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The Status of Construction Jobsite Emergency Alert Systems in the Construction Industry

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Signature Page

Construction Jobsite Emergency Alerts

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Dedication

I would like to dedicate this research in memory of Dean Robert A. Potter Jr.

Thank you for all you have done for me.

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I would like to thank my thesis advisor B. Gokhan Celik for guiding me through the process of writing this research paper. I would also like to thank my thesis committee, Michael Emmer, and Issa Ramaji for providing great guiding advice.

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Abstract

There are various types of emergency alert systems available in the construction industry from the air horn to more complex remote and app-based systems. This study utilizes an industry survey to identify the most commonly used emergency alert methods on jobsites, and the industry professionals' knowledge and perceptions of app-based and remote emergency alert systems. Results indicate that the air horn is the most commonly used method of emergency alerts, and the construction industry is willing to spend more on the remote emergency alert systems compared to the app-based emergency alert systems. The major concerns from the construction industry are the overall cost and reliability of the high tech systems, and the potential for false alarms. Results show that if the concerns of the construction industry are addressed, companies are willing to spend more on the app-based systems.

Chapter 1: Introduction

1.0 Introduction

Completing a successful construction project today is not only providing a high quality project on time and budget, but also includes a safe and healthy working environment for all workers on site. In order to ensure project safety, a good construction management company should establish a well written health and safety plan that covers actions and procedures that would be taken to mitigate health and safety risks. An important part of this health and safety plan is an emergency action plan. This emergency action plan organizes employer and employee actions in the event of a jobsite emergency, national emergency, or natural disaster. Under the Occupational Safety and Health Administration (OSHA) 1926 Safety and Health Regulations for Construction, 1926 Subpart C General Safety and Health Provisions, Standard 1926.35 it is stated "The emergency action plan shall be in writing and shall cover those designated actions employers and employees must take to ensure employee safety from fire and other emergencies." It is also written under this same standard that there must be an "alarm system" in order to notify all workers in the event of an emergency. This alert typically notifies all site personnel to evacuate the structure that they are working on, and to gather at the designated muster point on the project for further instruction. There are many different types of alerting systems available on the market today, ranging from extremely simple, to high technology.

The traditional method of emergency alerts on a construction job site, the simplest, and easily recognized is the air horn. Three blasts of an air horn indicates an emergency and that all trades people must cease work and evacuate the building. The main disadvantage to this method is the signal being inaudible to all workers at all locations of the project both inside and out. It

causes a delay in worker evacuation as the air horn must be sounded multiple times and at multiple locations to successfully notify all workers. This process takes valuable time for evacuation during an emergency.

The construction industry has also seen the introduction of higher tech systems such as app based emergency alerts and remote emergency alert systems. This is an effort to create safer jobsites and making emergency alerts more audible and to decrease evacuation time of workers. App based systems allow for the fast and efficient delivery of emergency notifications to workers via the use of software and compatible wireless devices. The software or licenses for the software necessary for operation must be purchased and maintained, and a contact list must be created and also maintained. These notifications can be ineffective, as they may be inaudible by some of the workers, workers may not have compatible devices, or due to a lack of wireless service in the area, the alert may never be received.

Remote emergency alert systems eliminate the issue of wireless service, and inaudible alerts. Remote systems provide both visual and audible alerts when the signal is sent out across the project. These systems provide call stations for workers to indicate there is a fire on the project or if a worker needs medical attention. Some faults of these systems are they can be cumbersome to use, as multiple devices need to be programed and located throughout the project, and they rely on batteries for power, and will eventually need to be changed. There is also the potential for false alarms that delay productivity, and a very large initial cost to the system.

Construction companies have options as to which emergency alert method they use on a construction site. From high tech to low tech, each method of emergency alerting has its advantages and disadvantages. Regardless of these benefits or faults, construction companies

should have an alert method in place for worker safety, because for any business, employees are their biggest asset and worker safety if of the upmost importance.

1.1 Contributions

This research will help to improve construction jobsite safety by encouraging the integration of advanced job site alert systems. This research will help determine if there is room in the market for a new emergency alert system, or if improvement to current products would increase the construction industry's willingness to integrate these systems into future projects.

