



# Research Project No. 634, "Safety Considerations for Night-time/Weekend Construction Activities"

## Final Report
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16. Abstract

State Departments of Transportation throughout the U.S. are increasingly executing construction activities during nighttime and weekend hours to avoid traffic congestion and other difficulties that commonly arise during daytime execution of work. However, nighttime construction activity introduces unique and significant challenges that must be proactively addressed to create safe work zone environments.

It is clear from this study that nighttime construction poses unique and serious hazards that must be proactively addressed to insure satisfactory safety performance. A comprehensive approach to safety management is required for success. This research conclusively demonstrates that a piecemeal strategy is likely to be ineffective and that safety performance will not be significantly improved by applying one or two innovations or best practice techniques. Detailed guidance, and associated recommendations for each category listed above, is presented in this report. This report will assist DOTs in their efforts to improve safety performance by identifying the likely effectiveness of numerous practices, innovations, and execution strategies prior to implementation.

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# SI* (MODERN METRIC) CONVERSION FACTORS

## APPROXIMATE CONVERSIONS TO SI UNITS

| SYMBOL | WHEN YOU KNOW | MULTIPLY BY | TO FIND | SYMBOL |
|---|---|---|---|---|
| | | **LENGTH** | | |
| in | inches | 25.4 | millimeters | mm |
| ft | feet | 0.305 | meters | m |
| yd | yards | 0.914 | meters | m |
| mi | miles | 1.61 | kilometers | km |
| | | **AREA** | | |
| $in^2$ | square inches | 645.2 | square millimeters | $mm^2$ |
| $ft^2$ | square feet | 0.093 | square meters | $m^2$ |
| $yd^2$ | square yard | 0.836 | square meters | $m^2$ |
| ac | acres | 0.405 | hectares | ha |
| $mi^2$ | square miles | 2.59 | square kilometers | $km^2$ |
| | | **VOLUME** | | |
| fl oz | fluid ounces | 29.57 | milliliters | mL |
| gal | gallons | 3.785 | liters | L |
| $ft^3$ | cubic feet | 0.028 | cubic meters | $m^3$ |
| $yd^3$ | cubic yards | 0.765 | cubic meters | $m^3$ |
| | | NOTE: volumes greater than 1000 L shall be shown in $m^3$ | | |
| | | **MASS** | | |
| oz | ounces | 28.35 | grams | g |
| lb | pounds | 0.454 | kilograms | kg |
| T | short tons (2000 lb) | 0.907 | megagrams (or "metric ton") | Mg (or "t") |
| | | **TEMPERATURE (exact degrees)** | | |
| °F | Fahrenheit | 5 (F-32)/9<br>or (F-32)/1.8 | Celsius | °C |
| | | **ILLUMINATION** | | |
| fc | foot-candles | 10.76 | lux | lx |
| fl | foot-Lamberts | 3.426 | $candela/m^2$ | $cd/m^2$ |
| | | **FORCE and PRESSURE or STRESS** | | |
| lbf | poundforce | 4.45 | newtons | N |
| $lbf/in^2$ | poundforce per square inch | 6.89 | kilopascals | kPa |

## APPROXIMATE CONVERSIONS FROM SI UNITS

| SYMBOL | WHEN YOU KNOW | MULTIPLY BY | TO FIND | SYMBOL |
|---|---|---|---|---|
| | | **LENGTH** | | |
| mm | millimeters | 0.039 | inches | in |
| m | meters | 3.28 | feet | ft |
| m | meters | 1.09 | yards | yd |
| km | kilometers | 0.621 | miles | mi |
| | | **AREA** | | |
| $mm^2$ | square millimeters | 0.0016 | square inches | $in^2$ |
| $m^2$ | square meters | 10.764 | square feet | $ft^2$ |
| $m^2$ | square meters | 1.195 | square yards | $yd^2$ |
| ha | hectares | 2.47 | acres | ac |
| $km^2$ | square kilometers | 0.386 | square miles | $mi^2$ |
| | | **VOLUME** | | |
| mL | milliliters | 0.034 | fluid ounces | fl oz |
| L | liters | 0.264 | gallons | gal |
| $m^3$ | cubic meters | 35.314 | cubic feet | $ft^3$ |
| $m^3$ | cubic meters | 1.307 | cubic yards | $yd^3$ |
| | | **MASS** | | |
| g | grams | 0.035 | ounces | oz |
| kg | kilograms | 2.202 | pounds | lb |
| Mg (or "t") | megagrams (or "metric ton") | 1.103 | short tons (2000 lb) | T |
| | | **TEMPERATURE (exact degrees)** | | |
| °C | Celsius | 1.8C+32 | Fahrenheit | °F |
| | | **ILLUMINATION** | | |
| lx | lux | 0.0929 | foot-candles | fc |
| $cd/m^2$ | $candela/m^2$ | 0.2919 | foot-Lamberts | fl |
| | | **FORCE and PRESSURE or STRESS** | | |
| N | newtons | 0.225 | poundforce | lbf |
| kPa | kilopascals | 0.145 | poundforce per square inch | $lbf/in^2$ |

*SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380.
(Revised March 2003)

TABLE OF CONTENTS

Table of Contents (Continued)

Table of Contents (Continued)

Page

LIST OF TABLES

LIST OF FIGURES

# CHAPTER I

# INTRODUCTION

Highway construction and maintenance workers are at risk of fatal and serious nonfatal injury when working in the vicinity of passing motorists, construction vehicles, and equipment. Each year, more than 100 workers are killed and over 40,000 people are injured as a result of motor vehicle accidents in work zones (1). For example, between 1992 and 1998, 841 workers were killed in highway and street construction and 492 (58.5 percent) were within a work zone. Of these, 465 were vehicle or equipment related, according to the Labor Department's Bureau of Labor Statistics. When motorists are included, the total work zone death toll was 868 in 1999 alone (1).

Some analysts contend that our nation's safety performance is not improving sufficiently. Certain safety data suggests they may be correct. The 868 death toll number of 1999 is a sharp jump from the 772 in 1998 and 693 in 1997, according to data published by the National Highway Traffic Safety Administration (NHTSA). However, in the year 2000, the number of fatalities in work zones climbed even further to a startling 1,026, and in 2001 the number of fatalities was 1,033. Likewise, injuries are on the rise, with 35,000 in 1997, 39,000 in 1998, and 51,000 in 1999 (1). While much has been done to improve work zone safety practices, it is clear that additional study and effort is required. One of the proactive measures often employed to improve this situation is the practice of performing construction and maintenance operations during nighttime hours when passing motorist traffic is minimized.

However, this practice introduces new risks on both sides of the work zone barrier. Issues related to general visibility, illumination and glare, signage and signaling devices, worker clothing, equipment and vehicle operation, accelerated construction techniques, and

motorist alertness are just a few of the areas requiring special work zone management and planning.

Historically, efforts to reduce worker injuries in this industry have principally focused on improving traffic control devices and work zone configurations to minimize confusion of motorists passing the work zone. Generally speaking these measures are designed to improve the safety of passing motorists. The question that must be answered is what additional measures can be taken during nighttime construction to improve safety and protect South Carolina Department of Transportation (SCDOT) employees, contractors, as well as, the general public.

The SCDOT recognizes the need for emphasizing safety during work operations. This SCDOT study, entitled "Safety Considerations for Nighttime and Weekend Construction Activities," addressed issues relating to the planning, safety, and traffic control aspects of nighttime construction and maintenance operations, addressing the advantages and disadvantages of the various safety measures that can be employed. The study proposes improvements for managing nighttime construction. Although there are many potential disadvantages and risks associated with working at night, it is believed that with experience, proper planning, and attention to worker and motorist safety can make night work a feasible, productive, and attractive alternative.

In January of 2002, the Civil Engineering Department of Clemson University began a research project for the SCDOT dealing with safety considerations for nighttime construction activities. Statistics trending national performance with respect to safety issues indicate that construction and maintenance workers are at risk in or near construction zones. This risk is generated from different factors including the motoring public, construction and maintenance vehicles, and construction equipment as illustrated in Figure 1.1.

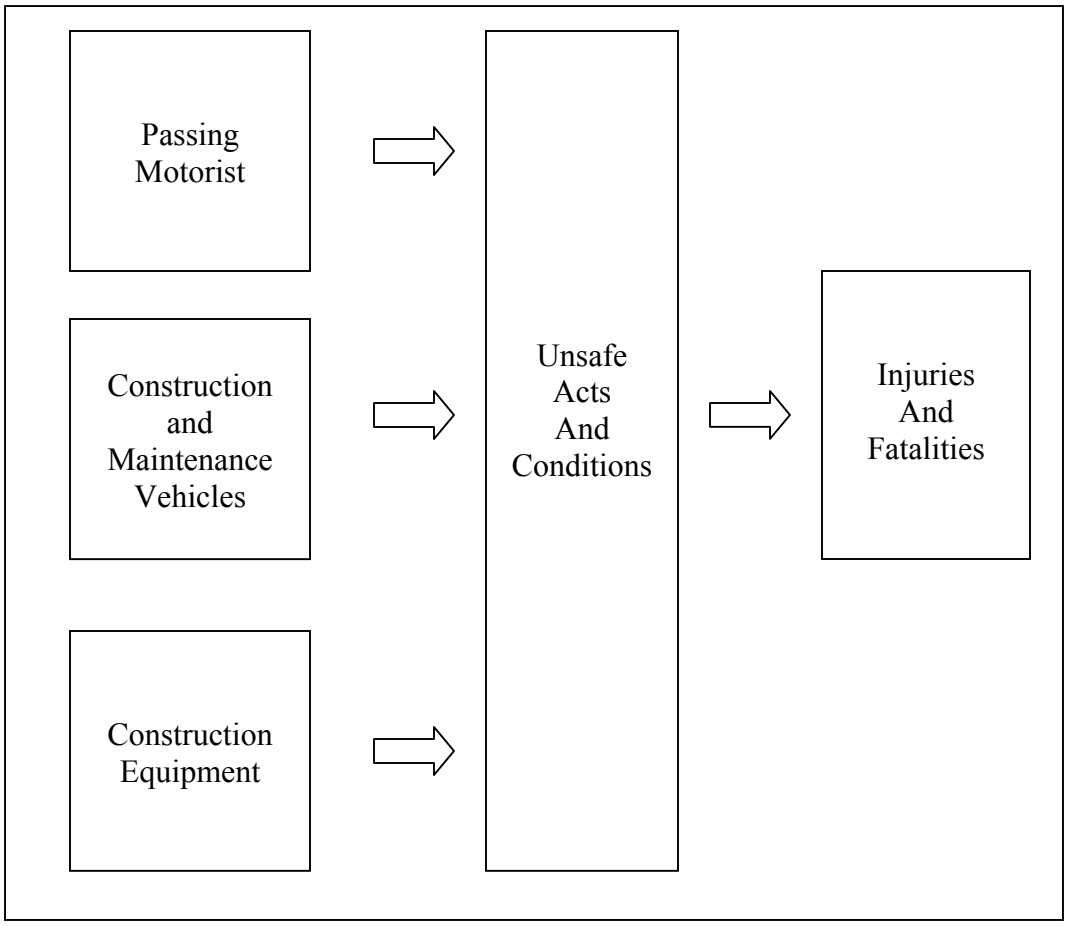



Figure 1.1. Causes of Injuries and Fatalities in Work Zones.

Construction sites or work zones create serious disruptions in the normal flow of traffic, resulting in major inconveniences and safety impacts for the traveling public as well as for the construction personnel performing the work. Current legislation and programs, at both state and federal levels, emphasize the need for a better understanding of work zone problems with a goal toward improving safety without compromise to productivity and quality of the work being performed. The sharp decline in overall safety performance across the United States, as described above, coupled with the temporary closure of more miles of highway every year for construction, rehabilitation, and maintenance, makes the analysis of safety at work zone sites a high priority item of many state DOTs. This is especially true of

nighttime construction where additional risk items must be carefully identified, assessed, and proactively controlled or mitigated.

One recently completed study found that 85 percent of accidents are the result of unsafe behavior, not necessarily the failure of the system (2). This finding has relevancy to this study in that it implies that improving overall safety performance is dependent on modifying behavior. If it can be understood how to modify behaviors, of both contractors and motorists, then a sharp decrease in collisions, injuries, and fatalities can be expected.

Most previously completed research related to this topic has investigated single issues, or aspects, rather than examining the work zone environment comprehensively as it relates to nighttime construction. For example, one recent study reported on a partnership between a highway contractor and the New Jersey DOT to develop a new lighting specification for work zones. They limited their analysis to a new hydraulically operated lighting system for pavers (3). Similarly, the Iowa DOT has recently published a study that is focused strictly on speed reduction measures designed to improve work zone safety (4). While useful, it is again quite narrow in scope. Another study released in year 2000 in the Occupational Health and Safety Journal provides an updated list of recommended practices for improving work zone safety (5). This study provides some useful practical tips but does not create or recommend specification standards for nighttime construction operations. There are numerous studies on specific subjects such as illumination, glare, and retroreflectivity.

In April of 2000, the Federal Highway Administration released a report entitled: "Work Zone Operations Best Practices Guidebook (6)." This guidebook summarizes best practices resulting from an investigation of 26 states during 1998; however, it is does not suggest best practices for nighttime construction. A recent study by the National Safety Council focuses on signage alone for work zones (7). The Transportation Research Board released a year 2000 report on work zone safety for rural, two-lane freeway segments (8). One final study deserving reference is a recent study conducted by the Virginia

Transportation Research Council (VTRC) to assess safety perceptions from the viewpoint of both motorists and transportation agency personnel (9). Unfortunately, insufficient data were collected to actually determine if nighttime work zones are actually less safe than daytime work zones, although several anecdotal recommendations/perceptions were contributed.

As noted above, most previously completed research related to this topic has investigated individual aspects related to nighttime construction. The significance and value of this research is its comprehensive evaluation of work zone safety practices specifically focused on nighttime operations.

# CHAPTER II

# OBJECTIVES, BENEFITS, AND METHODOLOGY

## Objectives

The objectives of this research are to comprehensively identify the safety issues related to nighttime construction and to suggest methodologies and practices designed to mitigate these risks. As part of this investigation, the research team conducted a broad industry statistics review, literature search, and survey of other state DOT practices/procedures to identify a broad list of both problems and current practices. The major components of investigation included, but were not limited to, research into lighting/illumination, retroreflectivity, variations in work zone planning and management for night versus day, construction patrol services, and an assortment of innovative technologies. Additionally, proactive construction practices that have been tested or recommended by other state DOT's were evaluated for applicability to this study. The merits and barriers associated with implementation of proposed practices were investigated and summarized.

## Benefits

The most direct benefit of this research is the potential for improved safety performance on SCDOT projects. The goal of this research is to achieve a significant mitigation of safety risks and thus reduce fatal and non-fatal injuries to contractor personnel and the traveling public. An added benefit is significant reduction in SCDOT and contractor liability. Very importantly, it should also be noted that improved safety performance has direct and significant impact on overall project cost and schedule compliance. While the results of this research also permit SCDOT to substantially improve the overall safety performance of nighttime work, it is believed that this research will also improve the safety environment for the general public within the state of South Carolina.

There are some important added benefits for contractors. On April 3, 2000, the Occupational Safety and Health Administration (OSHA) and the Federal Highway Administration (FHWA) announced a program named "Stay Alert" to increase public awareness and stem injuries and fatalities in work zones (10). As part of this program, OSHA will highly scrutinize a highway contractor's commitment to work zone safety and compliance with OSHA regulations. When a worker is killed or injured in a work zone, OSHA will conduct a swift investigation and may impose significant monetary and possible criminal penalties. Such a program creates strong incentive for contracting organizations to embrace safety improvement techniques. Since nighttime construction and maintenance operations carry higher levels of safety risk, this study is of particular importance and relevance.

Guidance information generated in this research is immediately applicable to SCDOT nighttime construction and maintenance activities. SCDOT may choose to require implementation of these recommendations by developing a comprehensive specification of procedures for such work. It should be noted that the research scope was not limited to a particular geographic region or type of construction. It is envisioned that a later study may be appropriate to develop detailed safety recommendations and state approved requirements. Such new standards, when implemented should be validated to quantify the resulting safety benefits.

## Methodology

The following sections detail the methodology employed for this research. As previously noted, the research methodology designed to identify safely issues regarding nighttime construction as well as proactive strategies that can be employed by the state DOT to mitigate these risks and concerns. Figure 2.1 graphically summarizes the methodology executed by the research team.

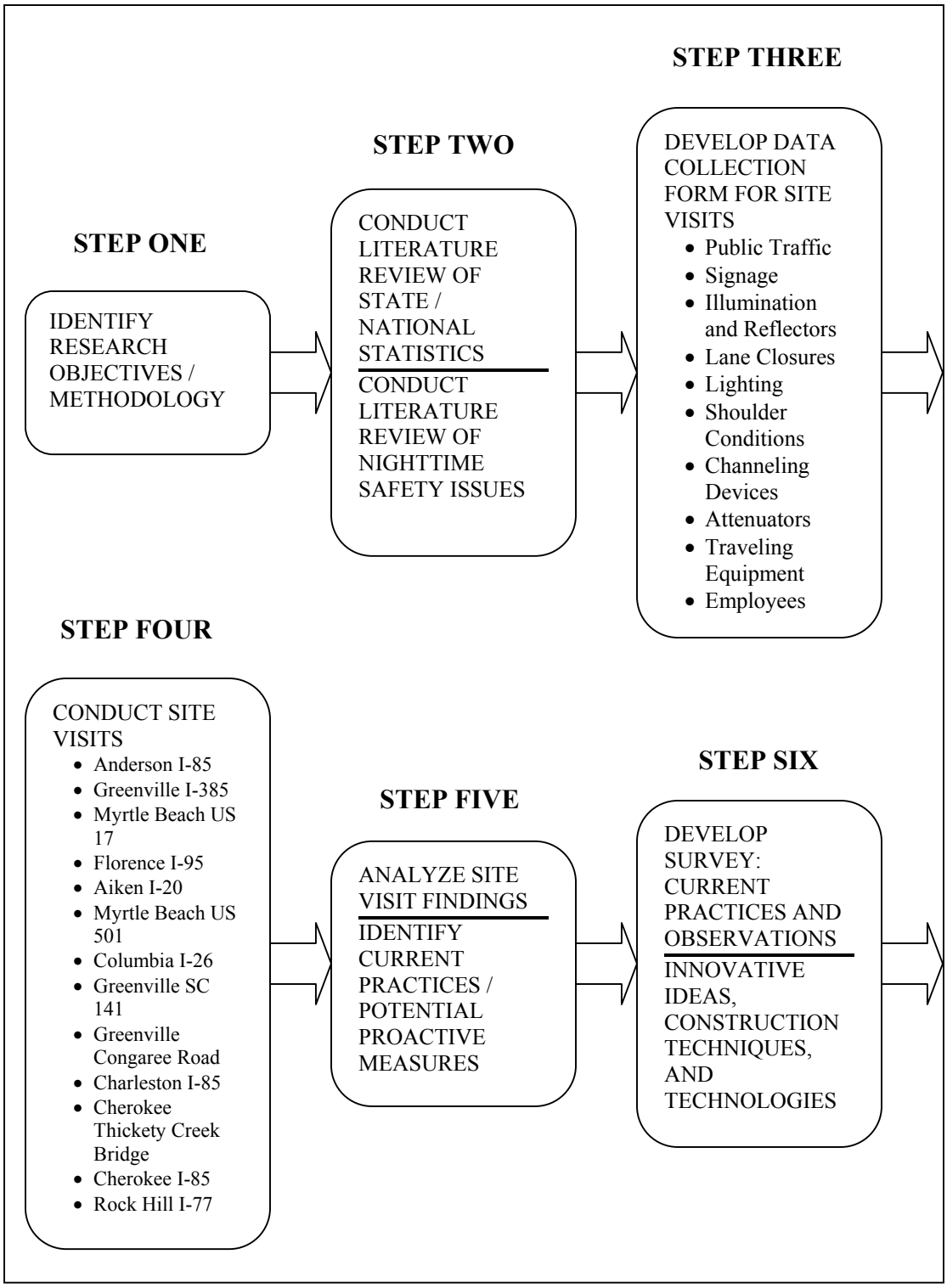



Figure 2.1. Research Methodology.

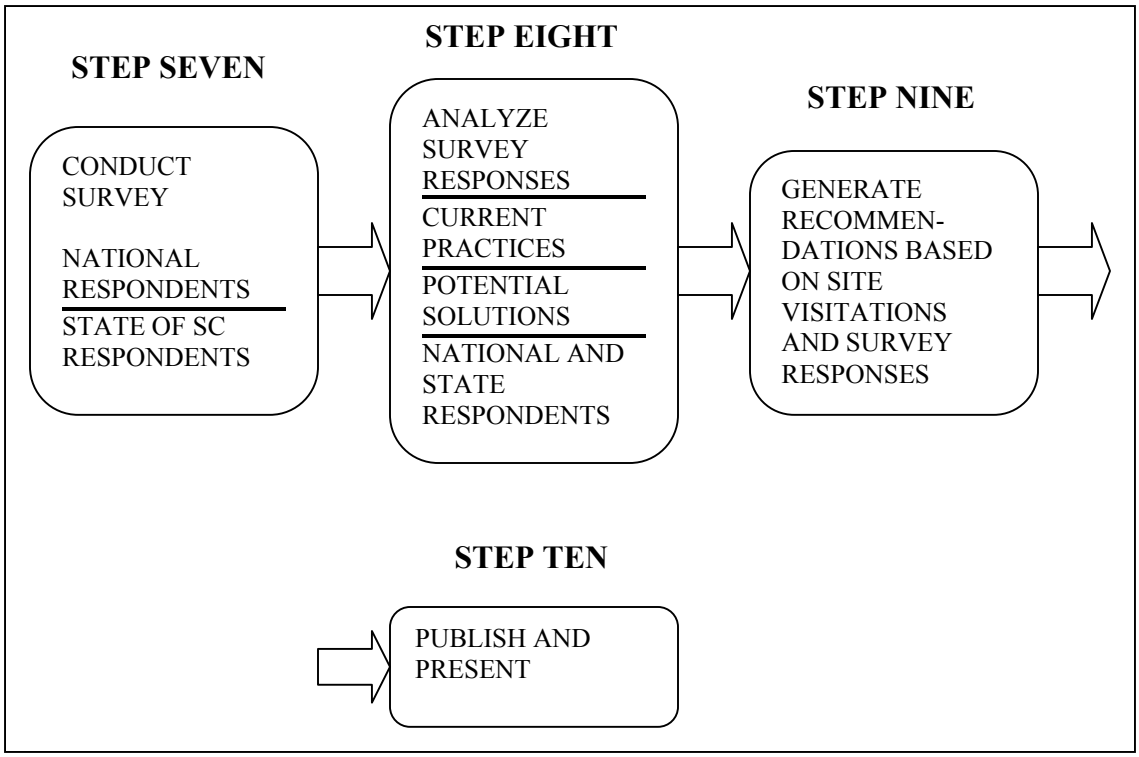



Figure 2.1. Research Methodology (continued).

Step 1

The first step of the research methodology was to detail the scope of the project and to formally establish objectives for the research. The main objectives were to conduct a comprehensive analysis of current construction practices and to provide SCDOT with recommendations to improve the overall safety of work zones on nighttime projects. The research team sought to accomplish these objectives through an extensive review of current literature and industry statistics, site visits, and a nationwide survey. The following sections in this chapter discuss the individual stages in greater detail.

Step 2

The second step of the research methodology was to conduct a detailed review of all pertinent industry statistics and relevant literature or published research documentation. The industry statistics review provided helpful information such as the volume of transportation

construction based on government funding at both the national and state levels. Additionally, statistics on accidents and fatalities for the nation as a whole, and South Carolina individually, were complied and analyzed. Statistics on work zones collisions, injuries, and fatalities were also compiled for daytime and nighttime scenarios for the U.S. and South Carolina.

After a thorough analysis of data related to the safety performance for daytime and nighttime construction in work zones, a detailed literature review of all related studies and documents to this topic was conducted. Research related to nighttime safety has been conducted and reported at both the state and federal levels. The research team established that substantial information is available addressing various aspects of work zone planning and management, but limited literature is available focusing specifically on the subject of nighttime construction safety practices. While it is acknowledged that much of this work is piecemeal in nature, it is important to summarize all such work into a comprehensive format to analyze and present its usefulness and applicability to this research. There are many industry wide recommendations resulting from detailed analyses or rigorous statistical study, while other recommendations are based on general or widely held opinion or anecdotal information. The research team compiled the most current information available about best practices for work zone planning. These practices, procedures, and recommendations have been individually evaluated with specific regard to nighttime construction.

Step 3

The third step in the research methodology was to generate a site-visit data collection form based on the safety issues and concerns revealed in the literature review. The items included in the form were summarized into 10 major issues identified during the literature review. These issues were as follows:

- Lighting

- Signage and signaling devices
- Employees
- Traveling equipment
- Illumination and reflectors
- Public traffic
- Lane closures
- Shoulder conditions
- Channelizing devices
- Attenuators.

These data collection forms also provided a structured format for collecting field observations on such conditions as compliance to regulations and all other aspects of work zone planning and management.

Step 4

The fourth step in the research methodology was to investigate current construction projects, within South Carolina, that were being performed during nighttime hours. This investigation included interviews with contractors and SCDOT officials, as well as other quantitative forms of data collection. This phase of the research helped the research team (a) assess current SCDOT work zone practices for nighttime projects, (b) evaluate first hand the applicability of current recommendations discovered in the literature review, and (c) identify areas/issues that required further study or analysis.

The nighttime data collection for this study focused on South Carolina projects that the SCDOT steering committee for this project believed were excellent representative cases. Thirteen different sites were visited, each exposing the research team to various construction scenarios based on conditions such as contractor experience, type of work being performed,

type of route, and volume of traffic. It was important to have multiple contractors included in this study to prevent the findings from being based too heavily on the construction practices of just a few contractors. As stated, the projects were of different types and magnitude, which benefited the overall study. Since these projects also had varied durations and construction activities, the research team was able to collect data at random points in the construction process. Each of the individual projects was observed for one entire night of construction operation. A wide variety of contractor activities were executed during the site visitations, permitting the research team to evaluate a very diverse set of job site conditions and execution practices. This diversity among projects added significant value to the data collection process.

Step 5

The fifth step of the research methodology consisted of an analysis of all site visitation findings. The research team reviewed current construction practices with regard to compliance to the state's safety standards and regulations. Along with the onsite review of current safety practices, the research team used the site visitation process to help assess the applicability of proactive safety strategies proposed in the literature.

Step 6

The sixth step of the research methodology was the development of a national survey on the subject of nighttime safety. The survey was composed of two principal parts. The first portion of the survey sought to identify and then summarize perceptions regarding highway projects that are executed at night. In short, this portion of the survey attempted to obtain a comprehensive listing of what state DOTs perceive to be the greatest challenges, problem areas, and critical issues with respect to nighttime construction. The second portion of the survey asked for DOTs to offer their opinion regarding various new techniques or innovative technologies that have been demonstrated in test cases to be effective in

improving safety performance or mitigating certain safety risks. Respondents were asked to assess the effectiveness, applicability, and appropriateness of a wide variety of proactive measures.

Step 7

The seventh step of the research methodology involved the distribution of the nationwide survey. The survey was sent to each state's Department of Transportation within the U.S., along with DOT districts within South Carolina. By distributing the survey at both the national and state level it was possible to statistically compare safety practices and perceptions between these two groups. This was particularly important in that this process helped to identify where the state of South Carolina may have untapped opportunities. Additionally, this process enabled the research team to benefit from lesson learned from other states because some states' current perceptions and safety practices are in alignment with a broader, national cross-section of industry / DOT practitioners and experts.

Step 8

The eighth step of the research methodology consisted of a detailed analysis of survey responses. Descriptive statistics were computed for both the national and state level responses. Each survey question was specifically addressed with regard to its application to current and/or prospective nighttime construction practices. General trends in the data provided the research team indications on the applicability, effectiveness, and recommendations as identified by the survey respondents.

Step 9

The ninth step of the methodology was the development of a comprehensive list of recommendations that the SCDOT can use as a basis for specifying work zone planning improvements designed to mitigate safety, productivity, and quality risks commonly

associated with nighttime construction operations. These recommendations result from the literature review, interviews, data collected from the site visitations, and survey responses. These comprehensive recommendations provide implementation guidance, keys to success, and practical tips; and identify common barriers that must be overcome for successful deployment.

Step 10

The final step of the research methodology was the completion of a final report. This report follows SCDOT directives and fully describes the findings of the research. Research findings are summarized in a user-friendly format to maximize the usefulness of the final product. The final report summarizes each phase of the research including the statistics review, literature review, site visitations and data collection, survey, analysis of data, and recommendations for implementation. Table 2.1 lists members from Clemson University and the SCDOT steering committee that have been involved in this research.

Table 2.1. Clemson and SCDOT Research Members.

| **Clemson Research Team Members** | **SCDOT Steering Committee Members** |
|---|---|
| Dr. Lansford C. Bell | Cole Page |
| Dr. W. Edward Back | Joe Sease |
| Steven Boatwright | Dennis Townsend |
| Chad Allen | Steve Gwynn |
| David Henderson | Thad Kitowicz |

# CHAPTER III

# LITERATURE REVIEW—INDUSTRY STATISTICS

The research team conducted a detailed review of industry statistics related to highway construction at both the national and state levels. The research team determined that information is abundant regarding the most pertinent statistics. The following sections within this chapter address different issues regarding highway construction. First, the rise in volume of construction is apparent through government funding for both federal and state agencies. The amount of construction at the national level has been increasing steadily in the past several years. South Carolina's volume of construction is at a substantial increase due to the accelerated "27 in 7" program (27 years of work in 7 years time). Along with these increases in construction, overall trends indicate that collisions/fatalities are also on the rise for both the nation and the state. Trends regarding all work zone collisions/fatalities, and trends regarding specific nighttime work zone collisions/fatalities, are on the rise for both the nation and the state.

