VISIBILITY-RELATED FATALITIES IN THE CONSTRUCTION INDUSTRY

By

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To my mother, Carlotta Edington.

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LIST OF ABBREVIATIONS

BLS	Bureau of Labor and Statistics
CFR	Code of Federal Regulations
Dba	Decibels (Acoustic)
EMR	Experience Modification Rating
FHWA	Federal Highway Administration
NIOSH	National Institute for Occupational Safety and Health
OSHA	Occupational Safety and Health Administration
PCMS	Portable Changeable Message Signs
PPE	Personal Protective Equipment
ROPS	Roll Over Protections System
TxDOT	Texas Department of Transportation

Abstract of Thesis Presented to the Graduate School
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The construction industry experiences one of the highest fatality rates in the United States every year. The factors that contribute to this dubious reputation include the nature of the work, the tools and equipment involved, and also the compact work zones. When a fatality occurs in the construction industry, it is reported to the Occupational Safety and Health Administration (OSHA). While OSHA distinguishes fatalities in a few general categories, not enough is known from this information to effectively target specific problem areas.

In order to improve the construction industry's safety performance record, it is necessary to study historical data and conduct in depth analysis into specified areas of concern. With targeted analysis, patterns emerge and causal factors can be identified. These findings may then be used to form the basis for recommendations that will help to improve the safety of construction workers.

It was discovered that not much research with this particular focus had been published. This research singled out vision or lack of good visibility as the major factor in construction fatalities. With in depth fatality case analysis, the focus was to uncover

the contributing factors in these particular fatalities and identify the agents of visual disruption.

This research involved the study of 289 subject related fatalities which were singled out through their content from a data pool of 13511 cases. It was discovered that blind spots, obstructions and the lighting conditions on a site were the most common factors contributing to vision related fatalities. This research also analyzed construction equipment and identified the contributing factors in each circumstance.

CHAPTER 1
INTRODUCTION

Overview

The construction Industry continues to rank among the most inherently dangerous industries in the United States and throughout the rest of the world. Construction workers continue to perform tasks daily in often crowded and sometimes hazardous settings in order to accomplish their job objectives. These dangers include, but are not limited to, falls, contact with power tools, working in close proximity to large equipment, working among trucks and cranes, as well as unseen electrical hazards.

Construction workers consistently experience lost time injury and fatality cases that outnumber similar cases in other industries. Many injuries are the result of workers being distracted when working near hazards. In some cases the hazards are not recognized by the workers. Still, others occurred as a result of working not fully observing all conditions associated with an activity.

Statement of Purpose

The intent of this research was to conduct an investigative approach into visibility–related fatalities. The purpose was to determine the extent to which vision (or the lack of good visibility) has played a role in construction worker fatalities and to identify the nature of those circumstances where visibility was an issue.

OSHA publishes fatality data for the construction industry and catalogued cases are in the form of narratives. The data contained in these narratives are grouped into five major categories. These categories include “falls”, “struck by”, “electrocutions”, “caught between” and “other”. While these categories satisfy a general point of reference for understanding the types of dangers faced by construction workers, they are broad categories and much more can be learned from the cases with closer analysis. The goal of this research was to examine vision related construction fatalities in depth in order to provide industry recommendations that would help to save workers' lives.

The objective of this study is to identify as many circumstantial factors as possible that had an effect in causing visibility related fatalities in order to detect commonly occurring themes. Once these themes have been identified a greater understanding and significance of these factors will be known. With the compilation of such data it is the intent of the researcher to provide valuable information that may be used to prevent future accidents from occurring.

CHAPTER 2
LITERATURE REVIEW

What is the Occupational Safety and Health Administration?

The Occupational Safety and Health Administration, (OSHA) is a government agency charged with improving work conditions for employees in the United States. OSHA was created in 1971 under the Occupational Safety and Health Act of 197O signed into action by President Richard Nixon (OSHA www.osha.gov). It was created with the intent of ensuring a safe work environment for employees by providing guidelines and enforcing regulations that prevent work related injuries, illnesses and deaths. Since its inception, OSHA has had a positive impact on the work environment, reducing fatalities by 62% and lowering injury occurrences by 42% since it started (OSHA www.osha.gov).

OSHA has had a positive industry wide impact on worker safety, and this is evident when considering injury rates prior to and after its establishment. Injuries and fatalities still occur despite the progress that has been made over the years. For example, in 2005 OSHA reported 4.2 million occupational injuries and illnesses among workers in the United States. OSHA reported that 4.6 of every 100 workers were injured on the job, and in 2006, 1226 construction workers died on the job (Wedekind, Jenna 2009).

Safety awareness continues to gain momentum in the construction industry as the collective goal among contractors is to bring injuries down to zero. OSHA continues to serve as a means for enforcing safety policy and setting a baseline safety standard that requires every employer to comply. The OSHA staff consists of 2,150 employees, 1,100 of which are compliance inspectors that enforce safety standards on jobsites across the nation. The main tasks of OSHA inspectors include the reporting of imminent dangers, investigating accidents or fatalities, addressing employee complaints, responding to referrals from other government agencies, and conducting targeted inspections. Non compliance with OSHA regulations can result in the fines of up $70,000 for repeated violations (OSHA www.osha.gov).

OSHA Recordable Injuries

OSHA recordable injuries fall under one of two categories: injuries which result in lost days of work, and those that do not. "The law requires the recording of work injuries other than minor injuries requiring only first aid treatment, and which do not involve medical treatment, loss of consciousness, restriction of work or motion or transfer to another job. Consequently, a work-related injury must involve at least 1 of these 4 conditions before it is deemed recordable" (BLS www.bls.gov). These injuries are reported on the Log and Summary of the OSHA No. 300 form. (Hinze, 2006).

OSHA investigates and records job-related injuries that occur throughout the Unites States. Not only does it legally demand that each employer abide by its guidelines, but it also provides a valuable database that allows firms to benchmark their safety practices against the industry. The OSHA log data provides a wealth of accident information and the contents found within it allow for a single point of information source for identifying exactly what it is that should be addressed in order to reduce these injury frequencies.

Construction Safety in the United States

Construction continues to rank as one of the most dangerous industries in the United States. Construction work is inherently dangerous in its nature. Injuries have always plagued the construction industry to the point that they have become accepted part of doing business. At one time fatalities were even accounted for in construction schedules and estimates because they occur so common. This way of thinking changed in the 1960's as sentiment switched in the public and political arenas. The U.S. construction industry accounts for around 7% of the total workforce, but the fatalities of construction workers account for about 20% of all industrial deaths. (MacCollum 1995). This death rate of 15.2 of every 100,000 workers makes construction the third most dangerous industry behind mining and agriculture (NIOSH www.cdc.gov/niosh). The steady death rate in the construction industry reached a recent high in the year 2004 with a reported 1272 fatalities. While this figure is alarming it does not account for independent contractors, piece workers or uninsured which would raise the numbers much higher (BLS www.bls.gov).

In the 1960's political pressure brought forth by public outcry sparked a need for a paradigm shift. The Construction Safety Act was enacted and set requirements for all federal funded projects to combat the negative influence of serious injuries on employees (MacCollum 1995). The purpose of this legislation was to improve worker safety on construction projects.

As a result of The Construction Safety Act, contractors for the first time were able to attach a dollar amount to the bid which would cover the cost of added safety measures to be enacted. This new law was soon incorporated into the Occupational Safety and Health Act of 1970 for all industries not just government contracts (MacCollum 1995). During the 1980's the construction industry witnessed an increase in injury rates because of a slackening of OSHA regulations. This easing of fines and restrictions on employers was brought on by the Reagan era's stance of attempting to mitigate the government’s role in monitoring safety, making it smaller and less bureaucratic, while at the same time aiming to air on the side of the contractors. Safety restrictions in the 1990’s again became more stringent and as a result injury rates have decreased. (MacCollum 1995).

Today’s construction climate has experienced radical changes since the 1990’s. The majority of today’s job site employees are no longer those of the general contractor but of subcontractors who may not hold the same ideals of safety. General contractors find themselves in a dangerous situation when they place the responsibility of safety on each individual subcontractor because of the chaos which ensues due to the lack of effectiveness when there is no central control over the safety of a workers’ environment. (MacCollum 1995).

Why is Construction Safety Important?

Construction safety is important for reasons that include society’s value for human well being, as well as reasons that are cost-influenced and are incurred when a company has a poor safety record. The occurrence of a serious injury slows progress, effects worker morale, increases the need for overtime, and interferes with progress as well as affecting the bottom line. When a construction company reports an injury, it will experience an increase in the worker’s compensation premium. For a company with a poor safety rating, this represents a large portion of their monthly operational costs. The single most notable cost reduction to a contractor with a proven safety record comes in the form of a reduced workers’ compensation premium. A company’s workers’ compensation premium is based on its Experience Modification Rating which is derived from company’s accident claims costs. This EMR is calculated based on accident claims that were reported on a three year time frame prior to the immediate past year.

Construction accidents often precipitate an increase in workers' compensation premiums, and are the reason liability claims and other indirect costs are incurred. Indirect costs include the expense of training replacement workers as well as other increases that arise when the crew is not as efficient as it once was. Injuries often cause delays and setbacks in the schedule that may lead to construction acceleration or a series of other costly problems. Poor safety practices lead to injuries which often result in the need for increased over time, increased wages, reduced productivity, additional clean-up costs, repair expenses, replacement of materials and equipment, OSHA and civil fines, and lawyer fees.

For the period of 1979 through1989, as a result of an increase in medical, legal and insurance expenses, the cost of injuries rose from an estimated $8.9 billion annually to $17.2 billion annually, and workers' compensation insurance rapidly increased from $2.74 billion annually to $5.26 billion. Implementing construction safety techniques can substantially reduce construction costs in the long run and have other added benefits such as higher quality of work and improved employee morale.

On many construction projects, today's safety goals call for a zero accident model. Employee safety orientation and training should be implemented in order to familiarize workers with the recognition and avoidance of safety hazards. Findings show that safety training and orientation provided for workers and supervisors reduce the amount of accidents(Levitt, 1993). New workers are a group that are at a higher risk for on the job injuries. A new worker is anyone that is new to a particular construction project, regardless of their age, experience or knowledge of the trade (Choudhry et al. 2000). Workers that have been on the job a month or less make up 25% of all construction related accidents. Because of the inherent danger associated with construction work, combined with the fact that construction projects experience high worker turnover, it is well known that worker safety is improved by targeting safety training to address the new worker injury susceptibility. With this knowledge there is an opportunity to focus attention on the safety training for new workers, and thereby to bring about a reduction in accidents.

Historically, every work day five construction workers in the United States die (OSHA www.osha.gov). In 2008, the most recent year for which job fatality data is available, OSHA reports showed that 969 construction workers died as a result of injuries sustained on the job, a decline from 1204 in 2007. Table 2-1 shows the amount of fatalities per year for the years 2003 through 2008.

Table 2-1. Construction Fatalities by Year. (Source: BLS www.bls.gov).

Year	Fatalities
2003	1131
2004	1272
2005	1224
2006	1226
2007	1204
2008	969

Construction Equipment

When equipment is brought onto the job site, the general contractor, subcontractor or the equipment rental companies have the responsibility to make sure it is in proper operating conditions. The equipment must be deemed safe after inspection for its proposed use, and in accordance with contract documents detailed during the preconstruction phase. Equipment, machines and tools can be broken into general categories (MacCollum 1995). These categories include the following;

Transporters: One fourth of construction injuries and deaths are the result of collision, upset and backing up of vehicles. The Code of Federal Regulations, Title 49 is a mandate which lists safe methods of transportation. “Transporters have been separated into seven basic groups: trucks, forklifts, conveyors, pipelines, railways, roadways, and aircraft (MacCollum 1995).”

Trucks: It is important that trucks and other motor vehicles be equipped with restraint devices such as seatbelts, which decrease the severity of injury in the event of an accident. Another increasing danger involved with trucks is the use of cellular phones and two way radios as operators take their hands off their steering wheels and also split their attention between their conversation and safely operating the vehicle (MacCollum 1995).

Back up alarms are proving valuable in helping to prevent accidents. There also exists the new technology of closed circuit televisions mounted inside these vehicles which are connected to rear-mounted cameras allowing the driver to get a real time image of what is directly behind them. In addition to having properly functioning back up alarms, trucks should not be allowed on the jobsite unless they are in proper working condition. This includes operational horns, head lights, brake lights, directional signals, mirrors, etc (MacCollum 1995).