1.3 Problem Statement:

Traditionally on a construction site, costs are a driving factor for just about anything, including safety. High cost items that are not a necessity will typically be avoided to keep the general conditions costs down or to increase the overhead and profit. User friendliness is also extremely important, as the construction industry is slow to evolve, and the introduction of new high tech devices can receive push back form the tradespeople on a job. New technology must prove to be effective, or it will fail to be adopted and used regularly within the industry. New technologies must also stand out from other products on the market, and prove to be the most beneficial option available. These factors lead into the development of the problem statement below.

- The construction industry is in need of an effective, efficient and user friendly emergency alert system that does not significantly increase project costs.

1.4 Research Questions:

The research questions listed below are a result of a preliminary investigation into the issue of emergency alerts, products, and their effectiveness on a construction site.

1.4.1 Primary:

- Is there room in the market for a new emergency alert product, or is the construction industry satisfied with current products?

1.4.2 Secondary:

- What types of emergency alert systems are available on the market?
- What is the most popular type of alert system on construction jobsites?
- What are the industry professionals' perceptions of construction emergency alert systems?

1.5 Research Objectives:

The objective of this research project is to improve construction jobsite safety through the integration of emergency alert methods and systems. This research can be broken down into primary and secondary objectives.

1.5.1 Primary Objective:

- Improve construction jobsite safety via the exploration of advanced emergency alert systems.

1.5.2 Secondary Objective:

- Investigate the types of, and the most popular emergency alert systems in the construction industry

- Explore the industry professionals' perceptions of the existing emergency alert systems.
- Explore if there is a gap in the market for a new emergency alert system, and its potential benefits to the construction industry.

1.6 Benefits of the Research:

A safe construction site is conducive to the wellbeing of everyone that enters the gate. Therefore this research will benefit all parties involved in a construction project, by providing insight on available advanced emergency alert systems, and possible improvements that can be made. These individuals include, but are not limited to, the Owner, Owner's Representative, Architects, Engineers, Construction Managers, General Contractors, Subcontractors, Suppliers, Consultants, and Product / Company Representatives.

1.7 Thesis Organization:

The organization and layout of this research is described in the following chapters. Chapter 1, introduction, describes the focus of the research. This chapter briefly describes the governing agency for construction site safety, their regulations in regards to emergency alerting, and describes some common methods of dispersing emergency alerts on jobsites. Chapter 2, Literature Review, evaluates current works of literature relevant to construction safety, governing agencies and documents, and various types of emergency alert systems available on the market today. Chapter 3, Methodology, describes how the use of a survey with carefully constructed questions help to dissect the construction industries familiarity and perception of

current available construction emergency alert systems. This section also explains the software used to create, organize, and analyze the results of the survey. Chapter 4, Results, brings forward the findings of the survey. This section shows the respondent demographics, their experiences, and their perception of the current emergency alert systems available to the construction industry. This section also reviles any correlations or comparisons made between the data produced by the survey. Chapter 6, Conclusion and Recommendations, contains conclusions made based on the survey data collected and contains recommendations that can be made for further research in this topic.

1.8 Assumptions, Limitations, and Constraints:

1.8.1 Assumptions:

- Respondents to the survey are construction industry professionals in the northeast.
- The limited sample of respondents is a good representation of the construction industry.

1.8.2 Limitations and Constraints:

- Low number of survey responses
- Low number of respondents having experience with any advanced emergency alert system
- Lack of feedback within the survey on advanced emergency alert systems.
- Potential of multiple subjects from the same company.

Chapter 2: Literature Search

2.0 Literature Review

2.1 Construction Industry Challenges and Trends

The U.S. construction industry is one of the largest in the world, employing over ten million workers and racking up over $1.2 trillion in expenditures annually for both goods and services (Wang, 2019). After taking a tremendous downturn during the 2008 recession, the construction industry has managed to make a significant comeback and is currently thriving. This upward swing of the industry has not come easy and is still presented with a number of challenges and obstacles to overcome.

Some of these challenges and obstacles have been the integration of new technologies into the industry, the very prominent skilled labor shortage, a stagnant productivity level, and a constant struggle with safety. The following sections outline the industry challenges in further detail.

