fit the construction activities, shorter cycle lengths should be used to reduce the queue length, signal heads should be relocated to fit with lane shifts and be located within the cone of visibility, the signal lenses should be 12-inch, and a left-turn bay should be included if there are left-turning movements.
- Intersections and Driveways: Street name signs should be large and relocated to where motorists can see, a large turning radius should be provided at all intersections and driveways, driveways should be clearly visible and sight distances should be checked at each driveway.
- Lane Closures: Arrow panels should be used on major arterials with high speed and volume, lane closures should not be set up where they would block upstream intersections and tapers should be 197 to 286 ft from intersections, driveways or medians.

- Speed Control: Speed restrictions should not be used unless necessary since most motorists do not follow them, advisory speed limit signs should not be placed near normal speed limit signs, and an area for police enforcement should be provided.
- Channelization: Channelizing devices should be placed at a distance apart of 1.0 times the speed limit to prevent motorists from driving in between the devices and entering into the work zone.
- Pavement Markings: The construction pavement markings should be raised since they are more visible and can be removed easily.

Ogden, Womack and Mounce *(19)* conducted a detailed survey of a reconstruction project on a four-lane urban arterial in Houston, Texas, to investigate the motorists' understanding of the signing applied in the work zone. The survey consisted of 205 participants at two locations along the work zone. Participants were asked the meaning of ROAD CONSTRUCTION 500 FT signs. Sixty-six percent of those surveyed correctly identified the sign as meaning construction on the road is located within 500 ft., while 25.2 percent incorrectly identified the sign as meaning the construction would continue for 500 ft. and then end. Participants were shown the sign with the symbol for right lane ends and 78.4 percent answered correctly. The low shoulder symbol sign was incorrectly identified by 84 percent as uneven pavement, the flagger ahead symbol was correctly identified by 77.5 percent of the participants, the crossover signs do not clearly convey where to perform the cross over maneuvers within the construction area and more than 40 percent of the participants were not able to distinguish the color coding of the construction signs. When asked about the major concerns of construction, most participants referred to the time period of the construction, length of the work zone and problems associated with work zones, such as delay, as opposed to the interpretation of signs and messages as their major concerns related to work zones. *(19)*

Ogden and Mounce *(20)* conducted another motorist survey on a four-lane undivided urban major arterial in Dallas, Texas to determine what drivers do not understand about the traffic control that is set up in urban arterial work zones. The construction on this arterial consisted of expanding the road to a six-lane divided arterial. There were 345 participants interviewed at

three different locations. The first part of the survey asked the participants about their opinions of the reconstruction project and the second part about the work zone traffic control.
Responses from the motorists to the first part of the survey indicate that their major concerns were those related to the hazardous conditions on the roads and the length of time the construction project will interfere with normal travel. Eighty-four percent of the survey respondents agree that the future benefits outweigh the present inconvenience.

The results of the second part of the Dallas, Texas survey *(20)* were similar to the results of the abovementioned survey in Houston, Texas *(19)*. Participants had similar misinterpretations of the same traffic signs and colors. Additionally, 38 percent of the participants of this survey responded incorrectly and 46 percent were not sure about the orange and white hazard markers, white delineators were interpreted correctly by 75 percent of the participants, the lane reduction transition symbol was interpreted correctly by 74 percent of the respondents and 88 percent correctly interpreted the DO NOT BLOCK INTERSECTION sign *(20)*.

2.4 Utility Work Zone Locations

Utilities such as electrical lines, telephone lines, gas lines, sewer lines, water lines, etc. are often located in various places within or outside the right-of-way based on the age of the surrounding developments. Older cities typically have their water and sewer utilities placed underneath the roadway pavement, while in newer cities and towns these utilities are typically located beyond the roadway, underneath the sidewalk. The actual location of the work for a utility company can range from within the roadway, on the shoulder, outside the roadway, overhead, or underground. According to the study conducted in Michigan *(3)*, most utility work projects take place on or beyond curbed or uncurbed shoulders in urban areas, often on local roads and residential streets with low to moderate operating speeds. Additionally, the length of utility work zones is generally short and the utility work zones are often in localized areas and extend to the limited area on or around the roads and highways.

2.5 Human Factors

Driver behavior through work zones depends on many factors including advanced notification of the work area through the use of warning signs, channelizing devices, recognition of potential hazards, necessary decision-making, vehicle control, and evasive actions to avoid a situation, if and when encountered by a motorist. The 'Positive Guidance' *(21)* model divides a potentially hazardous area into a series of information handling zones based on the informational requirements and the temporal response requirements at each point. Driver behavior issues are based on the drivers' ability to see, comprehend and then make a decision at each of these zones. Five information handling zones have been identified and they are: 1) the approach zone, 2) the advanced zone, 3) the non-recovery zone, 4) the hazard zone and 5) the downstream zone. Figure 2 shows the five information handling zones as they apply to a hypothetical work zone involving a single lane closure on a multi-lane road.

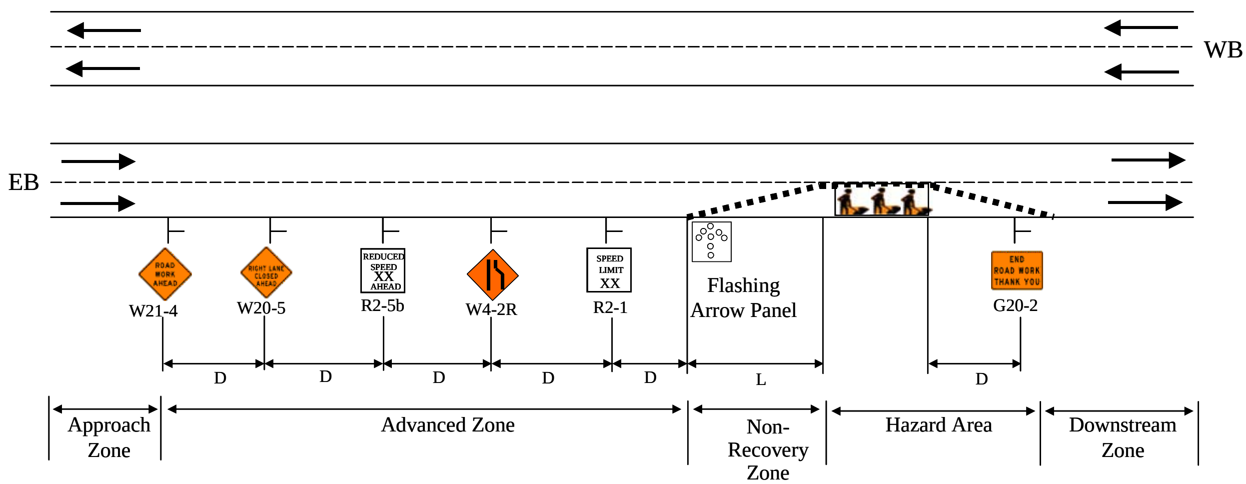

Figure 2. Information Handling Zones Applied to a Typical Highway Work Zone

The approach zone is the first zone and is the zone prior to the advanced zone. The advanced zone is the second zone encountered by a driver and is normally not very demanding to the driver in terms of information handling and driver performance. In this zone, drivers gather information through recognizing and understanding the stimuli presented to them through the traffic control devices (signs, pavement markings, channelizing devices, etc.) and then the drivers make a decision on how to proceed. After the advanced zone, the driver enters the non-recovery zone. At the beginning of the non-recovery zone, a driver would have processed the information from the advanced zone and determined if a stopping, lane changing or other maneuver was necessary in order to avoid a potentially hazardous situation. Thus, the non-recovery zone is a function of the stopping sight distance required to avoid a potential hazard located downstream. This then leads into the hazard zone where a potential hazard may exist if the proper driver action is not taken. Each of the zones requires specific responses from the driver for the safe and smooth operation through a work zone *(21).*

Some of the concepts from the 'Positive Guidance' approach *(21)* relate to the situations motorists often face when confronting a utility work zone and they are:

- Information gathering
- Information handling
- Primacy
- Information Overload
- Hazard detection and avoidance

Information Gathering

As stated in *A User's Guide to Positive Guidance (21)*, the key to successful driver performance is <u>efficient</u> information gathering and processing. If drivers only had to perform one given task at a time, this process would be straightforward. However, as a part of the driving task, drivers are confronted with numerous sources of information which they must process in order to make the proper response, which usually includes various levels of complexity. "At any instant, drivers generally gather information from more than one source, establish priorities relative to what information to attend to and process, make decisions, and perform control actions, often under time pressures" *(21).*

Information Handling

The driving task involves the repetition of 'information-decision-action' activities. There are many sources of information retained by a driver at any instant of time, including cues that assist the driver to successfully complete the driving task, in spite of other cues or distractions received from the environment. Drivers often have overlapping information needs associated with various activities. To fulfill these needs they "search the environment, detect information, receive and process it, make decisions, and perform control actions in a continual feedback process" *(21).* However, since people can only handle one source of visual information at a time, they end up 'juggling' several pieces of information at a time, and shift their attention from one source to another.

Primacy

Primacy is the process by which drivers process the relative importance of competing sources of information *(21)*. Drivers receive information from various roadway and roadside features, traffic signs, pavement markings, channelizing devices and other visual information provided along the roadway. The driver is always prioritizing information and cues received while driving. In turn, drivers are also continuously discarding information that seems less important or irrelevant *(21)*. Thus, the location in which the information is placed and the expected time in which the information will be received is critical for drivers in order to retain the relevant information and take the appropriate action when the circumstances demand.

Information Overload

Drivers may become overloaded when they have to process too much information. Such drivers may become confused or miss important information sources due to "high processing demands" *(21)*. Information overload often impacts the information processing function and thus, may lead to improper actions.

Hazard Detection and Avoidance

Hazard avoidance is dependent on a driver's ability to "search for hazards, detect their existence, recognize and identify them, determine their threat, decide on an appropriate hazard avoidance strategy, and perform the requisite maneuver in a continual feedback process" *(21)*.

These principles should be used as the underlying basis to assess the traffic control devices needed to give motorists the proper information and cues to respond properly and drive safely through utility work zones. Since the majority of utility work projects take place in urban areas, care should be taken to ensure that drivers are not provided too much information, as it could potentially create information overload making the traffic control devices less effective and subject the workers to additional risk.

Ullman and Schock *(22)* describe the application of positive guidance concepts in performing safety reviews of work zone traffic control in Texas, focusing on four main aspects: hazard visibility, expectancy violations, information overload, and information needs. As a part of this study, test subjects were used to assess the effectiveness of nine freeway work zones during the daytime and nighttime hours in order to identify the amount and types of features that create driver confusion. All work zones evaluated had at least two (and up to 10) confusing aspects or features, some of which are as follows *(22)*:

- Distracting light sources in the drivers field of vision at night (due to the opposing vehicles headlight glare, work vehicles, roadside businesses, etc.)
- Differences between alignment depicted through channelizing devices and the actual roadway alignment
- Difficulties reading the messages on portable changeable message signs (PCMS) and improper location of PCMS.

The authors then linked the confusing features with the violations of the four positive guidance concepts, as shown in Table 2.

Table 2. Driving Difficulties in Work Zones and Positive Guidance Principles [Source: Ullman and Schrock *(22)*]

Typical Reasons Subjects Reported Being Confused or Stressful at Work Zones	Deviations from Positive Guidance Principles
Difficulty seeing travel path due to extraneous nighttime light sources (vehicles, roadside businesses)	• Visibility of the hazard is reduced due to headlight glare • Presence of visual clutter within the overall information system due to roadside business light sources made path identification difficult
Confusion about temporary lane closures in the vicinity of ramps with long deceleration lanes or auxiliary lanes between adjacent ramps	• Information about which lane is affected is ambiguous when the lane closure signs are not placed properly
Confusion where alignment implied by barriers and barrels and actual travel lane alignment diverge	• Driver expectancy that the roadway alignment will continue to follow the barrier or barrels is violated
Surprise about how much steering control will be required to accommodate the conditions implied by lane shift signing	• Driver expectancy about the magnitude of the maneuver required to accommodate the lateral shift is violated
Confusion about meaning of words or phrases shown on portable dynamic message signs, or because only part of message could be read before passing the sign	• Driver information loading limits are exceeded • Use of terms or phrases not universally understood violates driver expectancy • Information is not "chunked" properly to promote understanding • Visual clutter adding to the overall information load
Portable dynamic message signs placed too close or too far away from the feature for which they are providing information	• Location of information not adequate to allow proper response by driver • Location of information too far upstream violates driver expectancy about presence of downstream hazard
Disagreement between sign information (which lanes to use) and actual lanes available for use during temporary lane closure	• Violates expectancy about proper response required by driver

The authors *(22)* acknowledge that current work zone traffic control procedures are already based on positive guidance principles; however, these may not be translated properly when implemented in the field. This is why field inspections or safety reviews are critical. The authors *(22)* recommend that four steps be incorporated into the systematic field inspection process which are:

- Hazard visibility assessment
- Expectancy violation determination
- Information overload analysis
- Information needs specification

Pietrucha *(23)* discusses the importance of human factors issues in providing safe work zone traffic control treatments. In order to provide the proper traffic control plan, it is important to understand the needs of the driver. According to the author, the driving process can be divided into three tasks that are performed by the driver: control, guidance, and navigation. The control task consists of the ways in which the vehicle is controlled by the driver such as steering and maintaining base speed, the guidance task consists of 'on-the-road' issues such as negotiating the congestion and the circumstances related to work zones, and the navigation task consists of route determination *(23)*.

The author *(23)* in this paper gives ways in which the information regarding these tasks should be provided to the driver. In order to aid the driver in the control tasks, the lane in which the driver is traveling through the work zone should be shown by pavement markings, delineators or channelizing devices and the appropriate work zone speed should be clearly marked. The guidance tasks require that all 'hazards' such as construction vehicles and equipment and traffic control devices be clearly seen by the driver and proper warning be provided before the work zone begins. For the navigation tasks, all locations and distances of driveways and intersections should be clearly marked since work zones often interfere with their locations. *(23)*

2.6 Implementation/Removal of Traffic Control Devices

An effective way to minimize risk to utility workers is to minimize the amount of time they are exposed to traffic. This can be accomplished by minimizing the amount of time required for the installation and removal of traffic control devices and also to complete the utility work in an efficient manner in the least amount of time.