Dump trucks should be held to the same standards as all other trucks but should additionally be equipped with a sturdy bumper bed body to protect the cab from being crushed in the event a rock rolls or falls forward. Dump trucks should also contain adequate roll over protection systems which will keep the driver safe in the event the truck turns over so the driver will not be crushed. This is particularly important in this study because accidents often occur when a truck operator is driving in reverse and does not see when they are steering into danger, resulting in running off the road or in striking a worker on the ground. In addition to these factors, audible alarms should be installed on these vehicles to let the operator know when the bed is still suspended in the air to avoid the driver inadvertently hitting objects that cannot be seen. Truck beds, depending on the type of truck, can be raised to 30 feet in the air. This creates the possibility for a driver to come in contact with a power line which they cannot see. Technology exists to alert the driver of the proximity with the truck bed and a potential hazard like a power line (MacCollum 1995).

Forklifts are another type of machine often involved in vision related injuries. Incidents occur when operator error causes the forklift to drive off of the loading dock or to back up into unsuspecting workers. The operation of these machines should not take place in the close proximity of others unless the operator is working with a teammate or spotter to alert the operator and others of potential dangers (MacCollum 1995).

Earthmovers and Excavators: these include equipment such as skid steer loaders, scrapers, backhoes, front end loaders, bull dozers, road rollers and should all be equipped with back up alarms, roll over protection systems, (ROPS) and seat belts (MacCollum 1995). These types of equipment are found on most construction sites because of their diverse functionality. They are known to spend as much time in reverse as they do moving forward.

Personal Protective Equipment

The main purpose of wearing protective apparel is to protect the workers from dangers in the work environment. The conditions often associated with workers not wearing appropriate safety equipment deal with garment wearability, comfort, fit and style. These factors lead to workers not complying with safety regulations and end in unsafe operating procedures. A survey conducted by the SH&E professionals in 2006 and 2007 showed that noncompliance with PPE regiment is a continuing problem. A 2007 National Safety Congress Survey showed that 87% of the attendees had witnessed workers not wearing proper PPE in situations where they should have been. This was an increase from 85% a year earlier. Despite the undeniable need for using protective equipment when performing hazardous work, many refuse to comply with safety standards thereby putting themselves at further risk (McPherson 2009).

The main reason for workers refusing to wear protective gear was that if it was “uncomfortable gear” as cited at 62% of the worker respondents that who were observed in non compliance. Workers felt that wearing the gear was unnecessary because it was either too hot, did not fit well or was unattractive. The survey also showed that 75% of the workers stated that they would be more inclined to wear the PPE gear if it were more comfortable. Eighty-four percent also stated that they would be more likely to purchase the more fashionable safety gear if it were more affordable. Another difficulty encountered when trying to implement the use of PPE in the construction industry is that there are no established standards for task specific protective apparel in the United States. “The key is to balance apparel function (protection factors) and apparel form (style, comfort and wearability factors) within the scope of a realistic hazard assessment and risk analysis” (McPherson 2009).

Safety Glasses

Safety glasses are important to construction workers for the protection they provide against eye injuries and vision impairments. These safety glasses are available with foam fog protection and particle shield features that provide foam surrounding around the lens of the glasses. This protects the eyes as well as reduces fogging, a factor that impacts worker vision (McPherson 2009).

High Visibility Clothing

It is recommended that high visibility garments with reflective strips should be worn at all times to improve the awareness of the presence of workers to their coworkers. While it is common for workers to refuse to wear proper safety gear because of the comfort factor, there is a certain increasing awareness among industry professionals that tailoring specific safety equipment to the situation results in a higher compliance rate by workers. “The hazard analysis and risk assessment procedure must be adjusted to the practical demands of the work task. If not, one runs the risk of either overprotection or under protection-both of which have serious consequences. Overprotection may lead to immediate problems, such as heat stress. In such cases, users may modify or incorrectly use the garment to avoid overheating” (McPherson 2009).

Casual Factors

Struck by Accidents

According to the analysis of OSHA data between 1985 and 1989, “struck by” accidents comprised 22% of construction fatalities. Of these struck by cases many are attributed to lack of visibility or a worker travelling into the blind spot of another employee. From preliminary research, stuck by cases are the most frequent when visibility factors come into the equation. Other struck by cases include cave-ins, struck by falling objects or, struck by equipment and private vehicles. Table 2-2 shows the frequency of struck-by accidents according to equipment type.

Table 2-2 Construction Equipment and Struck-by Accidents. (Source: Hinze et al. 2005)

Equipment	Frequency
Truck	19639.4
Private vehicle	5711.5

Table 2-2. Continued

Equipment	Frequency
Backhoe/excavator	6212.5
Crane	479.5
Forklift	224.4
Bulldozer	233.6
Hoisting	122.4
Roller	112.2
Saws	91.8
Scraper	40.8
Other	295.8
Total	497100.0

Work Zone Safety

Among the most dangerous segments of the construction industry is the civil construction sector. This includes the construction of bridges, roads, canals, airports and other public works projects. Policy makers have taken notice of the inherent danger of civil construction work and as a result new safety standards are being introduced. The Federal Highway Administration (FHWA) has established a policy for the use of high visibility safety apparel. The new law applies to workers that are working directly in the right of way lanes of federal highways, and is intended to reduce the amount of accidents and fatalities among workers who are on foot and exposed to traffic, or those operating construction equipment or vehicles while working in these areas (Roads and Bridges 2005).

Currently, the state of Texas has the highest rate of highway construction worker fatalities and injuries. Factors which may be attributing to these numbers are the extended length of the construction season, driver inattention and carelessness within construction sites and an increase in construction activity. The Texas Department of Transportation has conducted research in order to focus on ways to improve the safety of these highway construction workers in their work zones. The main focus has been to increase the visibility of work areas to motorists (Roads and Bridges 2005).

The Texas Transportation Institute has been involved in the creation of new methods of increased motorist awareness of construction work crews that are to be encountered on road projects. This new method involves the use of lane closures that employ the use of a sequence of drums that gradually taper to direct traffic, and are equipped with a sequence of flashing lights. This method has been used in the Houston area on a multi-lane project and has been proven to work very effectively. That TxDOT study found that the new systems alerts drivers to the work zones and encourages them to get out of the closing lane sooner. When this synchronized flashing warning lights system was used, the rate for passenger vehicles getting out of the affected lane one-thousand feet before it began to tapper had reduced by 25%. For commercial vehicles, the results were much higher as 66% of commercial vehicles were observed to exit the affected lane 1000 ft before it began to close.

Portable changeable message signs (PCMS) are also effective methods of alerting drivers about upcoming work areas however, the incandescent light bulbs which they use to signal motorists have been found to be insufficient. This has sparked the experimentation with a bulb that has higher illumination effect known as the light emitting diode or the “LED” light.

New technologies are also becoming available with the safety vest products market using electro illumination technology. Vests equipped with this technology contain a bendable wire that is powered by two AA batteries that covers the front and the rear of the vest. This battery powered bendable wire produces a neon light that allows the worker to be seen in the dark. (Roads and Bridges 2005).

Contractors have been known to perform an increasing amount of highway construction and maintenance at night because of the effect that these operations have on traffic flows. Because of this trend, the danger involved with construction workers not being visible increases and safety concerns are also escalated. As a result of the safety concerns, various state Departments of Transportation are beginning to implement lighting standards on night time projects. Regulations include a standard on the minimum level of light to be available on nighttime projects (Hyari and Rayes 2006).

Back Up Alarms

The construction industry has a high level of injuries involved with maneuvering construction equipment and trucks on the construction site. Because of many years of accidents involving trucks and equipment on construction projects, the federal government implemented The Code of Federal Regulations 29 CFR 1926.601 and 29 CFR 1926.602 which states that all trucks and mobile construction equipment must be equipped with an operable back-up alarm. These alarms must be loud enough to be audible over the surrounding noises present on construction sites and should be activated whenever equipment is put into reverse. Data show that about 13% of construction fatalities are attributed to the use of industrial vehicles and equipment (BLS www.bls.gov). However, despite years of familiarity with alarms and other safety procedures, about 6,500,000 workdays are lost each year in the construction industry because of injuries.

Nearly 98% of all work accidents are caused by unsafe behavior. Most workers are likely to have performed the same unsafe behavior many times in the past before being injured (Sawacha 1999). On a typical construction site it is common for mobile equipment, trucks and workers to all be present together in a relatively small or restricted space. Truck and equipment operators depend on back up alarms to alert workers on the ground about their equipment operations. In general, the noise level on a construction site tends to be rather high, often above 95-100 dBA (Helander 1991). While back up alarms provide a warning that a vehicle is engaged in reverse, back up alarms are not specific as to which vehicle is reversing and they serve only as announcements that a vehicle somewhere is in reverse. Construction workers need to use senses other than hearing alone, such as visual and tactile, in order to identify and successfully avoid potential dangers.

Decreasing Vigilance

Decreasing vigilance is the result of a worker that is engaged in a specific task while ignoring distracting noises. When a truck or piece of machinery is reversing, the workers must be cognizant of this while simultaneously focusing on working at their primary tasks. This awareness of the back-up alarm and the possible danger it signifies decreases as time goes on and as the worker focus sharpens onto their primary objective. In general, workers are probably more vigilant at the beginning of the project and pay more attention to alarm signals. As the project goes on, the alarms become routine to the workers, and the noise is processed more as an annoyance and it tends to be ignored. Workers usually expect equipment to remain on their known paths of operation, or they tend to work in spaces that they consider to be safe based on their knowledge of the site. Sometimes trucks and equipment do not follow their usual paths and this increases the likelihood for accident occurrence (Sawacha 1999).

When considering the hazards that construction workers face on jobsites in regard to back-up alarms, the most effective solution would be containment (Sawacha 1999). This problem continues to be a conflict of interaction between workers on the ground and equipment operating in the same area. Possible solutions to this problem include "(1) improving the workers signal detection through positive feedback; (2) improving the usefulness of signal detection through the use of narrow beam signals; (3) providing drivers and operator with systems to immediately detect obstructions in the path of intended movement" R.B. Blackmon (1995).

Fall Accidents

Falls result in hundreds of fatalities, thousands of injuries each year and thousands of dollars in costs associated with lost time and delays. Some of these incidents involve workers not being aware of potential dangers because the dangers are not visible to them. Construction is a dangerous industry for those who work in it and falls rank at the top of the list for construction related fatalities, accounting for one third of construction-related deaths. Although fall deaths can be prevented, their numbers have increased over the recent years and 2007 registered at least 442 fall related fatalities (OSHA www.osha.gov).

Falls from roofs are a specific area of concern in the construction industry because they account for the largest number of fall fatalities and for the period of 2003-2007 accounted for 686 fatalities (OSHA www.osha.gov).

"During the period 1992–2000, more than 50% of all fall-related deaths occurred in the construction industry, whereas during the same years, only 11% of the fall–

related fatalities occurred in the Services Division, and 9% of the fall-related fatalities occurred in the Manufacturing and the Agriculture–Forestry–Fishing Divisions.” Work-related falls including falls that occurred on the same level make up 16.4% of all serious injuries that occurred in the U.S. private sector in 1993 (BLS www.bls.gov). The BLS describes serious injuries that result in at least one day away from work after the day of the incident. Within the construction industry the specialty trade contractor sector have an elevated exposure to fall-related injuries when compared to heavy construction. Under the trade major group category, roofing, siding, sheet metal contractors and structural steel contractors are at an elevated risk for potential falls because of the tasks they routinely perform. Other trades such as masons, carpenters and painters are also exposed to fall risks, but not to the same extent as structural steel erectors or roofers. BLS statistical data shows that the average days away from work due to falls in the U.S. private industry was 8 days for all types of falls, but the median number however for a fall through a roof opening was 60 days.

Glare

Whether a construction worker operates heavy machinery or performs other tasks that do not involve vehicles or construction equipment, glare can reduce visibility and even make objects invisible. This is even more common in cases involving objects with low contrast (Rob Gray and David Regan 2007). Glare is classified by The International Lighting Vocabulary into two types known as discomfort glare and disability glare. Discomfort glare causes discomfort but does not necessarily cause visual impairment in an individual. Disability glare impairs the visibility of an object but does not necessarily cause discomfort (Fekete et al. 2006). When disability glare occurs, the light is scattered within the eye onto the retina which lowers the amount of contrast of the retinal image. When this reduced contrast occurs in an individual, this can the result in a worker running into another worker, an equipment operator crushing a worker on foot with equipment, an employee walking into a dangerous situation, and so on. While the effects of glare become more pronounced with age, it is not solely an issue affecting only older workers. Glare, especially the type experienced when the sun is at a low position, effects younger workers in the same manner as older workers. In order to prevent accidents caused by the lack of visibility that glare creates, one must increase their safety margin, or time allotted to complete a particular maneuver, as well as wearing eye protection that reduces the glare created by the sun's ray. (Gray and Regan 2007).