2.1.1 Technology Adoption

History shows that the construction industry as a whole has been significantly slow when it comes to adopting new technologies and putting them into use. New technologies are rapidly evolving, and an abundance of new technologies are introduced each year, but the problem that the construction industry faces is how to effectively implement them into daily operations. The KPMG (2017) Global Construction Survey interviewed 201 senior leaders within

contracting companies and owners from around the world, and it shows seventy two percent of its respondents felt that technology innovation or use of data plays a prominent role in their strategic plan or vision. That same survey also revealed that only about half of those respondents had a plan on how to integrate these technologies into their operations, and only 5 percent of the respondents felt that their companies were cutting edge when it came to technology.

Technologies such as Building Information Modeling (BIM) along with mobile devices have been used for years in the construction industry and have been integrated into projects around the world, but a large portion of the industry has yet to incorporate these technologies into daily operations. Emerging technologies such as Virtual Reality (VR), robots, the Internet of Tings (IoT), wearable technologies and autonomous equipment are also making appearances on projects around the world but, just like BIM, a vast majority of the industry is timid of these advanced technologies. According to the (KPMG, 2017) Global Construction Survey, 83 percent of respondents said that their companies have not implemented any new technologies such as robotics and VR, and only 1 percent said that they have already implemented these types of technologies across all projects. Meanwhile, 76 percent of these respondents feel that the industry will implement these types of technologies within the next five years. “Ironically, many of these technologies can be used to help address these other challenges the construction industry is facing. BIM, VR, project management software and mobile devices can help with scheduling and planning as well as communication

and collaboration which can lead to better productivity". (Jones K. , 4 Major Challenges Facing the Construction Industry, 2018)

These emerging technologies can truly benefit construction jobsites. For example, drones and wearable technologies can aid in keeping workers safe. "Drone systems can be used to inspect remote sites for hazardous conditions or unstable structures without placing workers at risk" (Dorsey, 2018). Wearable technologies are helping to monitor falls or hazardous conditions, and to alert workers of these situations. Construction companies are using VR to train workers in a safe and controlled environment while simulating real life situations. Robots and autonomous equipment are reducing the amount of strenuous activities, along with decreasing the work load on employees. Building Information Modeling (BIM) can detect clashes between the various building components prior to the start of construction, saving time and money in later coordination. BIM also offers savings to the owner of the project when a performance analysis is completed. In 2008, a case study was conducted to evaluate the performance of the DPR Construction Inc. headquarters building located in Sacramento California. The buildings information such as orientation, HVAC system, building envelope systems, etc. were all loaded into BIM, and it was determined that the LEED Gold certified building was saving the owner approximately $25,000 per year in energy costs. (Azhar, Brown, & Sattineni, 2010). This study shows that BIM can be applied to a new construction project and ensure that the proper systems are selected for the building, saving the owner thousands of dollars over the life of the building.

The construction industry is rapidly approaching the time where technology is going to become a critical component to everyday operations on construction sites. Companies that manage to adopt and implement these technologies will maintain their competitive edge in the industry, while other companies that refuse to become adventurous into the world of emerging technologies will struggle to survive in a rapidly changing environment.

2.1.2 Labor Shortages:

The Bureau of Labor Statistics website shows that during the recession of 2008 construction employment fell by 1.5 million, an overall 19.8 percent decline (Handi, 2011). Since then, the industry has slowly regained its strength and is currently flourishing, but the industry has failed to see employment back to its pre-recession numbers. This is not due to any financial constraints, it is due to a lack of applicants. During the 2008-2009 recession, workers that were laid off took positions in other industries or retired, never returning to the construction industry.

The younger generations hold little interest in entering a career in the skilled trades and an increasing number of them prefer careers in other fields. Tech-savvy millennials are not flocking to careers in construction as past generations have, which will continue to cause issues for firms as they seek to

meet growing demand. (Jones K. , 4 Major Challenges Facing the Construction Industry, 2018).