## National Volume of Construction

Statistics show that there has continued to be a steady increase in funding for highway projects over the last several decades. The U.S. population and the number of registered or licensed vehicles is increasing annually, placing greater demand on our national transportation systems. In response to this need, governmental units throughout the United States have consistently funded both new capital projects and maintenance projects. Table 3.1 summarizes capital spending over the past several years. It is clear from the data that highway construction and maintenance projects are increasing in volume in response to the nation's transportation needs (11).

Table 3.1. Total Capital Spending 1985-2001.

| Year | Capital Outlay (Billions) | Maintenance (Billions) | Total (Billions) |
|---|---|---|---|
| 1980 | 20.34 | 11.45 | 41.54 |
| 1981 | 19.73 | 12.17 | 41.63 |
| 1982 | 19.05 | 13.32 | 42.97 |
| 1983 | 20.22 | 14.24 | 45.86 |
| 1984 | 23.12 | 15.01 | 49.95 |
| 1985 | 26.65 | 16.59 | 56.95 |
| 1986 | 29.23 | 17.64 | 62.11 |
| 1987 | 30.74 | 18.15 | 65.4 |
| 1988 | 32.96 | 19.11 | 68.5 |
| 1989 | 33.14 | 18.95 | 70.08 |
| 1990 | 35.15 | 20.37 | 75.66 |
| 1991 | 36.15 | 20.38 | 77.73 |
| 1992 | 37.81 | 21.54 | 81.37 |
| 1993 | 40.48 | 22.6 | 86.38 |
| 1994 | 42.38 | 23.55 | 90.19 |
| 1995 | 44.23 | 24.32 | 93.48 |
| 1996 | 46.81 | 25.56 | 98.08 |
| 1997 | 48.36 | 26.78 | 101.95 |
| 1998 | 52.31 | 27.17 | 106.98 |
| 1999 | 57.23 | 30 | 108.81 |
| 2000 | 61.32 | 30.64 | 122.7 |
| 2001 | 65.97 | 31.68 | 129.9 |

Figure 3.1 illustrates the steady increase in spending that we have been experiencing as a nation. While Figure 3.1 shows that the amount of dollars the nation is spending on highway projects is increasing steadily, the degree of real growth in capital spending can only be evaluated when the economic data are adjusted for inflation.

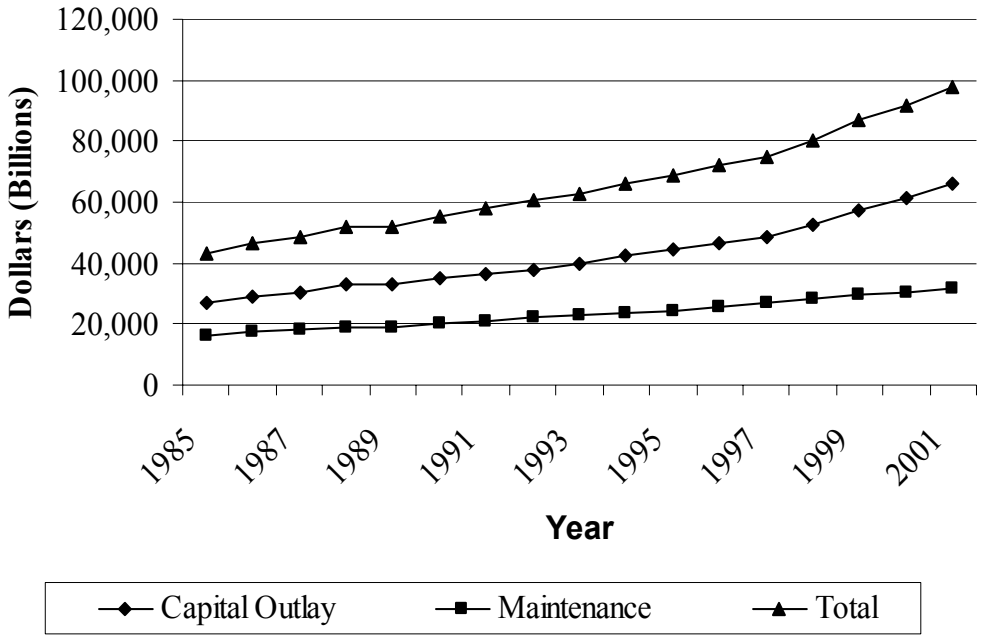



Figure 3.1. Highway Expenditures (Inflation Unaccounted) 1985–2001.

Figure 3.2 shows that the total expenditures are still on the rise even with inflation considered (1987 constant dollars). As illustrated in Figure 3.2, it is certainly true that spending for highway construction and maintenance is steadily growing. These statistics are important to this study because they indicate that there are an increasing number of projects on America's highways. Construction spending is increasing as well as the number of vehicles and U.S. motorists. The need to proactively manage work zone safety is increasingly important.

If one takes a closer look at the obligation of federal funds for highway improvements, it can be shown that a wide variety of highway projects have been financed. Such diversity in project types creates the need for a wide variety of project management practices. Managing for job site safety is always a primary concern. Table 3.2 summarizes the type of projects throughout the U.S. that are typical for one fiscal year. Total estimated costs for federally funded or federally assisted highway projects in

2001 exceeded $22,819,500,000 (12). This Table reports federal funding obligations for 2001.

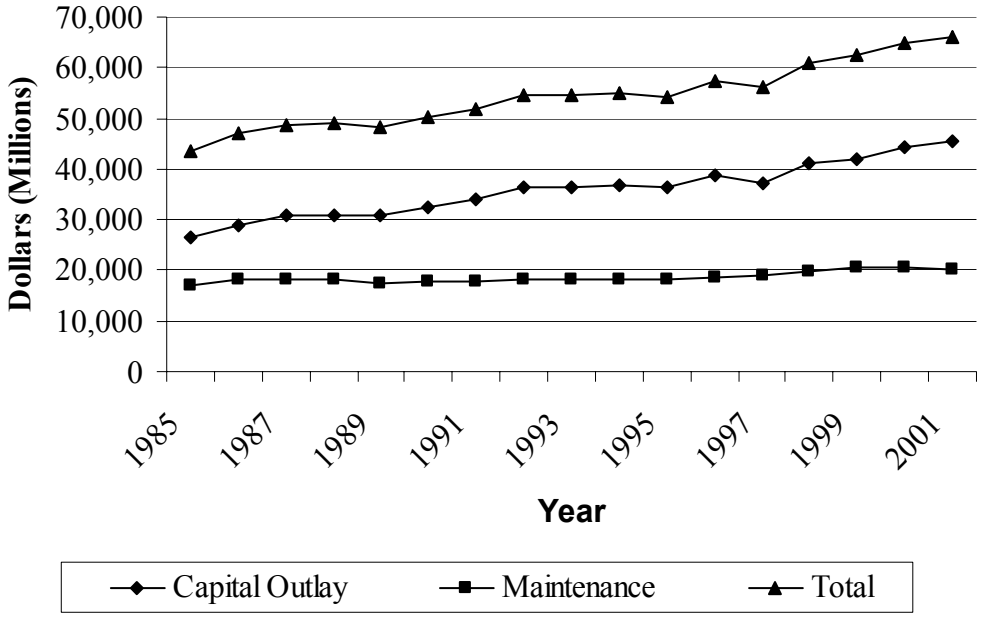



Figure 3.2. Highway Expenditures (Inflation Accounted) 1985-2001.

According to the FHWA, from 1997 to 2001, an approximate average of 23,745 miles of roadway had federally-aided improvement projects underway. From these statistics, it was estimated that over 9,100 new highway projects would be initiated in 2001 alone throughout the U.S (13). Such construction volume has significant impact on the traveling public. Table 3.3 summarizes, in broad terms, the type of projects that have been initiated within the national highway system over the five-year span from 1997 to 2001.

Table 3.2. Types of Projects Nationally and Total Funding 2001 (in thousands).

| Type of Improvement | Total | Type of Improvement | Total |
|---|---|---|---|
| **New Construction** | | **New Bridge** | |
| Number Of Miles | 323 | Number Of Bridges | 360 |
| Federal Funds | 1,272,765 | Federal Funds | 407,376 |
| Total Cost | 1,559,400 | Total Cost | 495,591 |
| **Relocation** | | **Bridge Replacement** | |
| Number Of Miles | 84 | Number Of Bridges | 2,460 |
| Federal Funds | 172,270 | Federal Funds | 1,916,079 |
| Total Cost | 215,034 | Total Cost | 2,373,596 |
| **Reconstruction-Add Capacity** | | **Major Bridge Rehabilitation** | |
| Number Of Miles | 679 | Number Of Bridges | 809 |
| Federal Funds | 1,228,077 | Federal Funds | 615,623 |
| Total Cost | 2,415,952 | Total Cost | 739,058 |
| **No Added Capacity** | | **Minor Bridge Rehabilitation** | |
| Number Of Miles | 1,738 | Number Of Bridges | 933 |
| Federal Funds | 1,714,367 | Federal Funds | 275,407 |
| Total Cost | 2,212,826 | Total Cost | 322,106 |
| **Major Widening** | | **Safety/Traffic Operations** | |
| Number Of Miles | 727 | Number Of Projects | 5,362 |
| Federal Funds | 1,435,672 | Federal Funds | 2,527,489 |
| Total Cost | 2,046,695 | Total Cost | 2,955,400 |
| **Minor Widening** | | **Environmentally Related** | |
| Number Of Miles | 316 | Number Of Projects | 1,614 |
| Federal Funds | 330,284 | Federal Funds | 694,187 |
| Total Cost | 410,562 | Total Cost | 879,342 |
| **Restoration and Rehabilitation** | | **Other** | |
| Number Of Miles | 3,438 | Number Of Projects | 2,142 |
| Federal Funds | 1,903,234 | Federal Funds | 711,005 |
| Total Cost | 2,220,238 | Total Cost | 876,188 |
| **Resurfacing** | | **U.S. Total** | |
| Number Of Miles | 8,357 | Number Of Miles | 15,662 |
| Federal Funds | 2,609,858 | Number Of Bridges | 4,562 |
| Total Cost | 3,097,582 | Number Of Projects | 9,117 |
| | | Total Federal Funds | 17,813,693 |
| | | Total Cost | **22,819,570** |

Table 3.3. Types of Projects Initiated 1997-2001.

| Year | Total (miles) | Capacity Additions (Percent) | New Route (percent) | System Preservation (percent) |
|---|---|---|---|---|
| 1997 | 15,197 | 19 | 3 | 78 |
| 1998 | 23,096 | 12 | 3 | 85 |
| 1999 | 29,030 | 11 | 3 | 86 |
| 2000 | 26,796 | 13 | 4 | 84 |
| 2001 | 24,606 | 12 | 3 | 85 |

State Volume of Construction

South Carolina estimated $1,177,390,000 in new project funding for 2001 (11). Total disbursements for South Carolina highways can be seen in Table 3.4. This heavy funding level is largely the result of the state's "27 in 7 Peak Performance" construction program. Simply stated, the state of South Carolina is working aggressively toward the goal of completing 27 years of typical highway construction in only 7 years. Such aggressiveness is in direct response to ever increasing highway demands as the number of motorists continues to increase considerably. State representatives have also declared that the state's growing economy is in need of improved transportation service.

Table 3.4. South Carolina Disbursements for Highways - 2001 (in thousands)

| CAPITAL OUTLAY | | | | MAINTENANCE AND SERVICES | | | |
|---|---|---|---|---|---|---|---|
| State Administered Highway | Locally Administered Roads | Federal Roads and Unclassified | Total | State Administered Highways | Locally Administered Roads | Federal Roads and Unclassified | Total |
| 482,620 | 116,952 | - | 599,572 | 231,833 | 77,286 | - | 309,119 |
| OTHER | | | | | | | |
| Administration and Miscellaneous | Highway Law Enforcement and Safety | Interest | Bond Retirement | Total Disbursements | | | |
| 73,454 | 167,960 | 17,132 | 10,153 | 1,177,390 | | | |

With this increased demand for transportation improvements comes the demand for expert management of transportation construction. As more projects are moved to nighttime hours for construction execution, there is a parallel need to improve safety practices in response to the special considerations associated with after-dark operations.

## National Trends Regarding Collisions/Fatalities

National statistics indicate that motor vehicle crashes in the United States are the leading cause of death for individuals 1 to 34 years of age. According to the U.S. Department of Transportation, the total societal cost of collisions exceeds $230 billion annually, or approximately $820 per person living in the U.S. (14). On average, approximately 100 persons die each day in motor vehicle collisions. This translates to an alarming rate of one fatality every 13 minutes in the U.S.

In 2002, the estimated number of persons killed in motor vehicle collisions increased 1.7 percent to the highest levels since 1990. As reported by the National Center for Statistics and Analysis, in 2001 the total number of persons killed in motor vehicle collisions was 42,116. This number increased to 42,850 in 2002. Fatal motor vehicle collisions increased from 37,795 in 2001 to 38,356 for the year 2002. While the total number of persons injured showed a slight improvement in 2002, when compared to 2001, the numbers are still astounding. Total persons injured in motor vehicle collisions were 3,033,000 in 2001 and 2,914,000 in 2002 (15). Clearly, the roadways of America present a significant safety hazard to the traveling public.

However, on a national basis, there is some good news when these same statistics are analyzed more closely. When examining the fatality rate per 100 million vehicle miles traveled (VMT), there has been a steady decline in the United States over the last several decades. This is significant. While the number of total fatalities has remained near the 40,000 person/year mark, it should be noted that the population has increased, the number of licensed drivers has increased, the number of registered vehicles has

increased, and the number of vehicle miles traveled has increased (16). This information is summarized in Table 3.5 and Figure 3.3.

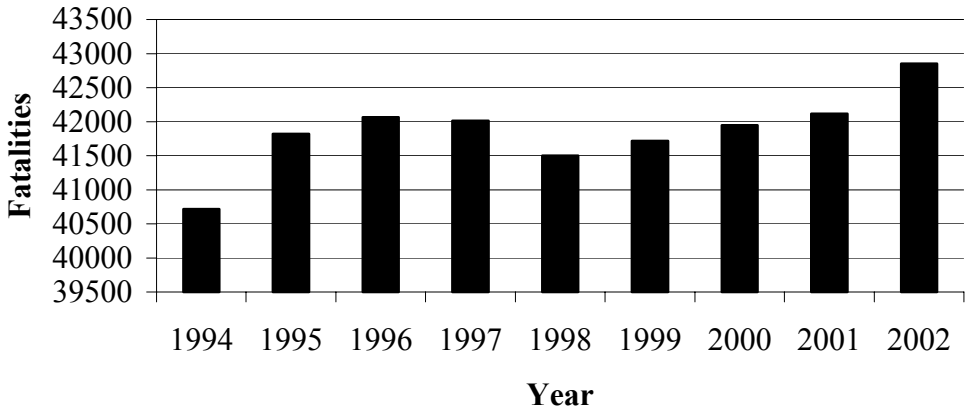



Figure 3.3. National Fatalities 1994–2002.

When reviewing the previous information, it seems evident that the following conclusions can be drawn. First it is inarguably true that the nation's roadways experience unacceptably high levels of motor vehicle collisions that lead to injury and fatality. However, it is also true that there are many more drivers (vehicles) on the roads today than ever before. Table 3.5 shows that as a nation, we are experiencing significant increases in the number of miles traveled by our population. While fatalities are increasing, the number of vehicle miles traveled is also increasing. Simply stated, there would appear to be some positive correlation between the increase in roadway utilization by the public and the number of resulting injuries and fatalities. However, it must be pointed out that this is a general trend and does not hold true for any given year. For instance, for 2002, the national number of fatalities increased over 2001 by 1.7 percent, while the fatality rate per 100 million vehicle miles traveled stayed constant at a value of 1.51 (16).

It is also encouraging to note that injury rates are improving with time. The injury rate, per 100 million vehicle miles traveled, decreased by 6 percent from 2000 to 2001. Also, as mentioned above, the total number of persons injured in 2002 improved over 2001 by nearly 4 percent. Table 3.6 illustrates that both the total number of persons injured each year and the injury rate per 100 million miles traveled are both in a general trend downward which is very good news for the traveling public (16).

Table 3.5. National Fatality Table 1988-2002.

| Year | Fatalities | Resident Population (Thousands) | Fatality Rate per 100,000 Population | Licensed Drivers (Thousands) | Fatality Rate per 100,000 Licensed Drivers | Registered Motor Vehicles (Thousands) | Fatality Rate per 100,000 Registered Vehicles | Vehicle Miles Traveled (Billions) | Fatality Rate per 100 Million VMT |
|---|---|---|---|---|---|---|---|---|---|
| 1988 | 47,087 | 244,499 | 19.26 | 162,854 | 28.91 | 177,455 | 26.53 | 2,026 | 2.32 |
| 1989 | 45,582 | 246,819 | 18.47 | 165,554 | 27.53 | 181,465 | 25.16 | 2,096 | 2.17 |
| 1990 | 44,599 | 249,464 | 17.88 | 167,015 | 26.7 | 184,275 | 24.2 | 2,144 | 2.08 |
| 1991 | 41,508 | 252,153 | 16.46 | 168,995 | 24.56 | 186,370 | 22.27 | 2,172 | 1.91 |
| 1992 | 39,250 | 255,030 | 15.39 | 173,125 | 22.67 | 184,938 | 21.22 | 2,247 | 1.75 |
| 1993 | 40,150 | 257,783 | 15.58 | 173,149 | 23.19 | 188,350 | 21.32 | 2,296 | 1.75 |
| 1994 | 40,716 | 260,327 | 15.64 | 175,403 | 23.21 | 192,497 | 21.15 | 2,358 | 1.73 |
| 1995 | 41,817 | 262,803 | 15.91 | 176,628 | 23.68 | 197,065 | 21.22 | 2,423 | 1.73 |
| 1996 | 42,065 | 265,229 | 15.86 | 179,539 | 23.43 | 201,631 | 20.86 | 2,486 | 1.69 |
| 1997 | 42,013 | 267,784 | 15.69 | 182,709 | 22.99 | 203,568 | 20.64 | 2,562 | 1.64 |
| 1998 | 41,501 | 270,248 | 15.36 | 184,861 | 22.45 | 208,076 | 19.95 | 2,632 | 1.58 |
| 1999 | 41,717 | 272,691 | 15.3 | 187,170 | 22.29 | 212,685 | 19.61 | 2,691 | 1.55 |
| 2000 | 41,945 | 282,125 | 14.87 | 190,625 | 22 | 217,028 | 19.33 | 2,747 | 1.53 |
| 2001 | 42,116 | 284,797 | 14.79 | 191,276 | 22.02 | 221,230 | 19.04 | 2,781 | 1.51 |
| 2002 | 42,850 | | | | | | | | 1.51 |

Table 3.6. National Injury Table 1988-2001.

| Year | Injuries | Resident Population (1000s) | Injury Rate per 100,000 Population | Licensed Drivers (1000s) | Injury Rate per 100,000 Licensed Drivers | Registered Motor Vehicles (1000s) | Injury Rate per 100,000 Registered Vehicles | Vehicle Miles Traveled (Billions) | Injury Rate per 100 Million VMT |
|---|---|---|---|---|---|---|---|---|---|
| 1988 | 3,416,000 | 244,499 | 1,397 | 162,854 | 2,098 | 177,455 | 1,925 | 2,026 | 169 |
| 1989 | 3,284,000 | 246,819 | 1,330 | 165,554 | 1,984 | 181,165 | 1,813 | 2,096 | 157 |
| 1990 | 3,231,000 | 249,464 | 1,295 | 167,015 | 1,934 | 184,275 | 1,753 | 2,144 | 151 |
| 1991 | 3,097,000 | 252,153 | 1,228 | 168,995 | 1,833 | 186,370 | 1,662 | 2,172 | 143 |
| 1992 | 3,070,000 | 255,030 | 1,204 | 173,125 | 1,773 | 184,938 | 1,660 | 2,247 | 137 |
| 1993 | 3,149,000 | 257,783 | 1,222 | 173,149 | 1,819 | 188,350 | 1,672 | 2,296 | 137 |
| 1994 | 3,266,000 | 260,327 | 1,255 | 175,403 | 1,862 | 192,497 | 1,697 | 2,358 | 139 |
| 1995 | 3,465,000 | 262,803 | 1,319 | 176,628 | 1,962 | 197,065 | 1,758 | 2,423 | 143 |
| 1996 | 3,483,000 | 265,229 | 1,313 | 179,539 | 1,940 | 201,631 | 1,728 | 2,486 | 140 |
| 1997 | 3,348,000 | 267,784 | 1,250 | 182,709 | 1,832 | 203,568 | 1,644 | 2,562 | 131 |
| 1998 | 3,192,000 | 270,248 | 1,181 | 184,861 | 1,727 | 208,076 | 1,534 | 2,632 | 121 |
| 1999 | 3,236,000 | 272,691 | 1,187 | 187,170 | 1,729 | 212,685 | 1,522 | 2,691 | 120 |
| 2000 | 3,189,000 | 282,125 | 1,130 | 190,625 | 1,673 | 217,028 | 1,469 | 2,747 | 116 |
| 2001 | 3,033,000 | 284,797 | 1,065 | 191,276 | 1,585 | 221,230 | 1,371 | 2,781 | 109 |

State Trends Regarding Collisions/Fatalities

At the state level, there is obviously a great deal of variability in factors affecting these statistics. Reasons for such variations include differing degrees of urbanization, amounts of travel, types of travel, types of vehicles common in the state, state laws, emergency care capabilities, weather, topography, and a variety of other factors. Looking specifically at South Carolina, it is evident that the state is confronting a motor vehicle safety challenge as significant as any other state in the U.S. The latest statistics indicate the problem. In the year 2000, there were 1,065 total traffic fatalities within South Carolina. Again in 2001, this number exceeded 1000 persons with a recorded number of 1,059 (17). The overall trends are disturbing. Figure 3.4 below summarizes data from 1994-2001.

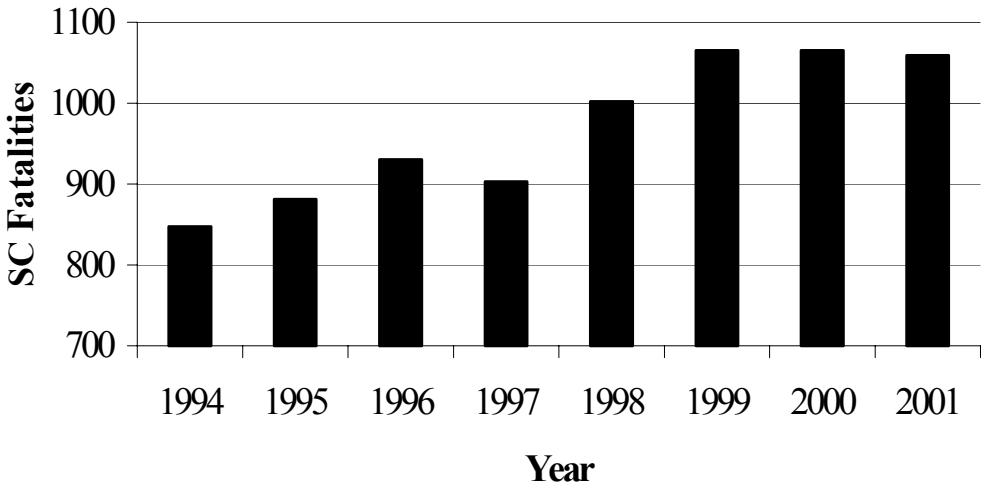



Figure 3.4. South Carolina Fatalities 1994-2001.

National Work Zone Accident Trends

Each year, more than 100 workers are killed and over 40,000 people are injured as a result of motor vehicle collisions in work zones throughout the nation (1). For example, between 1992 and 1998, a total of 841 workers were killed in roadway construction and 492 (58.5 percent) were within a work zone. According to the Labor Department's Bureau of

Labor Statistics, 465 of these were vehicle or equipment related. When public motorists are included, the total work zone death toll was 868 in 1999 alone (1). Unfortunately, this trend is heading the wrong direction and the problem is getting worse.

According to data published by the National Highway Traffic Safety Administration (NHTSA), the 868 total deaths of 1999 is an abrupt jump from 772 in 1998 and 693 in 1997. In the year 2000, the number of fatalities in work zones climbed even further to a startling 1,026. Likewise, in 2001 the number of fatalities increased to 1,033. These numbers clearly indicate a steady trend in the wrong direction. Injuries are also on the rise with 35,000 in 1997, 39,000 in 1998, and 51,000 in 1999 (1). While much effort has been done to improve work zone safety practices, these trends clearly indicate that additional study and effort is needed.

The steady increase in new construction and roadway maintenance projects throughout the United States has led to significant frustrations for much of the traveling public. As construction operations are undertaken, there is no choice but to interfere, to some degree, with the ability of motorists to travel unimpeded. Work zones, particularly in highway projects, create stress for travelers and motorists as normal traffic patterns are either diverted, slowed significantly, or both. The work zone itself is particularly important to consider. The work zone is an important and dangerous interface between construction activities and the traveling public, posing serious safety threats to workers and motorists alike. However, the continued need to construct new miles of roadway, to preserve existing roadways and facilities, and to perform necessary maintenance make work zones an unavoidable, critically important consideration of every state's department of transportation.

Work zones are very dangerous environments for the men and women who are engaged in construction and maintenance activities. As an example, for Laborers' International Union of North America (LIUNA) members, employment in the road

construction industry is especially hazardous. An internal survey of death certificates for LIUNA members who died on the job showed that while only 38 percent of the LIUNA's membership were employed in road and construction activities, over 73 percent of the on-the-job fatalities occurred in road and highway construction (18). In construction work nationwide, heavy and highway construction activities are among the most hazardous. As indicated in Table 3.7, highway construction results in twice the number of average fatalities as do the other construction trades, and over 6 times as many when compared to other industries.

Table 3.7. Highway Construction Fatalities Compared to Other Industries.

| Activity | Average Annual Fatality Rate (Deaths per 100,000 Workers) |
|---|---|
| Heavy and Highway Construction (SIC 1611) | 39 |
| All Construction Activities, Except SIC 1611 | 19 |
| All Industries, including SIC 1611 | 6 |

In the United States, conservative estimates indicate that 120–130 workers die each year in road construction activities. Of this total, approximately 23 percent of the fatalities are due to pedestrian workers being struck by traffic vehicles. Over 62 percent of the fatalities are not directly related to traffic issues (18). The major causes of fatalities and serious injuries in road construction work are summarized in Table 3.8.

Table 3.8. Major Causes of Fatalities and Serious Injuries Nationally.

| Fatalities | Serious Injuries |
|---|---|
| 74% of all Fatalities in SIC 1611 are Due to the Following Hazards: | 67% of the Non-fatal Serious Injuries Experienced by 20 Road Construction Contractors were Due to the Following Hazards: |
| 1. Pedestrian Workers Struck by Traffic - 23% | 1. Overexertion's - 27% |
| 2. Pedestrian Workers Struck by Work Zone Construction Vehicles - 18% | 2. Falls - 23% |
| 3. Work Zone Vehicle Operator and Occupant Events (e.g. Rollovers) - 18% | 3. Struck by Other Objects (e.g. Tools, Materials, Parts of Equipment, and Trees) - 17% |
| 4. Highway Travel Traffic Accidents - 15% | |

With regard to the general public, a total of 1,033 people were killed during 2001 in roadway construction work zone collisions according to federal data recently posted at the National Work Zone Safety Clearinghouse. There were 1,026 deaths in construction work zones in 2000 (19). Table 3.9 presents the seriousness of this problem by summarizing the total number of fatalities within work zones since 1994.

Table 3.9. National Work Zone Fatalities 1994-2001.

| Year | National Work Zone Total Fatalities |
|---|---|
| 1994 | 828 |
| 1995 | 789 |
| 1996 | 717 |
| 1997 | 693 |
| 1998 | 772 |
| 1999 | 872 |
| 2000 | 1026 |
| 2001 | 1033 |

In 1998, Congress authorized $217 billion in federal highway investment through 2003 to repair and make safety improvements to road and bridge conditions through the Transportation Equity Act for the 21st Century (TEA-21). This has resulted in a significant increase in the number of road construction sites nationwide as presented in

the data above. However, the accident and fatality rate within work zones is alarmingly high and must be addressed proactively. The American Road and Transportation Builders Association (ARTBA) focused on this very issue in late 2002 in a 72-page report entitled "Blueprint for Reauthorization," wherein ARTBA called on Congress to enact policies that improve operational safety in roadway construction zones with special focus on nighttime work, allowing the states greater flexibility in using federal work zone funds and increasing the federal government's role in work zone initiatives.

General observations concerning work zone safety include these facts:

- In the last five years alone, the number of persons killed in work zones has gone from a low in 1997 of 693 to a high of 1,033 in 2001. This is an average of 879 persons per year.

- On average, over 40,000 people per year are injured as a result of motor vehicle collisions in work zones.

- More than 100 people suffer disabling injuries each day as a result of motor vehicle collisions within work zones.

- In the last 5 years, more than 100,000 people were injured in highway work zone collisions.

- The percentage of fatal work zone collisions occurring on urban interstates is more than twice the percentage of all fatal collisions occurring on urban intersections.

- The majority of fatal work zone collisions for all vehicles (59 percent) and large trucks (71 percent) occurred on roads with speed limits of 55 miles per hour or greater (20).

## State Work Zone Accident Trends

Between 1997 and 2001, a total of 5,177 work zone crashes were reported in the state of South Carolina. From these crashes, 54 people died, and 2,305 had serious,

nonfatal injuries. As seen in Figure 3.5, the 1954 crashes in 2001 more than doubled the 946 in 2000 (21). Although these numbers were based on different reporting methods, this alarming statistic may be due largely to the increase in construction through the "27 in 7" program. Similar statistics may be reflected for the next few years until the accelerated construction has concluded. Obviously, an understanding of why these work zone crashes are occurring is important. Proactive measures are necessary to improve safety within work zones for the construction workers and traveling public.