Accidents involving construction equipment are frequently caused by impaired vision. Many factors contribute to these occurrences and may involve dust, limited visibility, negotiating obstacles, sunlight and rain. A machine operator often works in less than optimal conditions and the maneuvering of the equipment is influenced by the field of view, reaction time, the attention or focus level being maintained as well as the operator's depth perception. If any one of these key factors is inhibited, there lies the potential for disaster (Changwan et al. 2006).

CHAPTER 3
METHODOLOGY

The Occupational Safety and Health Administration collects information on injuries and fatalities that occur on U.S. construction jobsites. The information of interest for this study was contained in the construction fatality investigation abstracts that resulted from visibility-related impairments. The purpose of this research was to examine construction fatalities investigated by OSHA with the intent of discovering and quantifying the root causes of visibility-related fatalities. The goal of this research was to analyze the circumstances associated with fatal accidents involving disrupted vision functions. The objective was to identify the root causes for these specific types of accidents. The information should be helpful in developing preventative measures to create a safer work environment.

The data for this research was obtained from OSHA personnel. The information was saved to a Micro Soft Excel spreadsheet. The information documented U.S. construction fatality descriptions for incidents that occurred from 1990–2007. The data contained information on 13511 OSHA investigated fatalities. While some of this fatality information is accessible to the public on the OSHA web site (www.osha.gov), the information is limited in scope and it is not as searchable as the information provided by the OSHA personnel to the University of Florida.

The data were analyzed using Excel search functions that were word specific. This word-specific search included terminology that suggested visibility impairment as a causative factor in the accident occurrence. Terms that were included in the search included “blind spots”, “did not see”, “sight”, “blinded”, and “illuminated.” When word searches were conducted it was necessary to account for variations of a word that may have already yielded results. For example the term “illuminate” yielded certain results, but “illuminated” and “illumination” required individual searches and produced additional results. The same concept applied to phrase queries such as “did not see” and variations of the phrase such as “didn’t see.”

The search for the various visibility-related terms yielded 289 cases and this formed the working database on which the study of visibility-related fatalities was conducted. Cases were individually examined and categorized into four main groups, including “struck by” accidents, “falls”, “electrocutions”, and “other”.

The next step in the process was to analyze each of the four categories of visibility-related fatalities and determine the primary circumstances or factors that resulted in the worker deaths. Since illumination was a potential contributing factor in all visibility-related cases, each case was evaluated for lighting conditions at the time of accident occurrence. Circumstances included time of day and other available information that would suggest that lighting was an influential factor.

In struck by cases, vehicles and machinery were commonly involved in the fatality incidents. Since equipment was involved in many of these cases, the different cases were categorized by equipment type. Cases that were categorized as “falls”, “electrocutions” and “other” were analyzed based on lighting conditions that would compromise visibility.

“Struck by” fatalities required additional analysis in order to accurately identify the causal factors associated with accident occurrence. The struck by accidents was examined to determine whether or not the workers involved were wearing reflective vests. Lighting factors were examined in each group of visibility-related fatality cases.

This included a determination of whether there was an abundance or lack of illumination at the time of the fatality accident. The vehicle direction of travel was also examined when further evaluating accident causation to determine if this might have been a contributing factor. The data were also examined to assess whether the equipment had been outfitted with operable back-up alarms.

Figures were developed to present the most relevant findings. Since the involvement of dump trucks, graders, excavators and passenger vehicles comprised the majority of struck by cases, they were reported individually. All other equipment types were combined and the relevant data of these equipment types were reported as a single unit.

Cases were chosen for analysis based on whether there was sufficient evidence to suggest that vision impairment was a key factor in the accident. All cases that lacked convincing data to support the assumption that visibility was a contributing factor were not considered despite their possible relevance. Some cases, namely those involving multiple victims, were reported more than once in the OSHA database. This research did not consider the occurrence of multiple fatalities involved in the same accident. When cases were evaluated for distinct criteria, the desired information may not have been included in the OSHA case description. If the information of interest was not available, it was recorded as “unknown.”

Vision Search Terms

Backed
Backed up
Black
Blind
Blind spot
Blinded
Blinding
Blur
Bright
Could not See
Couldn’t see
Dark
Darkened
Did not see
Didn’t see
Dim
Dimly
Dull
Failed to see
Gloomy
Illuminate
Illuminated
Illumination
Light
Lighting
Lights
Lit
Obscure
Obstruct
Obstructed
Obstruction
Plastic sheet
Ran over
Reverse
Reversed
Seeing
Shine
Too bright
Too dim
Too light
View
Viewing
Visibility
Vision
Visqueen

CHAPTER 4
RESULTS

The information contained in each visibility-related fatality case was examined and the results were categorized. The cases examined were contained in an OSHA fatality database that provided descriptions of over 13,000 construction worker fatalities that occurred in the inclusive years of 1990–2007. The total number of visibility-related cases was determined to be 289. Of these 289 cases, the vast majority of them (263 cases) involved the decedent being struck by a piece of equipment or a vehicle involved in the construction process.

Most of the equipment involved in the struck by cases could be classified as "heavy equipment". This includes but is not limited to dump trucks, excavators, motor graders, scrapers, fork-lifts, dozers, cement trucks and roller compactors. Vehicles that are not considered heavy equipment but are involved in the construction process consist of cars, pickup trucks and truck hybrids that are commonly used on job sites, including "rack trucks".

Example Case 1: Struck by

> A motor grader operator, employee #1, was released by his employer to take a rest. The motor grader was being used to spread chert on the street of a new subdivision. A new operator was assigned to operate the motor grader. When the motor grader started to back up, employee #1 was seen on the edge of the northwest corner of the street. When the grader backed up to the piles of chert, employee #1 was not there. Suddenly, employee #1 was observed in front of the grader lying in the street. The grader had struck and killed him.

Visibility-related fatalities are categorized in Figure 4-1 into four types. These four types are listed as "struck by", "falls", "electrocutions", and "other". Figure 4-1shows how frequently each of these four types of visibility-related fatalities occurred.

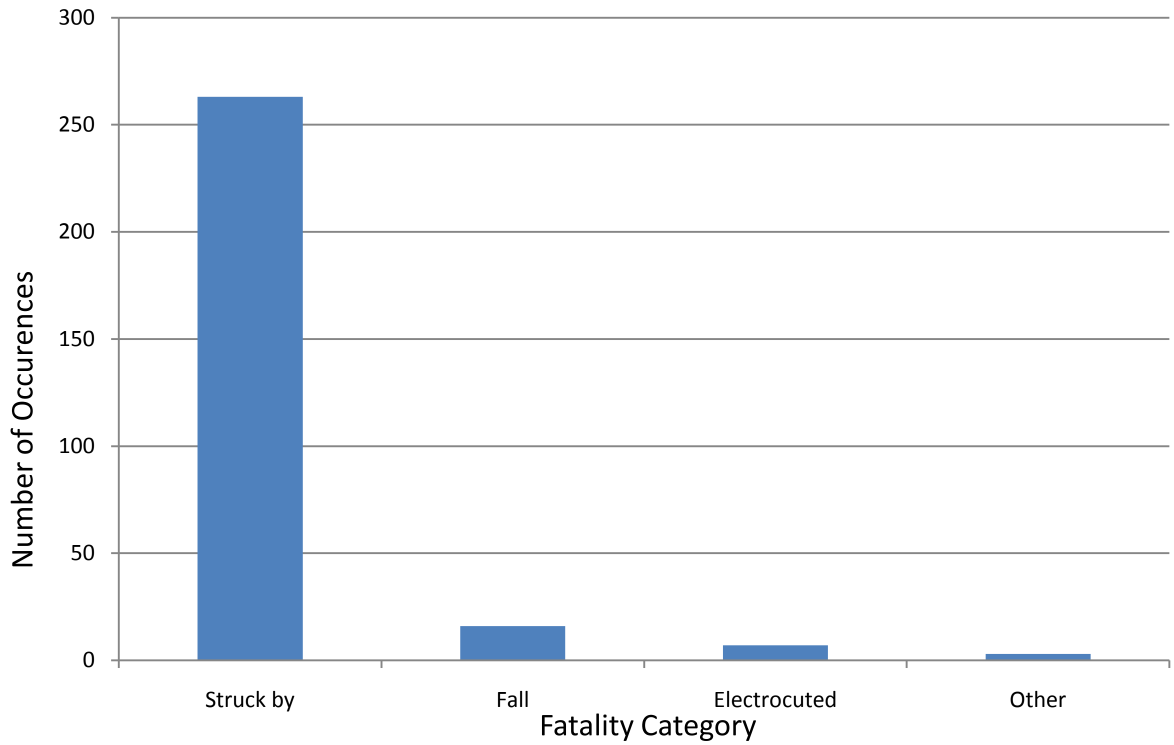

Figure 4-1. Classification of Fatalities (289 cases)

Falls ranked as the second leading category of vision-related fatalities with 16 occurrences. Cases that involved employees falling were attributed to vision occurred in two types of circumstances. The first scenario was too much light being present which would occur in a glare situation. The second circumstance was found to be a limited lighting presence which occurred in poorly illuminated job site areas. Some fatality cases could also been attributed to moving from a bright to dark area or vice-versa.

In the selected fall cases, lighting was found to be the general cause of the accidents. The workers' vision was impaired by the lighting conditions and as a result, they were unable to recognize the dangerous circumstance and ultimately suffered fatal accidents.

Example Case 2: Fatality caused by a fall

> The company was sandblasting and painting the interior of the cargo tanks of a ship that was in drydock. One crew of workers did the sandblasting and another crew was painting. After the sandblasting operation was completed a cleanup crew came in and cleaned up the sandblasting materials so that the painting could be done. An employee on the night shift of the clean-up crew went looking for foxtail brushes for the cleanup crew. The employee climbed down into the pitch black (totally dark) starboard fuel bunker tank of the vessel, looking for brushes. Approximately 15 feet down into the bunker tank there is a first level deck with an opening in the middle of it. The employee started walking around in the dark and he stepped into the deck opening. The employee fell approximately 30 feet to the bottom of the fuel bunker tank."

Other vision related fatalities included electrocutions which occurred because of poor lighting, where the danger was not visible to the employee. While most of the cases examined in this research involved the operation of heavy equipment, smaller types of equipment also resulted in visibility-related deaths. Bull floats are an example of a smaller type of equipment that resulted in fatalities due to contact with power lines.

Example Case 3: Electrocution

> An employee using a bull float was finishing a concrete highway slab when he raised the float, causing the metal handle to strike an energized overhead power line. The bull float had a 19' handle and the power lines were 17' above the ground. The accident happened at the end of the day when it was dark. No temporary lighting was installed. The employee was electrocuted as a result of contacting the overhead power line.

Figure 4-2 identifies each equipment type involved in visibility-related fatalities, and shows how many times each equipment was implicated. Dump trucks were the most frequently occurring equipment and this can be attributed to their large blind spots as well as the time they spend reversing. The next most frequently occurring equipment accidents were caused by excavators, passenger vehicles and motor graders, respectively.