Workers are exposed to the greatest risk while installing and removing the traffic control devices being used for temporary traffic controls since they are unprotected and vulnerable to the actions and decisions of the passing motorists. Thus, when assessing the relative risk of alternative temporary traffic control plans, the amount of time required to perform the work should be compared to the time required to set up and take down the temporary traffic control devices for various categories of work. According to the MUTCD, the time to set-up and take down the temporary traffic control devices may be more than the time to complete the work *(1)*.

The excessive amount of time needed to install and remove traffic control devices can be better shown with an example of Michigan's temporary traffic control requirements. According to the critical path rates developed by the Michigan Department of Transportation *(24),* in an eight hour work day, 50 freeway signs could be installed. This means that in a one hour period, six signs can be installed. The Michigan Department of Transportation *(25)* requires six signs per direction to be placed when there is a one lane or shoulder closure for a two-lane two-way roadway. This means that a total of 12 signs need to be installed, which would take two hours to complete. An additional two hours is needed to remove the signs. Therefore, a minimum of four hours is needed to install and remove the traffic control signs not taking into account the amount of time it takes to set up cones or barrels. With this in mind, workers that take less than four hours to complete their job would be spending more time setting up and taking down the traffic control than actually completing the work. The amount of time needed for traffic control can be minimized by using other devices such as portable traffic control signs, truck-mounted attenuators and strobe lights and others.

Additionally, the location of the work activity, type of roadway and operating speed also play a major role in assessing risk to the workers. It is assumed that the least risk would be associated with work activities of short time duration, taking place away from the roadway/shoulders adjacent to low-speed, low-volume roads. Correspondingly, projects requiring a full lane closure on a high-speed, high-volume road would be associated with a much higher risk to the workers.

2.7 Traffic Control Devices

The New York State Department of Transportation (NYSDOT) developed and adopted a quality assurance program *(26)* to asses the effectiveness of work zone traffic control at a statewide level for construction, maintenance and permit projects. This program focused on evaluating the overall quality and effectiveness of work zone traffic control. Drive-through inspections were conducted by a team of experts for a representative sample of projects throughout the state as a part of the study *(26)*. The information from the inspections were then used to rate the overall quality of work zone traffic control by project type, to identify areas of improvements, to facilitate the open discussion of traffic control issues and to improve work zone safety.

A standard form was used to evaluate the work zone, and an overall rating (0 to 5 scale) was assigned to each project site based on: construction signing/advance warning, channelization, pavement markings, flagging related issues, roadside characteristics, miscellaneous traffic control and various other 'emphasis points'. The main emphasis of this program pertains to construction projects; however, inspections were also performed on short duration maintenance projects. The sample of construction projects typically included at least 25 percent of the active projects at the time of the inspection for each region in the state. The sample of maintenance projects typically consisted of 5 to 10 sites per region *(26)*.

The results of this program from 1991 to 1999 indicated that the **performance ratings on maintenance and permit projects were not as high as on the construction projects**. In 1999, the statewide average for maintenance work zone was 3.97, and 88 percent of the individual projects were rated 3 or higher. This shows progress toward meeting the NYSDOT requirement for the regions to achieve an average quality rating of 4.0 with individual projects rated 3.0 or higher *(26)*.

A study was conducted by Paaswell et. al. *(27)* to assess mobile and short duration work zone safety based on the field observations of the New Jersey DOT's current practices. The authors developed criteria to measure and evaluate alternative traffic control devices used in mobile and short duration operations. Four operations were observed in the New Jersey area. The first one involved a mobile pothole patching operation that consisted of the automated pothole patching truck, two dump trucks with truck mounted attenuators behind the patching truck and the foreman's pickup truck in front of the patching truck. Both dump trucks contained a flashing arrow board and a "Road Work Ahead" sign mounted on the back, shown in Figure 3. The second operation consisted of a street sweeper and a single dump truck. The dump truck contained the same equipment as the first operation. The third operation involved litter pick up, a mobile maintenance operation and had two dump trucks, one with a truck mounted attenuator, and a landscape sprayer truck. The fourth operation consisted of a pothole patching crew with three dump trucks with truck mounted attenuators and the foreman's truck in the lead. The traffic control devices used in these operations were noted and subsequently evaluated according to the criteria developed by the authors.

Figure 3. New Jersey's Shadow Vehicle Used in Mobile Operation
[Source: Paaswell, et. al. *(24)*]

After observing the operations, the authors developed criteria to evaluate the traffic control devices used in mobile and short duration operations, which were classified based on the following: "Reducing exposure to the motorists/crew, Warn motorists/crew to minimize likelihood of crash, Minimize severity of crashes once they occur, Provide separation between work crew and traffic, and Improve work zone visibility/presence" *(27).*

Based on these criteria, several traffic control devices (those used by New Jersey DOT and other innovative technologies) were evaluated and a summary of their performance is shown in Table 3 below.

Table 3. Functionality Criteria Satisfied by Selected Work Zone Devices/Equipment [Adapted from Paaswell, et. al. (27)]

WORK ZONE DEVICE	CRITERION 1	2	3	4	5
Truck Mounted Attenuator	P	Y	P	P	Y
Vehicle Intrusion Alarm	N	Y	P	N	N
Rumble Strips	N	Y	N	N	N
All Terrain Sign and Stand	N	Y	N	N	P
Directional Indicator Barricade	N	Y	N	N	Y
Flashing Stop/Slow Paddle	N	Y	N	N	Y
Opposing Traffic Lane Divider	N	Y	N	N	P
Queue Detector	P	Y	N	N	P
Remotely Driven Vehicle	P	Y	P	P	Y
Portable Crash Cushion	P	N	Y	P	N
Cone Shooter	Y	N	P	N	P
Pavement Sealers	Y	N	P	P	P
Debris Removal Vehicle	Y	N	N	Y	P
Balsi Beam	Y	P	Y	Y	P
Robotic Highway Safety Marker	Y	N	N	P	N

N = Does Not Satisfy
P = Partly Satisfies
Y = Fully Satisfies

After conducting the study and evaluation of traffic control devices, the authors found that the New Jersey DOT mobile and short duration work zones comply to the MUTCD and that new devices should not only be selected to improve safety for both the motorists and the workers, but training and public outreach programs should be implemented to educate how each device works *(27).*

Fontaine and Hawkins *(28)* conducted a study to assess the different traffic control devices that could be used in temporary maintenance work zones. An evaluation was performed on a large number of innovative traffic control devices including fluorescent yellow-green worker vests and hard hat covers, portable variable message signs (VMS) and speed display trailers, fluorescent orange signs, radar-activated flagger paddles, radar drone retroreflective magnetic strips for work vehicles, portable rumble strips, Safe-T-Spins and strobe lights. The devices were evaluated for a two-year period to determine their effectiveness for a rural short-term work zone. The evaluation was based on the impact of the traffic control devices on vehicular speeds, conflicts and other measures.

Researchers found that the fluorescent yellow-green worker vests and hard hat covers, portable variable message signs (VMS) and speed display trailers produced positive impacts in temporary maintenance work zones. The fluorescent orange signs, radar-activated flagger paddle, radar drone and retroreflective magnetic strips for work vehicles presented modest benefits, but the authors noted that they need to be further investigated. The other devices including the portable rumble strips, Safe-T-Spins and work strobe lights did not produce positive impacts for temporary maintenance work zones, but they should be investigated further to determine their use in other work zone scenarios *(28)*.

Finley and Trout of the Texas Transportation Institute *(29)* developed maintenance traffic control plans (TCPs) for select mobile and short duration operations. They also developed guidelines for using protection vehicles on these types of projects based on roadway type, roadway volume, and the posted speed limit. A summary of the guidelines are provided in Table 4.

Table 4. Guidance for Use of Protection Vehicles on Mobile and Short Duration Operations [Adapted from Finley and Trout (29)]

Maintenance Operations	New TCPs	Protection Vehicle Guidelines
Striping, RPM installation /removal, and shoulder texture	1 mobile for undivided roadways 1 mobile for divided roadways	Trail vehicle
Spot pothole patching, spot edge repair, sweeping, herbicide, retroreflectivity measurements, core sampling, and temporary tab removal	1 mobile for undivided roadways. 1 mobile for divided roadways.	Shadow vehicle
Short-line striping and in-lane rumble strips	1 mobile for undivided roadways	NA
Sign, delineator, and lighting maintenance (work on or near shoulder)	1 short duration for undivided and divided roadways	NA

Warning Lights and Warning Light Systems

The FHWA publication *Traffic Control Handbook for Mobile Operations at Night Guidelines for Construction, Maintenance and Utility Operations (30)* provides guidance for mobile highway work operations (those that occupy a location a few minutes) scheduled to take place during the nighttime. It does not cover short duration or longer operations.

Typical mobile night operations carried out from moving work vehicles include installation and removal of pavement markings, raised pavement markers, post mounted delineators, small roadside signs and/or shoulder rumble strips, pavement sweeping, pavement repairs, debris cleanup, vegetation control, traffic signal repairs, cleaning drainage facilities, emergency repairs, and incident management *(30)*.

Most of the devices used to control traffic for mobile operations (continuously moving or moving frequently with only brief stops) are mounted on the work vehicles or are portable devices that can be set up and moved quickly. Various types of traffic control devices used in work zones (signs, channelizing devices, warning lights and markings on work vehicles, arrow panels, changeable message signs, service vehicles, truck-mounted attenuators, and work lights) are discussed in the *Traffic Control Handbook for Mobile Operations at Night Guidelines for Construction, Maintenance and Utility Operations (30)*. There are numerous types of warning light systems available for work vehicles, as there are currently no national standards. The handbook identifies several points for consideration when selecting work zone warning lights *(30)*:

- "Warning light colors other than yellow should be used only when permitted by the jurisdiction where the work will occur, and only when there is a specific need or reason for the alternate color" *(30)*.
- Strobe lights and flash/rotating incandescent lights are highly visible.
    - White strobe lights may appear blue at night, but are low cost and require low maintenance.
    - Flash/rotating incandescent lights are superior to strobe lights in terms of driver depth perception.
- Lights should be clearly visible from a distance of 3,000 feet at night.

- Two warning lights should be mounted on large trucks and equipment to ensure 360° visibility.
- Single warning lights should be mounted near the center of the roof on pickup trucks and passenger cars.
- Light bars provide good visibility, but may be difficult to properly mount on large trucks and equipment.
- It should be considered if the electrical system of the work vehicles is appropriate when selecting warning light systems.
- Four-way emergency flashers may be used to supplement, but not replace warning light systems.
- Retroreflective vehicle markings should also supplement warning light systems and ideally should be visible on all sides of the vehicle to make its perimeter visible in darkness.

Ullman performed a study *(31)* to determine the effect different combinations of vehicle warning lights have on driver perception and performance. The objective of the study was to determine if amber colored lights are sufficient in warning oncoming traffic, or if a different color or combination of colors would function better in warning the drivers of the upcoming work activity.

The author provided some basic concepts related to warning lights. Vehicle warning lights have two main functions that relate to their effectiveness: 1) the ability to attract attention and 2) to provide information about the situation so that drivers can take the appropriate action. Detection of a warning light system is dependent on the intensity of the flashing light source; however, if the intensity is too great, it may be blinding. Flash rate, on-off cycle, flash pulse shape, flash duration, and color also determine the effectiveness of the warning light. In addition, it has been established that red lights are easier to see during the day rather than blue lights, while blue lights are easier to see at night rather than red lights. However, the visibility of amber lights falls in between red lights and blue lights for both daytime and nighttime conditions *(31)*.

In order to determine how motorists differentiate between different colored lights and how they relate to their driving action, surveys were developed and distributed at Department of Public Safety (DPS) driver licensing offices in Texas. A total of 156 participating drivers responded to the survey. The surveys asked drivers to 1) rate the hazardousness of a situation based on the various color combinations of warning lights (i.e. amber; blue; red; amber and blue; amber and red; blue and red; and amber, blue and red), 2) indicate what driving action they would take when confronted with the various color combinations of warning lights and 3) indicate what colors they expected to see on top of certain vehicles (police vehicle, ambulance, fire truck, school bus, highway construction, maintenance vehicle, tow truck, or motorists assistance/ courtesy patrol vehicle) *(31).* Field studies were also performed by the authors *(31)* on five urban freeway sections to assess driver behavior in response to various types of warning lights. Maintenance vehicles equipped with amber lights, amber and blue lights, and amber, blue, and red lights were placed on the shoulder next to the moving traffic. Researchers videotaped driver reactions from 500 to 1500 feet upstream of the warning vehicles to quantify differences in vehicle speeds, lane choice and braking activity for each light configuration. The maintenance vehicle was placed on either the left or right side of the road in both daytime and nighttime conditions. Brake activations were only visible and thus, observed during nighttime conditions. The data was recorded in one hour intervals with an average of 120 vehicles per hour observed. Comparisons of speed, lane choice and braking activity were made for the various combinations of warning light colors with the amber color light only and also with 'no light' control condition *(31)*. The author performed statistical analyses of the comparisons at a 0.05 significance level, but the test statistic was not included in the paper.

A summary of the author's key findings from the filed study are as follows *(31)*:

- Two of the five test sites showed that vehicle speeds were lowered by 5-6 mph when the amber and blue light combination was displayed as compared to amber light only and the differences were statistically significant.
- Each combination of warning light colors did significantly lower speeds as compared to the situation with no warning lights.
- The warning light combinations did not have a significant effect on lane choice.

- Red, blue, and amber color light configurations had a significantly higher braking percentage at three of the four sites where nighttime data was collected, when compared to the amber light only scenario.
- Blue and amber color lighting combinations had a significantly higher percentage of breaking at one site when compared to the amber color lighting.

The author *(31)* concluded that the combination of amber and blue color lights “may have some incremental benefit above and beyond that of an amber light”, but also noted that “this combination did not generate quite as many brake light activities as the amber, blue and red warning light combination” *(31)*.

Kamyab and McDonald *(32)* prepared a synthesis of best practices for increasing protection and visibility of highway maintenance vehicles. As a part of this initiative, the authors conducted a literature review and a national current practice survey of state DOTs and county transportation agencies in Iowa on traffic control needs for mobile operations. The authors’ literature review addressed the use of warning lights on work vehicles, shadow vehicles, truck mounted attenuators (TMAs) and retroreflective markings on work vehicles. Highlights of the literature synthesis are as follows *(32)*:

- There is no consensus on the color or configuration of warning light systems on work vehicles
- No standards are available for the use of shadow vehicles or TMAs; however, other authors have presented guidelines for their use in mobile and short duration applications on freeways and non-freeways as a function of speed limit and exposure condition
- States such as New Jersey, Minnesota and Iowa use retroreflective markings on work vehicles to improve their conspicuity.