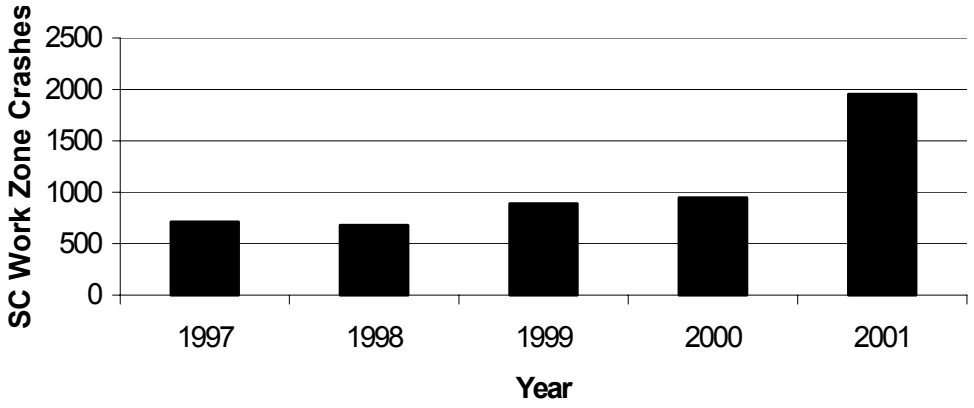



Figure 3.5. Work Zone Crashes in SC.

National Nighttime Work Zone Collisions

As DOT's across the United States have placed greater emphasis on preservation and new construction of roadways and bridges, daytime lane closures necessary to accommodate these activities have often presented serious traffic management problems. Lane closures on highways already near capacity, with respect to traffic levels, create significant congestion and delay problems. Also, seasonal traffic conditions are a consideration in rural areas where lane closures impact levels of service on highways to and from popular recreational areas. To counter the disruption of daytime traffic flow, more maintenance and construction activities are being performed at night. Nighttime maintenance and construction activities eliminate daytime disruption of traffic, but also

bring about a new set of factors and concerns. Cost, productivity, quality, noise, human factors, safety, public awareness, and lighting are some of the most important concerns associated with nighttime operations (22). Given the safety issues associated with work zones in general, an important question to answer is whether nighttime construction increases or decreases the safety conditions for a given operation.

While some may argue that nighttime construction operations are safer due to decreased traffic congestion, it is also true that there are added safety challenges resulting from performing operations in darkness. Some guidance and minimum requirements for dealing with these situations are provided in the *Manual on Uniform Traffic Control Devices* (MUTCD), but these are generally not considered sufficient for the planning, design, implementation, and operation of construction operations at night.

Table 3.10 presents data regarding fatal vehicle collisions with respect to the time of day for the year 2001 (23). As the data indicate, fatalities are generally more likely to occur on weekend nights than weekday nights. This may be due to issues related to alcohol consumption on weekends. Statistics indicate that 39 percent of fatal collisions involved alcohol. For fatal collisions occurring from midnight to 3 a.m., 76 percent involved alcohol (23). This dramatic increase in alcohol consumption by the traveling public creates a serious safety risk for all construction workers performing operations at night. This risk cannot be overstated.

The conditions of motorists at night are simply not the same as during the day, making nighttime construction inherently less safe. Construction workers realize this risk. In a recent national survey, 83 percent of survey respondents who perform nighttime construction operations said they preferred to work during the day and felt that nighttime activities were less safe than when the same activities were performed during daylight hours (22). When examining the data for fatal collisions closely, it is clear that except for the time period between 3 p.m. and 6 p.m. when traffic volumes are generally

at their highest, the nighttime periods are significantly more prone to fatalities than daytime.

Table 3.10. National Fatal Collisions with Respect to Time of Day (2001).

| Time of Day | Day of Week | | | | | | | Total |
|---|---|---|---|---|---|---|---|---|
| | Sun | Mon | Tues | Wed | Thur | Fri | Sat | |
| Midnight to 3am | 1236 | 436 | 357 | 412 | 446 | 588 | 1247 | **4722** |
| 3 am to 6 am | 703 | 286 | 266 | 273 | 315 | 349 | 694 | **2886** |
| 6 am to 9 am | 409 | 562 | 531 | 524 | 556 | 604 | 530 | **3716** |
| 9 am to Noon | 478 | 561 | 535 | 522 | 530 | 568 | 599 | **3793** |
| Noon to 3 pm | 713 | 682 | 681 | 676 | 651 | 825 | 765 | **4993** |
| 3 pm to 6 pm | 935 | 884 | 868 | 841 | 782 | 1022 | 925 | **6257** |
| 6 pm to 9 pm | 901 | 715 | 703 | 693 | 768 | 995 | 1037 | **5812** |
| 9 pm to Midnight | 591 | 609 | 607 | 628 | 724 | 1111 | 1051 | **5321** |
| Unknown | 68 | 42 | 26 | 28 | 27 | 38 | 49 | **295** |
| **Total** | **6034** | **4777** | **4574** | **4597** | **4799** | **6100** | **6897** | **37795** |

Another issue impacting work zone safety for nighttime construction operations is the issue of vehicle speed. When there is considerable traffic congestion, motorists are forced to move slowly through work zone areas. When that congestion is relieved, as is intended when construction operations are moved to the nighttime, motorists can, and do, speed. High speeds through work zones create added safety risks. Coupled with the consumption of alcohol as described above, it is evident that these risks are significant. Nighttime construction workers must rely on the motorist's willingness to obey all laws with respect to operating motor vehicles. There is no guarantee that these expectations will be met with consistency. Each time the alcohol and speed laws are violated, nighttime safety risks are multiplied for everyone.

## State Nighttime Work Zone Collisions

The number of construction operations performed during nighttime hours has increased due to SC's "27 in 7" program. The time of day at which collisions occur in work zones is an important factor that SCDOT continues to monitor as these nighttime

operations continue. Correspondingly, the number of nighttime work zone crashes in South Carolina has increased in parallel with this increase in nighttime operations. This trend is reflected by an increase in the percentage of work zone crashes that occur at night. In 1997, 22.4 percent of all work zone crashes occurred between 6:00 pm and 6:00 am. This increased to 29 percent by 2000, and dropped slightly to 26.1 percent in 2001 (21). Without further measures to improve work zone planning and management, these numbers will remain significant.

# CHAPTER IV

# LITERATURE REVIEW—SAFETY TOPICS

The research team determined that substantial information is available addressing various aspects of work zone planning and management, but limited literature is available focusing specifically on the subject of nighttime construction safety practices. Most existing research studies and reports from highway agencies, academia, and other organizations focus on the implementation effectiveness of singular technologies believed to improve nighttime safety. While it is acknowledged that much of the current literature is piecemeal in nature, it is important to summarize all such work into a comprehensive format to evaluate its usefulness and applicability to this research. Some of the recommendations presented in the literature result from detailed data analysis or rigorous statistical study, while other recommendations are based on general opinion or anecdotal information. The research team has attempted to compile the most current information available about best practices for work zone planning and has focused on those concerning nighttime construction. These practices, procedures, and recommendations have been individually evaluated with specific regard to nighttime construction issues.

## Previously Completed Research

Road construction work zones are set up and maintained to allow space for contractors to work effectively while minimizing the impacts to traveling motorists. Due to ever increasing traffic volumes on roadways during the day, many highway agencies have decided that conducting construction operations at night is a viable alternative. Not only is nighttime construction appealing in the sense of lighter traffic congestions, there is also a potential for work shifts to be longer than usual.

Even though nighttime construction appears to have many benefits overall, the decision to move construction operations to nighttime hours involves an analysis of many

different factors of day vs. nighttime scenarios that may impact the safety and efficiency of construction operations. The primary objective of the recently published NCHRP Report 475 was to formulate procedures to facilitate making decisions about undertaking nighttime work. In this process, the researchers considered all factors affecting the decision and summarized them into broad categories. For example, the report mentioned issues such as traffic-related factors, construction-related factors, social factors, economic factors, environmental factors, and other miscellaneous factors. Within these broad categories, the factors were broken down further into concerns such as the safety of construction workers and passing motorists, costs associated with night-work, quality of work performed, productivity of work crews, construction related noise, anticipated traffic volumes, and roadway capacities (24).

A recent research project by Oregon DOT sought to identify the factors that are used in deciding whether a construction operation should be performed during the daytime or at night. This research compiled information obtained from an extensive survey process. The findings were published in 2001 and detail the views of 446 respondents (practitioners) from 26 states with respect to nighttime construction issues and considerations. Interestingly, this study concluded that cost, quality, and productivity were not significantly different between daytime and nighttime operations. The quality of nighttime work was mostly related to lighting; so, with sufficient lighting projects produced similar quality to that of daytime work. Similarly, the study concluded that significant differences did not exist in productivity levels of construction crews between daytime and nighttime operations. However, the research did indicate that performing nighttime construction operations required different approaches (execution strategies) than daytime operations. Additionally, they also noted that there were increased safety risks at night that must be proactively mitigated. In summary, the Oregon Department of Transportation researchers concluded that the most important factors in making the

decision to undertake nighttime construction operations are congestion, traffic control, and the safety of all participants (22).

Similarly, a project for the Kentucky Transportation Cabinet found that safety, high daytime traffic, traffic control, road user costs, longer work periods, scheduling issues, contract incentives, and temperature concerns are the primary considerations in the decision to work at night (25).

## Specific Safety Issues

Once the decision to perform construction and maintenance operations during nighttime hours has been finalized, a number of safety issues and concerns are introduced. As the safety of construction employees and passing motorists has been considered one of the major factors in deciding whether or not to undertake nighttime construction, many specific safety issues have been researched to identify proactive strategies that will mitigate the safety risks.

A closely related study was recently completed by researchers with the Virginia Transportation Research Council for Virginia DOT (26). This study is particularly relevant because it is the only research completed to date that addresses general issues related to nighttime construction in a comprehensive manner. The vast majority of other studies have addressed individual considerations such as illumination, retroreflectivity, or signaling devices. Rather than examine one issue at a time, Virginia DOT conducted a survey wherein they asked other DOTs throughout the country to help identify the key problems associated with nighttime construction. Responses to the questionnaires were received from 28 DOTs, for a 56 percent response rate. Five DOTs, 18 percent of those responding, stated that they do not use night work zones. When asked if they use typical work zone traffic control for night work, 17 DOTs, or 74 percent answered yes. Three of the 17 indicated that there were exceptions to this practice.

The survey sought to identify the major problems associated with nighttime construction operations. Reduced visibility brought on by darkness was the most frequently cited problem. More impaired drivers was second, as recorded by eight DOT's. Four specified drunk drivers or driving under the influence and four specified impaired drivers, which included fatigued drivers. Six DOTs identified higher speeds and lower volumes, and six identified insufficient lighting for workers. Other problems were noise restrictions, worker fatigue, driver surprise, and glare.

The Virginia DOT study compiled a comprehensive list of responses from resident engineers concerning problems associated with nighttime construction. The resident engineers identified the following problems:

- Poor visibility
- Higher average speed
- Motorist inattention
- Inadequate lighting
- Maintenance of traffic control devices
- Complex confusing area
- Glare
- Drivers less alert (fatigue)
- Drunk drivers
- Tractor-trailers
- Motorists disobeying signage
- Adequate placement of lighting and lighting dependability
- Night work not expected
- Setting up work zone safely

- Lack of retroreflectivity safety clothes
- Inadequate vehicle lighting
- Contractor personnel tired
- Replacement items hard to obtain at night
- Limited resources available
- Unreliable media releases

The Virginia study proposed seven proactive measures to improve nighttime construction operations. Each of these measures has a positive impact on safety performance. The proposed measures are:

1) Improve the visibility of traffic control devices.
2) Improve the visibility of workers.
3) Improve the visibility of work vehicles.
4) Reduce speeding and increase driver attention.
5) Reduce glare from work lighting.
6) Manage queuing and traffic flow.
7) Manage other safety risk factors.

The Oregon DOT researchers identified issues such as lighting, worker condition, and driver condition relating to the safety of workers and motorists (22).

The previously mentioned NCHRP Report 475 research team believed that safety issues and concerns for nighttime construction were due primarily to reduced visibility and issues related to lighting, driver inattentiveness and weariness, higher percentage of impaired drivers, higher motorists' speeds, and the critical need for enhanced traffic controls (24).

As a result of repetitive reference in the literature review, ten categories were identified that summarize the key areas of concern with respect to safety hazards for nighttime construction operations. These categories were presented to the SCDOT steering committee and it was agreed these were the key areas of concern with respect to nighttime construction operations. All following phases of this research were based upon the categories listed within Figure 4.1 at the end of this chapter.

## Lighting

Lighting is a crucial element of any night project and is mentioned repeatedly as a major factor impacting overall safety on nighttime projects. Many recent efforts have been expended to provide adequate lighting for highway construction activities while minimizing the negative impacts of bright light (glare) to passing motorists. The Virginia Department of Transportation research report states that with the proper light, quality and productivity on a construction project are not compromised (9).

In 1999, the New Jersey Department of Transportation partnered with an established construction company to develop a lighting specification for work zones. Consultants from General Electric helped design a hydraulically operated lighting system for paving machines that included four 150-watt "stadium lights." The system is very flexible, capable of being moved vertically and horizontally to optimize the lighting angle for various construction activities. Diffusers were added to the system to reduce glare. The paving machines also contain 300-watt side lights and auger lights (3).

Another lighting innovation is the Airstar Balloon Light, which uses an outer "balloon" to diffuse glare from the light source. Airstar, Inc. recently introduced this lighting system and made it available for commercial use. With the introduction of the balloon light, Kentucky highway contractors immediately began to include the lighting system in their nighttime construction operations (25). Multiple reports concerned with nighttime construction issues mentioned effective use of the balloon-type lighting system.

## Signage and Signaling Devices

Resolving all lighting related issues for nighttime construction operations is particularly challenging. Even when lighting techniques are sufficient for work procedures, the retroreflectivity of signs, channelizing devices, and worker clothing may be poor or inadequate. Retroreflectivity issues must be proactively addressed to improve the ability of passing motorists to notice, and respond to, workers and equipment engaged in construction activities within the work zone. Visibility of both workers and equipment is critically important and fundamental to a safe work zone.

The MUTCD requires that signs be retroreflective for nighttime work, but there is no minimum in-service values given for the level of retroreflectivity. No matter what type of signs a contractor deploys, whether they are lightweight metal or have the ability to "roll up," their retroreflectivity will eventually degrade over time. In response to this issue, the FHWA initiated a research effort to establish minimum guidelines that would prescribe conditions requiring a sign to be replaced. The research team proposed a system to detect the luminance required for a sign based on different factors such as material properties and others. The system is referred to as the Computerized Analysis of Retroreflective Traffic Signs, or CARTS model. At the time of the research, propositions were sent from the FHWA's Office of Safety and Traffic Operations Research and Development to FHWA's Office of Highway Safety. The FHWA's Office of Highway Safety proposed minimum retroreflective guidelines to be implemented into the MUTCD. Although most states have supplemental specifications to accommodate the explicit requirements regarding signs for different scenarios, there are no minimum retroreflective guidelines established to date (26).

## Employees

A more controversial topic between contractors and governmental agencies has been retroreflective outfitting of worker apparel. Worker apparel is divided into three categories based on the amount of retroreflective material on the garment: Class I, II, and

III. Class I garments are normally specified when traffic speeds are less than 25 mph, workers are separated from approaching traffic, and the workers can give their undivided attention to oncoming traffic. Class II garments are normally specified when traffic speeds exceed 25 mph, work takes place in or near moving traffic, work takes place during inclement weather, and the workers' tasks occasionally divert their attention from traffic. Class III garments offer the greatest conspicuity and are normally specified for conditions where traffic speeds are greater than 50 mph, workers must be conspicuous through a full range of body motions at a minimum of 1,280 feet, and when workers must focus all their attention on their work and not traffic. Class III garments have the most retroreflective material in total and at different parts of the body, while Class I garments do not have as much (27).

Governing agencies, such as the FHWA, have contemplated standardizing the Class III garments for certain types of work, including highway construction. The only problem is that the garments are full body suits, which could be very uncomfortable for workers in certain climates. The Virginia DOT report introduced a practical alternative to this dilemma. Instead of requiring workers to wear a full body suit in warm temperature climates; it is recommend they wear bands of retroreflective material around their limbs, along with retroreflective tape on their hard hats (28).

## Traveling Equipment

According to the Labor Department's Bureau of Labor Statistics, 465 of 492 fatalities in work zones between 1992 and 1998 were related to passing motorists' vehicles or construction equipment. Realizing the significance of this statistic, the National Institute for Occupational Safety and Health (NIOSH) published *Building Safety Highway Work Zones: Measures to Prevent Worker Injuries from Vehicles and Equipment* in July of 2001. Research teams also collaborated on about 30 different items on which to focus the publication. Some of these items included worker and driver

training, model contract specifications for work zone safety, coordination with law enforcement, traffic control devices and personal protective equipment. The final product offers many tips and ideas that parties can utilize to make the work zone a safer place for employees, along with detailed scenarios of many recent construction accidents and fatalities caused by construction equipment (1).

## Public Traffic

Along with the traveling equipment in work zones, a commonly cited factor believed to have negative impacts on the safety of workers is the excessive speeds of passing motorists during nighttime hours. Many research projects have focused specifically on controlling vehicle speeds through work zones. The FHWA published a report discussing the advantages of using uniformed police officers as a proactive measure to deter high speeds during nighttime construction. The report stated that if the officers are visible to passing motorists, speeds are reduced, drivers are more alert, and the flow of traffic through the work zone is less problematic (29).

The New York DOT tested many different concepts and technologies in work zones to determine their usefulness in reducing speeds. Among these were uniformed police enforcement, variable message boards, and drone radar. Variable message boards are defined as portable or permanent electronic display panels that provide information concerning traffic conditions, delay, and/or detours to upcoming traffic. The variable message boards are placed to give motorists adequate time to respond accordingly and adjust their driving behavior to the upcoming scenario or incident. Drone radar is defined as a radar unit with a variable switching mechanism that simulates triggering of a radar gun by law enforcement. The NYDOT report established implementation guidelines for each of the concepts and/or technologies. It provided a listing of different scenarios where police officers should be used, along with possible ways to finance their

employment. The report also gave guidelines for where variable message signs should be placed and how drone radar should be used to alert radar detectors (30).

A similar study was conducted by the Texas Transportation Institute on various traffic control devices that could help reduce traffic speeds through work zones. The results were described more quantitatively than the New York DOT report. Speed display trailers reduced the average speeds by 5 mph, variable message signs produced 1-2 mph reduction in average speed, and drone radar also produced a 1-2 mph reduction in speed. These devices were researched primarily due to their ease of installation and implementation (31).

An additional research project completed by the Department of Civil Engineering of the University of New Mexico confirms the earlier conclusions regarding the benefits of a speed display trailer. The University of New Mexico researchers determined that the trailer was effective in reducing traffic speeds by 4-5 mph (32).

The inattentiveness and/or weariness of passing motorists is often cited as one of the main issues contributing to highway construction accidents and fatalities. Inspired by a fatal accident in 1999 in New York, the State Department of Transportation undertook a study on how to increase the attentiveness of passing motorists. Findings were summarized in a report entitled *A Work Zone Intrusion Initiative to Reduce Highway Construction Accidents*. The report concluded that there are many appropriate countermeasures that can be taken to counteract this behavior. Transverse rumble strips before work zones help to attract the driver's attention. Reducing channelizing device spacing acts as a means of providing positive guidance for drivers through confusing work zone areas. Enhancements to flagger stations, such as cones and barrels help drivers notice the stations. Variable message signs used to supplement standard highway signs serve as a means of conveying important information to drivers. Drone radar is used to activate radar detectors. Although it is unlikely that these measures slow passing motorists very much, they do have a positive impact on motorist alertness (33).

1. Lighting - "Lighting" addresses the overall lighting of the project area and how that lighting affects the workers ability to see adequately in that environment. Lighting also addresses glare concerns which deal with producing adequate light for visibility when operating equipment, while not causing glare issues to workers or passing motorists.

2. Signage and Signaling Devices - "Signage and Signaling Devices" addresses the ever-changing signs and variable message boards that are used in the nighttime construction environment.

3. Employees - "Employees" addresses all aspects of employees and their well being. It addresses how well other workers and passing motorists can see workers during the nighttime hours, whether workers are wearing proper safety equipment, and if workers are paying attention to their surrounding.

4. Traveling Equipment - "Traveling Equipment" addresses added difficulty of operating this type of machinery during nighttime hours and the manner in which employees are operating this equipment.

5. Illumination and Reflectors - "Illumination and Reflectors" addresses how well the channeling devices such as cones, barricades, and reflectors show a clear traveling path. Illumination also addresses the visibility of barrier wall during night hours.

6. Public Traffic - "Public Traffic" addresses how the traveling public responds to these nighttime work zones and what can be done to keep them alert throughout the work zone.

7. Lane Closures - "Lane Closures" addresses how well lane closures are set up, taken down, and maintained throughout nighttime operations. This section also addresses sign issues for signs special to lane closures.

8. Shoulder Conditions - "Shoulder Conditions" addresses issues regarding the visibility of shoulders during nighttime hours in work zones. Such issues are maintaining drop-off that are not too steep and proper spacing of barrels to keep traffic off of closed shoulders.

9. Channeling Devices - "Channeling Devices" addresses how well channeling devices (Cones, Barricades, Retroreflective Tape, Reflectors) lead motorists through the work zones and if these set ups confuse the motorist.

10. Attenuators - "Attenuators" addresses how well attenuators can be seen during night hours and whether they are set up properly to sustain an impact.

Figure 4.1. Key Areas of Concern in Nighttime Work Zones.

# CHAPTER V

# PROJECT SITE VISITS AND FIELD DATA COLLECTION

## Work Zone Safety Requirements

Work zone safety requirements are governed in general by the South Carolina Department of Transportation Standard Specifications for Highway Construction, 2000 Edition ("Blue Book"), the South Carolina Manual of Uniform Traffic Control Devices (SCMUTCD), South Carolina Department of Transportation Standard Specifications for Road Construction, NCHRP Report 350, and provisions that may be inserted into the construction contract as supplemental provisions. These documents are typically cross-referenced throughout the construction contract. All SCDOT construction operations are also subject to the regulations of the Occupational Safety and Health Administration.

The South Carolina Standard Specifications for Highway Construction, Division 600 which is titled "Traffic Control," cites the contractor's responsibility to develop and maintain a traffic control plan, and addresses night illumination, drop-offs, arrow panels, barricades, changeable message signs, traffic cones, plastic drums, temporary pavement markings, attenuators, flagging operations, lane closures, and other items governing work zone safety in some detail. Figures are included illustrating the traffic control zone components, taper and buffer spaces, acceptable signs and sign installation, flagging devices, channeling devices, and lane closures. The South Carolina Standard Drawings for Road Construction includes very specific drawings for lane and shoulder closures. Of particular interest to this research is Drawing No. 605-10, "Lane Closure Nighttime, Interstate Standards." The drawing, which includes extensive notes, addresses acceptable sign placements, taper barricades, plastic drum placements, advance warning arrow panels, message signs, and portable truck mounted attenuators.

Development of the Work Zone Safety Checklist

After the literature review was substantially complete, the research team began preparing to investigate current construction projects being performed during nighttime hours in the state of South Carolina. The first step in preparing for the nighttime construction site visits was to formalize a checklist that could be used on site to identify problems in the key areas of concern. In the development phase of the "Work Zone Safety Checklist" the team sought to have an organized, structured approach to data collection prior to visiting the various project locations.

When developing the "Work Zone Safety Checklist", the research team referred to the ten "key areas of concern" previously presented in Figure 4.1, and relied on experience from what they had observed while working in the field, suggestions from the SCDOT steering committee, and the comprehensive literature review. For each "concern" or safety issue listed in Figure 4.1, the team members identified certain items that should easily be evaluated in the field. A comments section was also included to capture site observations that were not otherwise covered in the data collection. When the preliminary checklist was complete, it was reviewed by the SCDOT steering committee. With minor modifications, the checklist was approved and reproduced for use on the various project site visits. Figure 5.1 presents the approved Work Zone Safety Checklist.

**Nighttime and Weekend Construction Checklist**

Location:
Contractor: Project Manager:
Date: Time:
Description of Work:

Public Traffic

- **Are proper measures taken to keep motorists obeying posted rules to assure safe conditions for workers and themselves (MUTCD, Inspectors, PM's)?**
  - **Adequate Signs _____**
  - **Proper Signs _____**
  - **Highway Patrol _____**
  - **Wrecker Service (to rapidly remove disabled vehicles) ___**
  - **Emergency Radio Stations in Work Zone _____**

**Comments:**

Signage

- **Are all signs in good and readable condition (MUTCD)? _____**
- **Are all signs placed at correct angle to be seen from oncoming traffic's headlights (Inspectors, PM's)? _____**
- **Do any signs contradict each other (Inspectors, PM's)? _____**
- **Are damaged signs replaced in a timely manner (MUTCD, Inspectors, PM's)? _____**
- **Are non-applicable signs covered in a proper and timely manner (MUTCD)? _____**
- **Are signs positioned properly for adequate warning of work zone conditions (PM's, MUTCD, Inspectors)? _____**
- **Are traffic signals within the work zone functioning properly (MUTCD)? _____**
- **Are signal heads positioned and adjusted to match active lanes in the work zone (PM's, Inspectors)? _____**

**Comments:**

Illumination and Reflectors

- **Are paint lines clearly visible at night (MUTCD)? _____**
- **Are paint lines correct width (MUTCD)? _____**
- **Are all lollipop reflectors in place and visible (MUTCD)? _____**
- **Are all reflectors on side of barrier wall in place and visible (MUTCD, Inspectors)? _____**
- **Is barrier wall too dull at night (MUTCD, Inspectors)? _____**
- **Are all Raised Pavement Markings (RPM's) in place and visible (MUTCD)? _____**
- **Have all unnecessary RPM's been removed (MUTCD, Inspectors)? _____**
- **Are message boards flashing properly (MUTCD)? _____**
- **Are message boards clear and concise (MUTCD)? _____**
- **Are all channeling devices properly illuminated (MUTCD)? _____**

**Comments:**

Figure 5.1. Work Zone Safety Checklist

Lane Closures

- **Are lane closures properly set up and taken down (MUTCD, PM's, Inspectors)? _____**
- **Do lane closures exceed maximum length (MUTCD)? _____**
- **If more than one lane closure, are they the minimum length apart (MUTCD)? _____**
- **Are all arrow boards in correct place and working properly (MUTCD)? _____**
- **Is crash truck in place (MUTCD)? _____**
- **Is crash truck attenuator in working order (MUTCD)? _____**
- **Is crash truck attenuator properly illuminated (MUTCD)? _____**

**Comments:**

Lighting

- **Do floodlights cause a glare problem for motorists (MUTCD)? _____**
- **Is work area adequately lit for safe work (MUTCD)? _____**
- **Are proper warning lights being used (MUTCD)? _____**
- **Are screens used if appropriate (MUTCD)? _____**

**Comments:**

Shoulder Conditions

- **Are disturbed shoulders properly identified by placement of barrels MUTCD)? _____**
- **Are any drop-offs greater than 2" (PM's, Inspectors, Specs)? _____**
- **Tapers adjacent to travel lanes 6:1 or flatter (PM's, Inspectors, Specs)? _____**
- **Stored material & parked equipment are 30' or more from unprotected roadway (PM's, Inspectors, Specs)? _____**

**Comments:**

Channeling Devices

- **Are all cones, barricades, and barrels properly spaced (MUTCD)? _____**
- **Are all cones, barricades, and barrels standing (PM's, Inspectors, MUTCD)? _____**
- **Are all cones, barricades, and barrels properly managed (PM's, Inspectors)? _____**
- **Do all channeling devices represent a clear traveling path (MUTCD)? _____**
- **Are cones, barricades, and barrels interrupting the flow of traffic (MUTCD)? _____**

**Comments:**

Figure 5.1. Work Zone Safety Checklist (continued).

Attenuators

- **Are attenuators in proper working order (MUTCD)? _____**
- **Are attenuators properly illuminated (MUTCD)? _____**

**Comments:**

Traveling Equipment (dump trucks, concrete trucks, front end loaders, etc.)

- **Are all signals, illumination and backup alarms working properly?**

**1) Yes ____ No _____**
**2) Yes ____ No _____**
**3) Yes ____ No _____**
**4) Yes ____ No _____**
**5) Yes ____ No _____**
**6) Yes ____ No _____**
**7) Yes ____ No _____**

**Are dump trucks and concrete trucks driving safely and obeying traffic rules _____**
**Are employees driving company trucks driving safely and obeying traffic rules _____**

Employees

- **Are employees paying attention to work area and surroundings (PM's, Inspectors)? _____**
- **Are employees equipped with proper communication devices (radios, phones)? _____**
- **Are employees horse playing (PM's, Inspectors)? _____**
- **Are employees operating equipment correctly (OSHA)? _____**
- **Are employees wearing proper safety equipment and illumination (MUTCD, OSHA)?**
  - **Hardhats _____**
  - **Safety Glasses _____**
  - **Vests _____**
  - **Steel toe shoes _____**
  - **Gloves _____**
  - **Other safety equipment and illumination needed _____**
- **Are flaggers properly dressed (MUTCD)?**
  - **Orange Shirt _____**
  - **Vest _____**
- **Are flaggers obeying correct procedures (MUTCD)?**
  - **Correct motions _____**
  - **Correct signs _____**
  - **Proper Radio Communication _____**
- **Are flaggers standing in correct positions (MUTCD)? _____**
- **Are flaggers trained and briefed on correct procedures (MUTCD)? _____**
- **Do flaggers adequately speak the same language (PM's, Inspectors)? _____**

**Comments:**

Figure 5.1. Work Zone Safety Checklist (continued).

Identification of Representative Project Sites

After completing the development of the Work Zone Safety Checklist, the research team conferred with the SCDOT steering committee to identify appropriate projects. Sites were identified by the SCDOT steering committee that were representative of typical projects within the state. The steering committee's recommendations were based upon the research team's request to observe diversified types of construction activities and tasks. Care was taken to diversify the selection to address differences in geographic location, volume of traffic, urban setting, and type of roadway. After the sites were identified, the research team acquired contact information for each site and established dates for which the sites could be visited. The SCDOT steering committee recommended the following sites for the data collection phase of the research.