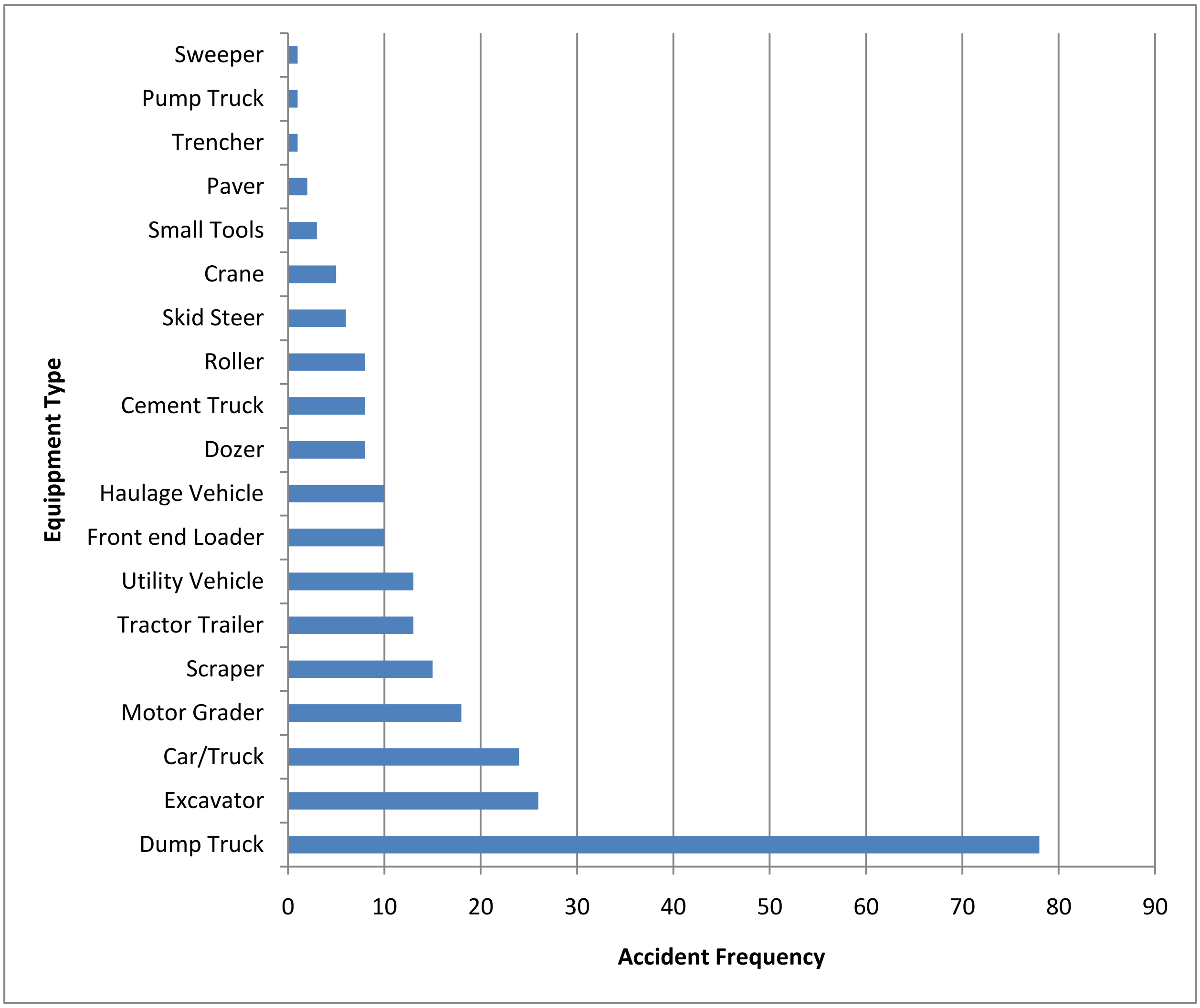

Figure 4-2. Fatalities grouped by equipment type.

The “struck by” cases were evaluated in terms of the type of equipment involved in the accidents. It was found that dump trucks had the highest frequency of involvement in vision-related fatalities. Dump trucks are hauling vehicles that are relatively high off the ground and are positioned on large rubber tires. The dump truck contains a transportation bed that is enclosed on all sides to prevent material from falling out. This bed creates a large “blind spot” for the operator who must rely on rear view mirrors that provide a limited range of view. Objects that are located towards the rear and directly behind the transportation box of the dump truck are often impossible to see and create a potentially dangerous situation when it must travel in reverse.

Because of the operational functions of a dump truck, it is common for a dump truck operator on a job site to be driving extensively in reverse. For all equipment and construction vehicles, blind spots are a frequent cause of visibility-related fatalities.

Blind spots are components of equipment or vehicles that block the view of surrounding areas. This blocked line of sight is caused by transportation beds, rollover protection systems, exhausts, equipment roofs, hoods, engines, as well as buckets or blades such as those on excavators. Other factors that affect blind spots are the vehicle direction of travel as well as the proximity of specific objects. Objects that are near to the equipment may also be obscured from view by blind spots.

Blind spots also include some of the moving components of equipment. These parts of the equipment will be referred to as "moving blind spots." Moving blind spots block an operator's visual path depending on the position of the movable components of the equipment. These components include buckets, blades, forks, arms, and any other components that may be raised and lowered or extended and retracted.

Example Case 4: Moving blind spot

> Employee #1 was working at a construction site inside alliance refinery. As she crossed an access road into the site, she was struck by a forklift tractor. The certified driver did not see her from his position because the forks of the forklift were raised about 2 1/2 ft to 3 ft above the ground and created a blind spot. The right side of the forklift ran over employee #1.

Equipment travel direction was noted in this research. Figure 4-3 shows the percentage of visibility-related fatalities that occurred with equipment in relation to travel direction. The percent entitled "unknown" refers to cases where the accident report did not state which direction the vehicle was headed and no inference could be made from the details. The “does not apply” percentage refers to cases where the equipment was stationary when the visibility-related fatality occurred such as an excavator crushing a worker while trenching.

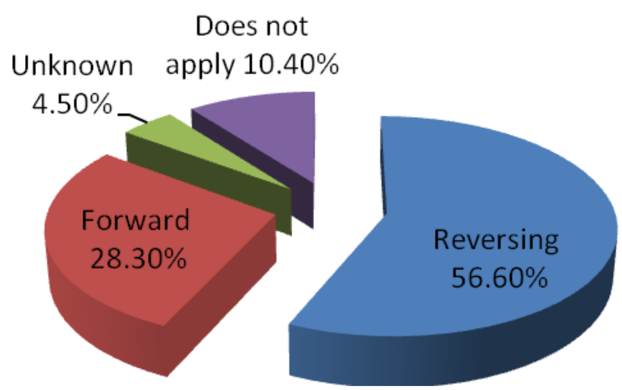

Figure 4-3. Travel Direction. (289 cases)

The construction equipment and vehicles that were involved in visibility-related fatalities were examined in terms of the direction of vehicle travel. The research showed that 162 were in the act of reversing, which is twice the amount of vehicles traveling forward. This statistic dramatizes the hazards associated with equipment when it travels in reverse.

All Equipment and Back Up Alarms

The Occupational Safety and Health Administration has specific regulations regarding the use of machinery when engaged in reverse. OSHA regulations, specifically Title 29 CFR 1926.601(b)(4), state “No employer shall use any motor vehicle equipment having an obstructed view to the rear unless:

(i) The vehicle has a reverse signal alarm audible above the surrounding noise level or:

(ii) The vehicle is backed up only when an observer signals that it is safe to do so.”

It is common for equipment to have blind spots located in the rear. The back-up alarm is a safety measure intended to warn anyone in the vicinity that equipment is engaged in reverse and that relocating to a safe position may be required. Figure 4-4 shows the amount of reversing vehicles that were equipped, not equipped, or did not have a reverse alarm. Many cases were found where equipment was operated in reverse in close proximity to others but that the equipment was not equipped with reverse alarms (21 occasions). It was specifically noted that 42 of the 162 vehicles traveling in reverse were equipped with a backup alarm, while 5 instances reported the presence of a reverse alarm that was inaudible because of job site noise. It was also found that when two backup alarms issue a warning at the same time that employee judgment can be impaired which renders the alarm ineffective.

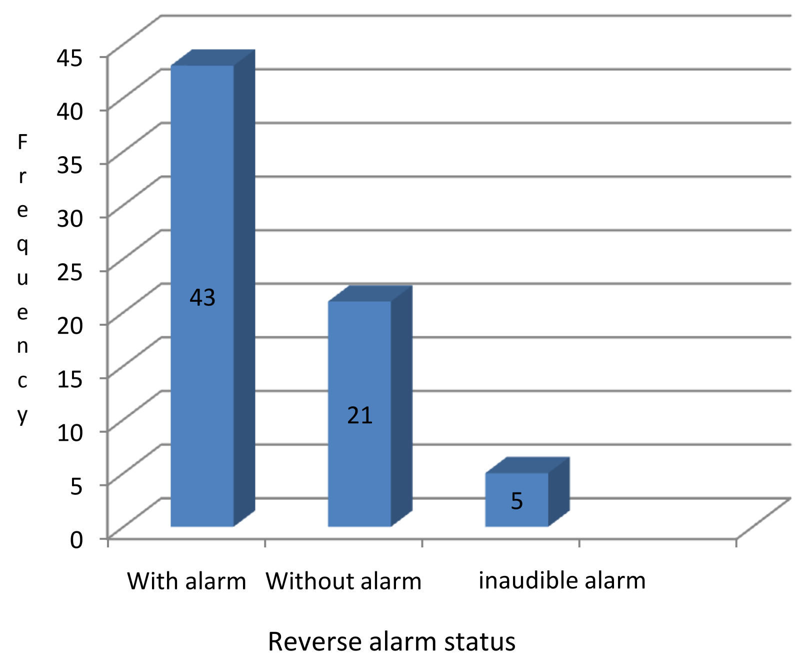

Figure 4-4. Reverse Alarms. (69 cases)

Reflective Vests

Reflective vests are fluorescent and brightly colored. They reflect light in areas of low illumination and they also make employees more visible in day time lighting conditions. Of the 32 reported cases involving visibility-related fatalities 20 of specifically noted that the employees were wearing reflective vests. Twelve cases reported that the deceased employees were not wearing reflective vests. Since most of the reports did not disclose whether or not the employees were wearing reflective vests, it was not possible to make an accurate assessment of the effect that wearing such equipment has on accident prevention. Figure 4-5 shows the amount of visibility-related fatality reports that stated whether a worker was wearing a reflective vest or not at the time of the fatality.

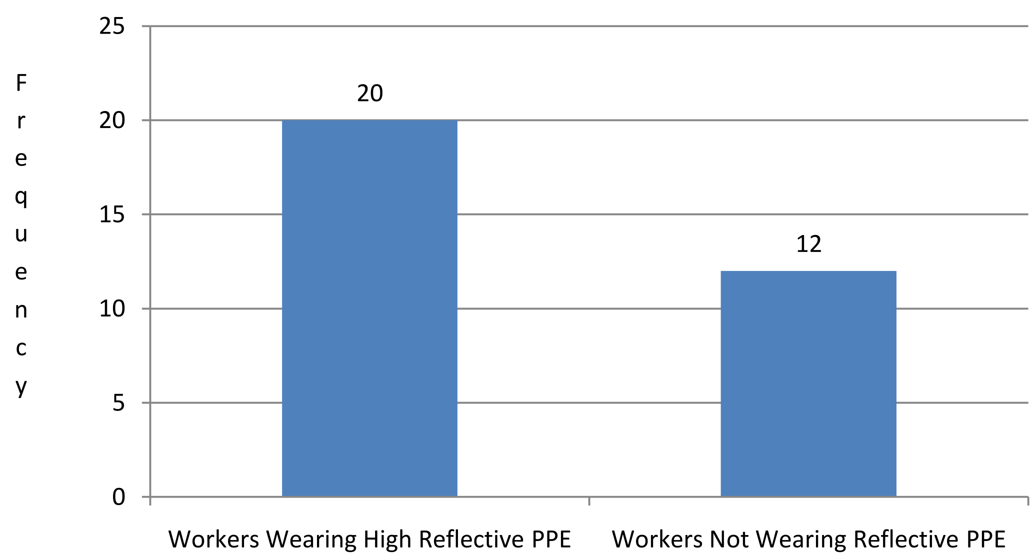

Figure 4-5. Reflective Vests (32 cases)

Equipment Type

Dump Trucks

Figure 4.6. (Source: www.archithings.com/search/john+deere_400d+ar 12/09).

Dump trucks had the greatest involvement in visibility-related fatalities. Figure 4-6 shows a picture of a dump truck similar to those commonly used in the construction industry. Dump trucks were involved in 31% of the struck by cases that resulted from visibility-related conditions. These statistics show that dump trucks are the particularly hazardous and this is especially the case when traveling in reverse. Ninety percent of these fatalities involved dump trucks traveling in reverse and this can probably be attributed to their large blind spot area (truck beds) as well as the frequency that they travel in reverse. Figure 4-7 shows the amount of visibility-related fatalities that occurred while dump trucks were reversing compared to when they were traveling forward travelling forward. There were 74 cases in which the dump truck was traveling in reverse at the time of the struck-by accident. There were 8 cases in which the dump truck was traveling forward at the time of the struck-by accident.