The authors conducted a current practices survey of 48 state DOTs and 99 county transportation agencies in Iowa to assess traffic control needs for mobile operations. Responses were received from 34 state DOTs and 61 Iowa county agencies. A summary of the authors findings are as follows *(32)*:

State DOT Responses *(32)*

- All state agencies used amber warning lights exclusively, or in combination with other colors. Strobe lights were preferred over rotating beacons.
- Retroreflective markings were being used on both large and small vehicles by most of the responding agencies. Orange and yellow are the primary colors used for maintenance vehicles.
- Almost all agencies use shadow vehicles, arrow panels, and truck mounted attenuators in some mobile operations.

Iowa County Agency Responses *(32)*

- Most county respondents indicated their vehicles are equipped with amber rotating or strobe lights and vehicle mounted warning signs. Only 11 counties used ground mounted signs.
- 75 percent of the respondents use retroreflective tape on their work vehicles for increased visibility.

The authors conclude that "more definitive guidelines and recommendations on a national level" *(32)* are needed to address safety concerns related to mobile operations and that more studies need to be performed to develop uniform practices across the country.

Hanscom and Pain *(33)* conducted a study to determine the appropriate use of service vehicle warning light systems in short-term and mobile work zones. Ground-mounted traffic control devices were also studied for various types of work zones. The analysis was carried out through field studies as well as through laboratory experiments. Multiple driver performance studies were conducted to understand the characteristics of the warning light systems and other devices and the drivers' response to various systems. Similarly, characteristics of warning lights such as flashing, intensity, placement, number and type of light were also studied to determine the driver's response to these systems.

The authors concluded the following *(33)*:

- Moving and short-term construction/maintenance activities have similar information requirements that must be met through traffic control applications.
- Human response to warning lights varied by the type of light.
- For shorter distances, under 1000 ft, a driver's ability to estimate the speed of the vehicle in front of him/her and to judge the rate of closure of the gap between the vehicles was not consistent.
- Rotating and strobe lights were not as effective as flashing lights in providing speed and closure rate information to the drivers, especially when the service vehicle was stopped. Therefore, several lighting recommendations combine two types of lights in order to ensure optimum information transmission and conspicuity.
- No simple answer to the trade-off between cost of device and safety can be made. A cost-benefit algorithm was developed to aid in making some of the decisions. The approach, if useful, may have further relevance to construction zone and other traffic control planning decisions.

Arrow Panels

Knapp and Pain *(34)* performed human factors analyses to assess interpretations of the arrow board configurations utilizing two different study approaches. The first study was conducted in order to investigate the meaning of the arrow board configuration and placement. Twenty human subjects were involved in this study. They were shown nine short film clips which displayed real-life scenarios of driving through a work zone. Whether the arrow board was placed on the shoulder (no lane closure) or in the closed lane, 75 percent of the respondents thought it meant that the lane was closed ahead.

A second study was conducted to determine if three different arrow board configurations (blinking arrow, sequencing arrow, and sequencing chevrons) could be used interchangeably or if they convey the same or different messages to the drivers. A sample of 109 drivers was used and the individuals were shown six short film clips presenting two different configurations simultaneously. This way, the respondents could compare and select which configuration best portrayed a lane closure. Based on the two surveys, it was concluded that the arrow board operating in a single on-off blinking mode (two pulses) conveys the message of a lane closure better than the sequential chevron (three pulses). The number of pulses refers to the number of times the arrow board must blink in order to display the entire message. The greater the number of pulses, the greater the chance was of misinterpreting the message *(34)*.

Based on decision sight distance (DSD) criteria and an operating speed of 55 miles per hour, the authors concluded that the arrow board "must be detectable and clearly recognized by 99 percent of the drivers at an absolute minimum distance of 1.5 miles." *(34)*

From past research, it was found that steady-rate signals created better impressions to the drivers about the intended message rather than flash rates that change. Flash rates of 50-230 flashes per minute are optimum for detecting a warning device, whereas 40-50 flashes per minute are appropriate when the arrow must be recognized. However, these flash rates may be overwhelming for certain situations such as in urban environments *(34)*.

The light from the arrow boards must be bright enough to capture the attention of the drivers, but not too bright to cause a glare. A field investigation of the glare characteristics at night was conducted using, "photometer readings of the ambient conditions, the background of the board, and the lamps." *(34)*

The recommended arrow board practices are as follows *(34)*:

1. "The preferred operation of the arrow board is in the single on-off blinking arrow mode
2. The blinking arrow should not be used as a cautionary display (i.e. for shoulder work)
3. A 360-degree lens hood should be used to cap dispersing light to the passing drivers and to direct the flashing lights outward in a straight line, perpendicular to the arrow board
4. Dimming of luminance could be upgraded to be more sensitive to inclement weather conditions and to begin dimming with lesser diminution of daylight
5. Arrow boards should be placed at the beginning of the taper (construction zone)" *(34)*

Griffith and Lynde *(35)* conducted a study to evaluate the effectiveness of the sequentially flashing diamond mode as an advance warning device by comparing it to the two other flashing modes, flashing line and flashing four-corner. An internet questionnaire survey was conducted to determine the use of arrow panel displays by the state DOTs. There were 33 state DOTs who responded to the survey and the results showed that most states use the flashing line and flashing four-corner arrow panel displays as an advance warning device in temporary work zones. Five states use the flashing diamond display. Another motorist survey was conducted where the three different display modes were set-up on arrow panel displays at two different locations in Oregon and motorists were given a survey about the modes. It was found that of those surveyed, 75 percent chose the diamond display as most effective, 61 percent said three displays were confusing particularly the flashing line and the flashing four-corner, 29 percent indicated the displays suggested a lane change, and 80 percent said they would like to see the diamond display used when work is taking place on the highway. *(35)*

The authors recommended that more emphasis be given to educate the traveling public about the use of caution modes on arrow panel displays. They also recommended that the diamond display be considered for use as an alternative to the line and four-corner displays for advance caution warning when working on the shoulder or alongside the roadway *(35)*.

Other Innovative Devices

Raytheon E-Systems *(36)* discusses the potential use of advanced vehicle control systems (AVCS) for shadow vehicles in work zone applications. Two prototypes have been developed for shadow vehicles: fully automated control and tele-operated control (remote driven vehicle – RDV control), the latter operated by personnel in the work zone.

Minnesota DOT has used the RDV technology since 1990 and is extremely pleased with its performance. This technology involved equipping a work truck with throttle, brake, steering and transmission control actuations to allow the truck to be driven via wireless remote control from several hundred feet away at low speeds. However, some disadvantages of a remote controlled vehicle include reliance on operator skill, low travel speed, and needing clear view of the vehicles from the operator's position *(36)*.

Fully automated vehicles are much more complex and expensive, but have many advantages over the remote controlled vehicle. These include no need for an operator, higher flexibility, use on high or low speed applications, and are equipped with on-board navigation and guidance systems that can calculate and execute vehicle movement. Fully automated technology for shadow vehicle purposes has only been tested in controlled environments, on test tracks and has not been deployed in the field *(36)*.

Humphreys and Sullivan *(37)* conducted a study to develop nationally accepted guidelines for the deployment of Truck Mounted Attenuators. The procedure for the development of the guide lines was described in the paper. Several states were contacted for a meeting for the discussion about the use of TMA's within the agency. The states that participated in the program were California, Iowa, North Carolina, Tennessee and Texas. A draft of suggested TMA use guidelines was prepared based on the information obtained during the discussion with the agency personnel. For all the states the initial support for the use of TMA's was obtained from the administrative level. Field personnel support the use of TMA's in states which are using the tilt-up versions of the TMA. The most common application of TMA was on shadow vehicles for moving operations. The field personnel were primarily concerned about the exposure of exposed workers. Data regarding accidents involving TMA equipped vehicles was available only for one of the states. The guidelines were modified according to the comments received from the industry personnel and was taken back to two of the originally visited states for their response. The response of these states indicated that the guidelines are too complicated for the use of field personnel. Also the draft materials were reviewed and comments were received later by those in attendance at the January 1990 committee meetings of the TRB on Road Safety Appurtenances and Traffic Safety in Maintenance and Construction Operations. A final set of guidelines was developed based on the review and comments received from the various agency and industry personnel and a number of other informal contacts *(37)*.

Factors that were considered for the use of TMA are location of work area, type of activity, special hazards, access control and speed limit. Activities taking place within the shoulders and operations involving personnel on foot or located in exposed positions on or within work vehicles are susceptible to accidents. Also activities on freeways and facilities involving higher operating speeds are more likely to be involved in accidents. Suggested priorities for the application of TMAs and for the assignment of the Shadow and Barrier Vehicles were presented in the paper. The study indicates TMAs are very highly recommended when there is no formal lane or shoulder closure on a freeway and are highly recommended on a non freeway when there is no formal lane closure and the speed is greater than 50mph. *(37).*

2.8 Worker Safety

The safety of utility workers is very important. The number of workers killed in work zones every year is very high and is continuing to rise. According to the Bureau of Labor Statistics for the years 1992 through 1996 as presented by the National Work Zone Safety Information Clearinghouse *(5)*, the majority of the highway worker fatalities (74%) are due to the following *(5)*:

- On-foot worker struck by passing vehicular traffic (23%)
- On-foot workers struck by construction vehicles (18%)
- Construction vehicle operator and occupant events (e.g., rollers) (18%)
- Highway traffic accidents (15%).

Turner, Simmons and Graham *(38)* conducted a study to determine which color of safety clothing makes the workers more visible to the motorists driving through a typical work zone. The safety clothing tested included fluorescent, non-fluorescent, and semi-fluorescent colors. The fluorescent colors included green, yellow-green, yellow, yellow-orange, red-orange, red-orange with yellow-green, red mesh with white background and pink, the non-fluorescent colors included yellow and orange and the semi-fluorescent color included yellow. Plywood dummies were used to represent construction workers in a highway work zones and were placed near the outer edge of the work zone where they have a greater chance of being involved in a crash. Participants were driven through the work zone and were asked the color of the safety clothing at different distances from the workers in the work zone. It was found that the fluorescent red-orange safety clothing was the most visible followed by fluorescent yellow-green, fluorescent red-orange with yellow-green and fluorescent pink. The authors stated that the reason the fluorescent red-orange may have been correctly identified by the participants is because that most people are used to seeing workers in orange and expect them to be wearing orange. The work zones tested did not contain any construction equipment and since this equipment is normally orange, it was recommended that in this case a different color other than orange be used to avoid having the worker blend in with the equipment. *(38)*

Arditi, Ayrancioglu and Jonathan *(39)* evaluated the effectiveness of safety vests on workers during nighttime construction. They claim that the luminance of the safety vest is more important than the actual color of the vest especially during nighttime construction because most crashes that occur during that time are a result of lack of visibility. The safety vests should contain the following characteristics:

1. "is sufficiently bright as positioned on the worker to provide noticeability at distances of interest
2. provides this noticeability from all directions whether the worker is in motion or not (360° protection)
3. furnishes recognition clues that the object sighted is a human being, that it is a construction worker and not an inanimate object or vehicle
4. reveals the motion of the construction worker as much as possible but is not totally dependent on its effect
5. if the high visibility materials are properly selected and located on the construction worker, it is not always necessary to use large areas of retroreflectivity to meet these requirements (ASTMF 923-00 2000) *(39)*"

2.9 Training Programs/Best Practices

In a workshop sponsored by the Federal Highway Administration, Belobraydich, Mudd and Griffith *(40)* recommended strategies on '*Reducing Exposure of Short-term Utility Work Zones Through Effective Safety Planning'*, by highlighting two 'successful' utility programs; that of the Louisville Water Company in Kentucky and Trench-It Inc. in Illinois. The authors concisely describe the uniqueness of typical utility construction work as "ephemeral, can be highly variable and are often conducted in conjunction with existing, on-going road projects. In any given 24 hour period, the average utility worker could be working at night, in hazardous weather, in low-visibility daylight, in the roadway, outside the roadway, on the shoulder, overhead, underground or in an urgent emergency situation" *(40)*. They also emphasize that the three main factors contributing to utility work zone variability include **worksite location**, **condition and duration** which makes traffic control planning a challenging task *(40)*.

The Louisville Water Company (LWC) in Louisville, Kentucky, developed a traffic control program with a multi-phase approach consisting of a three-tiered education program, the use of a traffic equipment contractor to install and remove traffic control devices, and a work zone audit program. In their educational program, all employees are trained during new employee safety training (level 1) and on an annual basis as a part of general safety training (level 2). Topics covered in this training include principles of traffic control, regulatory requirements and examples of work zone applications. The third level of training is directed towards crew leaders and supervisors, which covers more advanced topics on principles and regulatory requirements of traffic control and is typically presented by the Consultants *(40)*.

To effectively use resources, equipment and expertise, the LWC utilizes a traffic equipment contractor to install and remove traffic control as needed at the worksites. The LWC feels that "the investment in equipment and necessary labor are considered beyond the scope of normal operations" *(40)*.

The LWC program also involves an auditing process, whereby routine work zone audits are conducted by supervisors and health and safety representatives to assess the performance of both the crew and the contractor. As a result of the audits, safety deficiencies are discussed and measures to mitigate the problems are developed to help improve the overall safety program *(40)*.

Trench-It, Inc. developed a temporary traffic control policy to help regulate, warn and guide traffic through its work zones, which in turn will help prevent employee injuries, traffic crashes and injuries to motorists and pedestrians *(40)*. This policy defines the safety responsibilities of each type of employee (safety director, foremen, crew leaders, and employees). The safety director is responsible for ensuring that the guidelines are in agreement with the MUTCD. The foremen are responsible for their crews and they must ensure that the policies are followed by reviewing work zone layouts before the job commences, ensuring that the needed equipment is available, and disciplining employees in violation of the policy. Crew leaders are designated as the 'competent persons' for work zone traffic control setup and are responsible for the installation and removal of traffic control devices. The employees are responsible for setting up cones as needed around their work vehicles with the appropriate buffer area and tapers *(40)*.

Trench-It's procedures for work zone traffic control installation and removal are applicable for low to medium volume, urban roads; however, for high-volume roads and the multilane highways the traffic control responsibilities are delegated to the contractors. Trench It's in-house traffic control procedures begin with crew leaders and foremen meeting to review and select an appropriate traffic control plan for the job conditions from a set of typical applications and the MUTCD if necessary. Employees at the worksite will then install the traffic control devices as indicated on the approved plan, beginning at the furthest point downstream of the site. Then, all work vehicles are to be parked within the work zone and on the same side of the road, ensuring that the wheels are locked, with cones surrounding the vehicles. If a lane is to be closed, flaggers are used during the installation of the traffic control devices as an additional safety precaution. Once the utility work is completed, the traffic control devices are removed in the reverse order in which they were installed *(40)*.