- Anderson: I-85
- Greenville: I-385
- Myrtle Beach: US 17 By-Pass/501 Interchange
- Florence: I-95
- Aiken: I-20
- Myrtle Beach: US 501 and Frontage Road
- Columbia: I-26/US 378 Interchange
- Greenville: SC 141/I-85
- Greenville: Congaree Road
- Charleston: I-85/US 17-A Interchange
- Cherokee: Thickety Creek Bridge
- Cherokee: I-85/SC-11 Interchange
- Cherokee: Cherokee Creek and Broad River

- Cherokee: Buffalo Creek Bridge
- Rock Hill: I-77/US 21

After establishing a point of contact for each of the sites listed above, the research team began the tasks of site visitation and data collection. Unfortunately, all of the recommended sites could not be visited due to scheduling problems. The recommended Rock Hill project did not begin while the research team was still in the site visitation and data collection phase. The recommended Charleston project was in its closing phase and the weather conditions prevented the research team from visiting this site on the few opportunities that were available. However, the research team did visit some sites that were not on the initial recommended list, but also involved nighttime construction and were approved by the SCDOT steering committee. The visited sites are listed below:

1) Anderson: I-85—This site was visited on Tuesday, June 4, 2002. This was an interstate project that involved widening and resurfacing both northbound and southbound lanes of I-85 from two to three lanes. The activities observed while visiting this site included:
    - Concrete paving
    - Temporary lane shifts
    - Setting up and taking down of temporary lane closures
2) Greenville: I-385—This site was visited on Thursday, June 13, 2002. This was also an interstate project that consisted of widening and resurfacing a section of I-385 from two lanes to three. The activities observed while visiting this site included:
    - Setting up and taking down temporary lane closures
    - Temporary traffic shifts
    - Asphalt milling
    - Removal of old raised pavement markers (RMP's)
    - Asphalt paving

3) Anderson: SC-81 Bridge—This site was visited on Sunday, June 23, 2002. This was a bridge construction project on South Carolina Highway 81 that crossed over I-85. The activities observed while visiting this site included:

    - Shutting down Northbound I-85 and routing traffic around exit 27 so no traffic would go under the SC-81 Bridge
    - Police flaggers to control traffic
    - Setting of bridge girders

4) Greenville: I-385—This site was visited on Monday, June 24, 2002. This was the same project that was visited on June 13, 2002. The activities that were observed while visiting this site included:

    - Bridge Demolition
        - Removal of steel girders
        - Removal of 4 concrete columns
        - Destruction/Removal of concrete decking

5) Anderson: I-85—This site was visited on Tuesday, July 9, 2002. This was the same site that was visited on June 4, 2002. The work activities observed while visiting this site included:

    - Permanent lane shifts
    - Setting up and taking down double lane closures

6) Greenville: Whitehorse Road—This site was visited on Tuesday, July 9, 2002. This project was not an ongoing project. This was a quick project (short duration) that involved improving drainage across Whitehorse Road. The work activities observed while visiting this site included:

    - Setting up and taking down lane closure
    - Excavation of road and dirt in order to place storm drainage

7) Myrtle Beach: US 17 BP/501 Interchange—This site was visited on Tuesday, July 16, 2002. This project involved paving in downtown Myrtle Beach next to the Pavilion Amusement Park. Work activities observed during this site visit included:

- Setting up and taking down lane closures
- Asphalt paving
- Police flaggers controlling pedestrians to keep them from driving and walking across the asphalt

8) Florence: I-95—This site was visited on Wednesday, July 17, 2002. This was much like the Anderson, I-85 project. It involved widening and resurfacing a section of Interstate 95. The work activities observed while visiting this site included:

   - Setting up and taking down of multiple lane closures
   - Grinding and repainting traffic lines to prepare for a lane shift
   - Placement of a lane shift

9) Aiken: I-20—This site was visited on Wednesday, July 24, 2002. This project involved placement of the new cable barrier in medians and the reconstruction of damaged guardrail on the section of I-20 that runs through Aiken County. The work activities observed while visiting this site included:

   - Setting up and taking down two lane closures
   - Setting cable barrier
   - Replacement of damaged guardrail

10) Myrtle Beach: 501 and Frontage—This site was visited on Thursday, July 25, 2002. This project involved constructing a new bridge on US 501 over George Bishop Highway. The work activities observed while visiting this site included:

    - Concrete pour on the bridge deck
      - Using concrete trucks to pump concrete from underpass to bridge deck
      - Finishing of the concrete

11) Columbia: I-26/US-378 Interchange—This site was visited on Tuesday, July 30, 2002. This project involved repairing and replacement of beams on the bridge of US 378 that crossed I-26. The work activities that were observed while visiting this site included:

    - Setting up and taking down double lane closures (north and southbound)

- Replacement of beams on overpass bridge

12) Cherokee: I-85/SC-11 Interchange—This site was visited on Wednesday, July 31, 2002. This site was used to take the place of all four recommended Cherokee County sites. This was done because all the projects were in close range of each other and involved the same type of work. This particular project involved new bridge construction on SC-11 that crossed I-85. The work activities that were observed while visiting this site included:

    - Setting up and taking down multiple lane closures
    - Placement of girders on bridge

13) Spartanburg: I-85 and SC-14—This site was visited on Saturday, August 24, 2002. This project consisted of placing girders on the bridge of SC-14 that crossed I-85. The work activities observed while visiting this site included:

    - Placement of beam girders.

Figure 5.2 identifies, geographically, where in the state these projects occurred. The numbering scheme is in accordance with those from the previous descriptions and the summary list below.

**1. Anderson: I-85**

**2. Greenville: I-385**

**3. Anderson: SC-81 Bridge**

**4. Greenville: I-385**

**5. Anderson: I-85**

**6. Greenville: White Horse Road**

**7. Myrtle Beach: US 17 BP**

**8. Florence: I-95**

**9. Aiken: I-20**

**10. Myrtle Beach: 501/Frontage**

**11. Columbia: I-26/US 378 Inter.**

**12. Cherokee: I-85/SC 11 Interchange**

**13. Spartanburg: I-85/SC-14**

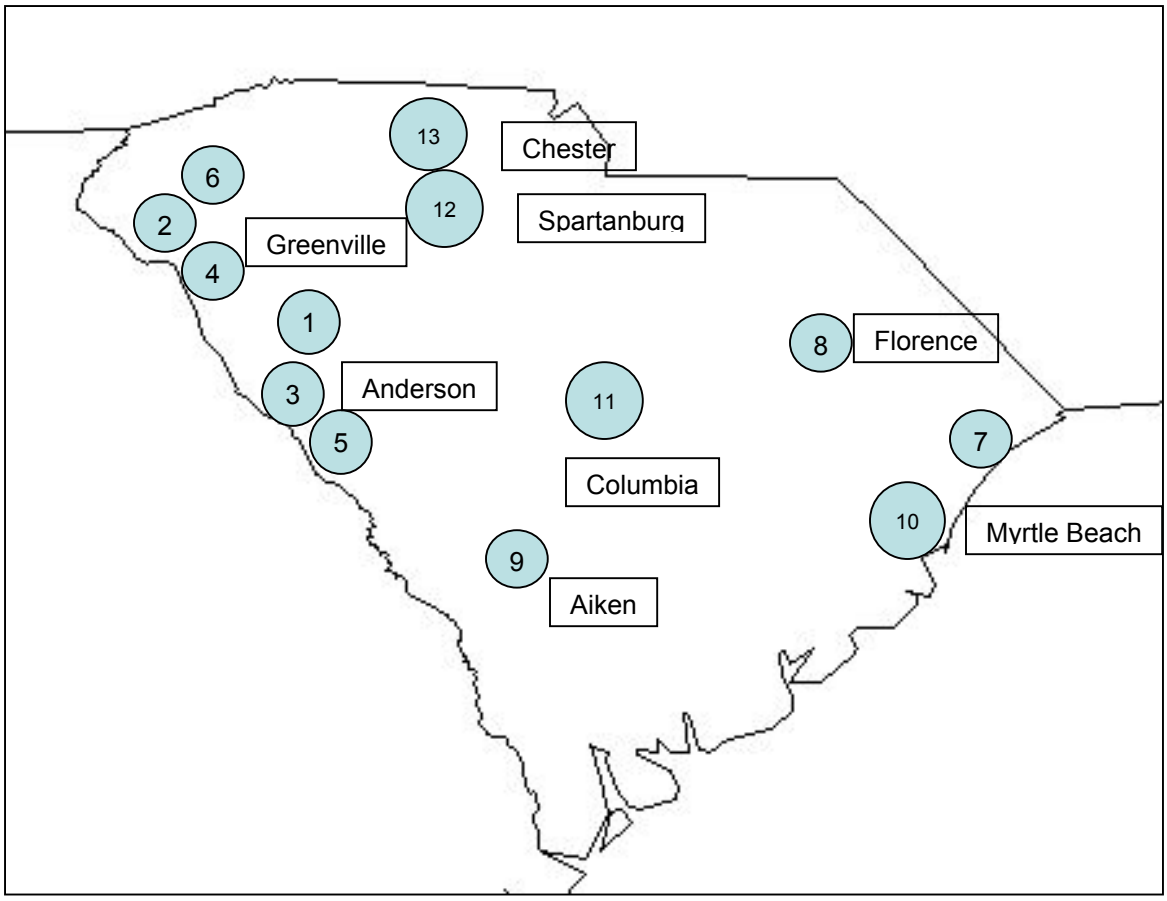



Figure 5.2. Locations of Project Sites in South Carolina.

## General Characteristics of Selected Projects

Figure 5.3 identifies the top six counties in South Carolina for work zone crashes. By noting the visited sites listed above, it can be seen that the research team visited four out of these top six counties for work zone accidents, which include: Greenville, Spartanburg, Horry, and Anderson. Charleston and York were not visited due to scheduling conflicts as explained earlier in this report. Greenville is an extreme outlier here with 1079 accidents between 1997 and 2001. This is believed to be due to the tremendous growth this county has been experiencing during this time period. There has been extensive construction taking place on the interstates that run through Greenville

County. Traffic volumes are also increasing due to economic growth. The research team believed that this disproportionate level of work zone accidents in Greenville County was directly contributable to this significant increase in construction volume.

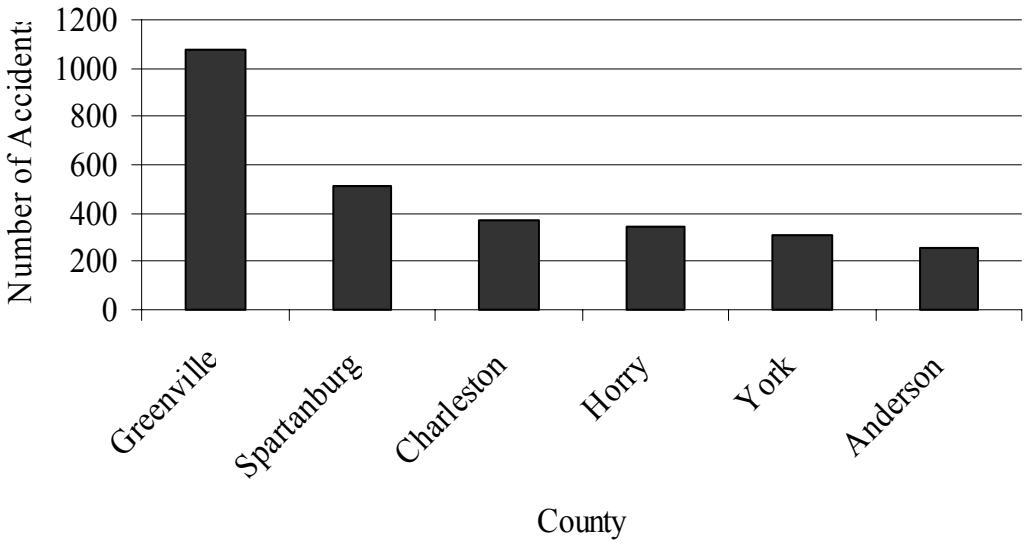



Figure 5.3. Top Counties for Work Zone Accidents in South Carolina 1997-2001.

Figure 5.4 shows that between 1997 and 2001, the leading routes in South Carolina with work zone accidents were Interstates and US Primaries. This, of course, also confirms the trends reported in the national statistics presented in Chapter III.

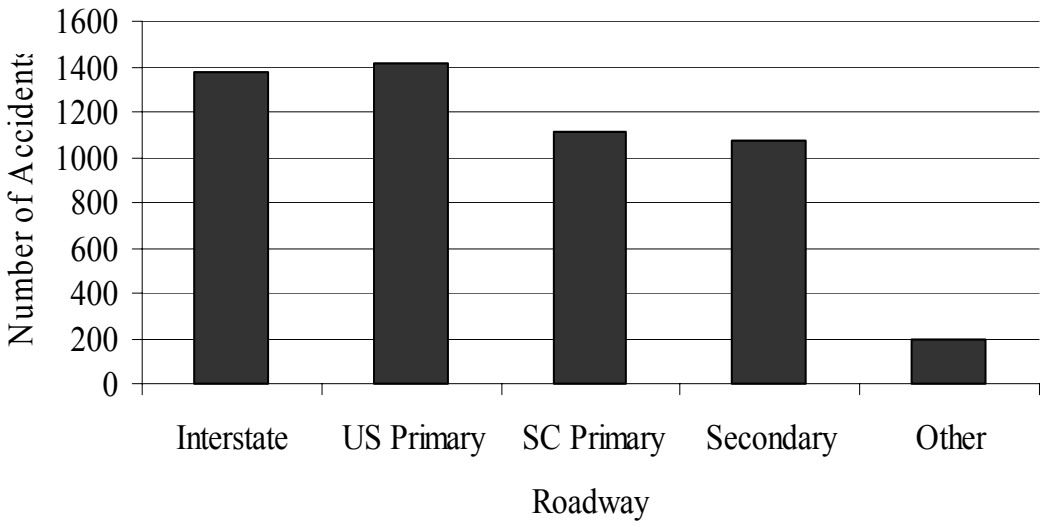



Figure 5.4. Work Zone Accidents by Route Category in South Carolina 1997-2001.

Table 5.1 shows the number of project sites that were visited when categorized by the various types of route. By comparing Figure 5.4 and Table 5.1, it can be seen that the research team was successful in aligning the type of sites visited with those most prone to work zone accidents in South Carolina between 1997 and 2001.

Table 5.1. Sites Visited Roadway Breakdown List.

| **Route** | **# of Sites Visited With These Routes** |
|---|---|
| Interstate | 9 |
| US Primary | 2 |
| SC Primary | 4 |
| Secondary | 2 |
| Other | 2 |

## Data Collection Methodology

The final step before the sites could be visited was the development of a site visitation plan. In devising the site visitation plan, it was decided that all sites would be visited in the same manner to keep consistency of the acquired information. The site

visitation plan was as shown in Figure 5.5.

- Site Arrival: Upon arrival on the site, the team members would find the SCDOT representative that was contacted in advance and who would be assisting them for that visit.

- Step One: The team usually rode with that SCDOT representative or drove their own vehicle and observed any lane closures or setups being erected for that evening's work.

- Step Two: After the initial ride-through was complete, the team would return to the main concentration of work and observe construction activities and tasks, behavior and patterns of passing motorists, lighting situations, etc.

- Step Three: During this phase of the project site visit, the team would conduct interviews with SCDOT representatives, contractor administrative personnel, and laborers. These interviews consisted of questions to help the research team identify what these personnel thought of nighttime construction and what they think could be done to improve it.

- Step Four: After conducting interviews, the team would walk through and observe construction taking place and take pictures to match notes that were taken. These pictures and notes were referenced in meetings while analyzing the data collected.

- Step Five: During this final phase of the project site visit, the team would conduct a final ride through of the job to inspect issues such as retroreflectivity, cone and barrel maintenance, lane closure maintenance, and glare issues that may affect the passing motorists.

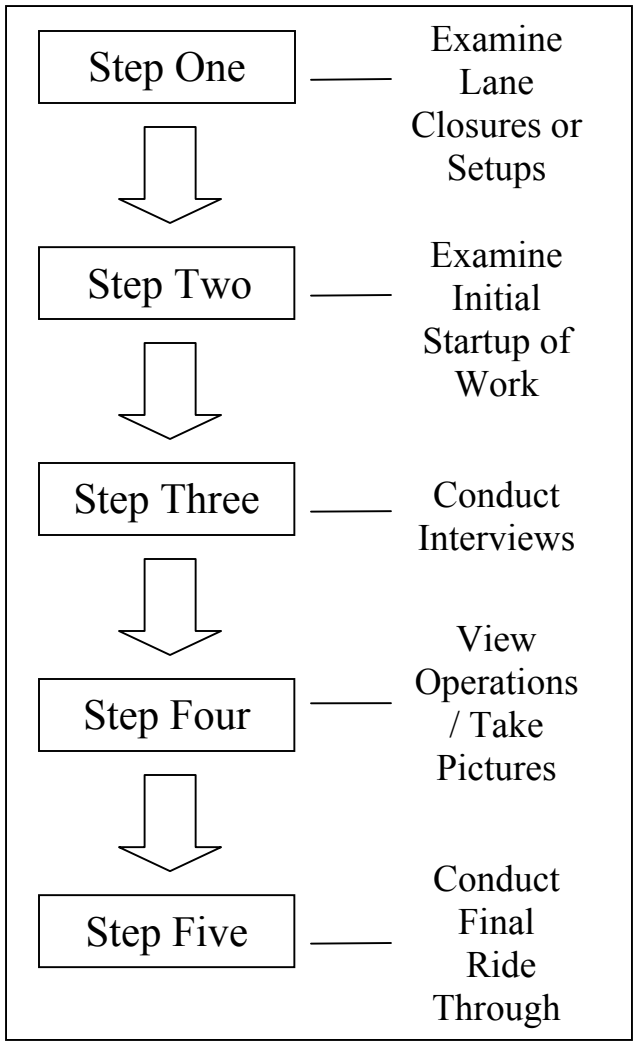



Figure 5.5. Site Visitation Flow Chart.

## Site Visit Observations

The comprehensive Work Zone Safety Checklist illustrated in Figure 5.1 was completed for each of the thirteen site visit locations. Although the research team members were very familiar with construction project safety in general, and highway work zone safety requirements in particular (one team member has 20+ years of experience as a senior construction project manager), the site visits were not construed as "official" documentation of specific violations of good safety practice that could be formulated by formally-trained and authorized safety professionals. Nor was it the intent of the research to formally evaluate SCDOT practices, but rather provide a general

summary of areas in which nighttime work zone safety practices could be improved. The following observations were documented in light of the frequently stipulated contract requirements stated above.

The site visits revealed confusing signage at some locations. Temporary signs were at times not readable and message boards were not functioning. Raised pavement markers and temporary paint lines were sometimes confusing. Normal speed limit signs were occasionally uncovered within the lane closures. Appropriate resources were not always allocated to the rolling roadblocks required to setup or dismantle lane closures. Cones and barrels appeared to be knocked over for extended periods of time, at times in the path of passing motorists. Backup alarms, headlights, and tail lights were not always functioning properly on construction equipment. Employees were not always wearing appropriate reflective clothing, hardhats, safety belts, or gloves.

These site observations were very helpful in highlighting current issues confronting DOT's and their contractors when executing nighttime operations. In these few site visitations, the research team witnessed first-hand the unique challenges that confront personnel performing complex activities at night. The research team used these experiences as key information in the development of the survey instrument. The variety of projects, and the unique characteristics of each, make it abundantly clear that not all innovative concepts are universally applicable. However, it was also clear that nighttime projects pose particular dangers and risks that must be better understood and addressed.

## Survey Development

The third phase of the research involved the creation and distribution of a survey for state departments of transportation regarding safety issues related to nighttime construction operations. The survey was distributed to every state DOT within the U.S. and to the seven DOT districts within the state of South Carolina. Twenty state DOTs

responded and 18 South Carolina responses were received. The survey was distributed in March 2003. The survey in its entirety can be found in Appendix B.

The literature review, and subsequent site visitations, revealed numerous issues regarding safety management for comprehensive nighttime construction operations. The research team identified a list of innovative concepts and proactive strategies that may be employed to improve safety performance and mitigate risks. Each of these concepts, tools, or strategies have different levels of effectiveness, cost, ease of application, and project appropriateness. The research team determined that a broad industry-wide survey was necessary to evaluate the concepts and strategies. Further, a survey instrument would help to validate the list of safety related issues and problems associated with nighttime construction. Perceptions and experience are so varied among practitioners that the survey process was necessary to have a credible consensus of issues and risks created with nighttime operations.

The survey was divided into sections, each designed to serve a different data-collection purpose. Simply stated, part A was intended to address the identification of risks, problems, and issues; while part B was designed to collect feedback and observations regarding the various innovative concepts and proactive strategies that may be applied to improve overall safety performance.

## Part A—Current Safety Observations

*Part A—Current Safety Observations* was designed to acquire information on current practices and construction techniques for nighttime construction along with observations on what respondents thought were problems regarding safety on nighttime construction projects. *Part A* was divided into categories representing the safety issues revealed from the literature review and site visits. These categories were listed as different topics and include:

- general
- lighting
- public traffic,
- employees,
- signage and channeling devices,
- lane closures,
- traveling equipment.

Respondents were given the opportunity to answer one of five ways for each question: strongly disagree, disagree, undecided, agree, and strongly agree.

Part B—Innovative Practices

*Part B—Innovative Practices* was also divided into the same categories as *Part A*. This section was designed to acquire information on innovative concepts, techniques, strategies, and safety equipment believed to have the potential to improve overall safety during nighttime projects. Respondents were asked to provide three different answers to questions in this section. They were asked to first answer if they thought the concept or technique was *ineffective, mildly effective, or effective*. Secondly, they were asked to answer if their home state implements the innovation concept or strategy *minimal implementation, occasional implementation*, or if it is a *standard practice*. Lastly, respondents were asked to answer if they *recommend* the idea or technique or if they feel it is *cost prohibitive*.

Part C—Comments

*Part C—Comments* consisted of three questions. These questions gave respondents the opportunity to provide the research team with other useful information.

The first question asked if respondents were aware of any other construction techniques or innovative practices that may lead to the improvement of overall safety on jobsites that were not addressed in the survey. The second question asked if they were aware of any other research studies or documentation on the safety of nighttime construction projects. The third question asked about any special safety considerations for weekend construction activities.

A copy of a blank survey form is included in Appendix B. Chapter VII discusses the relevancy of the data acquired from the survey.

# CHAPTER VI

# SURVEY SUMMARY STATISTICS

Upon collecting the survey data from 20 national and 18 state respondents, broken down by position in Table 6.1, the research team began breaking down and analyzing the data collected. The data is then explained and summarized in the following chapter in sections that correspond to the survey sections. Each section contains a key that has been bolded and italicized to indicate the respondents possible answer methods. It is also important to note that some survey respondents left portions or whole questions blank. It cannot be assumed in these instances that they were undecided or how they would have answered due to the detailing and possible answers to the survey question. Please note a copy of the entire survey is located in Appendix B.

Table 6.1. Survey Respondents.

| Job Title | Respondents |
|---|---|
| Office Director/Chief | 4 |
| District Engineer | 6 |
| Resident Construction Engineer | 12 |
| Construction Engineer | 9 |
| Traffic Engineer/Specialist | 4 |
| Other | 3 |
| Total | 38 |

## ***Part A—Current Safety Observations***

As a reminder, part A of the survey was used to compile a comprehensive list of issues and concerns related to performing construction operations during nighttime hours. Survey participants were asked to respond to each question in one of the following manners: ***Strongly Agree (SA), Agree (A), Undecided (U), Disagree (D), or Strongly Disagree (SD)***. Descriptive statistics on each question in the survey can be found in

Appendix C. Sample sizes of responses varied from question to question. The questions were designed to be independent of each other; therefore, the varied number of actual survey responses had no adverse or negative effect on the analysis. When the survey analysis showed trends in the response data, then the research team noted these in those sections.

For statistical analysis, each answer category was assigned a corresponding value. For example, SA equals 5, A equals 4, U equals 3, D equals 2, and SD equals 1. The average value for all national and all state respondents was then calculated. All of the results are summarized in Appendix C of this report. Each item discussed in this chapter is graphically represented. Table 6.2 as do all the tables in Appendix C state the question respondents answered then gives the total number of respondents followed by how each respondent answered. For example, Table 6.2 addresses the following issue: Construction work performed at night is often more unsafe than if the same work is performed during daytime hours. Out of 20 respondents Nationally, 5 or 25% disagreed with the statement, 1 (5%) was undecided, 11 (55%) agreed, and 3 (15%) strongly agreed. The reading method is the same for the state respondents. For reporting and summarizing purposes strongly disagree and disagree were combined as were agree and strongly agree, but the raw data can be found in its entirety in Appendix C.

Table 6.2. Abridged Part A Summary.

| Construction work performed at night is often more unsafe than if the same work is performed during daytime hours. | | | | |
|---|---|---|---|---|
| | National | | State | |
| Total Responses | 20 | % | 16 | % |
| Strongly Disagree | 0 | 0% | 0 | 0% |
| Disagree | 5 | 25% | 3 | 19% |
| Undecided | 1 | 5% | 0 | 0% |
| Agree | 11 | 55% | 10 | 62% |
| Strongly Agree | 3 | 15% | 3 | 19% |

General

### Nighttime Construction Safety

As reported in *Chapter 4*, the literature review revealed that many researchers and industry practitioners believe that nighttime construction operations are inherently less safe than when the same activities are performed in the daytime. The survey respondents generally have the same perception. Seventy percent of the national respondents agreed that nighttime construction operations were less safe, while 81 percent of the state respondents similarly agreed. Although the majority of respondents agree nighttime construction operations are less safe, the opinion is not universally held. Twenty-five percent of national respondents disagreed, while 19 percent of state respondents also disagreed with the premise.

### Quality

Another issue identified in the literature review was the question regarding whether or not product quality and construction productivity are adversely impacted when operations are performed at night. When asked if respondents believe that quality is negatively impacted as a result of nighttime construction, the answers varied between national respondents and state respondents. Forty percent of the national respondents agreed that quality is negatively impacted and 50 percent disagreed. Only 10 percent were undecided. On the other hand, more state respondents (69 percent) agreed that quality is negatively impacted while 25 percent disagreed and 6 percent were undecided.

### Productivity

When respondents were asked if they thought productivity is adversely impacted during nighttime construction, answers were generally the same between national and state respondents. Forty percent of the national respondents agreed that productivity is

less at night, while 40 percent disagreed and 20 percent were undecided. Similarly, 50 percent of the state respondents agreed and 50 percent disagreed.

## Enforcement of OSHA Standards

Site visitations in SC led the research team to believe that enforcement of OSHA standards and regulations may be an important issue on nighttime construction projects. Seventy-five percent of the national respondents disagreed that OSHA standard practices are less likely to be strictly enforced, while only 10 percent agreed and 15 percent were undecided. A bit in contrast, there was a mixed response with the state. Fifty percent of the state respondents agreed that OSHA standard practices are less likely to be strictly enforced at night and 44 percent disagreed. Only six percent were undecided about the issue.

## Employee Training

Another potential safety issue identified by researchers as a result of the site visitation process regards the training of employees on nighttime construction projects. When asked if contractor personnel are receiving adequate safety training, 60 percent of national respondents answered undecided. Only 25 percent of national respondents disagreed and 15 percent agreed. Here, there is some contrast between the two respondent groups. The majority of state respondents believe that contractor personnel are not receiving adequate training. Sixty-two percent of state respondents agreed, while none disagreed. Thirty-eight percent of state respondents were undecided.

## Planning for Nighttime Construction

Similar to the training issue was special planning for nighttime scenarios. When asked if contractors differentiate between daytime and nighttime safety considerations, national and state respondents overall agreed. Sixty-five percent of the national

respondents and 75 percent of state respondents agreed that contractors address the special planning considerations for nighttime construction projects.

## DOT Recommendations and Requirements

Contractor implementation of nighttime-specific training and planning techniques may depend on whether or not their respective DOT requires them. When asked if state DOTs require and/or recommend unique or proactive safety practices, national and state respondents agreed overall. Sixty-five percent of national respondents and 75 percent of state respondents agreed that their states require unique or proactive safety practices. Seventy percent of national respondents and 75 percent of state respondents agreed that their states recommend these practices.

## General Summary

Many noticeable trends were found in the data summarized from the "General" section, *Part A* of the survey. First, it is confirmed that a majority of DOT personnel commonly perceive nighttime construction operations as more unsafe than during daytime hours. The rest of the survey was designed to acquire information about why this may potentially be true. This section also informed the research team that more state respondents believe quality is adversely impacted by nighttime construction than do national respondents. Half of the state respondents also believe that OSHA violations are less likely to be strictly enforced at night. Other interesting findings include the fact that most state respondents believe contractor personnel are not currently receiving adequate nighttime-specific safety training.

## Lighting

### Adequacy of Lighting/Illumination

Lighting/illumination considerations of construction projects performed at night was identified as a major issue, both in the literature review and during the site visitations. When respondents were asked if lighting/illumination is generally inadequate or unevenly distributed throughout work zones, 55 percent of the national respondents agreed that this was true while only 25 percent disagreed and 20 percent were undecided. 88 percent of state respondents agreed that lighting is inadequate or unevenly distributed on nighttime projects. 6 percent disagreed, while 6 percent were undecided.

### Motorists Blinded by Glare

As a related issue, 50 percent of the national respondents believe that motorists are often blinded by glare from a typical (common) light apparatus within a construction work zone, while only ten percent disagreed. Forty percent of the national respondents were undecided on this subject. Likewise, 81 percent of state respondents believe that motorists are often blinded by glare, while only six percent disagreed and 13 percent were undecided.

### Lighting Summary

The "Lighting" section of *Part A* confirms that the lighting/illumination of work zones is a major concern for both national and state respondents with experience performing nighttime projects. Not only is having adequate light a problem, having too much light, or light that is not directionally controlled, can create serious glare hazards for passing motorists.

Public Traffic

### Law Enforcement in Work Zones

A principal objective for any DOT project is to keep workers safe. However, protecting the traveling public is equally important. The literature review and site visitation process identified many potential safety issues for passing motorists. One proactive approach to addressing these issues may be to increase law enforcement throughout work zones. Half of the national respondents agreed that there is adequate law enforcement within their state to police work zone activities during nighttime construction projects, while only 30 percent disagreed and 20 percent were undecided. Somewhat in contrast, 63 percent of state respondents believe that there is inadequate law enforcement in SC to police work zone activities during nighttime construction. Thirty-one percent disagreed; 6percent were undecided.