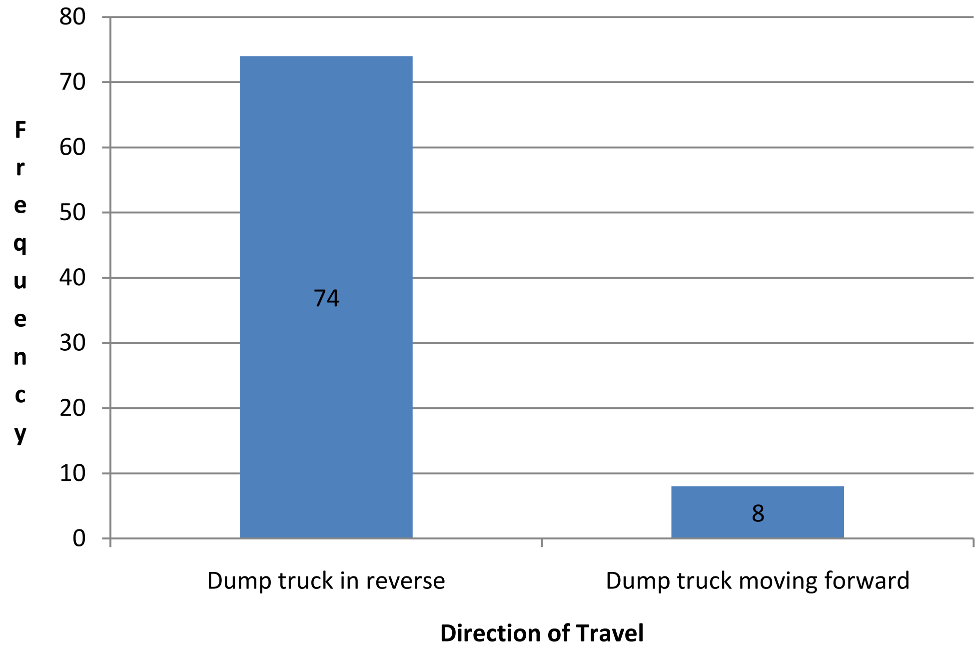

Figure 4-7. Dump truck travel direction (82 cases)

Figure 4-8 shows the number of dump trucks that were equipped with a backup alarm compared to the number of dump trucks that were not equipped with a backup alarm or did not state if there was a backup alarm at the time of the accident. There were 41 cases that did not state whether the vehicle had a backup alarm at the time of the accident. There were 33 cases in which the vehicle did have a backup alarm and 8 cases in which the vehicle did not have a backup alarm.

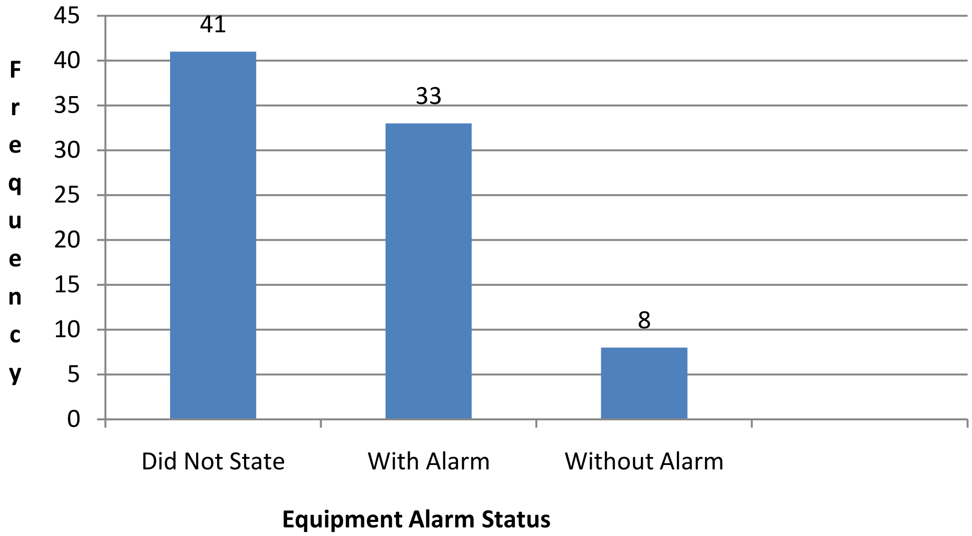

Figure 4-8. Dump trucks and reverse alarms (82 cases)

Dump Trucks and Reflective Vests

This finding showed that in 18% of the fatality cases caused by dump trucks, the workers were wearing reflective vests. This number of reflective vests worn might actually be larger, but the research was unable to determine this due to the infrequency of which the use of reflective vests were reported in the OSHA fatality database. Reflective vests increase the visibility of employees working in proximity to equipment and it can be deduced that the likelihood of preventing an accident would increase if everyone wore reflective vests at all times. Figure 4-9 shows the percentage of workers that were killed by dump trucks in relation to whether the worker was wearing a reflective vest or not. The majority of the cases studied did not state whether the worker was wearing a reflective vest at the time of the accident. Nearly 16%of the cases studied indicated that the worker was wearing a reflective vest at the time of the accident, while 3.7% indicated that the worker did not have a reflective vest on at the time of the accident.

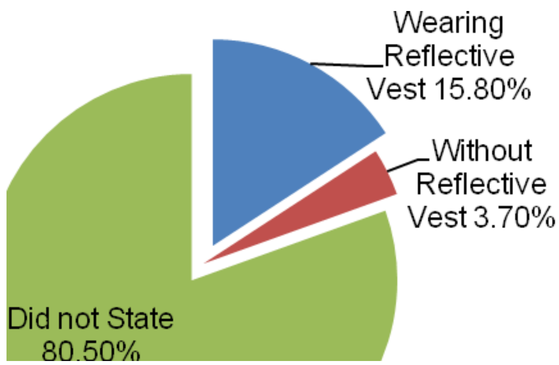

Figure 4-9. Dump trucks and reflective vest use (82 cases)

In each case examined in this study, one of the major goals of the research was to discover the root causes associated with visibility-related fatalities. The main contributing factors were grouped into four categories. The first of these categories were "too much lighting" as in the case of glare or a sudden change from a poorly illuminated area to one of overwhelming illumination. This type of situation would cause accidents when employees lost their visual reference of surrounding objects.

Example Case 5: Too much light (glare)

> At 9:00 A.M., the victim….was fatally injured when he was backed over by the right rear tires of a 10–wheel dump truck. The victim was the grade checker and ground set up person for an asphalt grinder. The grinder was grinding out a strip of asphalt on the shoulder of eastbound 180 just outside the eastbound #3 travel lane. The victim had parked, his service truck off the shoulder on the dirt well east of the work area and was evidently walking back to the grinder about 350 feet back to the west. At this time, a dump truck pulled out of the travel lane eastbound and onto the dirt shoulder in front of (west of) the victim. Because of the glare of the morning sun when facing east, the driver did not see the victim walking west bound on the edge of the asphalt shoulder. The driver was facing the sun glare in the east. Another truck came near enough to the pedestrian to cast a shadow on him. The first driver was startled to see the previously unseen pedestrian. While the driver took evasive measures, the victim was crushed by the second truck.

The second category used to group the data was “too dark”, instances where there was insufficient lighting. This topic of “too dark” often included scenarios of working at times that were between the hours of dusk and dawn. Improper illumination of the job site or darkly colored conspicuous objects also resulted in workers being involved in fatal accidents.

Example case 6: Too dark

> Employee #1 was inside a 180 ft diameter dome, greasing the pins on a kochring 6633 excavator bucket. A kenworth 10–wheel dump truck with an inoperable back up alarm backed into the dome, heading toward the excavator bucket. The excavator engine was running and employee #1 neither saw nor heard the dump truck approach. The truck driver, his vision impaired by the change in lighting from outside to indoors, did not see anyone around the backhoe. The right rear corner of the dump truck struck the excavator bucket, pinning employee #1 between the truck and the bucket. He sustained massive internal injuries, and was killed.”

The third category known as “obstructions” included situations where there was some sort of visual impediment that blocked the line of sight from the operator to the worker. An example of such an impediment would be a mound of dirt or fill material that hides an employee. If the equipment operator could not see the worker because of the broken line of visual contact due to a barrier, then such instance would be considered an obstruction and classified under this category.

The fourth and fifth categories are comprised of “blind spots” and “moving blind spots.” Figure 4-10 shows the type of visibility impairment in dump truck fatalities and how frequently each type occurred. Blind spots were the most frequently occurring type of visibility impairment with 46 cases reported. Obstructions were the second most frequently occurring type of visibility impairment with 19 cases reported. There were 11 cases where the type of visibility obstruction was not mentioned, five cases where the lighting was too bright and one case where the lighting was too bright.

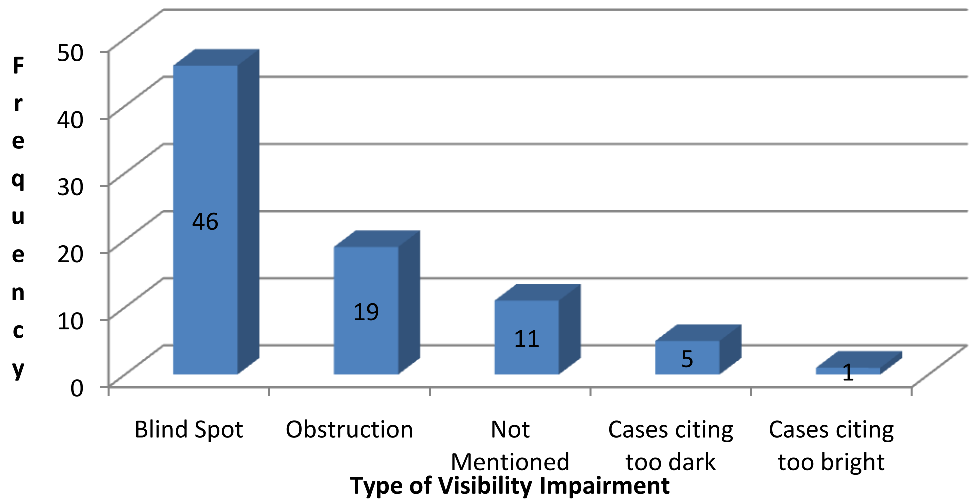

Figure 4-10. Vision factors attributed to dump truck fatalities (82 cases)

Passenger Vehicles

Figure 4-11. Passenger Vehicles (Source:
www.steadfastlinings.net/white_truck_rack.jpg 12/09).

Passenger vehicles such as cars and trucks are often involved in visibility fatalities. Figure 4-11 shows a common version of a passenger truck that is used in the construction industry. The majority of visibility fatalities involve a vehicle traveling in the forward direction. Research has shown that highway construction is often effected by these types of vehicle accidents whether it is due to the improper arrangement of warning devices and signals about oncoming traffic or poor illumination of work areas.

Example Case 7: Fatality involving passenger vehicle

> Employee #1 was attempting to cross an intersection when he was struck by an automobile and knocked 97 ft. The driver of the car stated that he initially did not see employee #1 walking in the intersection. When he did see employee #1, he applied the brakes to avoid hitting him. Employee #1 was not wearing any reflective equipment or clothing; the worksite was not

illuminated; and the highway warning signs were not distributed or spaced properly or mounted correctly.

Figure 4-12 notes the number of fatalities that involved passenger vehicles traveling in forward and in reverse. Passenger vehicles traveling in the forward direction were involved 21 fatalities. It was found that vehicles traveling in reverse were only involved in five fatalities.

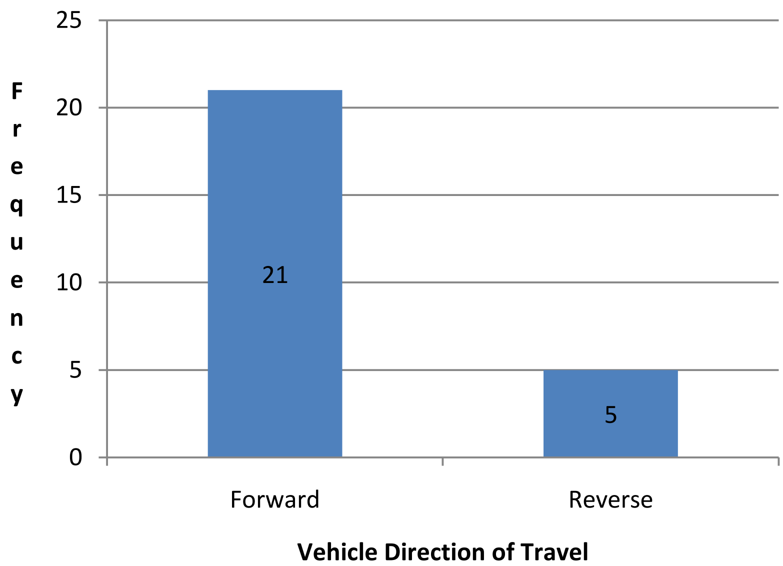

Figure 4-12. Vehicle travel direction (26 cases)

In the cases involving passenger vehicles, one case involved a vehicle that had an alarm, and three cases did not provide this information. All cases failed to report whether the decedent in the accident was wearing a safety vest or not. Figure 4-13 shows the amount of reversing passenger vehicles with alarms and the amount that were not mentioned.