Trench-It's policy also includes a training component which requires all employees to receive training on temporary traffic control in work zones. Employees are taught how to safely and correctly install and remove the temporary traffic control devices. They are also taught about the different safety responsibilities that each worker has. Worker safety audits are conducted on the crews and shared with all the workers during safety meetings. Retraining is provided once every two years, or as needed based on observed deficiencies. In addition, updated training is provided when there are changes to the policy or the MUTCD *(40)*.

Based on the commonalities of these two programs, the authors proposed a model program for utility work zones, which can be developed and adopted by any utility company seeking to "maximize road user and worker safety by minimizing exposure time and maintaining optimum traffic mobility" *(40)*. The recommended framework is as follows *(40)*:

A. "Training
    a. Education/Training
    b. Training appropriate to level of responsibility

B. Standards

    a. Clear objectives
    b. Standardized procedures
    c. Adherence to MUTCD and regional standards
    d. Written policy/program – supplemental manual or field reference
    e. On-going; up-datable program features

C. Responsibility

    a. Responsible employees
    b. Auditing
    c. Enforcement
    d. Monitoring
    e. Established criteria for use of outside services"

In a paper by Allsbrooke *(41)*, a comprehensive 16-hour, multiple day in-house training program on work zone safety for the City of Hampton, Virginia is described. The certification course included over ten hours of classroom instruction, four hours of field work and a two-hour written examination. The main references used in the development of the training program were the MUTCD and the *Virginia Work Area Protection Manual*. The training program curricula included topics such as human factors, legal liability/case studies, *Virginia Work Area Protection Manual*, traffic control plan design, example problems and a hands-on field exercise.

For the field exercise, students were required to set up a work zone on a four-lane divided roadway with on-street parking for a given scenario. Work zone traffic control devices such as signs and cones were available on site for use by the students, and they were only allowed to use the *Virginia Work Area Protection Manual* as a reference. After completion, the instructors critiqued the work zone traffic control set-ups *(41)*.

Students that pass the certification course were required to attend a half day refresher course every two years to stay abreast with the basic principles of work zone safety and to receive updates on the procedures. Since the in-house program was so successful, a free one-day workshop was subsequently developed and offered to contractors and utility companies. As over 500 individuals have attended these courses, major improvements in field work zone set-ups have been observed in the City of Hampton, Virginia *(41)*.

The Wisconsin DOT developed a handbook *(42)* which provides guidelines for temporary traffic control in construction, maintenance and utility work zones and includes typical applications based on Part 6 of the MUTCD and the Wisconsin MUTCD. This handbook covers fundamental principles, traffic control devices (signs, channelizing devices, warning lights, and pavement markings), elements of a work zone, planning layouts, typical applications, flagging procedures, and liability issues.

In terms of traffic control device guidelines, the handbook mentions that cones are most commonly used for short duration maintenance and utility work; when used at night they shall be retroreflectorized *(42)*.

When planning the layout for work zones, the handbook suggests that judgment be exercised based on <u>duration of work</u>, <u>work location</u> and <u>roadway characteristics</u>. Work duration is the main factor in determining the number and type of devices to be used (i.e., the longer the work the more devices are needed). The work duration categories defined in this handbook (mobile, short duration, etc.) are the same as those in the MUTCD. In terms of work location, the handbook states that, in general, the closer the work is to traffic, the more devices are needed to warn the motorists *(42)*.

The guidelines for roadway characteristics consider volume, speed, road alignment, highway rail crossings, intersections, pedestrians and bicycles. More traffic control is required "where volumes and/or speeds are high, visibility is poor and conflicts exist due to rail crossings, intersections, pedestrians and bicycles" *(42)*. Other noteworthy excerpts from this handbook are as follows:

> "Roads with low volumes have an average daily traffic volume (ADT) less than 400 vehicles per day. If the traffic volumes are not known, the following rule of thumb can be used to determine if the road can be treated as low volume.
>
> *Rule of Thumb* – Count the number of vehicles that pass a single reference point over a five (5) minute period. If not more than three vehicles pass the reference point in that period, then the road can be considered low volume." *(42)*

A total of 33 typical applications are provided in this handbook with four applications devoted to mobile operations and two involving sidewalk/pedestrian detours. Within the notes sections contained in the typical diagrams, exceptions/alternatives for short duration operations are mentioned, when feasible *(42)*.

In a paper written by Meakle *(43)*, a one-day workshop called *Road Safety Fundamentals* developed by the Cornell Local Roads Program in New York is explained. The workshop was created to train local highway superintendents about basic highway safety and reduce the road-related factors that contribute to crashes. In this paper, the term local refers to county highways and city/township and village streets which consist of, "most of the local roads, a large percentage of collectors, and some minor arterials" in New York *(43)*.

In New York, many of the state's townships elect a new Superintendent of Highways every two years. Even though some new superintendents have highway construction and maintenance experience, many do not, and therefore, need basic training. The *Road Safety Fundamentals* course is meant to:

- "Increase awareness of traffic safety problems
- Change the common attitude that local road safety is an intractable problem
- Increase the likelihood that local highway superintendents will take action or seek assistance when they note a road safety concern." *(43)*

The course is a combination of lecture, example problems and demonstrations, and is focused on six main areas:

1. "Basics of road safety
2. Planning considerations
3. Traffic control devices
4. Safety aspects of the road itself, such as skid resistance, geometry, etc.
5. Roadside safety
6. Intersection safety" *(43)*

A pilot session of this training program was held in July 2002. Based on comments from the pilot session, the course was revised and six more sessions were held in September and October of 2002. At the end of each workshop, the attendees were asked to fill out assessment forms, which were used to identify the strengths and weaknesses in the training. According to the author *(43)*, it is difficult to prove that the training program affected the safety of the road system. The program did however affect the behavior of those who attended which in turn will improve the road system because as a result of the program, the attendees now "are more aware of traffic safety issues and solutions, will use maintenance practices that improve safety and are more likely to take action when they note a safety concern." *(43)*.

There are also many other agencies that offer work zone safety training programs; however, there are few training programs that deal specifically with utility work zone safety. Some agencies that provide utility work zone safety training programs include American Traffic Safety Services Association (ATSSA), Iowa State University's Center for Transportation Research and Education, Wyoming Technology Transfer Center, Oregon Technology Center, and International Municipal Signal Association (IMSA). These training programs are briefly described in the following paragraphs.

The American Traffic Safety Services Association (ATSSA) has a training program to teach utility workers how to safely set-up temporary traffic control *(44)*. The program is a one-day class consisting of a presentation, a written examination, and then a certificate of completion given upon completion. ATSSA has also written a guidebook entitled 'Basic Traffic Control: A Guide to Temporary Traffic Control for Utility Operations', which provides the information included in the training program.

The temporary traffic control taught by ATSSA is based on Part 6 of the MUTCD. The program is designed to teach the utility workers how to set-up temporary traffic control in a safe and efficient manner. The class begins with an overview of utility work zone operations discussing the location of utility work zones and why proper traffic control is necessary to improve safety. The next topic covers the applicability of national and local standards to the utility work zones. Part 6 of the MUTCD is discussed and the importance of having a temporary traffic control plan is emphasized. The class continues with teaching the fundamentals of traffic control, the component parts of temporary traffic control including the advance warning area, transition area, work area and termination area, and a description of the different types of traffic control devices. The class continues with teaching the minimum traffic control devices that should be used and typical applications of these devices based on the location of the work. The last topic included in this program discusses the importance of properly documenting the traffic control plan. *(44)*

At Iowa State University's Center for Transportation Research and Education, workshops are held multiple times a year to provide work zone safety training *(45)*. These workshops are for those workers who work in or near work zones. The morning of this workshop consists of a general session where participants are taught about basic work zone safety. The afternoon of the workshop consists of breakout sessions where workers can learn more specifics about the type of work zones they encounter. One of the breakout sessions is for utility workers. During this session, participants learn about the safety of using proper traffic control for utility work zones. The MUTCD is taught as the guidelines for the traffic control. A certificate is given at the completion of the training program.

The Oregon Technology Transfer Center provides a workshop entitled 'Public Agency Work Zone Traffic Control' *(46)*. These workshops are available free for all local agencies. They are aimed at teaching maintenance and utility workers the safe and proper ways to set-up temporary traffic control according to Part 6 of the MUTCD.

The International Municipal Signal Association (IMSA) provides a work zone safety course where a certification is presented at the completion of the course. There is a study guide that accompanies the course entitled '2004 Work Zone Traffic Control Certification Study Guide' *(47)*. This study guide can also be used as a reference manual and is based on Part 6 of the MUTCD. The safe installation and use of a temporary traffic control at construction, maintenance and utility work zones is taught in this program.

The School of Traffic Control Training *(48)* in Texas provides courses on traffic control for people who deal with work zones. These courses deal with construction, maintenance and utility work and is based on Part 6 of the MUTCD. There is a series of three courses they offer, which includes a course on basic traffic control, a second course teaches intermediate level traffic control and the last course deals with advanced level traffic control. Besides learning about the proper traffic control to use, participants also learn how to lead others in creating a safe and efficient work zone, how to identify hazards that may appear in the work zone and about the legal aspects associated with work zone traffic control.

Some agencies do not provide workshops or teach organized classes, but they do have training material available on utility work zone safety for purchase by utility companies or others who may be involved in utility work zones. The Wyoming Technology Transfer Center has a 20 minute training video available for purchase that provides information on the traffic control that should be used for maintenance and utility work zones *(49).* The Institute for Transportation Research and Education at North Carolina State University has a guidebook entitled 'Guidelines for Construction, Maintenance and Utility Operations' also available for purchase *(50).*

J. J. Keller & Associates, Inc. *(51)* has developed an entire training kit that can be used by utility companies to teach their employees about safety in work zones. The training kit is called 'Work Zone Safety for Construction and Utility Employees' and consists of a 20-minute video, a manual for the employee, a guide for the instructor, identification cards for employees to show that they have received the training, an information card to be used in the field as a reminder and an awareness poster to hang in the work office. The video teaches various work zone topics including traffic control devices, standards and guidelines, hazards in the work zone and personal protective equipment. The employee manual provides the information that is taught on the video and can be used by the employees in the field *(51).*

The Occupational Safety and Health Administration *(52)* has a training program entitled 'Highway Construction Work Zones and Traffic Control Hazards' that can be downloaded from a website. The program consists of an introduction module and five other training modules. The introduction module provides background information about the program and presents safety statistics regarding fatalities and crashes involving highway workers. The first module is titled 'Work Zone Traffic Control'. It covers the main areas of traffic control and shows hazards that are associated with traffic control and ways in which they can be prevented. The second module, 'Safe Operations and Internal Traffic Control in the Work Space', covers topics including hazards in the work space, development of internal traffic control, safety issues related to night work, and safe operation of vehicles and equipment in the work area. The third module entitled, 'Heavy Equipment', discusses issues related to the risks and hazards associated with different types of equipment. The fourth module is titled 'Overhead and Underground Power Lines' and focuses on the hazards of working with power lines and ways to prevent injuries among the workers. The last module is 'Hand and Power Tools' and includes information regarding the hazards of power tools and measures that can be taken to prevent worker injury *(52).*

The National Work Zone Safety Information Clearinghouse *(5)* was used to locate other training programs and materials. There are many other work zone safety training programs and materials available through multiple agencies that do not specifically deal with utility work zones, but may still contain relevant information that pertains to work zone safety in general. Table 5 provides a summary of some of the available training programs and materials.

There are also training materials that pertain to specific elements of traffic control for work zones. The Federal Highway Administration has produced a video that deals with proper installation and usage of advanced warning arrow panels *(5).* The American Traffic Safety Services Association has a video on barrier delineation in work zones, which describes the standards and guidelines used for barrier delineation *(5).* These training materials deal with specific sections of the traffic control plan and contain information that may be relevant for a comprehensive training program.

There are multiple programs available in many states for training flaggers. Flagger training programs should be separate from the training programs for utility workers, since flaggers play an important role in the work zone.

Table 5. Summary of Training Programs and Materials

Title	Type of Material	Training Program Source	Description
A Traffic Plan to Live By	Course	NES-WorkSafe	This certification course consists of 13 different courses with topics relating to the different types of work zones that a worker may encounter (i.e., mobile operations, intersection work, city maintenance operations, etc.). Successful workers are given a certificate.
ABCs of Work Zone Safety	Video	American Traffic Safety Services Association	This video can be used to teach others about work zone safety by the ABCs of Work Zone Safety according to ATTSA.
Basic Traffic Control	Video	Federal Highway Administration	The video demonstrates the basics of traffic control for work zones.
Basic Traffic Control for Short Duration Activities	Videos	American Traffic Safety Services Association	This training material consists of 20 different video modules to help teach the different aspects of traffic control for short duration activities.
Design and Operation of Work Zone Traffic Control	Course	Federal Highway Administration	This course provides information on designing and installing traffic control as well as the legal, administrative, and operational aspects related to work zones.
Highway Work Zone Safety – Moving Operations/ Maintenance Safety	Video	Iowa Department of Transportation, Associated General Contractors of America & Iowa State University	This video focuses on the safety issues of moving operations and maintenance work since most of the work is done so close to traffic.
Jobsite Safety	Video Series	American Road & Transportation Builders Association	This video series consists of three modules including 'Developing Jobsite Traffic Control Plans', 'Installation, Inspection, and Maintenance of Work Site Traffic Control Devices' and 'Work Zone Safety Concepts'.