### Motorists' Stranded Vehicles

Another potential safety issue identified by site visits regards stranded motorists' vehicles left along the roadside throughout work zones. Half of the national respondents believe that stranded motorists' vehicles are a greater safety concern during nighttime projects, while 25 percent disagreed and 25 percent were undecided. Similarly, 81 percent of the state respondents also believe that this is true, while only 13 percent disagreed and 6 percent were undecided.

### Excessive Public Speeding at Night

Excessive speeding of passing motorists was identified by both the literature review and the site visitation process as one of the primary safety concerns for nighttime construction. Both national and state respondents indicated this is a commonly held perception. Forty-five percent of national respondents and 69 percent of state respondents agreed that excessive speeding by public motorists through construction

work zones is more prevalent during nighttime construction. Only 15 percent of national respondents and 13 percent of state respondents believe that excessive speeding is not a problem during nighttime construction. Forty percent of national respondents and 18 percent of state respondents were undecided regarding this issue.

When asked if respondents believe public motorists are often unaware that they are entering a construction work zone at night, national and state respondents generally agreed. Eighty percent of national respondents and 69 percent of state respondents think motorists are aware they are entering a work zone. Only 10 percent of national respondents and 18 percent of state respondents believe that motorists are unaware they are entering a work zone at night.

### Public Traffic Summary

General trends were apparent in the data for the "Public Traffic" section of *Part A*. First, respondents seemed to believe that public traffic could lead to unsafe scenarios in a number of ways. The most obvious way is excessive speeding by public motorists through construction work zones. Overall, the majority of both national and state respondents believe that this is true. According to the survey participants, another way that public traffic can negatively impact safety on a project is by leaving their cars stranded in work zones. Overall, national respondents believe that there is sufficient law enforcement in their state to adequately monitor public traffic through construction work zones at night. In contrast, over half of the state respondents believe that there is inadequate law enforcement within SC to police construction activities at night.

## Employees

### Retroreflective Clothing

According to the literature review, miscellaneous issues with construction employees in work zones exist that may present potential safety concerns. One of these

issues is the quality and amount or retroreflective clothing they wear. Sixty percent of the national respondents believe that workers' reflective clothing is adequate for nighttime construction while only 20 percent believe that it is inadequate and 20 percent were undecided. On the other hand, 50 percent of state respondents believe that workers' reflective clothing is inadequate. Thirty-seven percent of state respondents believe it is adequate and 13 percent were undecided regarding this issue.

### Nighttime-Specific Training

When asked if contractors adequately train personnel for the safety requirements/concerns unique to nighttime safety, 65 percent of national respondents were undecided. Only 15 percent agreed and 20 percent disagreed. On the other hand, 75 percent of state respondents agreed that contractors do not train their personnel for safety requirements/concerns unique to nighttime safety, while 25 percent were undecided. None of the state respondents agreed that contractors adequately train their employees for the safety requirements and concerns unique to nighttime construction.

### Nighttime Construction Safety Plans

When asked if contractors execute adequate safety plans for nighttime construction, more national respondents believe that this is true than state respondents. Forty-five percent of the national respondents agreed, 5 percent disagreed, and 50 percent were undecided. In contrast, state respondents were almost equally divided with their responses. Forty-four percent agreed that contractors execute adequate safety plans, 38 percent disagreed and 18 percent were undecided.

### DOT Resource Allocation

An issue identified during an interview on a site visit was the amount of DOT resources allocated for monitoring nighttime activities. Sixty-five percent of the national

respondents believe that state DOT resources are sufficient to monitor nighttime construction, whereas 25 percent believe that they are not sufficient. Ten percent responded as undecided. Likewise, 69 percent of state respondents believe that state DOT resources are adequately allocated and 31 percent agreed that they are not.

### DOT Personnel Alertness

When asked if nighttime construction negatively affects the alertness and effectiveness of DOT personnel to monitor safety, national and state respondents were generally in disagreement. For the most part, national respondents were equally divided in their responses. Thirty-five percent agreed and 35 percent disagreed, while 30 percent were undecided. In contrast, 75 percent of the state respondents believe that nighttime activity does affect the alertness and effectiveness of DOT personnel, while 19 percent disagreed. 6 percent were undecided.

### Employees Summary

The "Employees" section of *Part A* confirmed that national respondents believe that lack of worker safety clothing is not considered a safety issue for nighttime construction projects. In contrast, the majority of state respondents believe that workers' reflective clothing is inadequate. Also, the majority of state respondents believe that contractor personnel are not receiving adequate training specific to nighttime construction. All respondents generally believe that DOT resources are sufficient to monitor these projects, but only the majority of state respondents believe that nighttime construction activities affect the alertness and effectiveness of DOT personnel to monitor safety.

## Signage and Channeling Devices

### Adequacy of Signage

Issues with signage and channeling devices often deployed by contractors on nighttime projects were identified by the literature review as a potential safety concern. Seventy-five percent of the national respondents disagreed that contractors use inadequate signage for nighttime construction operations, while only 5 percent believe that contractors do not use enough appropriate signs. Twenty percent of national respondents were undecided about this issue. State respondents answered similarly. Eighty-one percent of state respondents agreed that contractors employ adequate signage, while only 13 percent disagreed and 6 percent were undecided.

### Inappropriate Signage

Even though the majority of respondents agreed that contractors employ enough appropriate signage at night, 77 percent of the national respondents believe that contractors often leave inappropriate signs showing during non-construction hours. Fifteen percent of national respondent were undecided and 8 percent disagreed. Fifty percent of the state respondents were undecided about this issue. Thirty-eight percent of state respondents agreed that contractors leave inappropriate signs showing, but 12 percent were undecided.

### Retroreflectivity Issues of Signage

Fifty percent of national respondents disagreed that reflectivity issues often hinder the effectiveness of signage at night. Forty percent agreed that this is true and 10 percent said they were undecided. 50 percent of the state respondents believe that reflectivity issues do hinder the effectiveness of signs. Thirty-eight percent disagreed and 12 percent were undecided.

## Unique Nighttime Signage Considerations

When asked if contractors generally do not appreciate the unique considerations associated with nighttime signage, the majority of respondents disagreed. Sixty-five percent of the national respondents disagreed and 50 percent of state respondents disagreed. Only 10 percent of national respondents agreed and 38 percent of state respondents agreed. Twenty-five percent of the national respondents and 12 percent of state respondents were undecided about this issue.

## Maintenance of Channelizing Devices and RPMs

Overall, respondents disagreed that channeling devices and raised pavement markings (RPMs) are maintained inadequately to sustain adequate retroreflectivity at night. Sixty percent of national respondents disagreed and 69 percent of the state respondents disagreed. Only 20 percent of the national respondents agreed, while 20 percent were also undecided. Twelve percent of the state respondents agreed, while 19 percent were undecided.

## Confusion of Travel Ways

The majority of respondents disagreed that channeling devices and RPMs in work zones are often placed in a manner that creates confusion for the traveling public at night. Seventy percent of the national respondents and 69 percent of the state respondents disagreed, indicating that they believe channeling devices and RPMs in work zones represent a clear travel way for the public. Twenty-five percent of the national respondents agreed that they are placed in a manner that creates confusion for the traveling public. Nineteen percent of the state respondents also agreed that channeling devices and RPMs often create confusion.

### Signage and Channelizing Devices Summary

From this section, it should be noted that the primary problem that respondents identified concerning signage and channeling devices is that contractors often leave inappropriate signage showing during non-construction hours. Other than that, respondents believe that contractors use enough appropriate signs for nighttime construction projects.

## Lane Closures

### Danger Associated with Lane Closure Procedures

The setting up/taking down of lane closures was repeatedly mentioned during site visits as one of the greatest safety concerns for contractors. There was generally strong agreement within groups on issues related to this subject. Overall, respondents believe that setting up and taking down lane closures subject contractor personnel to particular danger at night. Eighty-four percent of the national respondents agreed with this statement and 94 percent of state respondents agreed. Only five percent of national respondent disagreed and no state respondents disagreed.

### Maintenance of Lane Closures

National respondents believe that maintenance of lane closures is not a major concern while state respondents felt that maintenance is a major concern. When asked if improper maintenance of lane closures is a major issue on nighttime construction projects, 47 percent of national respondents disagreed and 37 percent agreed. Sixteen percent were undecided. On the other hand, 63 percent of state respondents agreed that this is a major issue, 25 percent disagreed, and 12 percent were undecided.

### Lane Closures Summary

A major finding from the "Lane Closures" section of *Part A* is that the majority of respondents believe that lane closures present safety concerns for contractor personnel at

night. This is primarily due to the fact that at the time workers are dealing with lane closures, they are working very close to the public travel way. Both groups of respondents indicated that they believe setting-up and taking-down lane closures is particularly dangerous for contractor personnel. SC respondents believe that maintenance of these lane closures presents major safety issues for contractor personnel as well.

## Traveling Equipment

### Ease of Identifying Construction Equipment

A research report referenced during the literature review specifically discussed safety issues and concerns commonly associated with construction equipment. Respondents were asked if the inability of passing motorists to identify construction vehicles during nighttime construction creates a hazard to the public. Forty-five percent of the national respondents agreed and 40 percent disagreed. Fifteen percent of the national respondents were undecided. On the other hand, more state respondents believe that this is much more of a problem. Fifty-six percent of state respondents agreed that the inability of passing motorists to identify construction vehicles creates a hazard to the public. Twenty-five percent of state respondents disagreed, while 19 percent were undecided.

### Identification Devices on Construction Equipment

The majority of all respondents disagreed that construction equipment is often not equipped well enough with the proper identification devices to alert workers of their presence. Fifty-five percent of the national respondents disagreed and 25 percent agreed. Twenty percent of the national respondents were undecided. Similarly, 63 percent of the state respondents disagreed with this statement. Only 12 percent of state respondents agreed and 25 percent were undecided.

### Traveling Equipment Summary

This section of the survey revealed no major safety issues associated with traveling construction equipment. The majority of respondents believe that motorists and workers can easily identify equipment when needed.

## Part B—Innovative Practices

Section A of the survey identified current issues and concerns of performing construction during nighttime hours. Section B sought to identify possible innovative ideas, construction practices, and/or technologies to address these issues and concerns and improve the overall safety in work zones. Survey participants were asked their opinion on the effectiveness of each idea, technique, and/or technology. They were also asked how often they implement each idea, technique, and/or technology, and whether or not they recommend each one, or if they feel they are cost prohibitive. Respondents were asked to answer in the following manners: ***Ineffective (I), Mildly Effective (ME), Effective (E); Minimal Implementation (MI), Occasional Implementation (OI), and Standard Practice (SP); Recommended (R) and Cost Prohibitive (CP).***

Consistent with *Part A* of the survey, each answer was assigned a value. For example, I equals 1, ME equals 2, and E equals 3; MI equals 1, OI equals 2, and SP equals 3; R equals 1, and CP equals 2. The average value for national and state respondents was calculated for each topic. Statistics for each question can be found in Appendices C and D. The following paragraphs discuss each idea, construction technique, and/or innovative technology and it's relevance to the general safety of workers and traveling public during nighttime construction operations.

Appendix C of this report graphically shows all of the results that are summarized in the following paragraphs. Table 6.3 is an example. It addresses the issue of Pre-qualification of contractors based on safety records. The table shows the total

respondents (TR), 16 in this case, and goes on to show that 3 of the 16 (19%) thought that pre-qualification of contractors based on safety records was ineffective, 56% (9 respondents) thought it was mildly effective and so on. The next category was whether it was implemented or not. In this example 79% said that it was minimally implemented. Finally, the respondents were asked if it was a recommended cost (RC) or if it was cost prohibitive (15% or 2 of 13, reported it was cost prohibitive). Again, Appendix C contains the data in its entirety.

Table 6.3. Abridged Part B Summary

| Pre-qualification of contractors based on safety records. | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| TR | 16 | % | TR | 19 | % | TR | 13 | % |
| I | 3 | 19% | MI | 15 | 78.9% | RC | 11 | 85% |
| ME | 9 | 56% | OI | 2 | 10.5% | CP | 2 | 15% |
| E | 4 | 25% | SP | 2 | 10.5% | | | |

General

Pre-qualification Based on Safety Records

Overall, survey participants believe that pre-qualification of contractors, based on existing safety records, is an effective practice that will improve the overall safety on construction projects. Fifty-six percent of the national respondents believe that this idea is mildly effective and 25 percent believe that it is effective. Although the majority of the national respondents stated this opinion, 79 percent of national respondents said that this practice is implemented only minimally. Eighty-five percent of the national respondents recommend that this practice be implemented on a regular basis. Similarly, all of the state respondents believe that this idea is effective. Forty-two percent of the state respondents said that this idea is mildly effective, while 58 percent said that it is effective. Fifty-eight percent of state respondents indicated that this idea is minimally

implemented, yet 92 percent recommended it be used on a regular basis.

### Prequalification Based on Safety Equipment

The majority of respondents believe that pre-qualifying contractors by safety records is helpful in improving safety on projects, but they do not feel the same way about pre-qualifying contractors based on an itemized inventory of contractor safety equipment. Sixty percent of the national respondents believe that this idea is ineffective while the rest (40 percent) believe that it is only mildly effective. Hence, 89 percent of the national respondents said that their states do not implement this idea in their pre-qualification of contractors. Seventy-three percent of the national respondents said that they believe this idea is cost prohibitive, while only 27 percent recommended that it be done. State respondents generally agreed. Twenty-nine percent of state respondent believe that it is ineffective and 71 percent believe it is mildly effective. Half of these respondents said that they either implement this procedure minimally (50 percent) or that it is implemented only occasionally (33 percent). The rest of the state respondents (17 percent) said that they implement this procedure as a standard practice in the pre-qualification of contractors. While most national respondents believe that this practice is cost prohibitive, all of the state respondents (100 percent) recommend that it be done regularly.

## Lighting and Illumination

### Balloon Lights as a Lighting Source

When asked if semi-stationary soft-glow illumination balloon lights are helpful in lighting construction work areas at night, both national and state respondents answered similarly. No national respondents believe that they are ineffective, 63 percent believe that they are mildly effective, and 37 percent think that they are effective. Likewise, no state respondents believe that they are ineffective, 33 percent think that they are mildly

effective, and 67 percent think that they are effective in lighting construction work zones. Thirty-three percent of the state respondents said that they employ these lighting systems minimally, 50 percent said that they implement these systems occasionally, and 17 percent said that they implement these lighting systems as a standard practice. Ninety-three percent of the national and 100 percent of the state respondents recommend semi-stationary soft-glow balloon lights to be used to light construction areas, while only 7 percent said that they are cost prohibitive.

## Balloon Lights to Prevent Glare

Survey participants were also asked if the same semi-stationary soft-glow illumination lighting systems are an effective measure in preventing glare to passing motorists. Once again, national and state respondents answered similarly. First, no respondents believe that these lights are ineffective at preventing glare to passing motorists. Seventy-one percent of the national respondents believe that these lights are effective and 29 percent believe that they are mildly effective. Fifty percent of the national respondents said that they implement these lights for this purpose minimally, 39 percent said that they implement them occasionally, and 11 percent said they implement them as a standard practice. Eighty-seven percent of the national respondents recommend that they be used to prevent glare to passing motorists, while only 13 percent said that they are cost prohibitive. State respondents answered similarly. Sixty-four percent of the state respondents said that these balloon lights are effective in preventing glare to passing motorists and 36 percent said that they are mildly effective. Thirty percent of state respondents said that they implement these lighting systems minimally, 50 percent said that they implement them occasionally, and 20 percent said that they are implemented as a standard practice. Ninety-two percent of the state respondents

recommend that these balloon lights be used as a measure to prevent glare to passing motorists, while only 8 percent said that they are cost prohibitive.

### Lighting Apparatus Attached to Equipment

An additional way to light construction areas is to have a lighting apparatus attached to operating equipment. Overall, none of the respondents believe that this is an ineffective method to light construction areas, and no respondents said that they implement this method a minimal amount. Once again, national and state respondents seemed to be in general agreement with their responses. Fifty-five percent of the national respondents believe that this method is mildly effective and 45 percent believe that it is effective. Fifty percent of the national respondents said that they implement this lighting method occasionally, and 50 percent said that it is a standard practice. The majority of national respondents (94 percent) recommend this lighting method. State respondents answered similarly. Fifty percent said that they believe this method is mildly effective and 50 percent believe that it is effective. The majority of the state respondents (92 percent) recommend that this method be used.

## Public Traffic

### Law Enforcement

When asked if traffic enforcement by full-time highway patrolmen throughout work zones is beneficial to the overall safety on construction projects, both national and state respondents answered similarly. Almost all of the national respondents (83 percent) believe that this technique is effective. Thirty-seven percent of national respondents said that their states implement this technique as a standard practice and 53 percent said that they implement it occasionally. Sixty-nine percent of the national respondents recommend that this technique be implemented regularly, while only 31 percent believe

that it is cost prohibitive. Likewise, all of the state respondents (100 percent) believe that traffic enforcement by full-time highway patrolmen throughout work zones is an effective technique to improve the overall safety on construction projects. Thirty-six percent of the state respondents said that they implement this technique as a standard practice and 55 percent said that they implement it occasionally. Seventy-seven percent of the state respondents recommend that this technique be implemented regularly and 23 percent said that it would not be feasible for reasons associated with the cost of implementation.

## Adaptive Cruise Control Technology

Adaptive Cruise Control technology, which is used to automatically decrease the speeds of vehicles entering work zones, was identified as a possible alternative for slowing passing motorists. National and state respondents showed mixed feelings as far as the effectiveness of this technology, but overall agreed that their respective states implement it minimally. National and state respondents also agree that Adaptive Cruise Control is prohibitive for cost reasons. Thirty-eight percent of the national respondents believe that this technology is ineffective, 25 percent think that it is mildly effective, and 37 percent think that it is effective. Ninety-five percent of the national respondents said that their states implement this technology minimally. Eighty-seven percent of the national respondents said that costs of implementing Adaptive Cruise Control technology would prohibit usage. Sixty-seven percent think that Adaptive Cruise Control is effective in slowing motorists, 16 percent think that it is mildly effective, and 17 percent think that it is ineffective. Eighty-five percent of the state respondents said that this technology is implemented minimally and 85 percent said that it is cost prohibitive.

## Wizard CB System

Another technology that may be helpful in improving the overall safety on construction projects is the Wizard CB System. This technology informs truckers at thirty-second intervals of upcoming work zones over their CB radios. Forty-seven percent of the national respondents believe that this is effective in improving safety and 41 percent think that it is mildly effective. Eighty-four percent of national respondents indicated that this technology is implemented at a minimum level. Sixty percent recommend it and 40 percent said it is not feasible for cost reasons. Sixty-four percent of state respondents believe that the Wizard CB system is helpful in improving safety. Fifty percent indicated its implementation minimally and 50 percent said that they implement it occasionally. Fifty-eight percent of state respondents recommend the Wizard CB System and 42 percent indicated its impracticality due to cost reasons.

## Intrusion Detection Alarms

Intrusion detection alarms are sometimes used to alert workers when unauthorized vehicles enter a work zone by sounding an alarm. For national respondents, 28 percent believe that these alarms are ineffective, 50 percent believe that they are mildly effective, and 22 percent believe that they are effective. The majority of national respondents (84 percent) indicated that their states implement these alarms a minimum amount. Thirty-six percent recommend that they be implemented and 64 percent said they are not feasible due to cost reasons. For state respondents, 50 percent believe that these alarms are effective and 42 percent believe that they are mildly effective. Seventy percent indicated that they minimally implement these alarms and 20 percent said that they implement them occasionally. Thirty-three percent of state respondents recommend that they be implemented regularly and 67 percent said that they cannot be used because they are cost prohibitive.

## Towing Services

Full-time towing services are often employed to assist stranded motorists in work zones. Fifty percent of the national respondents believe that these services are effective in improving the overall safety of work zones, 39 percent believe that they are mildly effective, and 11 percent believe that they are ineffective. Of the national respondents, 39 percent indicated that their states implement these services minimally, 35 percent said that they implement them occasionally, and 25 percent said that they implement them as a standard practice. The majority of the state respondents (72 percent) recommend that this practice be deployed to improve the safety of construction projects. Fifty-eight percent of the state respondents believe that these towing services are effective and 33 percent believe that they are mildly effective. Of the state respondents, 55 percent said that they implement these services minimally, 27 percent said occasionally, and 18 percent said that they implement them as a standard practice. Sixty-four percent of the state respondents recommend this practice and 36 percent think that it is not feasible due to reasons associated with cost.

## Designated Public Phone Number

Participants were asked if they think a designated phone number that the public can call for information on local work zones is a beneficial practice for increasing awareness and improving safety. Fifty percent of the national respondents think that it is effective and 50 percent think that it is mildly effective. Of the national respondents, 37 percent indicated that they implement it minimally, 37 percent indicated that they implement it occasionally, and 26 percent said they implement these phone numbers as a standard practice. All of the national respondents (100 percent) recommend that this practice be implemented. State respondents answered similarly. Thirty-nine percent think that a designated phone number is effective, 46 percent think that it is mildly effective, and 15 percent think that it is ineffective. Of the state respondents, 45 percent

indicated that they implement this type of phone number minimally, 36 percent said they implement it occasionally, and 9 percent said that it is a standard practice. Seventy-seven percent of the state respondents recommend implementation of such a phone number and 23 percent think that it is cost prohibitive.

## Public Notices of Work Zones

Public notices of conditions in local work zones were cited as an appropriate means to increase the overall awareness of and safety in work zones. For example, websites, newspapers, local TV news, etc. are means of notifying the public. When asked if these public notices are helpful, no respondents indicated that they believe they are ineffective. Seventy-four percent of the national respondents believe that these notices are effective and 26 percent believe that they are mildly effective. Thirty percent said that they implement these types of notices occasionally, and 70 percent said that they are standard practice. Ninety-five percent of the national respondents recommend that these notices be used on a regular basis. Once again, state respondents answered similarly. Forty-six percent of the state respondents believe that these public notices are mildly effective and 54 percent believe that they are effective. Ninety-two percent of the state respondents indicated that they implement these public notices as a standard practice. All of the respondents recommend that they be used regularly.

## Cell Phone Usage in Work Zones

Some states have tried to ban the usage of cell phones by public motorists while passing through work zones. When asked if this is useful in improving the overall safety in work zones, there were no apparent trends in responses. National respondents' answers varied. Thirty-five percent think this idea is effective, 24 percent think that it is mildly effective, and 41 percent think that it is ineffective. Eighty-four percent of the national respondents said that their states rarely implement this idea and 16 percent said

that it is a standard practice. Eighty-two percent of the national respondents recommend that cell phones be banned in work zones while only 18 percent said that this idea is cost prohibitive. State respondents were also in mixed agreement with their answers. An equal amount of respondents (33 percent) believe that this idea is effective, mildly effective, and ineffective. Seventy-three percent of the state respondents said that they implement this idea at a minimal amount of the time, 18 percent said they implement it occasionally, and 9 percent said that it is standard practice. Of these state respondents, 71 percent recommend that cell phones be banned in work zones while 29 percent believe that this idea is cost prohibitive.

## Transverse Rumble Strips

Another method often used to attract the attention of passing motorists is the deployment of transverse rumble strips. When respondents were asked if they think rumble strips are effective in attracting the attention of motorists, national and state respondents answered similarly. Fifty-three percent of the national respondents believe that they are effective and 41 percent believe that they are mildly effective. Only six percent said that they are ineffective. Of these national respondents, 55 percent said that their states implement transverse rumble strips minimally, 25 percent implement them occasionally, and 20 percent implement them as a standard practice. Sixty-four percent of the national respondents recommend that rumble strips be used and 36 percent said that they are cost prohibitive. Likewise, 42 percent of the state respondents believe that rumble strips are effective, 50 percent believe that they are mildly effective, and 8 percent believe that they are ineffective. Of the state respondents, 67 percent recommend the implementation of rumble strips and 33 percent think that they are too expensive to implement.

Signage

### Workers Present When Flashing Signs

When asked if "Workers Present When Flashing" signs should be used to alert motorists of workers in the work zones, national and state respondents were generally in agreement. Of the national respondents, 19 percent believe the signs are ineffective, 63 percent believe the signs are mildly effective, and 18 percent believe that they are effective. Seventy percent of the national respondents indicated minimal implementation of the signs and 20 percent said they implement them occasionally. Seventy-seven percent of the national respondents recommend that the signs be used on a regular basis. Fifty percent of the state respondents believe that the signs are effective, 36 percent believe that they are mildly effective, and 14 percent believe that they are ineffective. Of these state respondents, 46 percent indicated minimal implementation of the signs, 18 percent indicated occasional implementation, and 36 percent said they are implemented as a standard practice. Seventy-three percent of the state respondents recommend the implementation of these signs, while 27 percent believe that they are too expensive to implement.

### Variable Message Boards

Variable message boards have proven to be an effective way to relay vital construction information to passing motorists. Respondents were asked if variable message boards should be used instead of standard signage to inform motorists of conditions throughout the work zone. National and state respondents were generally in agreement with their answers. Sixty-six percent of the national respondents believe that the variable message boards are effective, 28 percent believe that they are mildly effective, and six percent believe that they are ineffective. Of these national respondents, none of them indicated that they implement these signs minimally. Forty-seven percent said that they implement these signs occasionally and 53 percent said that they implement

them as a standard practice. Eighty-eight percent of the national respondents recommend that variable message signs be used, while only 12 percent believe that they are cost prohibitive. Likewise, 69 percent of the state respondents believe that variable message boards are effective, 31 percent believe that they are mildly effective, and none believe that they are ineffective. Of the state respondents, 64 percent indicated that they implement variable message boards as a standard practice, 36 percent said they implement them occasionally, and no respondents answered that they implement them minimally. Ninety-two percent of the state respondents recommend variable message boards be used to inform motorists of vital information, while only 8 percent said that they are too expensive.

## Radar Boards

Radar boards are often used to check and display the speed of passing motorists throughout work zones. When respondents were asked if they are helpful in improving the safety of workers and public traffic in the work zones, national and state respondents' answers seemed to differ. Fifty-three percent of the national respondents believe that they are effective, 47 percent believe that they are mildly effective, and none believe that they are ineffective. Of these national respondents, 10 percent indicate that they implement radar boards as a standard practice, 75 percent said that they implement them occasionally, and 15 percent said that they implement radar boards minimally. Ninety-four percent of the national respondents recommend their implementation and six percent said that they are not used for cost reasons. On the other hand, not as many state respondents believe that radar boards are effective. Twenty-three percent of the state respondents believe that they are ineffective, 46 percent believe that they are mildly effective, and 31 percent think they are effective. Not as many state respondents as national respondents use radar boards. Nine percent of the state respondents indicated their implementation as a standard practice. Thirty-six percent of the state respondents

said that they implement radar boards occasionally, and 55 percent said that they implement them minimally. An even amount of state respondents (50 percent) recommend and said that radar boards are cost prohibitive.

## Display of the Frequency of Speeding Citations

Another method often used as a means to decrease the speeds of traffic passing through work zones is to deploy a message board indicating the number/frequency of speeding citations issued by law enforcement within a certain time period. Overall, national respondents' answers were mixed as far as the effectiveness of this idea. Forty percent said that it is effective, 20 percent said that it is mildly effective, and 40 percent said that it is ineffective. The majority of national respondents (90 percent) do not implement this idea, whereas only 10 percent said that it is standard practice. National respondents were half and half on whether or not they recommend this practice (50 percent). State respondents answered similarly. Fifty percent believe that this method is ineffective at slowing traffic, 21 percent believe that it is mildly effective, and 29 percent said that it is effective. Sixty-four percent of the state respondents indicated that they implement this idea at a minimal amount, 27 percent said they implement it occasionally, and one of 11 said it is a standard practice. Forty-five percent recommend this practice and 55 percent believe that it is too expensive.

## Signage Readability

The readability of signage deployed to warn traffic of work zone conditions is often considered a safety issue on nighttime projects. Limiting the number of re-uses of signs may be a potential solution to ensure adequate legibility by motorists is maintained. Overall, respondents did not show any apparent trends in their answers. Forty-seven percent of the national respondents believe that this is an ineffective procedure, 33 percent think it is mildly effective, and 20 percent believe that it is effective. Sixty-eight

percent of the national respondents said that they do not implement a limited number of re-uses of signs, 16 percent said they implement it occasionally, and 16 percent said it is a standard practice. Fifty-eight percent of the national respondents recommend this be done, while 42 percent believe that it is prohibitive for cost reasons. State respondents answered similarly. Twenty-five percent believe that this procedure is ineffective, 33 percent believe that it is mildly effective, and five (42 percent) believe that it is effective. Thirty-six percent of state respondents indicated minimal implementation of this procedure, 27 percent said they implement it occasionally, and 37 percent said it is a standard practice. Similar to national respondents, 58 percent of the state respondents recommend this practice and 42 percent believe that it may be too expensive.

Employees/Worker Personnel

Contractor Notification of Sign Technology

Frequent contractor notification of newest sign technology available for nighttime construction may help contractors keep up to date with what signs are commercially available for use. Respondents were asked if they thought this would help improve general safety on projects. For the most part, national and state respondents were in agreement with their answers. Thirty-three percent of the national respondents believe that this is effective and 67 percent believe that it is mildly effective. None believe that it is ineffective. Of the national respondents, 63 percent indicated that they do not notify contractors of newest sign technology, 11 percent said that they do occasionally, and 26 percent said that they do as a standard practice. Eighty-five percent of the national respondents recommend this type of contractor notification, while 15 percent believe that it would be too expensive. State respondents answered similarly. Sixty percent believe that this is an effective idea, 40 percent believe that it is mildly effective, and none believe that it is ineffective. Thirty-six percent of the state respondents indicated that they do not implement this contractor notification, 45 percent said that they do

occasionally, and 18 percent said that it is a standard practice. Eighty-five percent of the state respondents recommend this practice, while 15 percent said that it is too expensive.