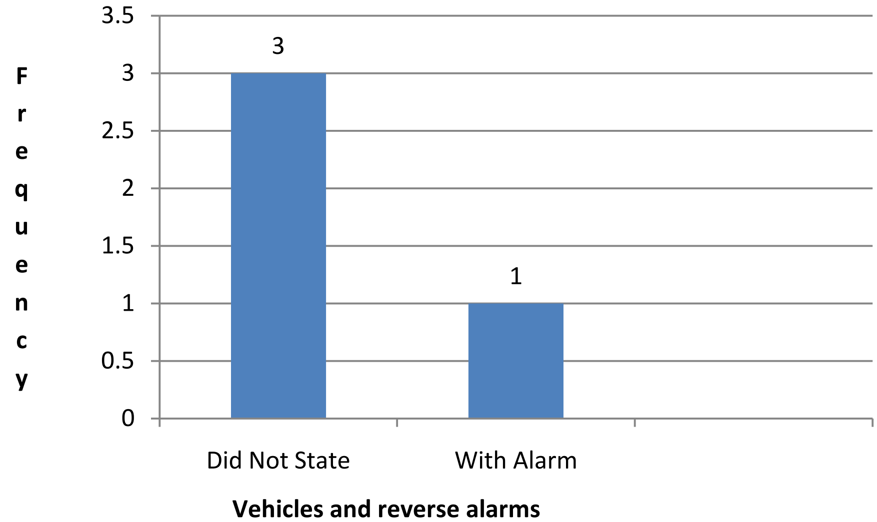

Figure 4-13. Vehicles equipped with reverse alarms (4 cases)

Figure 4-14 shows the number of visibility-related fatalities caused by passenger vehicles and the stated cause of the accident. In cases where the accident cause was cited, poor visibility caused by low lighting levels and obstructions were the most common causes cited. There were seven cases in which low lighting levels were cited as the cause of the accident. There were seven cases in which obstructions were cited as the cause of the visibility-related fatality. Blind spots were the next most common cause of visibility-related fatalities with three total cases. There were two reported fatalities where the lighting being too bright was cited as the cause of the accident.

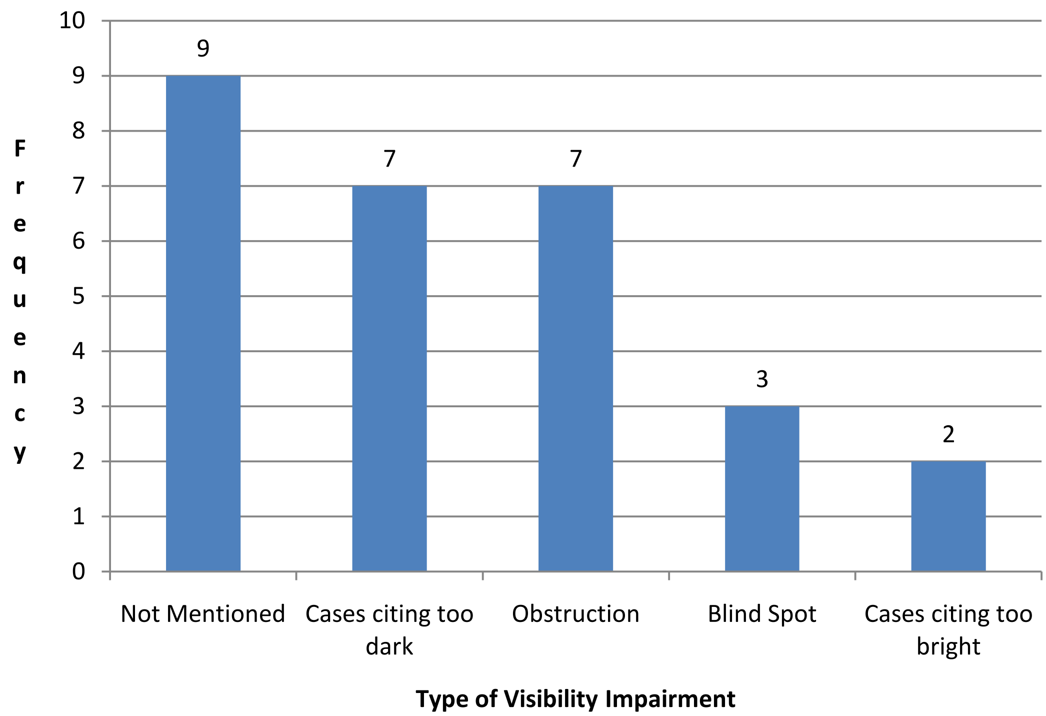

Figure 4-14. Vision factors attributed to vehicles fatalities (28 cases)

Motor Graders

Figure 4-15. Motor Grader (Source: www.equipment.forconstructionpros.com/product/620 12/09).

Figure 4-15 shows a typical motor grader commonly used for the construction of roads and highways as well as various other site work activities. Motor graders represent the second most frequent equipment involved in visibility-related fatalities.

Graders have large blind spots and usually operate in tandem with dump trucks in paving operations. This is a procedure with limited space that is inherently dangerous and relies heavily on signaling for communication because of the lack of visibility.

Example Case 8: Fatality involving motor grader

> A motor grader operator was backing up his vehicle at a project worksite. A grade checker was working on foot 20 feet north of the vehicle, obscured from view by the vehicle's blind spot. As the grader operator backed up, the picker of the vehicle struck the grade checker and knocked him over. The motor grader ran over the grade checker, fatally injuring him."

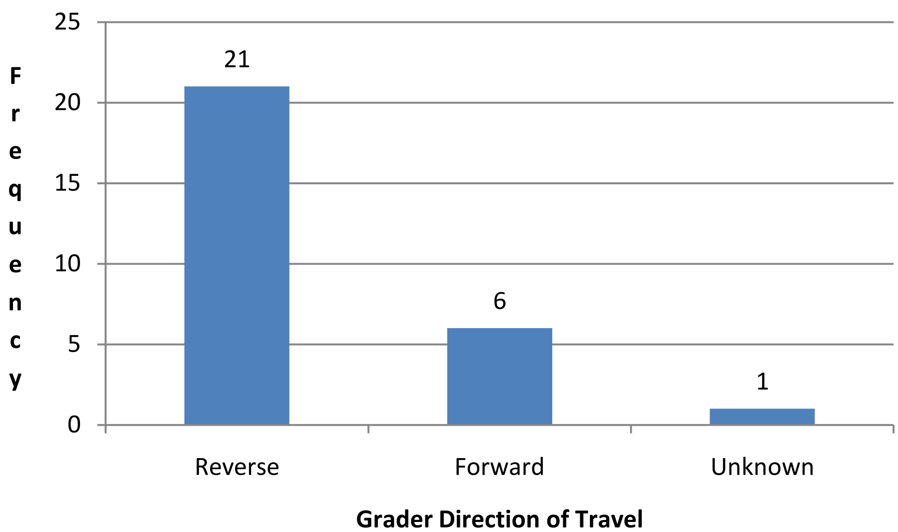

Figure 4-16. Grader direction of travel (18 cases)

Figure 4-16 shows the direction of travel of motor graders involved in visibility-related fatalities. There were 21 cases in which the grader was traveling in reverse at the time of a reported accident. There were six cases where the grader was traveling forward and one case where the direction of travel was unknown.

Figure 4-17 shows the number of graters involved in visibility-related fatalities and whether or not they were equipped with a backup alarm. There were 23 fatality cases reported where the grater was not equipped with a backup alarm. There were four cases that did not state if the grader was equipped with an alarm. There were no cases found of a visibility-related fatality where the motor grader was equipped with a backup alarm.

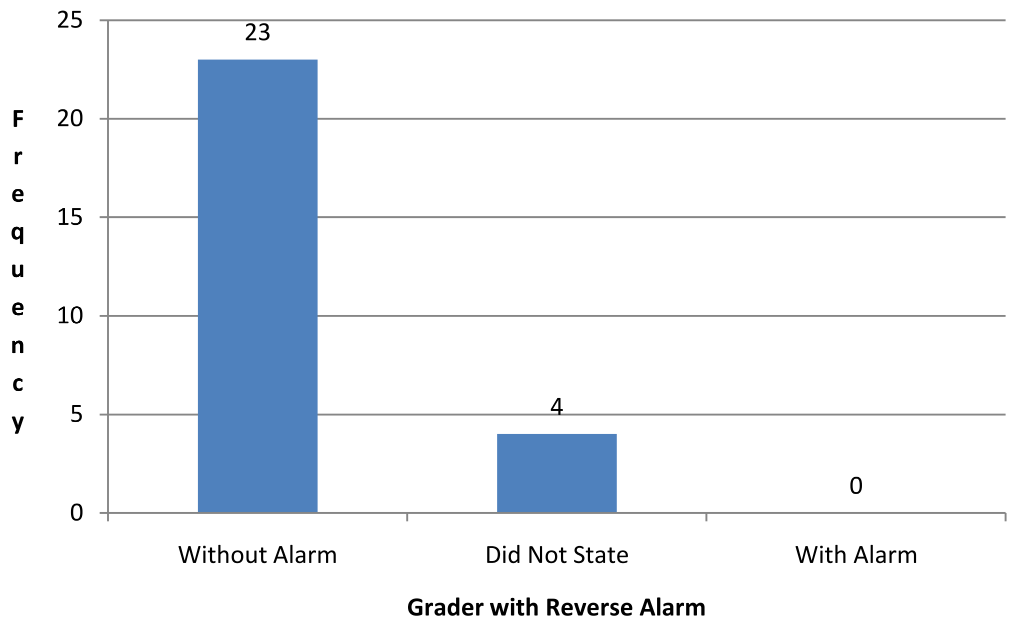

Figure 4-17. Graders equipped with reverse alarm (18 cases)

Figure 4-18 shows the number of visibility-related fatalities caused by motor graders and the stated cause of the accident. Blind spots were the most commonly cited reason for the visibility-related fatality with a total of 14 cases citing this as the cause. There were nine cases in which obstructions were cited as the cause of the accident. There were seven cases in which the cause of the visibility-related fatality was not cited. There was one reported fatality where the lighting being too bright was cited as the cause of the accident. There were no cases in which the ambient lighting being too dark was cited as the cause of the visibility-related accident.

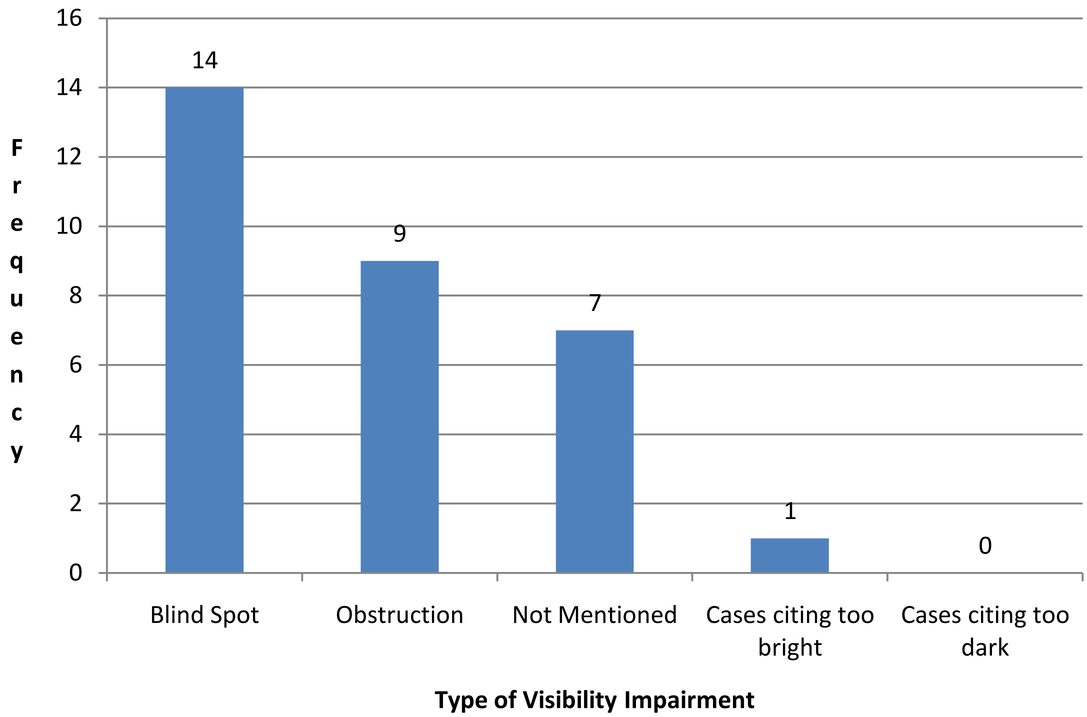

Figure 4-18. Vision factors attributing to grader fatalities (18 cases)

Excavators

Figure 4-19 shows a typical version of an excavator that is commonly used in the construction industry. Excavators like these are commonly used to perform various aspects of site work and can be employed on a wide variety of projects ranging from residential to commercial and from industrial to civil. They have many functions and may be used for tasks that range from digging to hoisting materials.

Figure 4-19. Excavator (Source: www.xcavator.com/used_excavator.htm 12/2009)

With regard to direction of travel at the time of accident, this research shows that most of the incidents involving excavators occurred when the equipment was traveling in the forward direction. Figure 4-20 shows the direction of travel of the excavator involved in a visibility-related fatality at the time of the accident. In 19.2% of cases, sufficient information to determine travel direction was not available.