Table 5. Summary of Training Programs and Materials (Continued)

Title	Type of Material	Training Program Source	Description
Life in Closed Lane	Video	American Traffic Safety Services Association	This video is used to teach workers about safety pertaining to installing, maintaining, and removing traffic controls.
Making Work Zones Work Better	Guidebook Workshops	Federal Highway Administration	This workshop is based on FHWA's Work Zone Best Practices Guidebook and is intended to encourage participants to use technology to improve the safety of the work zone.
Mobile Work Zone Operations	Video	Texas Department of Transportation	Through this video, viewers will learn how to use vehicles to protect themselves while performing work in a mobile work zone.
Prevention Strategies for Construction's Focus Four Hazards *(53)*	Course	National Safety Council	The purpose of this course is to train-the-trainer of the four main hazards associated with construction which include falls, electrocution, excavation and trenching and struck-bys.
Road Maintenance – Traffic Control During Maintenance	Video	American Road & Transportation Builders Association	This Road Maintenance series consists of 18 modules and is aimed at improving the quality of maintenance work. Module 2 involves traffic control of maintenance work zones.
Traffic Control – Traffic Sign Placement and Location	Video	American Road & Transportation Builders Association	This video series consists of seven modules aimed at teaching traffic control for different situations. Module 6 describes the placement and location of traffic controls.
Traffic Control Design Specialists	Course	American Traffic Safety Services Association	This course teaches those in charge of the design and plans for temporary traffic control what they need to know to have safe and efficient traffic controls.
Work Zone Safety for Roadway Maintenance Operations	Video	North Carolina State University Institute for Transportation Research and Education	This video can be used to train workers about safety issues that pertain to roadway maintenance operations.
Work Zone Safety for Rural Roads	Video	Federal Highway Administration	This video provides information for proper work zone traffic control set-up on rural roads.

Most of the existing training programs consider traffic control for utility work zones to be the same as other short duration work zones. There is a difference between maintenance, construction and utility work zones. There are unique issues associated with the different types of work zones especially utility work zones.

3.0 STATE-OF-THE-PRACTICE SYNTHESIS

To determine the current state-of-the-practice with regard to utility work zone safety and mobility, two survey instruments were developed and administered via e-mail as a part of this grant. One survey was distributed to the state and local highway agencies and another survey was distributed to the utility companies and the contractors. A copy of these surveys along with the data is included in Appendix III. While the operating practices of each survey group are clearly not identical, there was a substantial overlap of content on both surveys. The surveys asked about information regarding the type of guidelines and standards followed by the agency and if they differ depending on type, location and duration of utility work. They were also asked information about who is responsible for reviewing and approving the traffic control plans, if there is coordination between other agencies, past crash experiences, past tort liability cases and available training programs. Utility companies were also asked about the type of utility work they conduct and state Dots were asked if they provide real-time information to the motorists about the utility work zones.

3.1 Results of the Survey

Survey responses have been received from 24 state Department of Transportations and 27 utility companies. Figure 4 shows a spot map of the states whose DOTs responded to the survey. The responding states are shown with blue dots on the map of the United States (Figure 4).

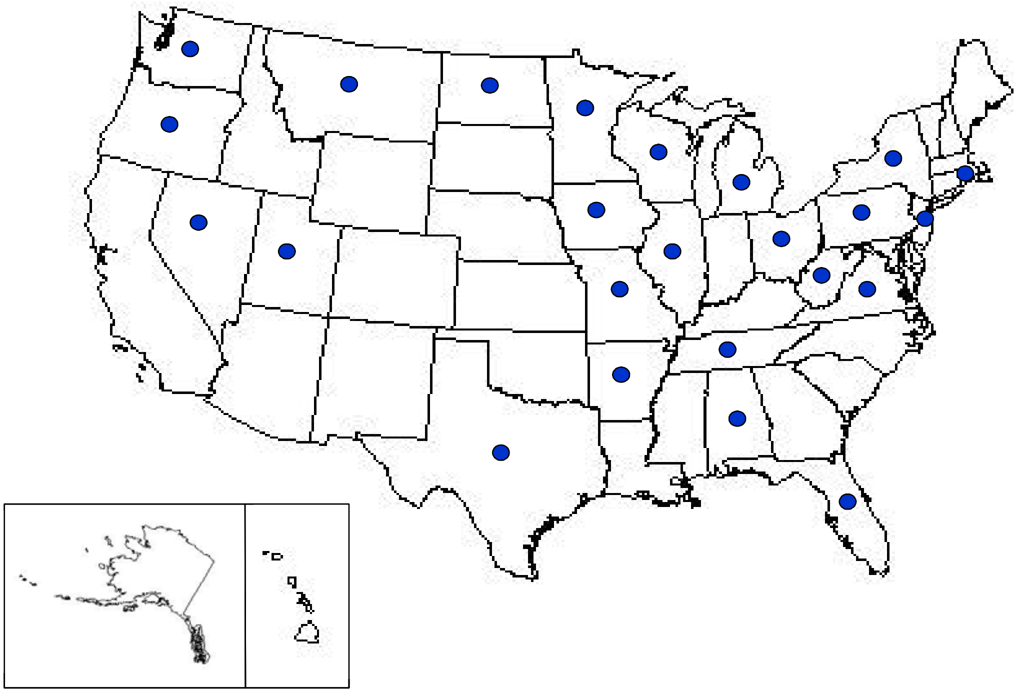

Figure 4. Spot Map of States Responding to Survey

According to the US Census Bureau, the 2006 population of the United States was 299,398,484. The total population of the states with DOTs that responded to the survey is 176,723,375, which is 59.03 percent of the total population of the United States. According to the Federal Highway Administration, the total road mileage of the United States is 3,955,644 miles as per 2005 estimate. The road mileage of the states with DOTs that responded to the survey is 2,351,293 miles, which is 58.85 percent of the total road length for the entire country. This data shows that over half of the population and road length of the United States was represented by the state DOTs that responded to the survey. Figure 5 contains a spot map of the states that are covered by the utility companies that responded to the survey.

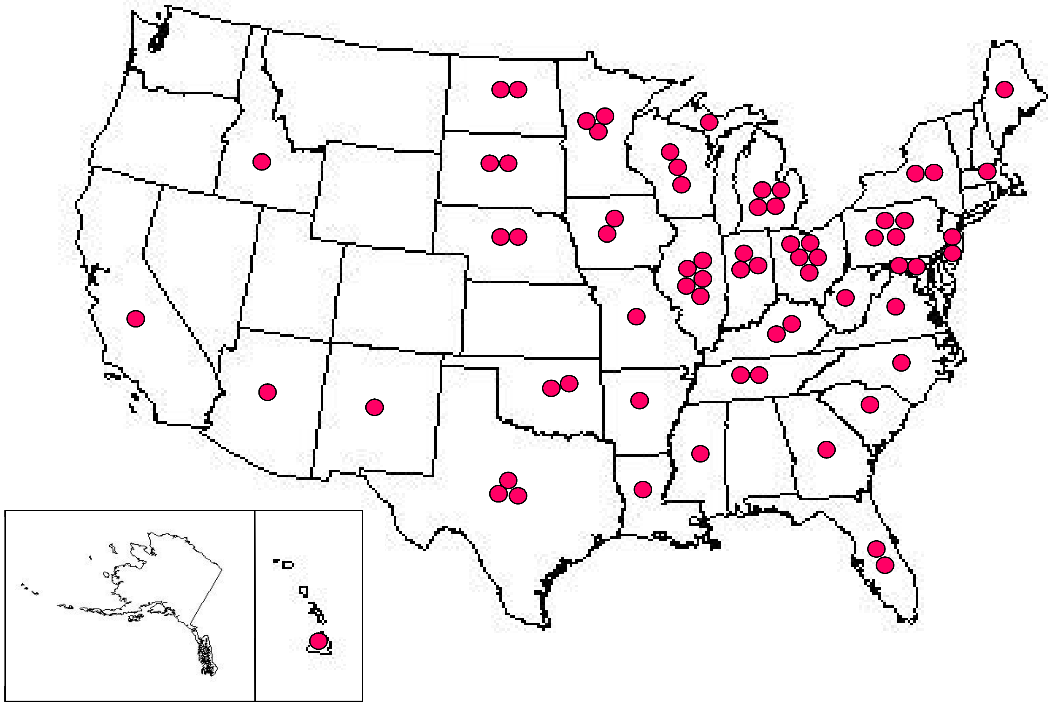

Figure 5. Spot Map of States that Responding Utility Companies Cover

The 2006 population, according to the US Census Bureau, of the states covered by the utility companies that responded to the survey is 262,645,467, which is 87.72 percent of the total population of the country. The total road mileage for 2005, according to the Federal Highway Administration, of the states covered by the utility companies that responded to the survey is 3,275,265, which is 81.97 percent of the total road mileage for the entire country. This data shows that in excess of 80 percent of the population and road mileage of the United States were represented by the utility companies that responded to the survey.

Ninety-three percent of the utility companies and 79 percent of the state DOTs that responded to the survey claimed to have established guidelines or standards for utility work zone traffic control. Only two of the responding DOTs were found to have separate utility work zone traffic control manuals, which essentially echoed the MUTCD language and provided a number of examples of typical utility applications. The majority of both utility companies and the state DOTs simply refer to or echo the language of the MUTCD and their respective state design manuals or provide shorter summary focusing on the aspects which typically apply to utility work.

In addition to the establishment of guidelines, respondents were asked whether their standards had differences based upon work duration, work location, work type, or roadway type. Work location was found to be the most prominent factor, as 78 percent of utility companies and 92 percent of state DOTs reported different standards based upon where the work was being performed. It should be noted that the survey defined work location in a similar manner as defined in the MUTCD, but included overhead work within work location. Work duration was also found to be also a determining factor for utility work zones, which are typically classified as short duration or mobile by the MUTCD. Among the respondents, 59 percent of the contractors and 71 percent of the state DOTs reported that they apply different standards based upon duration and, typically, respondents applied different standards to work lasting less than 15 minutes, less than 1 hour, or more than 8 hours. Roadway type was also an important factor as 74 percent of utility companies and 79 percent of state DOTs had different standards for projects conducted on or near freeways, arterials, and local roads. Due to the specialization of the utility companies, only 33 percent had different standards based upon type of work being performed (i.e., gas, electric, water main, etc.). However, it was found that only 25 percent of the state DOTs had different standards based upon type of work. This is likely due to the fact that the MUTCD classifies type of work based upon the entity conducting the work and/or the jurisdiction in which the work is being conducted (utility – overhead and underground, city/municipal work, county work, and contractor work). Consequently, although numerous types of unique utility projects are frequently encountered, state DOTs rarely account for the distinct features associated with each type of project.

In addition to the previous factors, emergency traffic control is often necessary for utility work zones, although the issue is not explicitly addressed in the MUTCD. With the absence of an appropriate section in the MUTCD, over 60 percent of utility companies had specific guidelines for such cases compared to only 25 percent of DOT respondents.

To ascertain the magnitude of the safety problems in utility work zones and their perceptions, respondents were asked whether they had experienced any crashes, injuries, or fatalities over the previous five years. Over 40 percent of the respondents (44 percent of utility companies and 42 percent of DOTs) indicated they did experience such during the past five years. In addition, to those who had experienced a utility work zone-related crash, 25 percent of the utility companies and 40 percent of the DOTs had been involved in subsequent tort liability cases.

Utility companies were also asked whether they had been subject to a review or citation by the local Occupational Safety and Health Administration (OSHA). Nine (33%) out of 27 companies reported that they have been cited for violations, though none of the reviews/citations were due to nonconformance to the provisions of the MUTCD. The violations were related either to personnel protective requirements or OSHA's general requirements.

As utility work is often transient or occurs within the context of larger construction projects, the MUTCD recommends that utility work "should be coordinated with appropriate authorities so that road users are not confused or misled by the additional TTC devices." Survey results showed that 85 percent of utility companies and 79 percent of State DOTs coordinated their utility work zone activities with other involved agencies.

The MUTCD recommends that temporary traffic control (TTC) plans be completed for all utility work and approximately 75 percent of respondents in both groups indicated that their agency or company had developed a site specific traffic control plan, or a set of standard traffic control plans for utility work zone operations. As the utility companies tended to be specialized, 35 percent had only one standard traffic control plan whereas 89 percent of state DOTs had several standard plans due to the wider range of utility projects typically considered. The remaining respondents indicated that project-specific TTC plans were developed prior to the start of each project.

State DOTs were asked which personnel were responsible for reviewing and/or approving temporary traffic control within their utility work zones. The majority of state DOTs placed this responsibility on either a traffic engineer or permits engineer, while 25 percent left it up to the contractor or utility company.

Utility companies were asked who the workers are directed to if they have any questions related to the utility work zone traffic control. Twenty-three (85%) of the companies have a safety manager who is responsible for answering such questions, while 19 (70%) agencies direct their questions to the job supervisor. In addition, 81 percent of utility companies conducted some periodic process reviews and in-field performance reviews. Conversely, only 46 percent of state DOTs who responded to the survey conducted periodic process reviews of their utility work zone programs.

One of the objectives of this utility work zone grant is the development of a training program focused on utility work zone safety and mobility guidelines. Among the utility companies who responded to the survey, 85 percent indicated that they offered a training program focused on utility work zone traffic control for their employees. Similarly, 71 percent of DOTs offered similar programs for their employees, as well as contractors and utility companies. The utility companies typically offered three options: (1) an in-house training program, (2) "Basic Traffic Control for Utility Operations" by the American Traffic Safety Services Association (ATSSA), or (3) a DOT or Local Technical Assistance Program (LTAP) -sponsored training program. Likewise, the DOTs either had their own training program available or utilized ATSSA training courses. In addition to this, 52 percent of utility companies and 54 percent of DOTs required flaggers to be approved through a formal certification process.

3.2 Summary of Current Practices Survey

Among those surveyed 93 percent of utility companies and 79 percent of state DOTs reported to have established guidelines for utility work zone traffic control. However, these statistics are somewhat inflated because the majority of survey respondents simply refer to the MUTCD and local design standards as their guidelines. The survey results helped to reveal a number of other issues faced by practicing professionals:

- Over 40 percent of utility companies and state DOTs had experienced a utility work zone-related crash, injury, or fatality in the past 5 years and approximately one-third of these agencies were subsequently faced tort liability cases.
- 33 percent of the utility companies were subject to OSHA reviews, but none were the result of non-conformance to the provisions of the MUTCD.

- Less than half of the responding state DOTs conduct periodic process reviews of their utility work zone programs; however, 81 percent of utility companies conducted periodic field and process reviews.
- Traffic control plans were typically approved by either a traffic or permits engineer, but 25 percent of state DOTs placed this responsibility directly on the contractor or utility company.
- States generally did not differentiate their standards based on the type of utility work being conducted, though clear differences may exist (e.g., overhead vs. at grade and underground work).
- More than half of the respondents in both groups acknowledged the differences in work duration, work location, and roadway type as being important for utility work zone traffic control. However, a substantial number of the utility companies and state DOTs utilized the same standards for all projects.
- Training programs were available to a vast majority of both state DOTs and utility companies, but some agencies did not use such programs. These training programs generally echo the statements and guidelines included in the MUTCD.
- Only slightly more than half of the respondents in both groups required traffic control personnel and flaggers to be certified.