### Retroreflective Clothing

Survey participants were asked if improvements to the retroreflectivity outfitting of employees/worker personnel in work zones is helpful. National and state respondents answered similarly. Eighty-nine percent of the national respondents believe that this is effective, 11 percent believe that it is mildly effective, and none believe that it is ineffective. Forty-five percent indicated minimal implementation, 10 percent indicated occasional implementation, and 45 percent indicated this as a standard practice. All of the national respondents recommend improvements to the retroreflectivity of worker outfitting. Likewise, 92 percent of the state respondents believe that this is effective, 8 percent believe that it is mildly effective, and none believe that it is ineffective. Thirteen percent indicated minimal implementation of this improved retroreflectivity, 53 percent said they implement this occasionally, and 33 percent said that it is a standard practice. All of the state respondents recommend improved retroreflectivity of worker outfitting.

### Nighttime-Specific Training for New-Hires

Respondents were asked if new-hires for nighttime construction should receive training specific to the scenarios that nighttime construction presents. Sixty percent of the national respondents believe that this training is effective towards improving safety, 40 percent believe that it is mildly effective, and none believe that it is ineffective. Fifty percent of the national respondents said that this training is a standard practice and 50 percent said that it is implemented occasionally. All of the national respondents (100 percent) recommend that new-hires get specific training for nighttime construction. State respondents answered similarly. Ninety-two percent of the state respondents believe that this training is effective, 8 percent believes that it is mildly effective, and none believe

that it is ineffective. Fifty-six percent of the state respondents indicated that this training is a standard practice while 44 percent said that they do this occasionally. All of the state respondents recommend this specific training for new-hires to nighttime construction projects.

### Required Training at Regular Intervals

Respondents were asked if specific nighttime training should be required at regular time intervals for all construction personnel on the job. Once again, national and state respondents' answers showed general agreement. Forty-seven percent of the national respondents believe that this is an effective measure and 53 percent believe that it is mildly effective. Sixty percent of the national respondents indicated that they implement this regular training minimally, 20 percent indicated that they implement it occasionally, and 20 percent indicated that it is a standard practice. Ninety-three percent of the national respondents recommend these repeated training sessions, while only one of fifteen believes that it would be cost prohibitive. Eighty-three percent of the state respondents believe that this training is effective and 17 percent believe that it is mildly effective. Twenty-five percent indicated minimal implementation, 42 percent indicated occasional implementation, and 33 percent said that it is a standard practice. All of the state respondents recommend regular training sessions.

### Anonymous Documentation of Lessons Learned

Survey participants were asked if anonymous documentation on "lessons learned" and "near misses" provides useful information for current and future projects. Thirty-three percent of the national respondents believe that this idea is effective, 60 percent believe that it is mildly effective, and 7 percent believe that it is ineffective. Sixty-five percent of the national respondents indicated that they implement this idea minimally, while 20 percent said they implement it occasionally and 15 percent said it is a standard practice. All of the national respondents recommend this practice. State respondents'

answers were somewhat similar. Fifty-eight percent believe that this documentation is effective, 25 percent believe that it is mildly effective, and 17 percent said that it is ineffective. Forty-five percent of the national respondents indicated minimal implementation of this documentation, while 36 percent said that they implement it occasionally and 19 percent said that it is a standard practice. Seventy-five percent of the state respondents recommend this practice, while 25 percent believe that it is cost prohibitive.

## Safety Incentive Programs

Respondents were asked if contractors should be required to offer safety incentive programs to promote the awareness of safety concerns and issues to their employees. Twenty-nine percent of the national respondents believe that this is effective in improving the safety awareness of employees, 59 percent believe that it is mildly effective, and 12 percent believe that it is ineffective. Seventy percent of the national respondents indicated minimal implementation of these incentives, 20 percent said they implement them occasionally, and 10 percent said they are a standard practice. Ninety-two percent of the national respondents recommend safety incentive programs while only 8 percent believe that they are too expensive to implement. Fifty percent of the state respondents believe that safety incentives are effective, 43 percent believe that they are mildly effective, and 7 percent believe that they are ineffective. Fifty percent of the state respondents indicated minimal implementation of safety incentives, 30 percent said they implement them occasionally, and 20 percent said that they are a standard practice. Fifty-eight percent of the state respondents recommend safety incentive programs, while 42 percent believe that they are too expensive.

Channeling Devices

### Camera Apparatus

Respondents were asked if project footage from camera apparatus installed in the work zones would be helpful to view when discussing safety actions. Twenty-seven percent of the national respondents believe that this is effective in discussing safety plans and actions, while 60 percent believe that it is mildly effective and 13 percent believe that it is ineffective. Of these national respondents, 80 percent said that they implement cameras for this purpose minimally, 10 percent implement them occasionally, and 10 percent implement them as a standard practice. Fifteen percent of the national respondents recommend cameras for this use, while 85 percent said that it would be too expensive. Forty-six percent of the state respondents believe that this idea is beneficial while discussing safety plans and actions, while 39 percent believe that it is mildly effective and 15 percent believe that it is ineffective. Seventy-three percent of the state respondents indicated that they implement cameras for this reason minimally, while 18 percent said that they implement them occasionally and nine percent said it is standard practice. Fifty percent of the state respondents recommend this practice while 50 percent think that it is cost prohibitive.

### Double-Stacking of Cones

Respondents were asked if cones should be double-stacked to prevent them from blowing into the travel way. Thirty-five percent of the national respondents believe that this is an effective measure in preventing channelizing devices from getting into the travel way, while 47 percent believe that it is mildly effective and 18 percent believe that it is ineffective. Thirty-three percent of the national respondents indicated minimal implementation of this idea, 56 percent said they implement it occasionally, and 11 percent said that it is standard practice. Ninety-two percent of the national respondents recommend that cones and barrels be doubled stacked to prevent them from blowing into

the travel way. Of the state respondents, 33 percent believe that this double-stacking method is effective, 50 percent believe that it is mildly effective, and 17 percent believe that it is ineffective. Fifty percent of the state respondents indicated minimal implementation of this idea, 42 percent said they implement it occasionally, and 8 percent said it is standard practice. Fifty percent of the state respondents recommend this idea and 50 percent believe that it costs too much.

### Barrel and Cone Maintenance

Respondents were asked, in general, if overall barrel and cone maintenance activities should be improved on nighttime construction projects. National and state respondents' answers showed general agreement. Eighty-nine percent of the national respondents believe that this is an effective idea and 11 percent believe that it is mildly effective. Forty-seven percent of the national respondents indicated that this is implemented occasionally and 47 percent indicated that it is standard practice. Six percent of the national respondents indicated minimal implementation. Ninety-four percent of the national respondents recommend that the maintenance of barrels and cones be improved while only 6 percent believes that it would cost too much. State respondents answered similarly. Sixty-two percent of the state respondents believe that this idea is effective and 38 percent believe that it is mildly effective. Thirty-six percent of the state respondents said that this is a standard practice, 46 percent said they implement this idea occasionally, and 18 percent showed minimal implementation of this idea. All of the state respondents recommend that barrel and cone maintenance activities be improved.

## Lane Closures

### Increased Number of Reflectors

Lane closures were identified by project site visits as a major safety concern/issue on nighttime construction projects. Respondents were asked a number of questions

regarding lane closures on nighttime projects. Respondents were asked if an increased number of reflectors commonly used throughout lane closures would be beneficial. Sixty-one percent of the national respondents believe that this is effective and 39 percent believe that it is mildly effective. Thirty-seven percent indicated that an increased number of reflectors in lane closures is a standard practice, while 58 percent said that they increase the number occasionally, and five percent said that they implement this strategy minimally. All of the national respondents recommend that the number of reflectors be increased in lane closures. Seventy-seven percent of the state respondents believe that this idea is effective; eight percent believe that it is mildly effective, and 15 percent believe that it is ineffective. Thirty-six percent of the state respondents indicated that they implement an increased number of reflectors minimally, 55 percent said they implement this strategy occasionally, and nine percent said it is a standard practice to implement the use of more reflectors. Sixty-seven percent of the state respondents recommend this idea while the other 33 percent believe that it is cost prohibitive.

## Enhanced Lane Closure Procedures

Setting up lane closure was found to be a particular safety concern on projects. A highway patrol car and crash truck, with flashing lights, to pace traffic while lane closures are being set up or removed may help in these situations. Respondents were asked what they thought about this technique. Sixty-five percent of the national respondents believe that this technique is effective and 35 percent believe that it is mildly effective. Thirty percent of the national respondents indicated minimal implementation of this technique, 45 percent said they implement it occasionally, and 25 percent said it is standard practice. Eighty-seven percent of the national respondents recommend this technique, while 13 percent believe that it is cost prohibitive. Almost all state respondents (92 percent) believe that this idea is effective while one of 12 believes that it is mildly effective. Fifty-five percent of the state respondents indicated minimal

implementation of this technique, while 36 percent said they implement it occasionally and 9 percent said it is standard practice. Sixty percent of the state respondents recommend this technique while 40 percent believe that it is cost prohibitive.

### Fines for Inappropriate Signage

Contractors often leave inappropriate signs showing throughout lane closures. Respondents were asked if contractors should be fined more for not having the proper speed limit signs showing before and inside lane closures. Twenty-seven percent of the national respondents agree that this strategy is effective, 40 percent believe it is mildly effective, and 33 percent believe that the idea is ineffective. Eighty percent of the national respondents indicated minimal implementation of this idea, five percent said they implement it occasionally, and 15 percent said that it is standard practice. Sixty-seven percent of the national respondents recommend that fines be increased while 33 percent believe that it would be too expensive to do so. State respondents answered somewhat similarly. Fifty-four percent believe that this idea is effective, 15 percent believe that it is mildly effective, and 31 percent believe that it is ineffective. Seventy-three percent of the state respondents indicated minimal implementation of increased fines while the rest (27 percent) said it is a standard practice. Fifty-eight percent of the state respondents recommend increased fines, while 42 percent believe that they are cost prohibitive.

## Traveling Equipment

### Pilot Vehicles

Respondents were asked if pilot vehicles should be used to lead traffic through lane closures on roads where the intended path of travel may not be clear. Sixty-five percent of the national respondents believe that this method is effective to show intended paths of travel and 35 percent believe that it is mildly effective. Thirty-five percent of the

national respondents indicated minimal implementation of pilot vehicles, 45 percent indicated occasional implementation, and 20 percent said it is a standard practice. Seventy-five percent of the national respondents recommend pilot vehicles be used, while 25 percent said that their use is cost prohibitive. Sixty-two percent of the state respondents believe that pilot vehicles are effective, 23 percent believe that they are mildly effective, and 15 percent believe that they are ineffective. Thirty-six percent of the state respondents indicated minimal implementation of pilot vehicles, 46 percent said they implement them occasionally, and 18 percent said they implement them as a standard practice. Seventy-five percent of the state respondents recommend their implementation and 25 percent believe that they are cost prohibitive.

## Drone Radar

Radar-triggering devices are sometimes installed in construction equipment and intended to "set-off" radar detectors in passing motorists' vehicles. Survey participants were asked what they think about this idea. National and state respondents were in general agreement. Forty-one percent of the national respondents believe that these devices are effective, 47 percent believe that they are mildly effective, and 12 percent believe that they are ineffective. Sixty-eight percent of the national respondents indicated minimal implementation of these devices, while 21 percent said they implement them occasionally and 11 percent said they implement them as a standard practice. Fifty percent of the national respondents recommend their implementation and 50 percent believe they are cost prohibitive. Sixty-one percent of the state respondents believe that these radar-triggering devices are effective, 31 percent believe that they are mildly effective, and eight percent believe that they are ineffective. Seventy-three percent of the state respondents indicated minimal implementation of these devices, 18 percent said they implement them occasionally, and nine percent said they implement them as a

standard practice. Forty-two percent of the state respondents recommend these devices be used, while 58 percent believe that they would cost too much.

## Equipment Back-up Alarms

Construction vehicles and/or equipment are often cited as a common cause for worker accidents on the job. A large majority of these accidents occur when vehicles and/or equipment are backing up. These vehicles could be equipped with improved back-up lights and alarms that are more alerting than normal. Thirty-one percent of the national respondents think this idea is an effective measure in improving the safety for workers, 56 percent believe that it is mildly effective, and 13 percent believe that it is ineffective. Sixty-eight percent of the national respondents said that they implement equipment with these types of alarming devices minimally, 11 percent said they implement them occasionally, and 21 percent said they implement them as a standard practice. Seventy-one percent of the national respondents recommend these devices on construction equipment, while 29 percent believe that they cost too much. Fifty-four percent of the state respondents believe that these devices are effective, 38 percent believe that they are mildly effective and 8 percent believe that they are ineffective. Fifty percent of the state respondents indicated minimal implementation of these devices, 33 percent said they implement them occasionally, and 17 percent said that they are standard practice. Fifty-eight percent of the state respondents recommend these devices on construction equipment, while 42 percent believe that it would cost too much to implement.

## Light Curtains

A new technology mentioned during one of the contractor interviews is “light curtains” installed on construction equipment. These curtains are basically laser beams that will detect movement within a certain range of construction equipment and shut

down automatically. Nineteen percent of the national respondents believe that this technology is effective in improving the safety of workers, 25 percent believe that it is mildly effective and 56 percent believe that it is ineffective. Eighty-nine percent of the national respondents rarely, or never, implement this technology, while 11 percent said that they implement it occasionally. Twenty-one percent of the national respondents recommend this technology be used, while 79 percent believe that it costs too much to implement. Of the state respondents, 46 percent believe that this technology is effective, 23 percent believe that it is mildly effective, and 31 percent believe that it is ineffective. Seventy-three percent of the state respondents indicated minimal implementation of this technology while nine percent said they implement it occasionally and 18 percent implement it as a standard practice. Forty-two percent of the state respondents recommend this technology, while 58 percent believe that it is cost prohibitive.

## Part C

This part of the survey was to give the respondents open-ended questions for chance to give recommendations, suggestions and insight about nighttime safety in addition to the survey answers. Listed below are the questions asked. The respondents provided insights of concepts already incorporated, ideas of concepts still to incorporate, as well as suggestions as to what could be incorporated. These valuable comments and suggestions were incorporated into the research and are incorporated throughout this report.

### Question 1

In this question, respondents were asked to list any other construction techniques or innovative practices that they think may lead to the overall improvement of the safety of worker personnel and passing motorists in work zones.

Question 2

In this question, respondents were asked to list any known research studies or reports within their state that have focused on the subject of work zone safety for nighttime construction.

Question 3

In this question, respondents were asked to identify any similar safety considerations/requirements for weekend construction.

# CHAPTER VII

# SUMMARY AND CONCLUSIONS

## Statistics Review

With the increase in the amount of construction for both national and state agencies, statistics regarding the amount of accidents and fatalities on highways were analyzed. The total numbers of accidents and fatalities for the nation as a whole have been at an increase over the past several years. The percentage of accidents, though, as far as vehicle miles traveled (VMT) and number of registered vehicles, has been at a slight decrease. At the state level, the number of accidents and fatalities has been at an increase, along with the percentage of accidents for VMT and registered vehicles. The research team believes that this is due primarily to the state's accelerated construction program.

Work zone accident and fatality statistics for both the nation and state indicate similar trends. Accidents and fatalities are on the rise. Even though many improvements have been made to improve the safety of work zones for workers and passing motorists in the past, the problem still exists. Further analysis of other statistics reveals factors affecting these statistics.

Statistics were analyzed on miscellaneous factors affecting safety of nighttime construction. Evidence shows that darkness, increased speeds, alcohol consumption, and driver inattentiveness all have an adverse effect on the overall safety of construction projects. Potential solutions to these factors were researched and considered in the recommendations of this report. Unfortunately, there are more alcohol related accidents in work zones at night than during the day. Researchers are led to believe that alcohol consumption is a major factor affecting the ability of passing motorists to drive safely

thorough work zones. Combined with darkness, excessive speeding, and driver inattentiveness, alcohol consumption by passing motorists creates an exceptionally dangerous environment in which to work. The importance of this cannot be over stated.

## Literature Review

The second phase of this project was a detailed literature review of, relevant documentation. Numerous documents, including research studies from governmental agencies and academia, were available for review. The objective of this phase was to identify potential safety concerns and issues with nighttime construction along with any possible ideas, construction techniques, or innovative technology presented as solutions to the issues. Evidence from the literature review shows a general consensus regarding safety issues and concerns that currently exist on nighttime construction projects.

A number of documents found in the literature review presented factors affecting construction operations at night. From these factors, decision-making models were formulated to help governmental agencies determine if they should perform construction operations at night instead of during the day. Some of the factors included in the decision making models were the safety of construction workers and passing motorists, costs associated with night-work, quality of work performed, productivity of work crews, anticipated traffic volumes, roadway capacities, congestion, traffic control, longer work periods, scheduling issues, contract incentives, and temperature concerns.

As the safety of workers and passing motorists was listed as a major factor affecting the decision to undergo nighttime construction operations, a number of research documents divided this factor into many specific nighttime safety issues and concerns. These issues and concerns were identified as lighting/glare, speeding by public traffic, retroreflectivity of signs and worker clothing, construction equipment, and awareness and alertness of public motorists.

Along with the safety issues and concerns that were presented in the literature review, various ideas, construction techniques, and innovative technologies were also presented as possible solutions to the issues and concerns. For example, some DOTs have taken measures to modify their specifications to include specific nighttime specification requirements such as lighting procedures. Also, many lighting systems are commercially available to help light construction areas with reduced glare for motorists. One researcher reported that with the correct lighting apparatus and procedures, quality and productivity on nighttime projects does not suffer (9). Other researchers presented ideas and technology believed to slow the speeds of motorists passing through work zones (29, 31, 32, 33). First, officers in the work zone were reported to have an impact on slowing motorists (29). Technology used for this purpose included variable message boards, rumble strips, drone radar, and speed display trailers (31, 32, 33). Other researchers found solutions to retroreflectivity issues (26, 28). The Computerized Analysis of Retroreflective Traffic Signs (CARTS) model was developed to help determine if traffic signs with retroreflective material were effective at night (26). Another researcher believes that workers can wear retroreflective bands of material around their limbs as an effective measure to counter heat problems associated with full body suits (28). Researchers also found that variable message boards, rumble strips, drone radar, and reduced reflector spacing help keep drivers' attention and keep them more alert (31, 32, 33).

## General

Many noticeable trends were found in the data in the "General" data section of Part A. It is confirmed that a majority of DOT personnel commonly perceive nighttime construction operations as more unsafe than during daytime hours. The remainder of the survey was designed to acquire information about why this may be true. The "General" section also informed researchers that more state respondents believe quality is

negatively impacted by nighttime construction than do national respondents. Half of the state respondents also believe that OSHA violations are less likely to be strictly enforced at night. Other interesting findings include the fact that most state respondents believe contractor personnel are not currently receiving adequate nighttime specific safety training. Differences between state and national responses are summarized in Chapter VI and detailed in Appendix C.

### Lighting

The "Lighting" section of Part A confirmed that the lighting/illumination of work areas is obviously a major concern for both national and state respondents on nighttime projects. Not only is having adequate light a problem, having too much blinding light / glare presents an unsafe scenario for passing motorists. Lighting related issues was discussed at length within the report.

### Public Traffic

General trends were apparent in the data for the "Public Traffic" section of Part A. First, respondents seemed to believe that public traffic can lead to unsafe scenarios in a number of ways. The most obvious way is excessive speeding by public motorists through construction work zones. Overall, the majority of both national and state respondents believe that this is true. According to survey participants, another way that public traffic can negatively impact safety on a project is by leaving their cars stranded in work zones. Overall, though, national respondents believe that there is enough police force in their state to adequately monitor public traffic through construction work zones at night. On the other hand, over half of the state respondents believe that there is inadequate law enforcement within SC to police construction activities at night.

## Employees

The "Employees" section of Part A confirmed that national respondents believe workers' reflective clothing is adequate and does not lead to safety issues for nighttime construction projects. On the other hand, the majority of state respondents believe that workers' reflective clothing may be inadequate at present. Also, the majority of state respondents believe that contractor personnel are not receiving adequate training specific to nighttime construction. The majority of all respondents believe that DOT resources are sufficient to monitor these projects, but more state respondents than national respondents believe that nighttime construction activities may be subject to the effectiveness of DOT personnel monitoring safety performance.

## Signage and Channelizing Devices

From the "Signage and Channelizing Devices" section of Part A, the main problem that respondents identified is that contractors often leave inappropriate signs showing during non-construction hours. Overall, respondents believe that contractors use appropriate signage for nighttime construction projects.

## Lane Closures

A major finding from the "Lane Closures" section of Part A is that the majority of respondents believe that lane closures present safety concerns for contractor personnel at night. This is primarily due to the fact that at the time workers are dealing with lane closures, they are working very close to the public travel way. SC respondents believe that maintenance of these lane closures presents major safety issues for contractor personnel as well.

## Traveling Equipment

The "Traveling Equipment" section of Part A of the questionnaire survey revealed no major safety issues associated with traveling construction equipment. The majority of

respondents believe that motorists and workers can adequately identify traveling equipment and that this issue does not adversely impact safety performance in a significant way.

Part B—Innovative Practices

### General

The "General" section of Part B of the survey identified a potential method to improve the overall safety of construction projects for both workers and public motorists. Differences and similarities between the state and national respondents were presented in Chapter VI. See Appendix C for a graphical presentation of the findings. General summary remarks are below.

### Prequalification

The majority of respondents believe that pre-qualification of contractors is an effective method. Overall, respondents indicated minimal implementation of this method, yet recommended that it be done on a regular basis.

### Lighting and Illumination

The "Lighting and Illumination" section of Part B of the survey identified potential solutions to improve the lighting of construction projects at night. Respondents indicated that they believe soft-glow illumination balloon lights are an effective system for lighting construction projects as well as reducing glare to passing motorists. The majority of respondents indicated at least an occasional amount of implementation of the lighting systems, yet recommended their use.

## Public Traffic

The "Public Traffic" section of Part B identified many potential ideas, techniques, and technology believed to improve the overall safety of nighttime construction projects. The majority of respondents indicated that they believe visible law enforcement helps modify driver behavior through work zones. With noticeable law enforcement the public traffic is more likely to abide by rules and regulations in the work zone. Respondents also believe that the Wizard CB system is effective in alerting truckers of upcoming work zones. Although some respondents believe this technology is expensive, it may be beneficial in improving overall safety of work zones. Respondents also believe that full-time towing services hired specifically for construction projects would help improve safety by preventing stranded cars from being left along the roadside in work zones. The last idea/technology identified in this section is transverse rumble strips. The majority of respondents believe that these devices are effective in capturing the driver's attention. Respondents indicated minimal implementation, yet recommended that they be deployed.

## Signage

The "Signage" section of Part B identified potential solutions regarding signage issues. Overall, respondents showed approval for three different sign types. First, speed-monitoring displays throughout work zones are an effective means of notifying motorists of their speeds. Similarly, variable message boards are an effective way to inform motorists of upcoming work zone conditions. "Workers Present When Flashing" signs are helpful in alerting the public when workers are present in the work zones. Overall, respondents showed at least an occasional amount of implementing these signs, yet recommended that they be deployed.

## Employees/Worker Personnel

This section of Part B identified potential solutions for issues related to employees and worker personnel. State respondents indicated that they believe enhancements to the retroreflective material on worker clothing is an effective measure for improving their safety. All respondents believe that nighttime-specific training for contractor personnel is also effective. Respondents indicated minimal implementation of these practices, yet recommended that they be used.

## Channelizing Devices

This section of Part B of the survey recognized the need to improve maintenance of channelizing devices throughout nighttime construction projects. Respondents believe that this is an effective measure for improving the overall safety on projects. Improved maintenance of cones and barrels was recommended by the majority of respondents.

## Lane Closures

The "Lane Closures" section of Part B of the survey identified a method to improve the safety of workers during lane closure procedures. The majority of respondents believe that a highway patrol car and crash truck pacing traffic while lane closures are being set-up or taken down is an effective measure to improve their safety. Respondents indicated minimal implementation of this procedure, yet recommended that it be used. Another issue with lane closures that was identified was the covering of inappropriate signs by contractors. The majority of respondents believe that contractors could do a better job at covering improper signs.

## Traveling Equipment

Part A of the survey did not identify any particular safety issues with traveling equipment on construction projects, yet Part B did recognize that some enhancements could be made to improve the safety of workers around the equipment. Respondents indicated that contractors could use equipment with enhanced "identification systems"

when they are backing up. More noticeable alarming sounds and flashing lights were recommended by respondents.

# CHAPTER VIII

# RECOMMENDATIONS

Based on the research conclusions presented in the previous chapter, the research team has prepared a list of recommendations to the South Carolina Department of Transportation. The research team recommends further study be conducted on the cost of implementation and economic impact of the following:

## General

- Formulate a decision making process, based on the factors that affect nighttime work, to decide if any specific project is more feasible at night than during the day. Consider the fact that alcohol consumption by public motorists is higher at night.

- If the decision to undergo nighttime construction projects is made, implement stronger enforcement of compliance to all applicable OSHA and MUTCD standard safety practices. Require more formal training programs by contractors for their employees. Consider OSHA voluntary programs as a means of ensuring standard safety practice compliance.

- Develop a pre-qualification process for contractors based on existing safety records.

- Designate a section in the SCDOT Standard Specifications to nighttime construction operations. Address the unique requirements of nighttime construction.

- Establish strong incentives for contractors that finish jobs without having employee and public motorist accidents.

## Lighting

- Lighting considerations for nighttime construction remain a national concern. Current SCDOT specifications are comparable to other state requirements and provide adequate direction/instruction for contractor personnel. However, it should be noted that lighting design, and lighting technology, is changing fairly rapidly with in the United States. Every DOT should keep abreast of new lighting techniques, stay current with literature, and consider updating lighting specifications on a more regular basis than is typically practiced. It is

recommended that the state(s) consider experimental applications of new lighting technologies. A more structured research approach is necessary to develop detailed lighting specifications that utilize new or innovative lighting approaches. Lighting specifications must remain broad to accommodate the wide variety of site characteristics that may be encountered.

- Adopt the use of soft-glow illumination balloon lights as a standard practice and replace other lighting systems that often lead to glare that blinds motorists.

## Public Traffic

- Consider adding full-time towing services and law-enforcement as line items in contracts when site conditions permit this option. Consider mandating full time highway or sheriffs' patrol on the project for enforcement of traffic regulations as a pay item in SCDOT contracts. One option would be to certify highway patrolmen to enforce OSHA regulations and administer citations for standard safety practice violations as described in this report.

- Deploy temporary rumble strips at the entrance to work zones to attract the attention of passing motorists.

- Load the public with information regarding local workzones through the use of websites, newspapers, TV news, etc. Establish a local phone number such as "511" that the public can call to hear about local workzone conditions and any upcoming construction.

- Implement use of the Wizard CB system to alert commercial truckers of upcoming workzones. This technology would be particularly helpful in alerting out-of-state truckers.

- Recommend that employees are certified in workzone traffic control.

## Employees

- Require contractors to make improvements to the reflective material on worker clothing. Require full compliance with SCDOT clothing requirements. Compliance efforts must be a priority.

- Address the issue of employee training on nighttime construction projects. Require contractors to offer more formal training programs. Do not allow workers on the jobsite until they have completed all relevant training programs.

## Signage

- Install speed-monitoring displays throughout work zones to inform motorists of their traveling speeds.

- Increase the use of variable message boards to inform public motorists of upcoming work zone conditions.

- For long-term construction projects, deploy "Workers Present When Flashing" signs. Only flash the lights when workers are actually in the work zone.

## Illumination and Reflectors

- Increase the number of reflectors used in work zones to provide better delineation for the travel way of public motorists.

- Enforce replacement of missing, old, or ineffective reflectors.

## Channeling Devices

- Address the issue of the quality of channelizing devices and other safety equipment. Create a minimum standard level of quality for these devices.

- Implement stronger enforcement of the maintenance of channelizing devices by contractor personnel.

## Traveling Equipment

- Require contractors to use construction equipment with enhanced alarming mechanisms to alert workers of their presence. Lights that flash when backing up or alarms that sound even greater than the common "beeping."

- Consider installing drone radar in construction equipment to set off the radar detectors of passing motorists.

Lane Closures

- Enforce contractors to take better care in covering inappropriate speed limit signs in lane closures. If these signs are showing, the public may have the perception that they can still travel at the normal speed limit.

***APPENDICES***

Appendix A

Compiled Work Zone Data Collection Form

## Nighttime and Weekend Construction Checklist

**Location:** sample
**Contractor:** sample
**Project Manager:** sample
**Date:** sample
**Time:** sample
**Description of Work:** sample

### Public Traffic

- Are proper measures taken to keep motorists obeying posted rules to assure safe conditions for workers and themselves (MUTCD, Inspectors, Project Managers--PM's)?