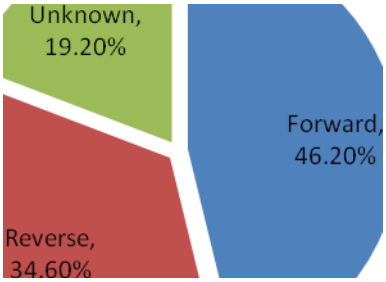

Figure 4-20. Excavator direction of travel (26 cases)

In all cases of visibility-related fatalities with excavators involved, the presence of the bucket at the front of the excavator creates an inherently dangerous condition. This can be attributed to the large blind spot that may be stationary or moving depending on the location of the excavator bucket as illustrated in example case 9 below. Example 9 highlights the dangers associated with operating an excavator that contains a moving blind spot.

Example Case 9: Fatality involving excavator

> The backhoe operator was loading a spoil pile into a dump truck as a worker was removing metal from the spoil pile on the opposite side. The backhoe operator accidentally struck and killed the worker with the bucket because he did not see him.

Excavators may be rubber-tired or tracked. They are versatile machines that may spend large amounts of time in a stationary position as is common with the operation of a track hoe, or they may move about frequently which is normal with a back hoe. They often contain booms which attach to a bucket and this component may be long in order for the operator to reach over obstacles and to access the excavation material. Excavators are common on many jobsites and often must operate in close quarters, next to buildings and people. Because of their large demand and operation conditions, they are frequently involved in construction fatalities.

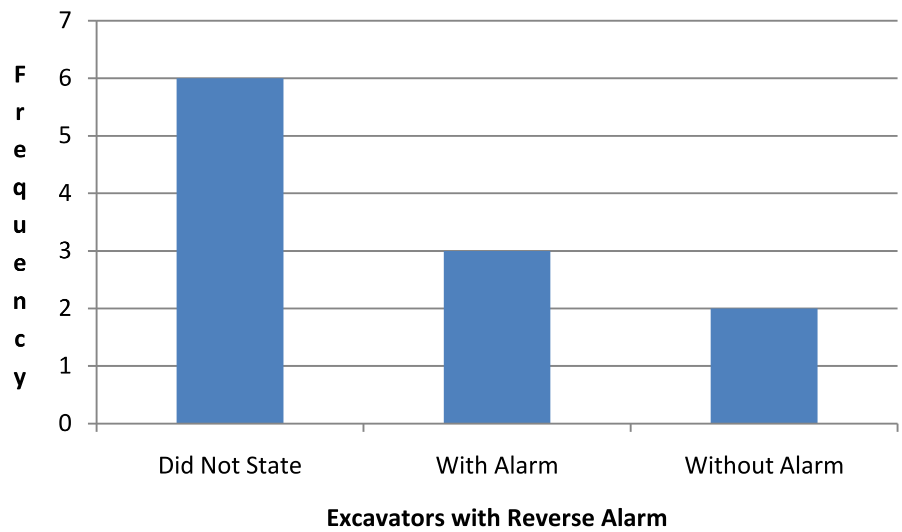

Figure 4-21. Excavators and reverse alarms (11 cases)

Figure 4-21 above shows the status of the excavators reverse alarm at the time of a visibility-related accident. Six cases did not state whether the vehicle was equipped with a reverse alarm at the time of the accident. Three cases indicated that the excavator was equipped with a reverse alarm and two cases indicated that the excavator was not equipped with a reverse alarm.

Figure 4-22 below shows the number of vision-related excavator fatalities and the factors attributed to those fatalities. Obstructions were the most frequent cause associated with excavator visibility-related fatalities with 10 cases citing obstructions as the cause. Moving blind spots were the second most cause with 8 cases stating them as the cause. These two leading causes can be attributed to both the nature of excavation work as well as the unavoidable creation of moving blind spots due to the equipment configuration and operation.

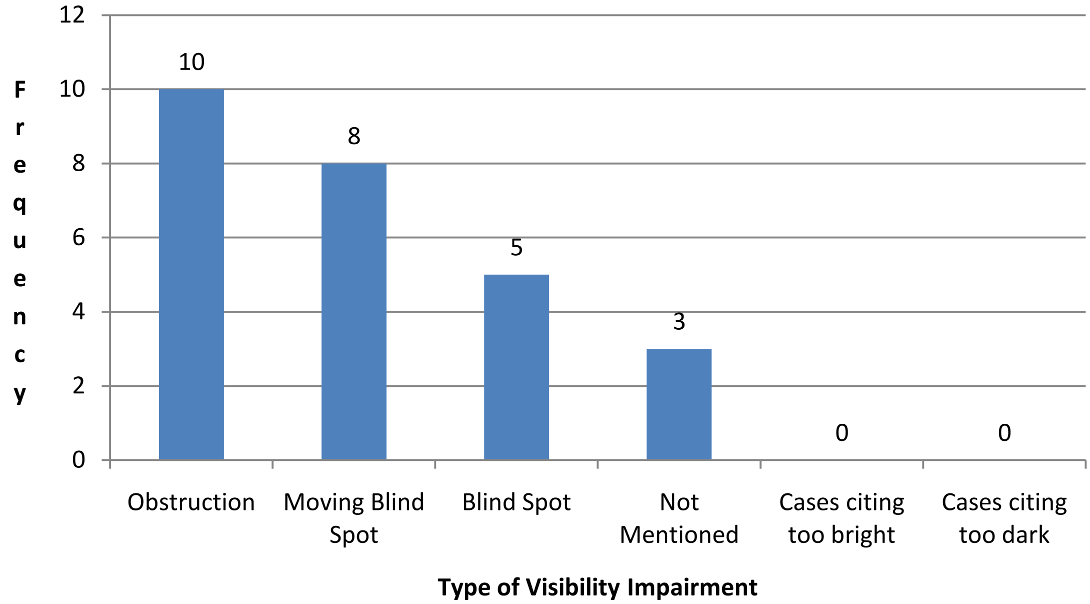

Figure 4-22. Factors attributed to excavator fatalities (26 cases)

All other Equipment and Vehicles

The four equipment types that most frequently were involved in visibility-related fatalities were reported individually. All remaining vehicle and equipment types have been analyzed individually but reported as a single unit. Figure 4-23 below shows the total number of visibility-related fatalities for all remaining equipment types compared to the direction of travel at the time of the accident. There were 49 total cases in which the vehicle was traveling in the reverse direction and 40 total cases where the vehicle was traveling in the forward direction. There were nine reported cases in which the vehicle direction of travel was unknown and two reported cases where the vehicle direction of travel was not applicable.

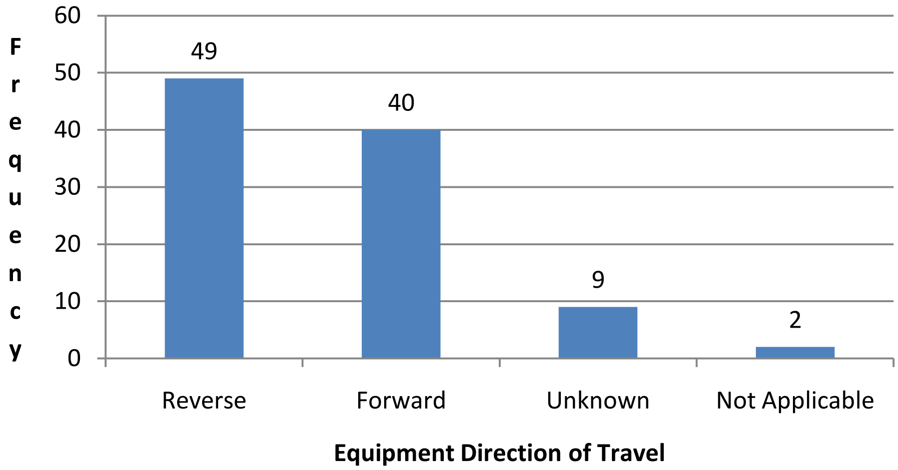

Figure 4-23. Direction of travel (100 cases)

Figure 4-24 below shows the total number of visibility-related fatalities for all remaining equipment types and the status of their reverse alarm at the time of the accident. The majority of the cases reported did not state whether or not the vehicle was equipped with a reverse alarm at the time of the accident. Thirteen cases indicated that the vehicle was equipped with a reverse alarm at the time of the accident and eight cases indicated that there was no reverse alarm present.

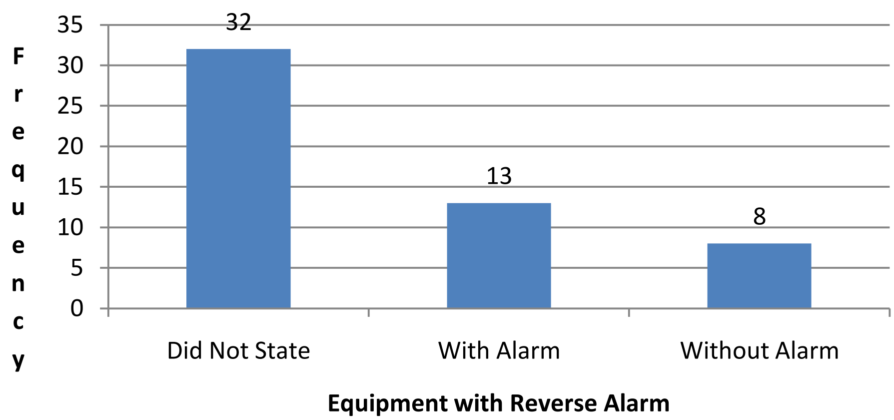

Figure 4-24. All other equipment with reverse alarms (53 cases)

Figure 4-25 below shows the total number of vision-related fatalities for all remaining types of equipment and whether or not the decedent was wearing a reflective vest at the time of the accident. There were 65 reported fatalities in which the decedent was not wearing a reflective vest at the time of the accident. There were 5 reported cases in which the decedent was wearing a reflective vest at the time of the accident and 5 cases in which the status of the reflective vest was unknown.

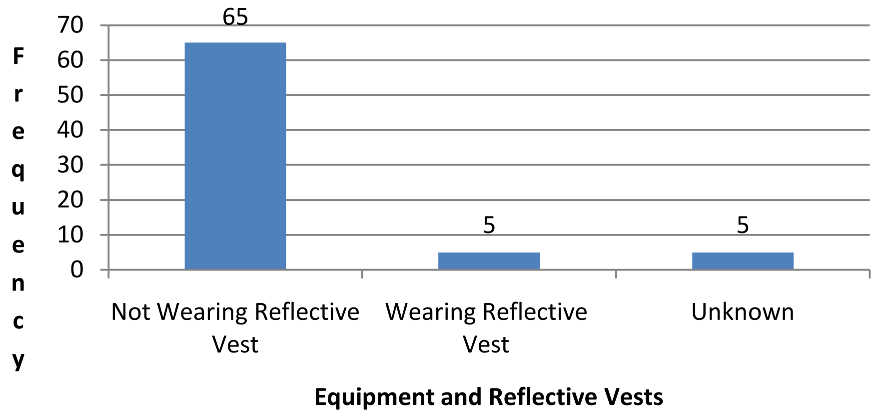

Figure 4-25. All other equipment and reflective vest use (75 cases)

Figure 4-26 below shows the total number of vision-related fatalities involving all other types of equipment and the stated cause of the accident. Blind spots were the most commonly cited cause of accidents with 39 total occurrences. There were 20 cases in which the cause attributed was not mentioned. There were 15 cases where obstructions were cited as the cause, ten cases in which the lighting being too dark was cited as the cause and eight cases where a moving blind spot was cited as the cause. There were no cases that cited the lighting being too bright as the cause of the vision-related fatality.