4.0 CONCLUSIONS

Utility work zone traffic control often poses some unique challenges to the local highway agencies as well as the utility workers due to their transient and unpredictable nature of work and the available guidelines for temporary traffic control being very general in nature. The following represents the conclusions based on the existing literature, their conclusions/observations and also the responses from the current practices survey:

1. Definitions of duration of work related to utility work zones are based on various time categories included in the MUTCD *(1)*. Long-term stationary and intermediate-term stationary seem to be compatible with risks associated with such work zones. Mobile operations are also quite clear in meaning and intent; however, short-term stationary and short duration work seems to be based on somewhat arbitrary time categories. The utility

work categories defined in terms of their functionality and safety risks along with the time based definitions in the MUTCD may assist the highway agencies, utility companies and contractors to have better uniformity of traffic control and to minimize traffic crash and injury risks.

2. The number of fatalities in utility work zones is relatively low as compared to construction and maintenance work zones *(5, 15)* which may be in part due to errors and inconsistencies in reporting crashes. The number of fatalities for utility work zones has remained relatively consistent (8 to 21 fatalities per year) for the past 12 years *(5)*. These fatalities can be avoided by providing proper safety training to the workers and providing sufficient warning of the work zone through temporary traffic control to the motorists. Studies have shown that most work zone crashes and injury crashes took place in interstate and major arterial work zones *(8, 10, 15)*, most work zone crashes were rear-end, sideswipe or fixed object *(8, 10, 15, 16)*, most crashes occurred in the activity area of the work zone *(10)* and heavy vehicles were involved in a higher percentage of work zone crashes as compared to non work zone crashes *(15, 16).*

3. Urban work zones face unique challenges due to the frequency of intersections and multiple distractions from commercial displays *(17).* Urban work zones also have high speed variations, high volumes, frequent turning movements, frequent crossing movements and frequent traffic signals which provide challenges for the temporary traffic control *(18)*. These issues result in a need for modifications to the temporary traffic control plans. Some improvements that should be considered include providing large street name signs and business signs so the motorists can see them far in advance *(17, 18)*, providing cones on the edge of curves to improve visibility and recognition *(17)*, using arrow panels for lane closures when speed and volumes are high, only reducing speed when completely necessary since most motorists do not follow speed limits unless they perceive a safety risk or threat of enforcement and providing raised pavement markings because they are more visible and easily removable *(18).* Adequate information should be provided to the motorist to help alleviate the problems that arise due to the urban environment.

4. Utility work most often occurs on the shoulder or further off the shoulder of roadways in urban areas *(3).* They mostly occur on local roads with moderate speeds over a short distance *(3).* The location of the utility work is very important in determining the type of traffic control that should be used. Different risks are associated with different locations of work zones and different speeds and volumes of the roadways on or near the work zones. The type of temporary traffic control may be determined based on the type of utility work being completed, rather than the duration of the work because it may take different lengths of time to complete the same type of utility work.

5. Human Factor issues related to the road users through the work zones have been studied *(21, 22, 23)* and the researchers have found that they play an important role in the way the driver understands and reacts to the information given about the work zone. Drivers should only be given information they need so that they can gather the information and correctly react. If a driver is overloaded with information, they may become confused and miss information that may have been important for safe operation of their vehicle through a complicated driving environment *(21).* The amount of information that is given to a driver should be adequate to help the driver perform their task of driving without causing confusion *(23).*

6. Since the utility work is normally short in duration, most workers do not want to spend too much time setting up the temporary traffic control especially since the traffic control set-up may sometimes take longer than the actual work *(1).* The safety risks associated with setting up the traffic control are very high because the workers are directly exposed to the passing vehicles, which results in a higher chance of the worker being involved in a crash.

7. Traffic control devices in the short duration work zones were evaluated by several researchers to determine the safety of both the motorists and the workers *(26, 27, 28, 29).* New and innovative traffic control devices should be used for mobile and short duration work zones and training should be provided on the use of each device to ensure the device is properly and safely used *(27).* It was found that fluorescent yellow-green worker vests and hard hat covers, portable variable message signs and speed display trailers had a positive

impact on maintenance work zones *(28)*. Guidelines have also been developed for the type of protection vehicle that should be used for mobile and short duration work zones based on the roadway type, volume and speed limit *(29).*

8. Warning lights and warning light systems were evaluated to determine the effect of these lights on the safety of work zones *(30, 31, 32, 33)*. When using warning lights on vehicles, considerations should be given including the color of the lights should be yellow when used on work vehicles unless otherwise noted, there should be two warning lights when mounted on trucks or other equipment to ensure visibility all the way around the vehicle, when possible flashing/rotating incandescent lights are recommended since they are more visible in terms of depth perception, single warning lights should be mounted in the center of a vehicle's roof, and four-way emergency flashers and retroreflective vehicle markings cannot replace the warning lights, but may be used as a supplement *(30)*. A combination of amber and blue lights is the most effective color combination *(31)* and flashing lights are more effective than rotating and strobe lights *(33).* There is a need for national guidelines and standards for warning lights *(32)*

9. Arrow panels should be used as advanced warning devices for work zones *(34, 35)*. The arrow panels should use a diamond display instead of the line and four-corner display when used to warn motorists of work on the shoulder or side of a roadway *(35)*. The arrow board should also consist of a single on-off blinking mode and the brightness should be adjusted as to be bright enough for the motorist to see, yet not cause a glare *(34)*.

10. The safety of the workers is a very important aspect of any work zone. The main reason why crashes occur involving the utility worker is because the worker may not be seen by a motorist traveling through the work zone or by another worker operating construction vehicles or equipment. In order to avoid these crashes, workers should wear safety clothing that makes them clearly visible to all others. The safety clothing should be fluorescent red-orange unless the work zone contains other orange equipment and cones, then the worker should wear fluorescent yellow-green, fluorescent red-orange with yellow-green or

fluorescent pink *(38).* The luminance of the safety clothing should be bright enough so the worker can be seen from far distances and from all angles *(39).*

11. Innovative traffic control devices for temporary traffic control included vehicle control systems for shadow vehicles *(36)* and guidelines for using truck mounted attenuators *(37)*. The vehicle control systems researched involved fully automated and tele-operated control *(36)*. The guidelines for using truck mounted attenuators were based on location and type of work, special hazards, access control and the speed limit. They are recommended on freeways with no formal lane closure or shoulder closure and on non freeways with no formal lane closure and speeds greater than 50 mph *(37)*.

12. There are currently multiple training programs available on the topic of work zone safety *(5, 41, 42, 43, 46, 47, 48, 49, 50)*; however, there are few training programs and training materials that deal specifically with utility work zones *(40, 44, 45, 51).* Training for construction, maintenance and utility work zones may not be combined with general work zone training. Each type of work zone has special features and characteristics that should be addressed separately. The training programs for utility work zones should focus on the challenges associated with the utility work and be more specifically focused on the need of the utility workers and others involved in the utility work zones.

13. A current practices survey was distributed to multiple utility companies and state DOTs to determine their current practices for utility work zones and traffic control standards. The results showed that most utility companies and state DOTs claimed to have established standards or guidelines for utility work zone traffic control. Only two of the state DOTs actually have separate utility work zone traffic control manuals. All others refer to or echo the language of the MUTCD and state design manuals as their guidelines. Most states do not have different standards based on the type of utility work, but do have different standards based on the duration of work, location of work and the roadway type. Sixty percent of the utility companies and 25 percent of the state DOTs have specific guidelines for emergency traffic control. Over 40 percent of the companies and DOTs have experienced crashes related to utility work zones in the past five years and one-third were faced with tort liability

cases. Thirty-three percent of the utility companies had been cited for a violation by the local Occupational Safety and Health Administration (OSHA) for either personal protective requirement violation or OSHA general requirement violation. Twenty-five percent of the state DOTs place responsibility for reviewing and approving the temporary traffic control plans on the contractor or utility company. The other state DOTs place the responsibility on either the traffic or permits engineer. Eighty-five percent of the utility companies and 71 percent of the state DOTs currently offer training programs geared towards utility work zone traffic control for their employees.

The state-of-the-art literature review and current practices survey will aid in the next step of the project, which involves conducting a gap study and needs assessment of the existing utility work zone safety and mobility guidelines and training. All gaps in the current practices of agencies will be addressed and examined to determine the relevance of the gap with regard to worker and motorist safety and whether the gap represents a need in this program.

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APPENDIX II – TABLE OF ADDITIONAL REFERENCES

Author	Title	Publisher	Goals	Relevance to Utility Work Zones
Anderson, H. L.	Work Zone Safety	Federal Highway Administration & Transportation Research Board	This report describes the safety program initiated by the Federal Highway Administration in the 1970s.	3
Anderson, R. W.	AASHTO Issues New Report on Accidents in Work Zone	TransSafety Reporter	This article contains information regarding work zone crashes in the 1980s and discusses recommendations to improve the safety of the work zones.	2
Andrew, L. B. and J. E. Bryden	Managing Construction Safety and Health: Experience of New York State Department of Transportation	Transportation Research Board	This report describes a program developed by the New York State Department of Transportation to successfully manage safety and health during construction projects.	3
Benekohal, R. F. and E. Shim	Multivariate Analysis of Truck Drivers' Assessment of Work Zone Safety	ASCE Journal of Transportation Engineering	The study conducted a survey of truck drivers to obtain characteristics of the driver and vehicle, receive the drivers' assessment of work zone features and traffic control devices, learn about their high risk driving experiences and obtain suggestions to improve traffic flow and safety throughout work zones.	4
Benekohal, R. F. and J. Shu	Speed Reduction Effects of Changeable Message Signs in a Construction Zone	Illinois Cooperative Highway Research Program & Federal Highway Administration	This paper focused on reducing the speed of vehicles in work zones by using Changeable Message Signs.	2
Benekohal, R. F. and L. M. Kastel	Evaluation of Flagger Training Session on Speed Control in Rural Interstate Construction Zones	Transportation Research Board	The study focused on the effectiveness of training flaggers on speed reduction in rural construction work zones.	2

Relevance Rating: 1-Directly Related 2-Marginally Related 3-Not Directly Related 4-Not Related

Author	Title	Publisher	Goals	Relevance to Utility Work Zones
Benekohal R. F. and L. Wang	Relationship Between Initial Speed and Speed Inside the Work Zone	Transportation Research Board	This paper analyzed the speeds of vehicles in the advanced warning area versus the speed of vehicles inside the work zone.	2
Bernhardt, K. L., M. R. Virkler, and N. M. Shaik	Evaluation of Supplementary Traffic Control Measure for Freeway Work Zone Approaches	Transportation Research Board	The study focused on evaluating the effectiveness of white lane-drop arrows, the citizens band wizard alert system and orange rumble strips in reducing vehicular speeds and improving merging.	3
Bligh, R. P., W. L. Menges and R. R. Haug	Crashworthy Work-Zone Traffic Control Devices	National Cooperative Highway Research Program	This report evaluated the crashworthiness of commonly used work zone traffic control devices with emphasis on cost and functionality.	2
Brewer, M. A., G. Pesti, and W. H. Schmeider	Effectiveness of Selected Devices on Improving Work Zone Speed Limit Compliance	Transportation Research Board	This study focused on determining which devices would help drivers obey the speed limits in work zones.	2
Brown, D. B.	Comparative Analysis of Work Zone Crashes	University of Alabama Institute of Communication Research	The study compares all types of work zone and non work zone crashes from 1992 to 1993.	2
Bryden, J. E	Crash Tests of Work Zone Traffic Control Devices	Transportation Research Board	Crash tests were performed on various traffic control devices to evaluate their impact on work zones.	2
Bryden, J. E. and D. J. Mace	A Procedure for Assessing and Planning Nighttime Highway Construction and Maintenance	Transportation Research Board	The study was done to determine the proper traffic control needed for a safe nighttime work zone.	3
Bryden, J. E. and L. B. Andrew	Serious and Fatal Injuries to Workers on Highway Construction Projects	Transportation Research Board	This study investigated fatal and injury crashes in NYSDOT construction work zones from the year 1993 to 1997.	3
Burns, D. M., L. A. Pavelka and R. L. Austin	Durable Fluorescent Materials for the Work Zone	Transportation Research Board	The study focused on comparing the visibility of fluorescent retro-reflective sheeting, conventional fluorescent films and ordinary retro-reflective materials.	3

Relevance Rating: 1-Directly Related 2-Marginally Related 3-Not Directly Related 4-Not Related

Author	Title	Publisher	Goals	Relevance to Utility Work Zones
Bushman, R. M., J. Chan and C. A. Berthelot	Canadian Perspective on Work Zone Safety, Mobility and Current Technology	Canadian Society for Civil Engineering	This study evaluated work zone crashes throughout Canada and the use of Intelligent Transportation Systems.	3
Carlson, P., M. Fontaine, and H. Hawkins	Evaluation of Traffic Control Devices for Rural High-Speed Maintenance Work Zones	Texas Transportation Institute	This paper was conducted to evaluate the effectiveness of innovative work zone traffic control devices in high speed areas.	3
Chambless, J., A.M. Ghadiali, J. K. Lindly and J. McFadden	Multistate Work Zone Crash Characteristics	Institute of Transportation Engineers Journal	Work zone crash data was analyzed from Alabama, Michigan and Tennessee to determine if any trends exist.	2
Chambless, J et. al.	Identification of Over-Represented Parameters for Work Zone Crashes in Alabama, Michigan and Tennessee	Transportation Research Board	Crash data for Alabama, Michigan and Tennessee was analyzed to compare different characteristics of work zone crashes in different states.	2
Cottrell, B. H.	Improving Night Work Zone Traffic Control	Virginia Transportation Research Council & Federal Highway Administration	The study identifies traffic control issues that are present during nighttime work zones and provides recommendations to improve those issues.	3
Dixon, K. K., J. E. Hummer, and A. R. Lorscheider	Capacity of North Carolina Freeway Work Zones	Transportation Research Board	The purpose of this study was to determine the capacity of rural and urban freeway work zones based on lane configuration and site location.	3
Dudek, C. L. and G. L. Ullman	Traffic Control for Short Duration, Maintenance, Operations on Four Lane Divided Highway	Transportation Research Board	The paper focused on evaluating maintenance work zone traffic control devices for four-lane divided highways	2
Dudek, C. L. and S. H. Richards	Traffic Capacity through Urban Freeway Work Zones in Texas	Transportation Research Board	The traffic capacity of urban freeway work zones was studied to assist in determining the capacity of future work zones.	3