    - Enough Signs → ***YES, too many, see comment 1***
    - Proper Signs → ***NO, see comment* 2**
    - Highway Patrol → ***NO, see comments 3, 4***
    - Wrecker Service (remove disabled vehicles)→ ***NO, see comment 5***
    - Emergency Radio Stations in Work Zone _____

**Comments:**

1) *There were too many signs, motorists became overwhelmed with too much info*
2) *Improper speed limit signs were not covered.*
3) *Highway Patrol arrived very late to jobsite; traffic was very confused until they arrived.*
4) *No full time officers, only 1 or 2 to patrol jobsites from county line to county line.*
5) *Statement: Job was only temporary, therefore we don't need it*

### Signage

- Are all signs in good and readable condition (MUTCD)? →***NO see comment 1***
- Are all signs placed at correct angle to be seen from oncoming traffic's headlights (Inspectors, PM's)? _____
- Do any signs contradict each other (Inspectors, PM's)? _____

- Are damaged signs replaced in a timely manner (MUTCD, Inspectors, PM's)? _____
- Are non-applicable signs covered in a proper and timely manner (MUTCD)? ***→NO see comment 2***
- Are signs positioned properly for adequate warning of work zone conditions (PM's, MUTCD, Inspectors)? → ***NO see comment 3***
- Are traffic signals within the work zone functioning properly (MUTCD)? _____
- Are signal heads positioned and adjusted to match active lanes in the work zone (PM's, Inspectors)? _____

**Comments:**

1) *Signs are not readable, contractor suggested new type of composite sign for temporary signs.*
2) *Many speed limit signs not covered in lane closure.*
3) *Message boards not placed correctly (not required 2 miles back from start of lane closure) to give adequate warning.*

**Illumination and Reflectors**

- Are paint lines clearly visible at night (MUTCD)? ***→ NO, see comment 1***
- Are paint lines correct widths (MUTCD)? _____
- Are all lollipop reflectors in place and visible (MUTCD)? _____
- Are all reflectors on side of barrier wall in place and visible (MUTCD, Inspectors)? _____
- Is barrier wall too dull at night (MUTCD, Inspectors)? _____
- Are all RPM's in place and visible (MUTCD)? ***→ NO, see comment 1***
- Have all unnecessary RPM's been removed (MUTCD, Inspectors)? _____
- Are message boards flashing properly (MUTCD)? ***→NO see comment 2***
- Are message boards clear and concise (MUTCD)? ***→NO see comment 2***
- Are channeling devices properly illuminated (MUTCD)?**→NO see *comment 3***

**Comments:**

1) *Paint lines and RPM's do not represent clear paths. Doubling up on reflectors is one way to help see in extra dark areas or during bad weather conditions.*
2) *Message boards flashing to fast for motorist to read information before passing.*
3) *Cones and barrels have been run over so many times they are too scuffed up to see clearly.*

Lane Closures

- Are lane closures properly set up and taken down (MUTCD, PM's, Inspectors)? ***→YES, but not as safe as could be, see comment 1***
- Do lane closures exceed maximum length (MUTCD)? _____
- If more than one lane closure, are they the minimum length apart (MUTCD)? _____
- Are all arrow boards in correct place and working properly (MUTCD)? _____
- Is crash truck in place (MUTCD)? ***→NO, see comment 2***
- Is crash truck attenuator in working order (MUTCD)? _____
- Is crash truck attenuator properly illuminated (MUTCD)? _____

**Comments:**

1) *Lane closures are being set up and taken down according to MUTCD and specs, but there are no rolling roadblocks by police or crash trucks following them on many high speed roads.*
2) *Crash truck would be in place initially, but as the work moved further down the way, no one would follow with the crash truck.*

**Lighting**

- Do floodlights cause a glare problem for motorists (MUTCD)? ***→YES, see comment 1***
- Is work area adequately lit for safe work (MUTCD)? ***→NO, see comment 2***
- Are proper warning lights being used (MUTCD)? _____
- Are screens used if appropriate (MUTCD)? _____

**Comments:**

1) *Lights would be pointed directly in to the flow of traffic virtually blinding motorists.*
2) *Workers could not see properly in many cases, in one instance they were working by truck lights.*

**Shoulder Conditions**

- Are disturbed shoulders properly identified by placement of barrels MUTCD)? _____
- Are any drop-offs greater than 2" (PM's, Inspectors, Specs)? _____
- Tapers adjacent to travel lanes 6:1 or flatter (PM's, Inspectors, Specs)? _____

- Stored material & parked equipment are 30' or more from unprotected roadway (PM's, Inspectors, Specs)? _____

**Comments:**

**Channeling Devices**

- Are all cones, barricades, and barrels properly spaced (MUTCD)? _____
- Are all cones, barricades, and barrels standing (PM's, Inspectors, MUTCD)? ***→ NO, see comment 1***
- Are all cones, barricades, and barrels properly managed (PM's, Inspectors)? ***→NO, see comment 1***
- Do all channeling devices represent a clear traveling path (MUTCD)? ***→ NO, see comment 2***
- Are cones, barricades, and barrels interrupting the flow of traffic (MUTCD)? ***→YES, see comment 1***

**Comments:**

1) *Cones and barrels would be knocked down for over an hour at times and traffic crew would pass by and not pick them up.*
2) *Some cones, barrels, reflectors would confuse motorists merging to off and on ramps.*

**Traveling Equipment (dump trucks, concrete trucks, front end loaders, etc.)**

- Are all signals, illumination and backup alarms working properly?

  1) Yes ____ No _____
  2) Yes ____ No _____
  3) Yes ____ No _____
  4) Yes ____ No _____→ → → ***NO, see comment 1***
  5) Yes ____ No _____
  6) Yes ____ No _____
  7) Yes ____ No _____

- Are dump trucks and concrete trucks driving safely and obeying traffic rules _____
- Are employees driving company trucks driving safely and obeying traffic rules _____

**Comments:**

1) *Back up alarms would not be functioning and Inspectors would know, but still allow the equipment on the jobsite.*

**Attenuators**

- Are attenuators in proper working order (MUTCD)? _____
- Are attenuators properly illuminated (MUTCD)? _____

**Comments:**

**Employees**

- Are employees paying attention to work area and surroundings (PM's, Inspectors)? _____
- Are employees equipped with proper communication devices (radios, phones)? _____
- Are employees horse playing (PM's, Inspectors)? _____
- Are employees operating equipment correctly (OSHA)? →***NO, see comment 1***
- Are employees wearing proper safety equipment and illumination (MUTCD, OSHA)?
    - Hardhats → ***NO, see comment 2***
    - Safety Glasses → ***NO, see comment 2***
    - Vests → ***NO, see comment 2***
    - Steel toe shoes → ***NO, see comment 2***
    - Gloves → ***NO, see comment 2***
    - Other safety equipment needed → ***NO, see comment 2***

- Are flaggers properly dressed (MUTCD)?
    - Orange Shirt _____
    - Vest _____

- Are flaggers obeying correct procedures (MUTCD)?
    - Correct motions _____
    - Correct signs _____
    - Proper Radio Communication _____

- Are flaggers standing in correct positions (MUTCD)? _____

- Are flaggers trained and briefed on correct procedures (MUTCD)? _____
- Do flaggers adequately speak the same language (PM's, Inspectors)? _____
- Are truck spotters properly dressed (MUTCD)?
  - Vest _____
  - Flag or Signal Flashlight _____

**Comments:**

*1)* Employees would be running across beams without being tied off at all
*2)* Employees would not be wearing vests, or hardhats, gloves, and safety glasses when procedures required them.

Appendix B

Raw Survey Form

**Survey of Current and Proposed Practices**
**For Nighttime Construction Activities**

South Carolina Department of Transportation

## INTRODUCTION

Clemson University has been selected to conduct research on the topic of "Safety Considerations for Nighttime Construction Activities" for the South Carolina Department of Transportation. The objectives of this research are two fold. The first objective is to identify the safety issues related to current nighttime construction practices. The second objective is to identify construction techniques, ideas, and innovative technology that may help mitigate adverse impacts resulting from nighttime construction activities. Please assist us in this research by answering the questions below from your experienced perspective. Your cooperation and truthfulness in completing this survey is greatly appreciated. Data resulting from this survey will only be reported in summary form. Individual responses will not be identifiable to protect the confidentiality of all respondents. It is anticipated that the time required to complete this survey is approximately twenty minutes. Please reply by Friday, April 25. Thank you in advance for your cooperation.

Please return the completed survey by email or fax to:

Dr. W. Edward Back, Room 200, Lowry Hall
Department of Civil Engineering, Clemson University
Clemson, South Carolina 29634-0911
Fax: (864) 656-2670 Phone: (864) 656-2818
Email: wmeback@ces.clemson.edu

**Respondent Information:**

**State:** _____

**Name:** _____

**Title:** _____

**Email:** _____

What percent of your general construction activity is performed at night? _____

## A. Current Safety Observations

This section addresses typical issues or concerns related to nighttime construction activities. Please complete this section by selecting a phrase that most closely corresponds to your observations of current practices within your state.

Select the phrase that most closely represents your professional opinion. Mark the selection by placing an "X" over the circle.

**SD - Strongly Disagree**
**D - Disagree**
**U - Undecided**
**A - Agree**
**SA - Strongly Agree**

***Example***

This research study will prove very effective in increasing safety on nighttime construction projects.

(SD) (D) (U) (A) 

***General***

Construction work performed at night is often more unsafe than if the same work is performed during daytime hours.

(SD) (D) (U) (A) (SA)

Quality is often negatively impacted as a result of nighttime construction.

(SD) (D) (U) (A) (SA)

Construction productivity is often negatively impacted during nighttime construction.

(SD) (D) (U) (A) (SA)

OSHA standards are less likely to be followed by contractors during nighttime operations.

(SD) (D) (U) (A) (SA)

Contractor personnel in your state are not currently receiving adequate safety training for nighttime construction.

(SD) (D) (U) (A) (SA)

Contractors within your state do not differentiate between daytime and nighttime safety considerations.

(SD) (D) (U) (A) (SA)

Your state DOT requires unique or proactive safety practices for nighttime construction operations.

(SD) (D) (U) (A) (SA)

Your state DOT recommends unique or proactive safety practices for nighttime construction operations.

(SD) (D) (U) (A) (SA)

***Lighting***

Lighting (illumination) is often inadequate and/or unevenly distributed to support nighttime work zone activities.

SD D U A SA

Glare, sufficient to blind motorists, is a common occurrence at night.

SD D U A SA

***Public Traffic***

There is often inadequate law enforcement within your state to police work zone activities during nighttime construction activities.

SD D U A SA

Stranded motorists' vehicles, within the work zone, are a greater safety concern during nighttime construction projects.

SD D U A SA

Excessive speeding by public motorists through construction work zones is more prevalent doing nighttime construction.

SD D U A SA

Public motorists are often unaware that they are entering a construction work zone at night.

SD D U A SA

***Employees***

Workers' reflective clothing is often inadequate for nighttime construction.

SD D U A SA

Contractors often do not adequately train personnel for the safety requirements/concerns unique to nighttime construction.

SD D U A SA

Contractors often do not execute adequate safety plans for nighttime construction.

SD D U A SA

State DOT resources are often not sufficiently available to provide adequate inspection / monitoring of nighttime construction.

SD D U A SA

Nighttime construction activities often negatively impact inspector personnel alertness and effectiveness when monitoring safety.

SD D U A SA

***Signage and Channeling Devices***

Contractors often employ inadequate or improper signage for nighttime construction operations.

SD D U A SA

Contractors often leave inappropriate signs showing during non-construction hours.

SD D U A SA

Reflectivity issues often hinder the effectiveness of signage at night.

SD D U A SA

Contractors within your state generally do not appreciate the unique considerations associated with nighttime signage.

SD D U A SA

Channeling devices and RPMs (Raised Pavement Markings) in work zones are often maintained inadequately to sustain adequate retro reflectivity at night.

SD D U A SA

Channeling devices and RPMs in work zones are often placed in a manner that creates confusion to the traveling public at night.

SD D U A SA

***Lane Closures***

Setting up/taking down lane closures presents particular safety concerns for contractor personnel at night.

SD D U A SA

Improper or insufficient maintenance of lane closures is a major issue on nighttime construction projects.

SD D U A SA

***Traveling Equipment***

The inability of passing motorists to identify construction vehicles, during nighttime construction, creates a hazard to the public.

SD D U A SA

Construction equipment is often not equipped with the proper identification devices to alert workers of their presence.

SD D U A SA

## B. Innovative Practices

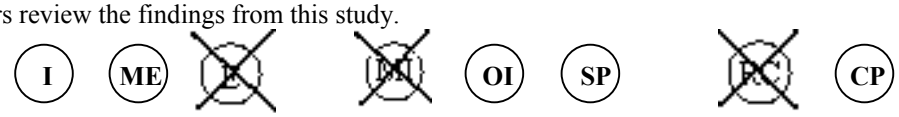
This section presents new ideas, techniques, or innovative technologies that may prove effective in efforts to improve safety performance for nighttime construction operations. Please complete this section by choosing **three** values for each line item that most closely corresponds to your assessment of the effectiveness, applicability, and appropriateness of each item.

Select a phrase from each of the subgroups listed below that most closely represents your professional opinion. Mark the selections by placing an "X" in the circle.

| | | |
|---|---|---|
| **I - Ineffective** | **MI - None / Minimal Implementation** | **RC - Recommended** |
| **ME - Mildly Effective** | **OI - Occasional Implementation** | **CP - Cost Prohibitive** |
| **E - Effective** | **SP - Standard Practice** | |

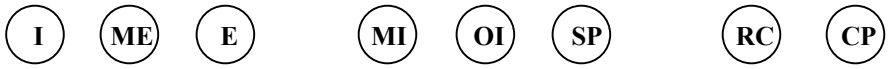
***Example***

Contractors review the findings from this study.

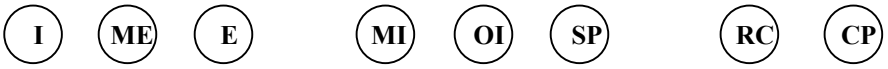



***General***

Pre-qualification of contractors based on safety records.

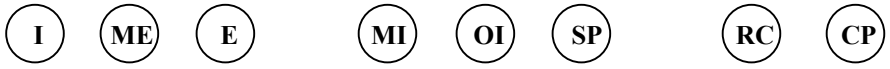



Pre-qualification of contractors based on an itemized inventory of safety equipment.

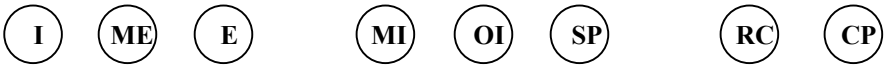



***Lighting and Illumination***

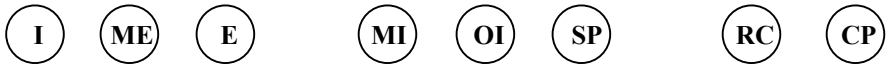
Semi-stationary soft-glow illumination "balloon lights" to light construction work areas.




Semi-stationary soft-glow illumination "balloon lights" employed to prevent glare blindness for passing motorists.

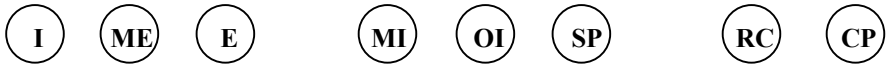



Lighting apparatus attached to operating equipment to light construction activities within the work zone.

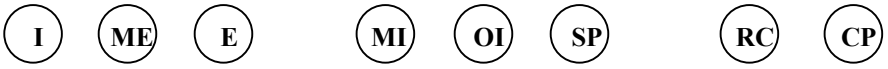



***Public Traffic***

Traffic enforcement by full-time highway patrolmen throughout the work zone.




Adaptive Cruise Control technology (automatically decreases the speed of vehicles entering work zones).



***Public Traffic (cont.)***

Wizard CB System (e.g. inform truckers at 30 second intervals of upcoming work zones).

I ME E MI OI SP RC CP

Intrusion Detection Alarms (sounds alarms or sirens when an unauthorized vehicle enters work zone.)

I ME E MI OI SP RC CP

Full-time towing services employed to assist stranded vehicles.

I ME E MI OI SP RC CP

Designated phone number (example: 511) for information on local work zones.

I ME E MI OI SP RC CP

Public notices of conditions in local work zones (ex. Website, newspaper section, TV news, etc.).

I ME E MI OI SP RC CP

Banning of cell phone usage within a specified distance of work zones.

I ME E MI OI SP RC CP

Rumble-strips used as a means of capturing the driver's attention when entering work zones.

I ME E MI OI SP RC CP

***Signage***

Mandatory "Workers Present when Flashing" signs to alert motorists of workers in work zones.

I ME E MI OI SP RC CP

Changeable message signs used instead of standard signage to inform motorists of conditions throughout the work zone.

I ME E MI OI SP RC CP

Use of a radar board, with flashing lights, to inform motorists of their speed when entering the work zone.

I ME E MI OI SP RC CP

Changeable message sign indicating the number/frequency of speeding violations issued by law enforcement in the previous week (or certain time period).

I ME E MI OI SP RC CP

Limiting the number of re-uses of signs by contractors to ensure that minimum legibility by passing motorists is maintained.

I ME E MI OI SP RC CP

Frequent contractor notification of newest sign technology available for nighttime construction.

I ME E MI OI SP RC CP

***Employees / Worker Personnel***

Improved retroreflectivity outfitting of employees/worker personnel in work zones (Class III Garments).

I ME E MI OI SP RC CP

Specific nighttime safety training for new-hires.

I ME E MI OI SP RC CP

Require specific nighttime safety training at regular time intervals for all construction personnel.

I ME E MI OI SP RC CP

Anonymous documentation on "lessons learned" and "near misses" to provide useful information on current and future projects.

I ME E MI OI SP RC CP

Contractor safety incentive programs to promote the awareness of safety concerns and issues of their employees.

I ME E MI OI SP RC CP

Installation of a camera apparatus in the work zone to permit the use of actual project film footage when discussing safety actions.

I ME E MI OI SP RC CP

***Channeling Devices***

Double-stack cones to prevent them from blowing into travel way.

I ME E MI OI SP RC CP

Improved barrel and cone set-up and maintenance activities.

I ME E MI OI SP RC CP

Decreased spacing of reflectors and RPMs commonly used to show travel ways through work zone.

I ME E MI OI SP RC CP

***Lane Closures***

Highway patrol car and crash truck, with flashing lights, to pace traffic while lane closures are being set up or removed.

I ME E MI OI SP RC CP

More fines to contractors for not having the proper speed limit signs placed before and inside lane closures.

I ME E MI OI SP RC CP

"Pilot vehicles" to lead traffic through lane closures on roads where travel way may not be clear.

I ME E MI OI SP RC CP

***Traveling Equipment***

Radar triggering devices in construction equipment to "set-off" radar detectors in passing motorists' vehicles.

I ME E MI OI SP RC CP

Construction vehicles equipped with back-up lights that flash rapidly when backing up.

I ME E MI OI SP RC CP

"Light curtains" (laser beams) on large construction equipment so the equipment will shut down when movement is detected within the work zone.

I ME E MI OI SP RC CP

## C. Other Recommendations

1. Please list any other construction techniques or innovative practices that may lead to improvements to overall safety performance.

2. List any known research studies or reports within your state that have focused on the subject of work zone safety for nighttime construction.

3. While this survey is particularly focused on nighttime construction operations, are there similar issues/considerations you can identify for weekend construction? If so, please list all such issues below.

4. Comments

Appendix C

Survey Summary Data

## Part A - Current Safety Observations
## National and State Respondents

### General

| Construction work performed at night is often more unsafe than if the same work is performed during daytime hours. | | | | |
|---|---|---|---|---|
| | National | | State | |
| Total Responses | 20 | % | 16 | % |
| Strongly Disagree | 0 | 0.00% | 0 | 0.00% |
| Disagree | 5 | 25.00% | 3 | 19.00% |
| Undecided | 1 | 5.00% | 0 | 0.00% |
| Agree | 11 | 55.00% | 10 | 62.00% |
| Strongly Agree | 3 | 15.00% | 3 | 19.00% |

| Quality is often negatively impacted as a result of nighttime construction. | | | | |
|---|---|---|---|---|
| | National | | State | |
| Total Responses | 20 | % | 16 | % |
| Strongly Disagree | 2 | 10.00% | 1 | 6.00% |
| Disagree | 8 | 40.00% | 3 | 19.00% |
| Undecided | 2 | 10.00% | 1 | 6.00% |
| Agree | 7 | 35.00% | 5 | 31.00% |
| Strongly Agree | 1 | 5.00% | 6 | 38.00% |

| Construction productivity is often negatively impacted during nighttime construction. | | | | |
|---|---|---|---|---|
| | National | | State | |
| Total Responses | 20 | % | 16 | % |
| Strongly Disagree | 1 | 5.00% | 0 | 0.00% |
| Disagree | 7 | 35.00% | 8 | 50.00% |
| Undecided | 4 | 20.00% | 0 | 0.00% |
| Agree | 8 | 40.00% | 6 | 37.50% |
| Strongly Agree | 0 | 0.00% | 2 | 12.50% |

| OSHA standards are less likely to be strictly enforced during nighttime operations. | | | | |
|---|---|---|---|---|
| | National | | State | |
| Total Responses | 20 | % | 16 | % |
| Strongly Disagree | 4 | 20.00% | 0 | 0.00% |
| Disagree | 11 | 55.00% | 7 | 44.00% |
| Undecided | 3 | 15.00% | 1 | 6.00% |
| Agree | 2 | 10.00% | 8 | 50.00% |
| Strongly Agree | 0 | 0.00% | 0 | 0.00% |

| Contractor personnel in your state are not currently receiving adequate safety training for nighttime construction. | | | | |
|---|---|---|---|---|
| | National | | State | |
| Total Responses | 20 | % | 16 | % |
| Strongly Disagree | 0 | 0.00% | 0 | 0.00% |
| Disagree | 5 | 25.00% | 0 | 0.00% |
| Undecided | 12 | 60.00% | 6 | 38.00% |
| Agree | 3 | 15.00% | 7 | 44.00% |
| Strongly Agree | 0 | 0.00% | 3 | 19.00% |

| Contractors within your state do not differentiate between daytime and nighttime safety considerations. | | | | |
|---|---|---|---|---|
| | National | | State | |
| Total Responses | 20 | % | 16 | % |
| Strongly Disagree | 1 | 5.00% | 1 | 6.00% |
| Disagree | 12 | 60.00% | 11 | 69.00% |
| Undecided | 4 | 20.00% | 2 | 13.00% |
| Agree | 3 | 15.00% | 1 | 6.00% |
| Strongly Agree | 0 | 0.00% | 1 | 6.00% |

| Your state DOT requires unique or proactive safety practices for nighttime construction operations. | | | | |
|---|---|---|---|---|
| | National | | State | |
| Total Responses | 20 | % | 16 | % |
| Strongly Disagree | 1 | 5.00% | 0 | 0.00% |
| Disagree | 3 | 15.00% | 3 | 19.00% |
| Undecided | 3 | 15.00% | 1 | 6.00% |
| Agree | 12 | 60.00% | 8 | 50.00% |
| Strongly Agree | 1 | 5.00% | 4 | 25.00% |

| Your state DOT recommends unique or proactive safety practices for nighttime construction operations. | | | | |
|---|---|---|---|---|
| | National | | State | |
| Total Responses | 20 | % | 16 | % |
| Strongly Disagree | 1 | 5.00% | 0 | 0.00% |
| Disagree | 2 | 10.00% | 3 | 19.00% |
| Undecided | 3 | 15.00% | 1 | 6.00% |
| Agree | 12 | 60.00% | 9 | 56.00% |
| Strongly Agree | 2 | 10.00% | 3 | 19.00% |

## Lighting

| Lighting (illumination) is often inadequate and/or unevenly distributed to support nighttime work zone activities. | | | | |
|---|---|---|---|---|
| | National | | State | |
| Total Responses | 20 | % | 16 | % |
| Strongly Disagree | 0 | 0.00% | 0 | 0.00% |
| Disagree | 5 | 25.00% | 1 | 6.00% |
| Undecided | 4 | 20.00% | 1 | 6.00% |
| Agree | 11 | 55.00% | 11 | 69.00% |
| Strongly Agree | 0 | 0.00% | 3 | 19.00% |

| Glare, sufficient to blind motorists, is a common occurrence at night. | | | | |
|---|---|---|---|---|
| | National | | State | |
| Total Responses | 20 | % | 16 | % |
| Strongly Disagree | 0 | 0.00% | 0 | 0.00% |
| Disagree | 2 | 10.00% | 1 | 6.25% |
| Undecided | 8 | 40.00% | 2 | 12.50% |
| Agree | 10 | 50.00% | 11 | 68.75% |
| Strongly Agree | 0 | 0.00% | 2 | 12.50% |

## Public Traffic

| There is often inadequate law enforcement within my state to police work zone activities during nighttime activities. | | | | |
|---|---|---|---|---|
| | National | | State | |
| Total Responses | 20 | % | 16 | % |
| Strongly Disagree | 1 | 5.00% | 0 | 0.00% |
| Disagree | 9 | 45.00% | 5 | 31.00% |
| Undecided | 4 | 20.00% | 1 | 6.00% |
| Agree | 4 | 20.00% | 6 | 38.00% |
| Strongly Agree | 2 | 10.00% | 4 | 25.00% |

| Standard motorists' vehicles, within the work zone, are a greater safety concern during nighttime construction projects. | | | | |
|---|---|---|---|---|
| | National | | State | |
| Total Responses | 20 | % | 16 | % |
| Strongly Disagree | 0 | 0.00% | 0 | 0.00% |
| Disagree | 5 | 25.00% | 2 | 13.00% |
| Undecided | 5 | 25.00% | 1 | 6.00% |
| Agree | 9 | 45.00% | 4 | 25.00% |
| Strongly Agree | 1 | 5.00% | 9 | 56.00% |

| Excessive speeding by public motorists through construction work zones is more prevalent during nighttime construction. | | | | |
|---|---|---|---|---|
| | National | | State | |
| Total Responses | 20 | % | 16 | % |
| Strongly Disagree | 0 | 0.00% | 0 | 0.00% |
| Disagree | 3 | 15.00% | 2 | 12.50% |
| Undecided | 8 | 40.00% | 3 | 18.75% |
| Agree | 7 | 35.00% | 5 | 31.25% |
| Strongly Agree | 2 | 10.00% | 6 | 37.50% |

| Public motorists are often unaware that they are entering a construction work zone at night. | | | | |
|---|---|---|---|---|
| | National | | State | |
| Total Responses | 20 | % | 16 | % |
| Strongly Disagree | 4 | 20.00% | 1 | 6.25% |
| Disagree | 12 | 60.00% | 10 | 62.50% |
| Undecided | 2 | 10.00% | 2 | 12.50% |
| Agree | 2 | 10.00% | 2 | 12.50% |
| Strongly Agree | 0 | 0.00% | 1 | 6.25% |

## Employees

| Workers reflective clothing is often inadequate for nighttime construction. | | | | |
|---|---|---|---|---|
| | National | | State | |
| Total Responses | 20 | % | 16 | % |
| Strongly Disagree | 2 | 10.00% | 0 | 0.00% |
| Disagree | 10 | 50.00% | 6 | 37.50% |
| Undecided | 4 | 20.00% | 2 | 12.50% |
| Agree | 4 | 20.00% | 8 | 50.00% |
| Strongly Agree | 0 | 0.00% | 0 | 0.00% |

| Contractors often do not adequately train personnel for the safety requirements/concerns unique to nighttime construction. | | | | |
|---|---|---|---|---|
| | National | | State | |
| Total Responses | 20 | % | 16 | % |
| Strongly Disagree | 0 | 0.00% | 0 | 0.00% |
| Disagree | 3 | 15.00% | 0 | 0.00% |
| Undecided | 13 | 65.00% | 4 | 25.00% |
| Agree | 4 | 20.00% | 12 | 75.00% |
| Strongly Agree | 0 | 0.00% | 0 | 0.00% |

| Contractors often do not execute adequate safety plans for nighttime construction. | | | | |
|---|---|---|---|---|
| | National | | State | |
| Total Responses | 20 | % | 16 | % |
| Strongly Disagree | 0 | 0.00% | 0 | 0.00% |
| Disagree | 9 | 45.00% | 7 | 43.75% |
| Undecided | 10 | 50.00% | 3 | 18.75% |
| Agree | 1 | 5.00% | 6 | 37.50% |
| Strongly Agree | 0 | 0.00% | 0 | 0.00% |

| State DOT resources are not sufficiently allocated to appropriately monitor nighttime construction. | | | | |
|---|---|---|---|---|
| | National | | State | |
| Total Responses | 20 | % | 16 | % |
| Strongly Disagree | 1 | 5.00% | 1 | 6.25% |
| Disagree | 12 | 60.00% | 10 | 62.50% |
| Undecided | 2 | 10.00% | 0 | 0.00% |
| Agree | 5 | 25.00% | 2 | 12.50% |
| Strongly Agree | 0 | 0.00% | 3 | 18.75% |

| Nighttime construction activity often negatively impacts DOT personnel alertness and effectiveness when monitoring safety. | | | | |
|---|---|---|---|---|
| | National | | State | |
| Total Responses | 20 | % | 16 | % |
| Strongly Disagree | 1 | 5.00% | 0 | 0.00% |
| Disagree | 6 | 30.00% | 3 | 19.00% |
| Undecided | 6 | 30.00% | 1 | 6.00% |
| Agree | 5 | 25.00% | 9 | 56.00% |
| Strongly Agree | 2 | 10.00% | 3 | 19.00% |

## Signage and Channeling Devices

| Contractors often employ inadequate or improper signage for nighttime construction operation. | | | | |
|---|---|---|---|---|
| | National | | State | |
| Total Responses | 20 | % | 16 | % |
| Strongly Disagree | 2 | 10.00% | 0 | 0.00% |
| Disagree | 13 | 65.00% | 13 | 81.00% |
| Undecided | 4 | 20.00% | 1 | 6.00% |
| Agree | 1 | 5.00% | 2 | 13.00% |
| Strongly Agree | 0 | 0.00% | 0 | 0.00% |

| Contractors often leave inappropriate signs showing during non-construction hours. | | | | |
|---|---|---|---|---|
| | National | | State | |
| Total Responses | 13 | % | 8 | % |
| Strongly Disagree | 1 | 8.00% | 1 | 12.50% |
| Disagree | 0 | 0.00% | 0 | 0.00% |
| Undecided | 2 | 15.00% | 4 | 50.00% |
| Agree | 10 | 77.00% | 3 | 37.50% |
| Strongly Agree | 0 | 0.00% | 0 | 0.00% |

| Reflectivity issues often hinder the effectiveness of signage at night. | | | | |
|---|---|---|---|---|
| | National | | State | |
| Total Responses | 20 | % | 16 | % |
| Strongly Disagree | 1 | 5.00% | 0 | 0.00% |
| Disagree | 9 | 45.00% | 6 | 37.50% |
| Undecided | 2 | 10.00% | 2 | 12.50% |
| Agree | 7 | 35.00% | 8 | 50.00% |
| Strongly Agree | 1 | 5.00% | 0 | 0.00% |

| Contractors within your state generally do not appreciate the unique considerations associated with nighttime signage. | | | | |
|---|---|---|---|---|
| | National | | State | |
| Total Responses | 20 | % | 16 | % |
| Strongly Disagree | 1 | 5.00% | 0 | 0.00% |
| Disagree | 12 | 60.00% | 8 | 50.00% |
| Undecided | 5 | 25.00% | 2 | 12.50% |
| Agree | 2 | 10.00% | 6 | 37.50% |
| Strongly Agree | 0 | 0.00% | 0 | 0.00% |

| Channeling devices and RPMs (Raised Pavement Markings) in work zones are often maintained inadequately to sustain adequate retro reflectivity at night. | | | | |
|---|---|---|---|---|
| | National | | State | |
| Total Responses | 20 | % | 16 | % |
| Strongly Disagree | 0 | 0.00% | 1 | 6.25% |
| Disagree | 12 | 60.00% | 10 | 62.50% |
| Undecided | 4 | 20.00% | 3 | 18.75% |
| Agree | 4 | 20.00% | 2 | 12.50% |
| Strongly Agree | 0 | 0.00% | 0 | 0.00% |

| Channeling devices and RPMs in work zones are often placed in a manner that creates confusion for the traveling public at night. | | | | |
|---|---|---|---|---|
| | National | | State | |
| Total Responses | 20 | % | 16 | % |
| Strongly Disagree | 0 | 0.00% | 1 | 6.25% |
| Disagree | 14 | 70.00% | 10 | 62.50% |
| Undecided | 1 | 5.00% | 2 | 12.50% |
| Agree | 5 | 25.00% | 3 | 18.75% |
| Strongly Agree | 0 | 0.00% | 0 | 0.00% |