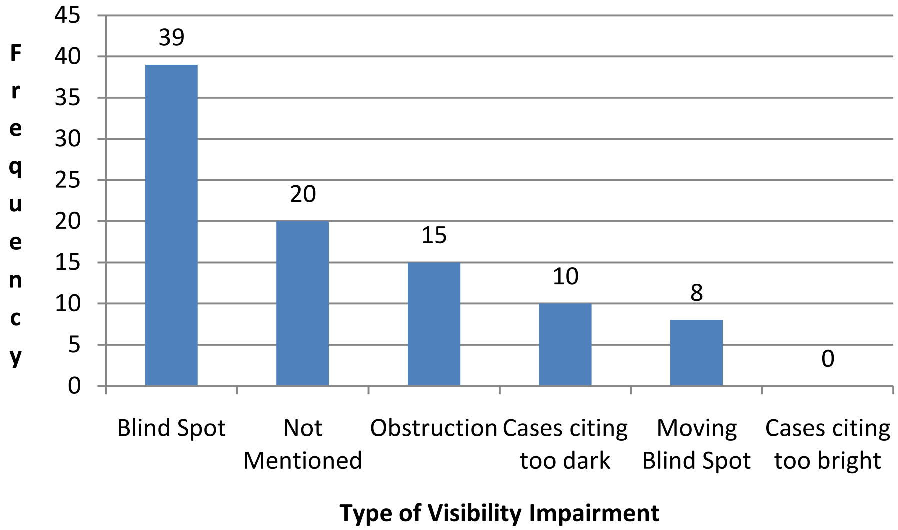

Figure 4-26. Causes attributed to all other equipment fatalities (92 cases)

All Equipment Combined

This next section is dedicated to the analysis of all vision-related fatalities for all types of construction equipment combined. Figure 4-27 shows the total number of vision-related fatalities for all types of equipment and the cited cause of the accident. The most frequently cited cause of vision-related fatalities for all types of construction equipment was the presence of blind spots. Blind spots were cited as the cause of nearly 130 visibility-related fatalities. Obstructions were the second most frequently cited cause of visibility-related fatalities with 68 fatalities attributed to this cause. There were over 54 cases reported in which the cause of the visibility impairment was not mentioned. There were 21 fatalities attributed to the lighting conditions at the time of the accident being too dark and only three cases where the lighting conditions were too bright.

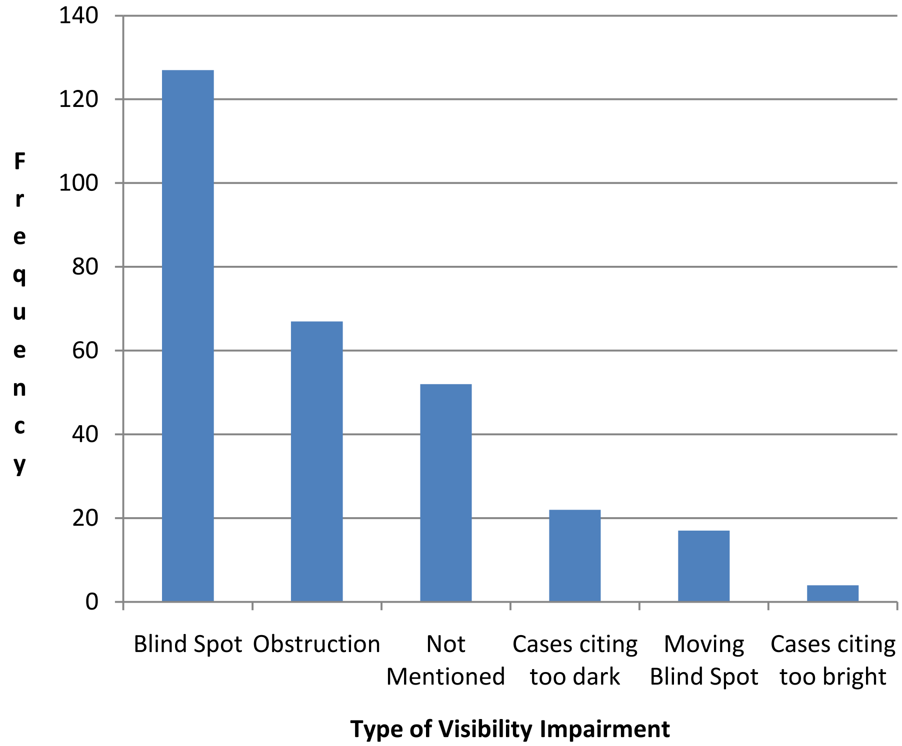

Figure 4-27. All vision related fatalities involving all equipment (289 cases)

The presence or absence of light was also factor in visibility-related fatalities. In some instances, workers were blinded by glare prior to their involvement in a fatality or were unable to react to a certain object because illumination was lacking. This point is illustrated by example cases number ten and eleven below.

Example Case 10: Too Dark

> Victim 1 was assigned the task of laying the string for the paving equipment to follow. His task was performed about 100 yards ahead of the paving operation. No additional lighting was provided. The dump trucks were on their second cycle of the evening for dropping paving material when the incident occurred. A truck arrived, dumped his trailer at the paver, drove east on the street past Victim 1, unhooked and parked the empty trailer. A Reed truck was waiting near the center median to leave the work area. The truck moved to the right to pass between the cones set up for traffic control and the Reed truck waiting to leave. The first driver struck and subsequently ran over Victim 1.

Example Case 11: Too Bright

> An employee who was flagging traffic was struck by a west-bound truck. The truck driver stated that the sun blinded him and he did not see the flagger.

Most heavy construction equipment contains headlights for operating in less than optimal lighting conditions and it is important that they are utilized at appropriate times. Figure 4-28 below shows the total number of visibility-related fatalities and the time of day that they occurred. The hours of 10am through 12 pm were the most common times in which visibility related fatalities occurred. There were 28 vision-related fatalities that occurred during this time frame.

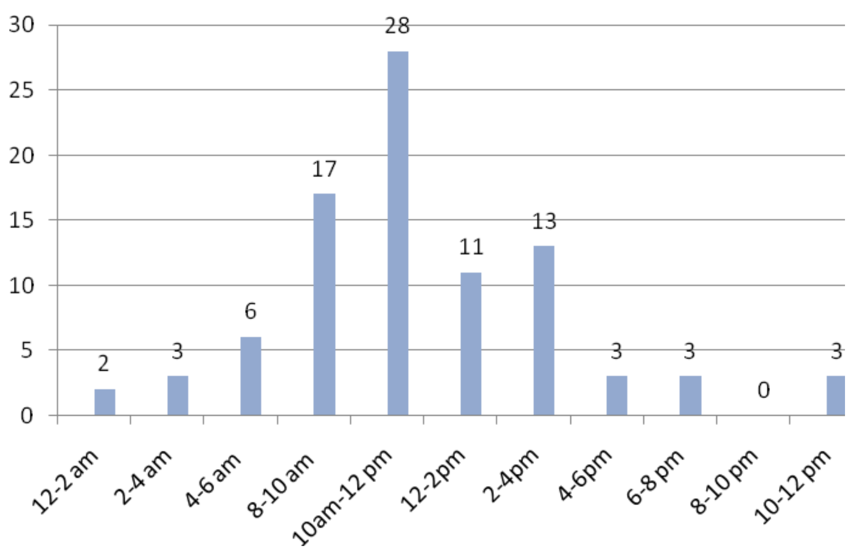

Figure 4-28. Vision related fatalities with reported time of occurrence (89 cases)

There were 17 visibility-related fatalities that occurred between the hours of dusk and dawn. For the purposes of this study dusk through dawn is defined as 6pm through 6am. This number represents nearly 20% of all vision-related fatalities for all types of construction equipment studied.

CHAPTER 5
CONCLUSION AND RECOMMENDATIONS

The focus on worker safety continues to grow in importance throughout the construction industry. Safety is a major priority that has been and will likely continue to be emphasized by public opinion, policy makers and construction managers. Fatalities on construction jobsites are no longer considered a part of doing business and as construction research continues to identify areas for safety improvement, there are reasons to suggest that fatality numbers will continue to decline.

This research targeted visibility-related fatalities in the construction industry with the aim of discovering relevant patterns of unsafe practices that need to be addressed. The role of specific factors that contributed to worker fatalities were identified. By increasing the knowledge base and the known facts surrounding these incidents, the application of an improved safety model would contribute to improved methods of operation to reduce fatalities. It was determined that visibility-related construction fatalities accounted for nearly two percent of all construction fatalities in the years between 1990-2007.

Research into visibility-related fatality cases showed that specific safety practices could be implemented to reduce the number of fatalities that occur. For example, it was found that the majority of the visibility-related fatalities were “struck by” accidents. Of these “struck by” cases, dump trucks were involved in over 29% of the fatalities. This large number was attributed to the extensive number of blind spots on dump trucks which compromise maneuverability and safe operations, especially when traveling in reverse.

These research findings suggest that visibility-related fatalities were the result of five causal factors. These factors were comprised of situations involving excessive lighting, insufficient lighting, visual obstructions, blind spots and moving blind spots. The research findings showed that when equipment was involved in a fatality, over 45% of the incidents were the result of blind spots.

The findings of this research point to key visibility factors that facilitate the conditions for fatalities to occur. One of the main problem areas was identified as the lack of high visibility of workers on the ground to equipment operators. This could possibly be addressed by the use of reflective vests. This research showed that of the 32 cases where the presence or absence of reflective vests was reported, 12 (37%) of the incidents occurred when the victim was not wearing a reflective vest. Empirical data addresses the absolute necessity for recognizing objects on the ground to appropriately navigate around them.

The equipment direction of travel was found to be important to understanding the increased risk associated with equipment usage on construction sites. A high percentage of accidents occurred when equipment was traveling in reverse. The findings confirm the escalated risk that is involved when operating in reverse with heavy equipment. Proactive solutions to addressing this dilemma include requiring all equipment operators to familiarize themselves with site layouts and areas of foot travel. The use of two-way radios or hand signaling can improve communications and compensate for the inability of operators to visually see objects while traveling in reverse.

Additional methods of alerting workers on the ground to the close proximity of equipment includes ensuring that all equipment is equipped with operable reverse warning systems or that flaggers/spotters assist in equipment maneuvers. Additionally, the use of spotters on the ground that maintain constant communications with equipment operators is also an important facet of safe procedures and their importance cannot be overstated. Spotters can direct the movement of equipment as well as alert passing vehicles and workers of the presence of danger.

While certain operations were found to be more dangerous in reverse, some equipment experienced higher accident rates when traveling forward. These cases were specifically recognized in excavator operations. This can be attributed to the movable blind spots that were created by extensions of the equipment. Since excavators require the constant adjustment of the bucket height, the increased likelihood of a broken line of sight to a potential victim remains a significant factor of concern.

Moving blind spots require the operator to exercise a greater level of vigilance and conduct repeated vicinity checks to identify workers on the ground, along with other major obstructions. This research suggests that there is a need to conduct inspections of areas that may appear unconventional to the operator. Several of the cases that were analyzed involved a worker located underneath the equipment or inside of an excavation. Operators are typically not accustomed to expect workers in certain locations. Safety training should familiarize the operators with the potential of striking workers on the ground. Potential conflicts should be expected in all areas of operation, including underneath the equipment and anywhere in the vicinity of the task performance area. This also involves checking areas previously known to be clear of personnel. Certain areas may have been re-occupied prior to the equipment's return. Excavations and travel paths that may have previously been clear of workers may later become occupied and taking this for granted could result in an accident.

Illumination factors are an important aspect of construction safety; however, they are frequently not recognized in the accident descriptions. When an accident occurs, the typical response is to attribute the cause to the most obvious agent. For example, a worker may be struck by and killed by a vehicle. Conventional industry procedure is to classify this incident as a "struck by" fatality, and the assumption from this occurrence is that equipment is dangerous. While this may in fact be a "struck by" accident, closer examination of the root cause may reveal that vision impairment was the primary factor and the equipment, because of its size and weight, was a secondary factor. This research showed that in 14% percent of all visibility-related cases, lighting was the primary contributing factor.

A study of the time of day when accidents occurred showed a correlation between lighting factors and accident frequency. While this research found that the majority of accidents occurred during the hours of 8:00 AM to 10:00 AM when the sun was at an angle to produce maximum glare, other factors made it impossible to single out glare as the key contributing factor. In order to make this assumption, additional factors would have to be identified. Causative factors were clear when the incident reports specifically stated that the equipment operator was blinded by glare.

Similar difficulties existed when quantifying the effect that a lack of illumination had on visibility-related fatalities. With this assumption in mind, it is likely that actual cases involving insufficient illumination occurred more frequently than reported in these findings. Several cases were found where there were poor lighting conditions. What can be concluded from the OSHA fatality data is that reflective PPE worn by employees on the jobsite when these conditions occur would improve the operator's awareness of workers on the ground and reduce the likelihood of accidents. Increasing jobsite illumination through the use of spot lighting or warning signals in the case of highway construction would help considerably in making potential victims visible to operators and drivers.

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BIBLIOGRAPHIC SKETCH

Mitchell Thurston was born in Eleuthera, Bahamas. He received his high school diploma from Essex Catholic High School in East Orange, New Jersey in 1998 and attended Rutgers University in the fall of 1998. He majored in business management and minored in management information systems. Upon graduating with a bachelors' degree of science in 2002 he was introduced to the construction industry as a project engineer for a family home building business. He decided to pursue a master's degree in building construction at the M.E. Rinker, Sr. School of Building Construction in 2008. Upon graduating with a master's degree in building construction, he intends to work in the construction industry as a field engineer and one day as a superintendent.