Relevance Rating: 1-Directly Related 2-Marginally Related 3-Not Directly Related 4-Not Related

Author	Title	Publisher	Goals	Relevance to Utility Work Zones
Dudek, C. L, R. D. Huchingson and D. L. Woods	Evaluation of Temporary Pavement Marking Patterns in Work Zones: Proving-ground Studies	Transportation Research Board	The study evaluated the effectiveness of ten different temporary pavement marking treatments for work zones.	2
Edara, P. K. and B. H. Cottrell	Estimation of Traffic Mobility Impacts at Work Zones: State of the Practice	Transportation Research Board	This study conducted a state of the practice survey to determine which tools are being used by State DOTs to estimate the traffic mobility impacts on their work zones.	2
Elias, A. M., and Z. J. Herbsman	Risk Analysis Techniques for Safety Evaluation of Highway Work Zones	Transportation Research Board	This study developed an approach to determine the risks that are present in highway work zones.	2
Faulkner, M. J. and C. L. Dudek	Field Evaluation of Moving Maintenance Operations on Texas Urban Freeways	Transportation Research Board	This paper evaluated the safety problems with moving maintenance operations on freeways in Texas.	2
Faulkner, M. J. and C. L. Dudek	Flashing Arrowboards in Advance of Freeway Work Zones	Transportation Research Board	The objective of this paper was to evaluate the use of flashing arrow boards for freeway lane closures.	3
Federal Highway Administration	Investigation of Highway Work Zone Crashes	Federal Highway Administration	Highway work zone crashes were investigated using the Highway Safety Information System to determine characteristic of crashes, examine how they are reported and provide ways to improve problems that were found.	3
Federal Highway Administration	Meeting the Customer's Needs for Mobility and Safety during Construction and Maintenance Operations	Federal Highway Administration	The objective of this report was to determine how effective the policies and procedures provided by FHWA and State DOTs are at improving mobility and increasing safety through construction and maintenance operations.	2

Relevance Rating: 1-Directly Related 2-Marginally Related 3-Not Directly Related 4-Not Related

Author	Title	Publisher	Goals	Relevance to Utility Work Zones
Federal Motor Carrier Safety Administration	2000 Work Zone Traffic Crash Facts	Federal Motor Carrier Safety Administration	This study identified number and percentages work zone-related crashes and work zone-related large truck crashes for 2000.	4
Finley, M. D., B. R. Ullman and N. D. Frout	Motorist Comprehension of Traffic Control Devices for Mobile Operations	Transportation Research Board	This paper identified and evaluated traffic control devices that could be used for mobile and short duration maintenance operations and determined the motorists understanding of the devices.	2
Finley, M. D., G. L. Ullman and C. L. Dudek	Work Zone Lane Closure Warning–Light System	Texas Transportation Institute	The study focuses on determining the effectiveness of a sequential waning light system on drums in work zones at night.	3
Fontaine, M. D.	Guidelines for Application of Portable Work Zone Intelligent Transportation Systems	Transportation Research Board	This study evaluated the use of Portable Work Zone Intelligent Transportation Systems by various agencies.	3
Garber, N. and S. Srinivasan	Influence of Exposure Duration on the Effectiveness of Changeable-Message Signs in Controlling Vehicles Speeds at Work Zones	Transportation Research Board	Changeable Message Signs were evaluated to determine the effect they have on speeding drivers in Virginia.	3
Hall, J. W. and V. W Lorenz	Characteristics of Construction Zone Accidents	Transportation Research Board	The paper focused on identifying characteristics of crashes in New Mexico construction work zones to improve safety.	3
Ha, T. J. and Z. A. Nemeth	Detailed Study of Accident Experience in Construction and Maintenance Zones	Transportation Research Board	This study used crash data to identify the causes and effects of construction and maintenance work zone crashes.	2
Hummer, J. E. and C. R. Scheffler	Driver Performance Comparison of Fluorescent Orange to Standard Orange Work Zone Traffic Signs	Transportation Research Board	The study was conducted to determine the safety related operational measures of fluorescent orange and standard orange traffic signs.	2

Relevance Rating: 1-Directly Related 2-Marginally Related 3-Not Directly Related 4-Not Related

Author	Title	Publisher	Goals	Relevance to Utility Work Zones
Hinze, J., and D. L. Carlisle	Variables Affected by Nighttime Construction Projects	Transportation Research Board	The paper focused on determining the issues that are related to nighttime construction projects.	3
Khattak, A. J., A. J. Khattak and F. M. Council	Effects of Work Zone Presence on Injury and Non-injury Crashes	Accident Analysis and Prevention	This study analyzed crash data to determine the effect of work zone duration on injury and non-injury crashes and compare pre-work zone crashes with crashes occurring during the work zone period.	2
Kononov, J. and Z. Znamenacek	Risk Analysis of Freeway Lane Closure During Peak Period	Transportation Research Board	The purpose of this study was to provide state DOTs with an effective way to use lane closures.	3
Koushki, P. A. and F. Al-Kandaru	Road Safety: Prioritization of Roadside Hazard Improvement	Transportation Research Board	This study was conducted in Kuwait to identify hazards that exist along roadways.	4
Krammes, R. A., and G. O. Lopez	Updated Capacity Values for Short-term Freeway Work Zone Lane Closures	Transportation Research Board	The study focused on estimating the capacity of short-term lane closures in freeway work zones.	3
Kuemmel, D. A.	Maximizing Legibility of Traffic Signs in Construction Work Zones	Transportation Research Board	The study focused on improving the legibility of work zone traffic control signs by rearranging legends, increasing stroke width, and using upper case lettering.	2
Levine, S. Z. and R. J. Kabat	Planning and Operation of Urban Highway Work Zones	Transportation Research Board	The objective of this paper was to determine ways in which the problems associated with planning and operation of freeway work zones can be safely alleviated.	2
Lew, A	Construction Zone, Detour and Temporary Connection Accidents	California Department of Transportation	Crash analysis was done in construction work zones to evaluate the problems that are occurring and recommend ways to improve those problems	2
Lipscomb, H. J., J. M. Dement, and R. Rodriguez-Acosta	Deaths from External Causes of Injury Among Construction Workers in North Carolina	Applied Occupational and Environmental Hygiene	This paper studies the causes for deaths among construction workers.	2

Relevance Rating: 1-Directly Related 2-Marginally Related 3-Not Directly Related 4-Not Related

Author	Title	Publisher	Goals	Relevance to Utility Work Zones
Lozier, W. C., M. E. Kimberlin, and T. L. Grant	Case Study of Highway Maintenance Management	Transportation Research Board	A study was conducted to evaluate the maintenance management program developed by Ohio DOT.	3
Mak, K. K., R. P. Bligh and L. R. Rhodes	Crash Testing and Evaluation of Work Zone Barricades	Transportation Research Board	The paper focused on evaluating three types of barricades as traffic control devices to reduce crashes in work zones.	2
Mak, K. K., R. P. Bligh and L. R. Rhodes	Crash Testing and Evaluation of Work Zone Traffic Control Devices	Transportation Research Board	This study evaluated the effectiveness of traffic control devices including plastic drums, sign substrates, temporary and portable sign supports, plastic cones and vertical panels when impacted by vehicles.	2
Maze, T., G. Burchett and J. Hochstein	Synthesis of Procedures to Forecast and Monitor Work Zone Safety and Mobility Impacts	Federal Highway Administration	The study was performed to determine what is currently being done by State Transportation Agencies to plan, manage, operate and evaluate work zone safety and mobility.	2
McGee, H. W. and B. G. Knapp	Visibility Requirements for Traffic Control Devices in Work Zones	Transportation Research Board	The study focused on developing standards for traffic control devices in work zones based on visibility requirements.	2
McGee, H. W., D. B. Joost and E. C. Noel	Speed Control at Work Zones	Institute of Transportation Engineers Journal	This article presents a user guideline that was prepared for controlling vehicle speeds in work zones.	3
Melia M. K.	How to Improve Work-Zone Safety	Traffic Safety	This article discusses the certification requirements for flaggers in multiple states.	2
Melia M. K.	Warning: Work Still Ahead on Work-Zone Safety	Traffic Safety	This article discusses the safety of motorists in work zones particularly dealing with flaggers.	2
Michalopoulos, P. G. and R. Plum	Determining Capacity and Selecting Appropriate Type of Control at One-lane Two-way Construction Sites	Transportation Research Board	The study was conducted to evaluated different traffic controls including stop signs, signals, and flaggers for one-lane two-way construction work zones.	2

Relevance Rating: 1-Directly Related 2-Marginally Related 3-Not Directly Related 4-Not Related

Author	Title	Publisher	Goals	Relevance to Utility Work Zones
Migletz, J. and J. L. Graham	Work Zone Speed Limit Procedures	Transportation Research Board	The goal of this study was to develop uniform procedures for determining the speed limit of work zones.	3
Mohan, S. B. and P. Gautam	Cost of Highway Work Zone Injuries	ASCE Practice Periodical on Structural Design and Construction	The study was performed to estimate the direct and indirect costs for different types of work zone crashes.	2
Mohan, S. B. and W. C. Zech	Characteristic of Worker Accidents on NYSDOT Construction Projects	Journal of Safety Research	This paper provides information on work zone crashes to help develop safety plans to provide safer work zones for the workers and motorists.	3
Morelli, C. J., J. D. Brogan and J. W. Hall.	Accommodating Pedestrians in Work Zones	Transportation Research Board	This report focuses on the safety on pedestrians in work zones.	2
Noel, E. C., C. L. Dudek, O. J. Pendleton and Z. A. Sabra	Speed Control Through Freeway Work Zones: Technique Evaluation	Transportation Research Board	The study focused on evaluating ways in which speed of vehicles can be controlled through work zones.	3
Paniati, J. F.	Redesign and Evaluation of Selected Work Zone Sign Symbols	Transportation Research Board	The study evaluated work zone traffic signs including Pavement Width Transition, Flagger Ahead, Low Shoulder and Uneven Pavement to determine if a redesign is better understood by drivers.	2
Polivka, K. A., R. K. Faller, J. R. Rohde, and D. L. Sicking	Crash Testing and Analysis of Work-Zone Sign Supports	Transportation Research Board	The paper evaluated the design of traffic control work zone signs and determined the safety impacts of different sign supports.	2
Qi, Y., R. Srinivasan, H. Teng and R. Baker	Frequency of Work Zone Accidents on Construction Projects	New York State Department of Transportation	This study focused on work zone crashes in the state of New York to improve the safety of the work zones and recommend ways to improve the crash database.	3
Raub, R. A. and O. B. Sawaya	Effects of Under-Reporting Construction Zone Crashes	Transportation Research Board	This report analyzed the issues related to under-reporting crashes.	3

Relevance Rating: 1-Directly Related 2-Marginally Related 3-Not Directly Related 4-Not Related

Author	Title	Publisher	Goals	Relevance to Utility Work Zones
Richards, S. H. and M. Faulkner	An Evaluation of Work Zone Traffic Accidents Occurring on Texas Highway in 1977	Transportation Research Board	This paper focused on evaluating crashes that were occurring in work zones in Texas during the 1970s.	3
Richards, S. H., H. Stephen and C. L. Dudek	Implementation of Work-Zone Speed Control Measures	Transportation Research Board	This study was conducted to determine measures that can be taken to reduce speeds in work zones.	3
Richards, S. H., R. C. Wunderlich and C. L. Dudek	Field Evaluation of Work Zone Speed Control Techniques	Transportation Research Board	Speed control methods including flagging, law enforcement, Changeable Message Signs, effective lane width reduction and rumble strips were tested to determine their effect on reducing speed in work zones.	3
Richards, S. H., R. C. Wunderlich and C. L. Dudek	Visibility in Construction and Maintenance Work Zones	Transportation Research Board	The paper discusses multiple studies conducted in the 1970s about visibility requirements and improving visibility in construction and maintenance work zones.	2
Sarasua, W. A., W. J. Davis, D. B. Clarke, J. Kattappally and P. Mulukutla	Evaluation of Interstate Highway Capacity for Short-term Work Zone Lane Closures	Transportation Research Board	The study focused on developing a model to estimate the capacity of work zones in South Carolina based on roadway characteristics, traffic and work zone activity.	3
Sarasua, W. A., W. J. Davis, M. A. Chowdhury and J. K. Ogle	Estimating Interstate Highway Capacity for Short-term Work Zone Lane Closures: Development of Methodology	Transportation Research Board	The objective of the study was to determine a way to estimate the capacity of an interstate highway during a short-term lane closure.	3
Sayer, J. R. and M. L. Mefford	High Visibility Safety Apparel and Nighttime Conspicuity of Pedestrians in Work Zones	Journal of Safety Research	Retroreflective safety garments were studied to determine if it helps to see pedestrians in nighttime work zones.	3
Shepard, F. D.	Improving Work Zone Delineation on Limited Access Highways	Transportation Research Board	Steady-burn lights and raised pavement markers were studied to determine their role in guiding vehicles through work zones.	2

Relevance Rating: 1-Directly Related 2-Marginally Related 3-Not Directly Related 4-Not Related

Author	Title	Publisher	Goals	Relevance to Utility Work Zones
Sicking, D. L., J. R. Rohde, and J. D. Reid	Development of Trailer Attenuating Cushion for Variable Message Signs and Arrow Boards	Transportation Research Board	This paper focused on the design of new trailer attenuating cushions to increase the safety of variable message sign trailers and arrow board trailers.	2
Sisiopiku, V. P. and R. W. Lyles	Study of Speed Patterns in Work Zones	Transportation Research Board	The purpose of the study was to determine the impact of various posted speed limits on the actual speed of vehicles in a work zone.	2
Tooley, M. S., J. L. Gattis, R. Janarthanan and L. K. Duncan	Evaluation of Automated Work Zone Information Systems	Transportation Research Board	This paper determined the effectiveness of Automated Work Zone Information Systems in determining the presence of backups at work zones and in notifying motorists of work zone	3
Turner, J.D.	What is a Work Zone?	Public Roads	This article describes the problems that result because there is not a set definition of work zone that everyone uses.	2
Ullman, G. L.	Effect of Radar Transmissions on Traffic Operations at Highway Work Zones	Transportation Research Board	The purpose of this paper was to determine if transmitting radar signals without using visible enforcement effects vehicular speeds and maneuvers at the beginning of and throughout highway work zones.	3
Ullman, G. L. and S. Z. Levine	An Evaluation of Portable Traffic Signals at Work Zones	Transportation Research Board	The study evaluated the use of portable traffic signals to replace flaggers at work zones.	2
Ullman G. L., B. R. Ullman and M. D. Finley	Evaluating the Safety Risk of Active Night Work Zones	Texas Transportation Institute	The study evaluated the different safety risks of workers and motorists in work zones at night.	3
Ullman G. L., C. L. Dudek, B. R. Ullman, A. William and G. Pesti	Improved Work Zone Portable Changeable Message Sign Usage	Texas Transportation Institute	This paper focuses on the proper use of portable changeable message signs in work zones.	3