## Lane Closures

| Setting up/taking down lane closures presents particular safety concerns for contractor personnel at night. | | | | |
|---|---|---|---|---|
| | National | | State | |
| Total Responses | 19 | % | 16 | % |
| Strongly Disagree | 0 | 0.00% | 0 | 0.00% |
| Disagree | 1 | 5.00% | 0 | 0.00% |
| Undecided | 2 | 11.00% | 1 | 6.00% |
| Agree | 11 | 58.00% | 5 | 31.00% |
| Strongly Agree | 5 | 26.00% | 10 | 63.00% |

| Improper maintenance of lane closures is a major issue on nighttime construction projects. | | | | |
|---|---|---|---|---|
| | National | | State | |
| Total Responses | 19 | % | 16 | % |
| Strongly Disagree | 0 | 0.00% | 0 | 0.00% |
| Disagree | 9 | 47.00% | 4 | 25.00% |
| Undecided | 3 | 16.00% | 2 | 12.50% |
| Agree | 5 | 26.00% | 7 | 43.75% |
| Strongly Agree | 2 | 11.00% | 3 | 18.75% |

**Traveling Equipment**

| The inability of passing motorists to identify construction vehicles, during nighttime construction, creates a hazard to the public. | | | | |
|---|---|---|---|---|
| | National | | State | |
| Total Responses | 20 | % | 16 | % |
| Strongly Disagree | 0 | 0.00% | 0 | 0.00% |
| Disagree | 8 | 40.00% | 4 | 25.00% |
| Undecided | 3 | 15.00% | 3 | 19.00% |
| Agree | 8 | 40.00% | 8 | 50.00% |
| Strongly Agree | 1 | 5.00% | 1 | 6.00% |

| Construction equipment is often not equipped with the proper identification devices to alert works of their presence. | | | | |
|---|---|---|---|---|
| | National | | State | |
| Total Responses | 20 | % | 16 | % |
| Strongly Disagree | 0 | 0.00% | 0 | 0.00% |
| Disagree | 11 | 55.00% | 10 | 63.00% |
| Undecided | 4 | 20.00% | 4 | 25.00% |
| Agree | 5 | 25.00% | 1 | 6.00% |
| Strongly Agree | 0 | 0.00% | 1 | 6.00% |

**Part B -**
**Nati**

Key: Total Respondents (TR), Ineffective (I), Mildly Effective (ME), Effective (E); Minimal Implement

**General**

| Pre-qualification of contractors based on safety records. | | | | | |
|---|---|---|---|---|---|
| TR | 16 | % | TR | 19 | |
| I | 3 | 19.00% | MI | 15 | |
| ME | 9 | 56.00% | OI | 2 | |
| E | 4 | 25.00% | SP | 2 | |

| Pre-qualification based on an itemized inventory of contractor safety equipment. | | | | | |
|---|---|---|---|---|---|
| TR | 15 | % | TR | 18 | |
| I | 9 | 60.00% | MI | 16 | |
| ME | 6 | 40.00% | OI | 2 | |
| E | 0 | 0.00% | SP | 0 | |

## Lighting and Illumination

| Semi-stationary soft-glow illumination balloon lights to light construction work areas. | | | | | |
|---|---|---|---|---|---|
| TR | 16 | % | TR | 18 | |
| I | 0 | 0.00% | MI | 8 | |
| ME | 10 | 62.50% | OI | 7 | |
| E | 6 | 37.50% | SP | 3 | |

| Semi-stationary soft-glow illumination balloon lights employed to prevent glare blindness for passing motorists. | | | | | |
|---|---|---|---|---|---|
| TR | 17 | % | TR | 18 | |
| I | 0 | 0.00% | MI | 9 | |
| ME | 5 | 29.00% | OI | 7 | |
| E | 12 | 71.00% | SP | 2 | |

| Lighting apparatus attached to operating equipment to light construction activities within the work zone. | | | | | |
|---|---|---|---|---|---|
| TR | 20 | % | TR | 18 | |
| I | 0 | 0.00% | MI | 0 | |
| ME | 11 | 55.00% | OI | 9 | |
| E | 9 | 45.00% | SP | 9 | |

## Public Traffic

| Traffic enforcement by full-time highway patrolmen throughout the work zone. | | | | | |
|---|---|---|---|---|---|
| TR | 18 | % | TR | 19 | |
| I | 1 | 6.00% | MI | 2 | |
| ME | 2 | 11.00% | OI | 10 | |
| E | 15 | 83.00% | SP | 7 | |

| Adaptive Cruise Control technology (automatically decreases the speed of vehicles entering work zones.) | | | | | |
|---|---|---|---|---|---|
| TR | 16 | % | TR | 19 | |
| I | 6 | 37.50% | MI | 18 | |
| ME | 4 | 25.00% | OI | 1 | |
| E | 6 | 37.50% | SP | 0 | |

| Wizard CB System (e.g. inform truckers at 30 second intervals of upcoming work zones.) | | | | | |
|---|---|---|---|---|---|
| TR | 17 | % | TR | 19 | |
| I | 2 | 12.00% | MI | 16 | |
| ME | 7 | 41.00% | OI | 2 | |
| E | 8 | 47.00% | SP | 1 | |

| Intrusion Detection Alarms (sounds alarms or sirens when there is unauthorized vehicle entry into work zone.) | | | | | |
|---|---|---|---|---|---|
| TR | 18 | % | TR | 19 | |
| I | 5 | 28.00% | MI | 16 | |
| ME | 9 | 50.00% | OI | 2 | |
| E | 4 | 22.00% | SP | 1 | |

| Full-time towing services to assist stranded vehicles. | | | | | |
|---|---|---|---|---|---|
| TR | 18 | % | TR | 20 | |
| I | 2 | 11.00% | MI | 8 | |
| ME | 7 | 39.00% | OI | 7 | |
| E | 9 | 50.00% | SP | 5 | |

| Designated phone number (example: 511) for information on local work zones. | | | | | |
|---|---|---|---|---|---|
| TR | 16 | % | TR | 19 | |
| I | 0 | 0.00% | MI | 7 | |
| ME | 8 | 50.00% | OI | 7 | |
| E | 8 | 50.00% | SP | 5 | |

| Public notices of conditions in local work zones (ex. Website, newspaper section, TV news, etc.). | | | | | |
|---|---|---|---|---|---|
| TR | 19 | % | TR | 20 | |
| I | 0 | 0.00% | MI | 0 | |
| ME | 5 | 26.00% | OI | 6 | |
| E | 14 | 74.00% | SP | 14 | |

| Banning of cell phone usage within a specified distance of work zones. | | | | | |
|---|---|---|---|---|---|
| TR | 17 | % | TR | 19 | |
| I | 7 | 41.00% | MI | 16 | |
| ME | 4 | 24.00% | OI | 0 | |
| E | 6 | 35.00% | SP | 3 | |

| Rumble-strips used as a means of capturing the driver's attention when entering work zones. | | | | | |
|---|---|---|---|---|---|
| TR | 17 | % | TR | 20 | |
| I | 1 | 6.00% | MI | 11 | |
| ME | 7 | 41.00% | OI | 5 | |
| E | 9 | 53.00% | SP | 4 | |

## Signage

| Mandatory "Workers Present when Flashing" signs to alert motorists of workers in work zones. | | | | | |
|---|---|---|---|---|---|
| TR | 16 | % | TR | 20 | |
| I | 3 | 18.75% | MI | 14 | |
| ME | 10 | 62.50% | OI | 4 | |
| E | 3 | 18.75% | SP | 2 | |

| Variable message boards used instead of standard signage to inform motorists of conditions throughout the work zone. | | | | | |
|---|---|---|---|---|---|
| TR | 18 | % | TR | 19 | |
| I | 1 | 5.56% | MI | 0 | |
| ME | 5 | 27.78% | OI | 9 | |
| E | 12 | 66.67% | SP | 10 | |

| Use of a radar board, with flashing lights, to inform motorists of their speed when entering the work zone. | | | | | |
|---|---|---|---|---|---|
| TR | 17 | % | TR | 20 | |
| I | 0 | 0.00% | MI | 3 | |
| ME | 8 | 47.00% | OI | 15 | |
| E | 9 | 53.00% | SP | 2 | |

| Message board indicating the number/frequency of speeding violations issued by law enforcement in the previous week (or ce |
|---|

| | | | | | |
|---|---|---|---|---|---|
| TR | 15 | % | TR | 20 | |
| I | 6 | 40.00% | MI | 18 | |
| ME | 3 | 20.00% | OI | 0 | |
| E | 6 | 40.00% | SP | 2 | |

Limiting the number of re-uses of signs to ensure that minimum legibility by passing motorists is maintained.

| TR | 15 | % | TR | 19 | |
|---|---|---|---|---|---|
| I | 7 | 47.00% | MI | 13 | |
| ME | 5 | 33.00% | OI | 3 | |
| E | 3 | 20.00% | SP | 3 | |

## Employees/Worker Personnel

Frequent contractor notification of newest sign technology available for nighttime construction.

| TR | 12 | % | TR | 19 | |
|---|---|---|---|---|---|
| I | 0 | 0.00% | MI | 12 | |
| ME | 8 | 67.00% | OI | 2 | |
| E | 4 | 33.00% | SP | 5 | |

Improved retro-reflectivity outfitting of employees/worker personnel in work zones.

| TR | 18 | % | TR | 20 | |
|---|---|---|---|---|---|
| I | 0 | 0.00% | MI | 9 | |
| ME | 2 | 11.00% | OI | 2 | |
| E | 16 | 89.00% | SP | 9 | |

Specific nighttime safety training for new-hires.

| TR | 15 | % | TR | 12 | |
|---|---|---|---|---|---|
| I | 0 | 0.00% | MI | 0 | |
| ME | 6 | 40.00% | OI | 6 | |
| E | 9 | 60.00% | SP | 6 | |

Require specific nighttime training at regular time intervals for all construction personnel.

| TR | 15 | % | TR | 20 |
|---|---|---|---|---|
| I | 0 | 0.00% | MI | 12 |
| ME | 8 | 53.00% | OI | 4 |
| E | 7 | 47.00% | SP | 4 |

Anonymous documentation on "lessons learned" and "near misses" to provide useful information on current and future project

| TR | 15 | % | TR | 20 |
|---|---|---|---|---|
| I | 1 | 7.00% | MI | 13 |
| ME | 9 | 60.00% | OI | 4 |
| E | 5 | 33.00% | SP | 3 |

Contractor safety incentive programs to promote the awareness of safety concerns and issues of their employees.

| TR | 17 | % | TR | 20 |
|---|---|---|---|---|
| I | 2 | 12.00% | MI | 14 |
| ME | 10 | 59.00% | OI | 4 |
| E | 5 | 29.00% | SP | 2 |

## Channeling Devices

Installation of a camera apparatus in the work zone to permit the use of actual project film footage when discussing safety acti

| TR | 15 | % | TR | 20 |
|---|---|---|---|---|
| I | 2 | 13.00% | MI | 16 |
| ME | 9 | 60.00% | OI | 2 |
| E | 4 | 27.00% | SP | 2 |

Double-stack cones to prevent them from blowing into travel way.

| TR | 17 | % | TR | 18 |
|---|---|---|---|---|
| I | 3 | 18.00% | MI | 6 |
| ME | 8 | 47.00% | OI | 10 |
| E | 6 | 35.00% | SP | 2 |

Improved barrel and cone maintenance activities.

| | | | | | |
|---|---|---|---|---|---|
| TR | 18 | % | TR | 19 | |
| I | 0 | 0.00% | MI | 1 | |
| ME | 2 | 11.00% | OI | 9 | |
| E | 16 | 89.00% | SP | 9 | |

## Lane Closures

Increased number of reflectors commonly used when performing nighttime construction operations.

| TR | 18 | % | TR | 19 | |
|---|---|---|---|---|---|
| I | 0 | 0.00% | MI | 1 | |
| ME | 7 | 39.00% | OI | 11 | |
| E | 11 | 61.00% | SP | 7 | |

Highway patrol car and crash truck, with flashing lights, to pace traffic while lane closures are being set up or removed.

| TR | 17 | % | TR | 20 | |
|---|---|---|---|---|---|
| I | 0 | 0.00% | MI | 6 | |
| ME | 6 | 35.00% | OI | 9 | |
| E | 11 | 65.00% | SP | 5 | |

More fines to contractors for not having the proper speed limit signs placed before and inside lane closures.

| TR | 15 | % | TR | 20 | |
|---|---|---|---|---|---|
| I | 5 | 33.00% | MI | 16 | |
| ME | 6 | 40.00% | OI | 1 | |
| E | 4 | 27.00% | SP | 3 | |

## Traveling Equipment

Pilot vehicles to lead traffic through lane closures on roads where traveling may not be clear.

| TR | 17 | % | TR | 20 | |
|---|---|---|---|---|---|
| I | 0 | 0.00% | MI | 7 | |
| ME | 6 | 35.00% | OI | 9 | |
| E | 11 | 65.00% | SP | 4 | |

Radar triggering devices in construction equipment to "set-off" radar detectors in passing motorists' vehicles.

| TR | 17 | % | TR | 19 |
|---|---|---|---|---|
| I | 2 | 12.00% | MI | 13 |
| ME | 8 | 47.00% | OI | 4 |
| E | 7 | 41.00% | SP | 2 |

| Construction vehicles equipped with back-up lights that flash rapidly when backing up. | | | | |
|---|---|---|---|---|
| TR | 16 | % | TR | 19 |
| I | 2 | 13.00% | MI | 13 |
| ME | 9 | 56.00% | OI | 2 |
| E | 5 | 31.00% | SP | 4 |

| "Light curtains" (laser beams) on large construction equipment so the equipment will shut down when movement is detected v | | | | |
|---|---|---|---|---|
| TR | 16 | % | TR | 19 |
| I | 9 | 56.00% | MI | 17 |
| ME | 4 | 25.00% | OI | 2 |
| E | 3 | 19.00% | SP | 0 |

## Part B - Innovative Practices
## State Respondents

### General

| Pre-qualification of contractors based on safety records. | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| TR | 12 | % | TR | 12 | % | TR | 12 | % |
| I | 0 | 0.00% | MI | 7 | 58.00% | RC | 11 | 92.00% |
| ME | 5 | 42.00% | OI | 3 | 25.00% | CP | 1 | 8.00% |
| E | 7 | 58.00% | SP | 2 | 17.00% | | | |

| Pre-qualification based on an itemized inventory of contractor safety equipment. | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| TR | 7 | % | TR | 12 | % | TR | 11 | % |
| I | 2 | 29.00% | MI | 6 | 50.00% | RC | 11 | 100.00% |
| ME | 5 | 71.00% | OI | 4 | 33.00% | CP | 0 | 0.00% |
| E | 0 | 0.00% | SP | 2 | 17.00% | | | |

### Lighting and Illumination

| Semi-stationary soft-glow illumination balloon lights to light construction work areas. | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| TR | 12 | % | TR | 12 | % | TR | 12 | % |
| I | 0 | 0.00% | MI | 4 | 33.00% | RC | 12 | 100.00% |
| ME | 4 | 33.00% | OI | 6 | 50.00% | CP | 0 | 0.00% |
| E | 8 | 67.00% | SP | 2 | 17.00% | | | |

| Semi-stationary soft-glow illumination balloon lights employed to prevent glare blindness for passing motorists. | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| TR | 11 | % | TR | 10 | % | TR | 12 | % |
| I | 0 | 0.00% | MI | 3 | 30.00% | RC | 11 | 92.00% |
| ME | 4 | 36.00% | OI | 5 | 50.00% | CP | 1 | 8.00% |
| E | 7 | 64.00% | SP | 2 | 20.00% | | | |

| Lighting apparatus attached to operating equipment to light construction activities within the work zone. | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| TR | 12 | % | TR | 11 | % | TR | 13 | % |
| I | 0 | 0.00% | MI | 0 | 0.00% | RC | 12 | 92.00% |
| ME | 6 | 50.00% | OI | 4 | 36.00% | CP | 1 | 8.00% |
| E | 6 | 50.00% | SP | 7 | 64.00% | | | |

## Public Traffic

| Traffic enforcement by full-time highway patrolmen throughout the work zone. | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| TR | 12 | % | TR | 11 | % | TR | 13 | % |
| I | 0 | 0.00% | MI | 1 | 9.00% | RC | 10 | 77.00% |
| ME | 0 | 0.00% | OI | 6 | 55.00% | CP | 3 | 23.00% |
| E | 12 | 100.00% | SP | 4 | 36.00% | | | |

| Adaptive Cruise Control technology (automatically decreases the speed of vehicles entering work zones.) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| TR | 12 | % | TR | 13 | % | TR | 13 | % |
| I | 2 | 16.67% | MI | 11 | 85.00% | RC | 2 | 15.00% |
| ME | 2 | 16.67% | OI | 2 | 15.00% | CP | 11 | 85.00% |
| E | 8 | 66.67% | SP | 0 | 0.00% | | | |

| Wizard CB System (e.g. inform truckers at 30 second intervals of upcoming work zones.) |
|---|

| TR | 11 | % | TR | 10 | % | TR | 12 | % |
|---|---|---|---|---|---|---|---|---|
| I | 1 | 9.00% | MI | 5 | 50.00% | RC | 7 | 58.00% |
| ME | 3 | 27.00% | OI | 5 | 50.00% | CP | 5 | 42.00% |
| E | 7 | 64.00% | SP | 0 | 0.00% | | | |

| Intrusion Detection Alarms (sounds alarms or sirens when there is unauthorized vehicle entry into work zone.) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| TR | 12 | % | TR | 10 | % | TR | 12 | % |
| I | 1 | 8.00% | MI | 7 | 70.00% | RC | 4 | 33.00% |
| ME | 5 | 42.00% | OI | 2 | 20.00% | CP | 8 | 67.00% |
| E | 6 | 50.00% | SP | 1 | 10.00% | | | |

| Full-time towing services to assist stranded vehicles. | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| TR | 12 | % | TR | 11 | % | TR | 14 | % |
| I | 1 | 8.33% | MI | 6 | 55.00% | RC | 9 | 64.00% |
| ME | 4 | 33.33% | OI | 3 | 27.00% | CP | 5 | 36.00% |
| E | 7 | 58.33% | SP | 2 | 18.00% | | | |

| Designated phone number (example: 511) for information on local work zones. | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| TR | 13 | % | TR | 11 | % | TR | 13 | % |
| I | 2 | 15.38% | MI | 5 | 45.45% | RC | 10 | 77.00% |
| ME | 6 | 46.15% | OI | 4 | 36.36% | CP | 3 | 23.00% |
| E | 5 | 38.46% | SP | 2 | 18.18% | | | |

| Public notices of conditions in local work zones (ex. Website, newspaper section, TV news, etc.). | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| TR | 13 | % | TR | 12 | % | TR | 12 | % |
| I | 0 | 0.00% | MI | 0 | 0.00% | RC | 12 | 100.00% |
| ME | 6 | 46.00% | OI | 1 | 8.00% | CP | 0 | 0.00% |
| E | 7 | 54.00% | SP | 11 | 92.00% | | | |

| Banning of cell phone usage within a specified distance of work zones. |
|---|

| TR | 12 | % | TR | 11 | % | TR | 14 | % |
|---|---|---|---|---|---|---|---|---|
| I | 4 | 33.30% | MI | 8 | 73.00% | RC | 10 | 71.00% |
| ME | 4 | 33.30% | OI | 2 | 18.00% | CP | 4 | 29.00% |
| E | 4 | 33.30% | SP | 1 | 9.00% | | | |

| Rumble-strips used as a means of capturing the driver's attention when entering work zones. | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| TR | 12 | % | TR | 11 | % | TR | 12 | % |
| I | 1 | 8.00% | MI | 9 | 82.00% | RC | 8 | 67.00% |
| ME | 6 | 50.00% | OI | 1 | 9.00% | CP | 4 | 33.00% |
| E | 5 | 42.00% | SP | 1 | 9.00% | | | |

## Signage

| Mandatory "Workers Present when Flashing" signs to alert motorists of workers in work zones. | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| TR | 14 | % | TR | 11 | % | TR | 11 | % |
| I | 2 | 14.00% | MI | 5 | 45.45% | RC | 8 | 73.00% |
| ME | 5 | 36.00% | OI | 2 | 18.18% | CP | 3 | 27.00% |
| E | 7 | 50.00% | SP | 4 | 36.36% | | | |

| Variable message boards used instead of standard signage to inform motorists of conditions throughout the work zone. | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| TR | 13 | % | TR | 11 | % | TR | 12 | % |
| I | 0 | 0.00% | MI | 0 | 0.00% | RC | 11 | 92.00% |
| ME | 4 | 31.00% | OI | 4 | 36.00% | CP | 1 | 8.00% |
| E | 9 | 69.00% | SP | 7 | 64.00% | | | |
| Use of a radar board, with flashing lights, to inform motorists of their speed when entering the work zone. | | | | | | | | |
| TR | 13 | % | TR | 11 | % | TR | 12 | % |
| I | 3 | 23.00% | MI | 6 | 55.00% | RC | 6 | 50.00% |
| ME | 6 | 46.00% | OI | 4 | 36.00% | CP | 6 | 50.00% |
| E | 4 | 31.00% | SP | 1 | 9.00% | | | |

| Message board indicating the number/frequency of speeding violations issued by law enforcement in the previous week (or certain time period). | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| TR | 14 | % | TR | 11 | % | TR | 11 | % |
| I | 7 | 50.00% | MI | 7 | 64.00% | RC | 5 | 45.00% |
| ME | 3 | 21.00% | OI | 3 | 27.00% | CP | 6 | 55.00% |
| E | 4 | 29.00% | SP | 1 | 9.00% | | | |

| Limiting the number of re-uses of signs to ensure that minimum legibility by passing motorists is maintained. |
|---|

| TR | 12 | % | TR | 11 | % | TR | 12 | % |
|---|---|---|---|---|---|---|---|---|
| I | 3 | 25.00% | MI | 4 | 36.36% | RC | 7 | 58.00% |
| ME | 4 | 33.00% | OI | 3 | 27.27% | CP | 5 | 42.00% |
| E | 5 | 42.00% | SP | 4 | 36.36% | | | |

## Employees/Worker Personnel

| Frequent contractor notification of newest sign technology available for nighttime construction. | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| TR | 10 | % | TR | 11 | % | TR | 13 | % |
| I | 0 | 0.00% | MI | 4 | 36.36% | RC | 11 | 85.00% |
| ME | 4 | 40.00% | OI | 5 | 45.45% | CP | 2 | 15.00% |
| E | 6 | 60.00% | SP | 2 | 18.18% | | | |

| Improved retro-reflectivity outfitting of employees/worker personnel in work zones. | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| TR | 13 | % | TR | 15 | % | TR | 12 | % |
| I | 0 | 0.00% | MI | 2 | 13.33% | RC | 12 | 100.00% |
| ME | 1 | 8.00% | OI | 8 | 53.33% | CP | 0 | 0.00% |
| E | 12 | 92.00% | SP | 5 | 33.33% | | | |

| Specific nighttime safety training for new-hires. | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| TR | 13 | % | TR | 9 | % | TR | 12 | % |
| I | 0 | 0.00% | MI | 0 | 0.00% | RC | 12 | 100.00% |
| ME | 1 | 8.00% | OI | 4 | 44.00% | CP | 0 | 0.00% |
| E | 12 | 92.00% | SP | 5 | 56.00% | | | |
| Require specific nighttime training at regular time intervals for all construction personnel. | | | | | | | | |
| TR | 12 | % | TR | 12 | % | TR | 12 | % |
| I | 0 | 0.00% | MI | 3 | 25.00% | RC | 12 | 100.00% |
| ME | 2 | 17.00% | OI | 5 | 42.00% | CP | 0 | 0.00% |
| E | 10 | 83.00% | SP | 4 | 33.00% | | | |

| Anonymous documentation on "lessons learned" and "near misses" to provide useful information on current and future projects. | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| TR | 12 | % | TR | 11 | % | TR | 12 | % |
| I | 2 | 17.00% | MI | 5 | 45.45% | RC | 9 | 75.00% |
| ME | 3 | 25.00% | OI | 4 | 36.36% | CP | 3 | 25.00% |
| E | 7 | 58.00% | SP | 2 | 18.18% | | | |

| Contractor safety incentive programs to promote the awareness of safety concerns and issues of their employees. |
|---|

| TR | 14 | % | TR | 10 | % | TR | 12 | % |
|---|---|---|---|---|---|---|---|---|
| I | 1 | 7.00% | MI | 5 | 50.00% | RC | 7 | 58.00% |
| ME | 6 | 43.00% | OI | 3 | 30.00% | CP | 5 | 42.00% |
| E | 7 | 50.00% | SP | 2 | 20.00% | | | |

## Channeling Devices

| Installation of a camera apparatus in the work zone to permit the use of actual project film footage when discussing safety actions. | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| TR | 13 | % | TR | 11 | % | TR | 12 | % |
| I | 2 | 15.38% | MI | 8 | 73.00% | RC | 6 | 50.00% |
| ME | 5 | 38.46% | OI | 2 | 18.00% | CP | 6 | 50.00% |
| E | 6 | 46.15% | SP | 1 | 9.00% | | | |

| Double-stack cones to prevent them from blowing into travel way. | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| TR | 12 | % | TR | 12 | % | TR | 12 | % |
| I | 2 | 17.00% | MI | 6 | 50.00% | RC | 7 | 58.00% |
| ME | 6 | 50.00% | OI | 5 | 42.00% | CP | 5 | 42.00% |
| E | 4 | 33.00% | SP | 1 | 8.00% | | | |

| Improved barrel and cone maintenance activities. | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| TR | 13 | % | TR | 11 | % | TR | 12 | % |
| I | 0 | 0.00% | MI | 2 | 18.18% | RC | 12 | 100.00% |
| ME | 5 | 38.00% | OI | 5 | 45.45% | CP | 0 | 0.00% |
| E | 8 | 62.00% | SP | 4 | 36.36% | | | |

## Lane Closures

| Increased number of reflectors commonly used when performing nighttime construction operations. | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| TR | 13 | % | TR | 11 | % | TR | 12 | % |
| I | 2 | 15.00% | MI | 4 | 36.00% | RC | 8 | 67.00% |
| ME | 1 | 8.00% | OI | 6 | 55.00% | CP | 4 | 33.00% |
| E | 10 | 77.00% | SP | 1 | 9.00% | | | |

| Highway patrol car and crash truck, with flashing lights, to pace traffic while lane closures are being set up or removed. | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| TR | 12 | % | TR | 11 | % | TR | 13 | % |
| I | 0 | 0.00% | MI | 6 | 55.00% | RC | 8 | 62.00% |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| ME | 1 | 8.00% | OI | 4 | 36.00% | CP | 5 | 38.00% |
| E | 11 | 92.00% | SP | 1 | 9.00% | | | |

| More fines to contractors for not having the proper speed limit signs placed before and inside lane closures. | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| TR | 13 | % | TR | 11 | % | TR | 12 | % |
| I | 4 | 31.00% | MI | 8 | 73.00% | RC | 7 | 58.00% |
| ME | 2 | 15.00% | OI | 0 | 0.00% | CP | 5 | 42.00% |
| E | 7 | 54.00% | SP | 3 | 27.00% | | | |

## Traveling Equipment

| Pilot vehicles to lead traffic through lane closures on roads where traveling may not be clear. | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| TR | 13 | % | TR | 11 | % | TR | 12 | % |
| I | 2 | 15.00% | MI | 4 | 36.36% | RC | 9 | 75.00% |
| ME | 3 | 23.00% | OI | 5 | 45.45% | CP | 3 | 25.00% |
| E | 8 | 62.00% | SP | 2 | 18.18% | | | |

| Radar triggering devices in construction equipment to "set-off" radar detectors in passing motorists' vehicles. | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| TR | 13 | % | TR | 11 | % | TR | 12 | % |
| I | 1 | 7.69% | MI | 8 | 73.00% | RC | 5 | 42.00% |
| ME | 4 | 30.77% | OI | 2 | 18.00% | CP | 7 | 58.00% |
| E | 8 | 61.54% | SP | 1 | 9.00% | | | |

| Construction vehicles equipped with back-up lights that flash rapidly when backing up. | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| TR | 13 | % | TR | 12 | % | TR | 12 | % |
| I | 1 | 8.00% | MI | 6 | 50.00% | RC | 7 | 58.00% |
| ME | 5 | 38.00% | OI | 4 | 33.00% | CP | 5 | 42.00% |
| E | 7 | 54.00% | SP | 2 | 17.00% | | | |

| "Light curtains" (laser beams) on large construction equipment so the equipment will shut down when movement is detected within the work zone. | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| TR | 13 | % | TR | 11 | % | TR | 12 | % |
| I | 4 | 31.00% | MI | 8 | 73.00% | RC | 5 | 42.00% |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| ME | 3 | 23.00% | OI | 1 | 9.00% | CP | 7 | 58.00% |
| E | 6 | 46.00% | SP | 2 | 18.00% | | | |

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