Relevance Rating: 1-Directly Related 2-Marginally Related 3-Not Directly Related 4-Not Related

Author	Title	Publisher	Goals	Relevance to Utility Work Zones
Ullman, G. L, M. D. Finley and B. R. Ullman	Analysis of Crashes at Active Night Work Zones in Texas	Transportation Research Board	This paper focused on the crash issues related to nighttime highway work zones.	3
Van Winkle, J. and J. B. Humphreys	Effectiveness of City Traffic-Control Programs for Construction and Maintenance Work Zones	Transportation Research Board	This study consisted of a state-of-the-art survey and field investigation to determine the risks involved with city traffic-control programs for work zones.	2
Venugopal, S. and A. Tarko.	Safety Models for Rural Freeway Work Zones	Transportation Research Board	The study was done to develop models to predict the number of crashes on sections of rural freeways approaching work zones and inside work zones.	3
Wang, J, et. al	Investigation of Highway Work Zone Crashes	Federal Highway Administration	This study focused on issues related to work zone crashes and provided recommendations to improve those issues.	2
Yodock, J. L. and M. Christensen	Increasing Work Zone Safety - Water-Filled Barricades Guide Through Dangerous Work Areas	Public Works Magazine	This article focuses on the use of water-filled barricades to improve safety through work zones.	3
Zhu, J. and F. F. Sacromanno	Safety Implications of Freeway Work Zone Lane Closures	Transportation Research Board	The paper focused on determining the safety implications that result from freeway lane closures including right lane closures, left lane closures and an alternative lane closure	3

Relevance Rating: 1-Directly Related 2-Marginally Related 3-Not Directly Related 4-Not Related

APPENDIX III – SAMPLE SURVEYS AND DATA

QUESTIONNAIRE SURVEY OF CURRENT UTILITY WORK ZONE PRACTICES OF CONTRACTORS AND UTILITY COMPANIES

The objective of this survey is to collect detailed information on agency standards, policies, and local guidelines for UTILITY WORK ZONE safety and traffic control. Collectively, these survey results will be used to determine the state of the practice in utility work zone traffic control. They will also be utilized in developing utility work zone safety and mobility guidelines for FHWA. Your response and input in this guideline development process is very important, and your cooperation is greatly appreciated. You may type directly onto this survey form and return it via mail, e-mail, or fax to the contact listed at the end of the form and return the survey as soon as possible.

1. Has your company established standards for traffic control in utility work zones?

☐Yes ☐No

If Yes, please send a copy of the standards/guidelines to the address listed at the end of this survey, or if it is available online please provide the website where it can be obtained on the following line:

____

2. Does your company follow the Manual of Uniform Traffic Control Devices (MUTCD)?

☐Yes ☐No

3. Does your company conduct periodic process reviews of its utility work zone programs?

☐Yes ☐No

If Yes, how frequently? ____

4. Has your company established specific standards/guidelines for emergency traffic control in utility work zones?

☐Yes ☐No

5. Does your company have different standards/policies for roadway work based upon work duration?

☐Yes ☐No

If Yes, please check policy-specific durations as appropriate. (Check all that apply.)

☐1 hour or less ☐1-2 hours ☐2-4 hours ☐4-8 hours ☐8 hours or more
☐Other(s): ____

6. Does your company have different standards/policies for roadway work based upon work location?

☐Yes ☐No

If Yes, please check as appropriate. (Check all that apply.)

☐On roadway ☐On shoulder ☐Above roadway ☐Outside shoulder within ROW
☐All of the above

7. Does your company have different standards/policies for roadway work based upon the type of work?

☐Yes ☐No

If Yes, check all that apply.

☐Electric ☐Gas ☐Cable ☐Phone ☐Sanitary sewer ☐Storm sewer ☐Water main
☐Traffic signals ☐Street lights ☐Other(s): ________________________________

8. Does your company have different standards/policies for roadway work based upon roadway type?

☐Yes ☐No

If Yes, please check as appropriate.

☐Local Roads ☐Collectors ☐Arterials ☐Freeways

☐All of the above

9. Does your company coordinate its utility work zone projects with other agencies or the public?

☐Yes ☐No

If Yes, please check as appropriate.

☐State DOT ☐Local/County Highway Agency ☐Media ☐Citizens Groups

☐All of the above

10. Does your company have a standard traffic control plan for utility work zones?

☐Yes, one standard plan

☐Yes, several standard plans based on project type

☐No

11. If a worker has questions as to the appropriateness of a utility work zone traffic control plan, whom are they directed to contact? ____

12. Has your company personnel/contractors been involved in any utility work zone-related crashes, injuries, or fatalities in the past five years?

☐Yes ☐No

If Yes, please provide a contact name, phone number, and e-mail address where further details may be obtained.

____

13. Has your company been involved in any tort liability cases in the past five years?

☐Yes ☐No

If Yes, please provide a contact name, phone number, and e-mail address where further details may be obtained.

____

14. Has your company been subject to review and/or citation by the local Occupational Safety and Health Administration (OSHA)?

☐Yes ☐No

If Yes, please provide the most appropriate reason(s) (Check all that apply):

☐Non-conformance to MUTCD

☐Violation of OSHA safety training and education requirements

☐Violation of OSHA personal protective equipment requirements

☐Violation of OSHA general requirements

☐Other(s): ____

15. Does your company offer any training programs for utility work zone traffic control for contractors or employees?

☐Yes ☐No

If Yes, please send a copy of the training materials to the address listed at the end of this survey or if it is available online, please provide the website where it can be obtained on the following line:

____

16. Do you require that traffic control personnel and flaggers be certified?

☐Yes ☐No

Please list any certification programs available through your company or other agencies:

____

____

17. What type of utility work does your company conduct? (Check all that apply.)

☐Electric ☐Gas ☐Cable ☐Phone ☐Sanitary sewer ☐Storm sewer ☐Water main
☐Traffic signals ☐Street lights ☐Other(s): ____

18. Your Name and Title: ____

Company Name: ____

Address: ____

Telephone No.: ____

Fax No.: ____

E-Mail: ____

Thank you for participating in this survey. Your help is greatly appreciated.

Please mail, e-mail, or fax your completed survey to:

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Contractors and Utility Companies Survey Results

Has your company established standards for traffic control in utility work zones?

Yes	25	93%	No	2	7%

Does your company follow the Manual on Uniform Traffic Control Devices (MUTCD)?

Yes	25	93%	No	2	7%

Does your company conduct periodic process reviews of its utility work zone programs?

Yes	22	81%	No	5	19%

Has your company established specific standards/policies based for:

Emergency traffic control in utility work zones?

Yes	17	63%	No	10	37%

Roadway work based upon work duration?

Yes	16	59%	No	11	41%

Roadway work based upon work location?

Yes	21	78%	No	6	22%

Roadway work based upon the type of work?

Yes	9	33%	No	18	67%

Roadway work based upon roadway type?

Yes	20	74%	No	7	26%

Does your company coordinate its utility work zone projects with other agencies or the public?

Yes	23	85%	No	4	15%

Does your company have a standard traffic control plan for utility work zones?

Yes	20	43%	No	27	57%

If a worker has questions as to the appropriateness of a utility work zone traffic control plan, whom are they directed to contact?

Crew Supervisor	19	70%	Safety Professional	23	85%

Have your company personnel/contractors been involved in any utility work zone-related crashes, injuries, or fatalities in the past 5 years?

Yes	12	44%	No	15	56%

Has your company been involved in any tort liability cases in the past five years?

Yes	3	11%	No	24	89%

Has your company been subject to review and/or citation by the local Occupational Safety and Health Administration (OHSA)?

Yes	11	41%	No	16	59%

Does your company offer any training programs for utility work zone traffic control for contractors or employees?

Yes	23	85%	No	4	15%

Do you require that traffic control personnel and flaggers be certified?

Yes	14	52%	No	13	48%

QUESTIONNAIRE SURVEY OF CURRENT UTILITY WORK ZONE PRACTICES OF STATE AND LOCAL AGENCIES

The objective of this survey is to collect detailed information on agency standards, policies, and local guidelines for UTILITY WORK ZONE safety and traffic control. Collectively, these survey results will be used to determine the state of the practice in utility work zone traffic control. They will also be utilized in developing utility work zone safety and mobility guidelines for FHWA. Your response and input in this guideline development process is very important, and your cooperation is greatly appreciated. You may type directly onto this survey form and return it via mail, e-mail, or fax to the contact listed at the end of the form and return the survey as soon as possible.

1. Has your agency established standards/guidelines for traffic control in utility work zones?

☐Yes ☐No

If Yes, please send a copy of the standards/guidelines to the address listed at the end of this survey, or if it is available online please provide the website where it can be obtained on the following line:

____

2. Does your agency follow either the National or State version of the Manual of Uniform Traffic Control Devices (MUTCD) for utility work traffic control?

☐Yes, National MUTCD ☐Yes, State MUTCD ☐No, neither version

3. Does your agency conduct periodic process reviews of its utility work zone programs?

☐Yes ☐No

If Yes, how frequently? ____

4. Has your agency established acceptable delay thresholds for utility work zone projects?

☐Yes ☐No

If Yes, what are these thresholds? ____

5. Has your agency established specific standards/guidelines for emergency traffic control in utility work zones?

☐Yes ☐No

6. Who is responsible for reviewing and/or approving temporary traffic control at the utility work zones governed by your agency?

☐Traffic Engineer ☐Permits Engineer ☐Contractor ☐Utility Company
☐Other(s): __________________

7. Does your agency have different standards/policies for roadway work based upon work duration?

☐Yes ☐No

If Yes, please check policy-specific durations as appropriate. (Check all that apply.)

☐1 hour or less ☐1-2 hours ☐2-4 hours ☐4-8 hours ☐8 hours or more
☐Other(s): ____

8. Does your agency have different standards/policies for roadway work based upon work location?

□Yes □No

If Yes, please check as appropriate. (Check all that apply.)

□On roadway □On shoulder □Above roadway □Outside shoulder within ROW

□All of the above

9. Does your agency have different standards/policies for roadway work based upon the type of work?

□Yes □No

If Yes, check all that apply.

□Electric □Gas □Cable □Phone □Sanitary sewer □Storm sewer □Water main

□Traffic signals □Street lights □Other(s): ________________________________

10. Does your agency have different standards/policies for roadway work based upon roadway type?

□Yes □No

If Yes, please check as appropriate.

□Local Roads □Collectors □Arterials □Freeways

□All of the above

11. Does your agency coordinate its utility work zone projects with other agencies or the public?

□Yes □No

If Yes, please check as appropriate.

□Other Municipalities □Contractors/Utility Companies □Media □Citizens Groups

□All of the above

12. Does your agency have a standard traffic control plan for utility work zones?

□Yes, one standard plan

□Yes, several standard plans based on project type

□No

13. Has your agency experienced any utility work zone-related crashes, injuries, or fatalities in the past five years?

□Yes □No

If Yes, how many such crashes in the past five years?

____

14. Has your agency been involved in any tort liability cases related to utility work zone crashes, injuries, or fatalities in the past five years?

□Yes □No

If Yes, please provide a contact name, phone number, and e-mail address where further details may be obtained.

____

15. What is the approximate road mileage within your jurisdiction?________________________

16. Does your agency offer any training programs for utility work zone traffic control for contractors, employees, or utility companies?

☐Yes ☐No

If Yes, please send a copy of the training materials to the address listed at the end of this survey or if it is available online, please provide the website where it can be obtained on the following line:

____

17. Do you require that traffic control personnel and flaggers be certified?

☐Yes ☐No

Please list any certification programs available through your agency or other agencies:

____

____

18. Does your agency provide real-time utility work zone information to motorists?

☐Yes ☐No

If Yes, by what means does your agency provide this information. (Check all that apply.)

☐Radio ☐Television ☐Internet ☐Variable Message Signs ☐Other(s): ___________________

19. Your Name and Title: ____

Agency Name: ____

Address: ____

Telephone No.: ____

Fax No.: ____

E-Mail: ____

Thank you for participating in this survey. Your help is greatly appreciated.
Please mail, e-mail, or fax your completed survey to:

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Wayne State University-Transportation Research Group
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State DOTs Survey Results

Has your agency established standards for traffic control in utility work zones?

Yes	19	79%	No	5	21%

Does your agency follow either the National or State version of the Manual on Uniform Traffic Control Devices (MUTCD) for utility work zone traffic control?

Yes	24	100%	No	0	0%

Does your agency conduct periodic process reviews of its utility work zone programs?

Yes	11	46%	No	13	54%

Has your agency established acceptable delay thresholds for utility work zone projects?

Yes	6	25%	No	18	75%

Who is responsible for reviewing and/or approving temporary traffic control at the utility work zones governed by your agency?

Traffic Engineer	9	38%	Permits Engineer	14	58%
Contractor	2	8%	Utility Company	5	21%

Has your agency established specific standards/policies based for:

Emergency traffic control in utility work zones?

Yes	6	25%	No	18	75%

Roadway work based upon work duration?

Yes	17	71%	No	7	29%

Roadway work based upon work location?

Yes	22	92%	No	2	8%

Roadway work based upon the type of work?

Yes	6	25%	No	18	75%

Roadway work based upon roadway type?

Yes	19	79%	No	5	21%

Does your agency coordinate its utility work zone projects with other agencies or the public?

Yes	19	79%	No	5	21%

Does your agency have a standard traffic control plan for utility work zones?

Yes	18	75%	No	6	25%

Have your agency personnel/contractors been involved in any utility work zone-related crashes, injuries, or fatalities in the past 5 years?

Yes	10	42%	No	14	58%

Has your agency been involved in any tort liability cases in the past five years?

Yes	4	17%	No	20	83%

Does your agency offer any training programs for utility work zone traffic control for contractors or employees?

Yes	17	71%	No	7	29%

Do you require that traffic control personnel and flaggers be certified?

Yes	13	54%	No	11	46%

Does your agency provide real-time utility work zone information to motorists?

Yes	6	25%	No	18	75%