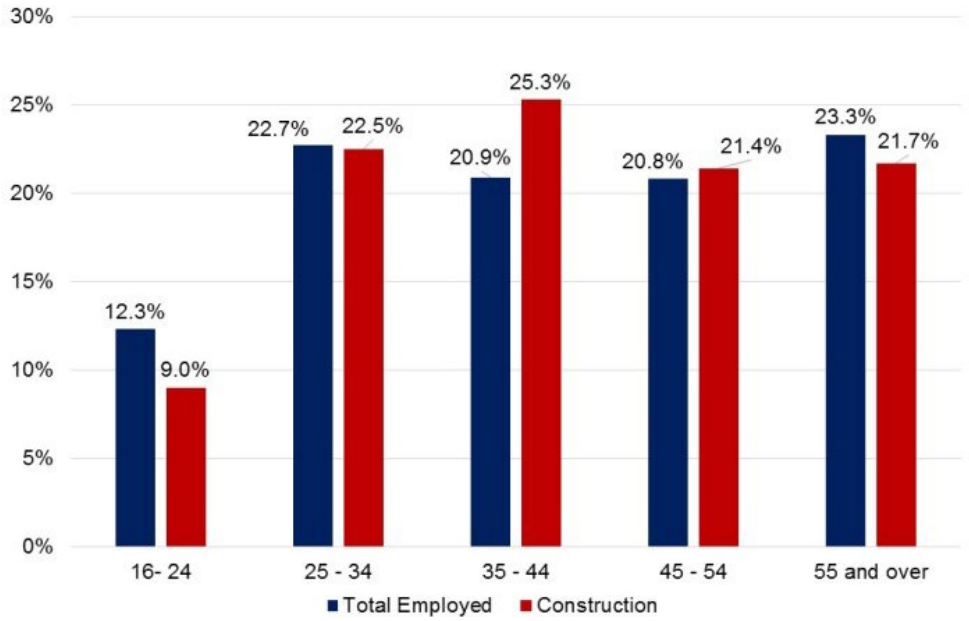

Figure 2.1 Age Breakdown: Construction Industry vs. All Industries 2018 (ZHAO, 2019)

Millennials are showing more interest in jobs in industries such as technology and software, healthcare, and financial rather than the construction industry (Tockey, 2017)

The National Association of Home Builders (2019) shows the current average age of a construction worker is 42 years old, which is one year older than the rest of the labor force. Some states in the U.S hold a median age around 50 for construction workers. This increase shows a lack of younger individuals entering the industry and provides statistical evidence of a labor shortage. Figure 2.1

illustrates a comparison of construction workers' age ranges to workers from other industries. The graph shows that the construction industry, when compared to other industries, holds more workers between the ages of 35 and 54. Figure 2.1 also shows a significantly low percentage of young construction workers between the ages of 16 and 24 years old when compared to other industries. When analyzing this data, it is clear that the construction industry is aging while lacking a sufficient number of younger individuals entering the industry.

2.1.3 Stagnant Productivity Levels:

While other industries in the United States are experiencing increased productivity levels through the years, the construction industry has been struggling to follow similar trends. McKinsey & Co. (2017) reports on increasing construction productivity, and the study shows while many US sectors including agriculture and manufacturing have increased productivity ten to 15 times since the 1950s, the productivity of construction remains stuck at the same level as 80 years ago. In fact, current measurements reveal that there has been a consistent decline in the construction industry's productivity since the late 1960s. Some reasons for this slow decline are the construction industry is extremely fragmented (The Economist, 2017), lack of digitization (Buncio, 2017), a decline in the skilled labor force (Giatec Scientific Inc. , 2019) and a lack of safety (Mumford, 2014).

A lack of safety on a construction site can lead to delays in productivity. OSHA inspections, jobsite injuries, and jobsite fatalities all lead to costly delays

on a project, which results in an overall productivity decrease. When provided proper safety equipment and properly maintained equipment, workers will have a higher productivity rate than if provided equipment in disrepair or not proper equipment to complete their task. “Increased productivity doesn’t have to come at the expense of safety, but companies wishing to improve both need to take a more strategic, operations-oriented approach that helps workers get the job done, rather than simply demanding that they get things done faster” (Mumford, 2014).

As construction projects become increasingly complex, a stagnant productivity level is troubling. Poor productivity can be caused by a multitude of different factors. Inadequate scheduling and project planning, poor or no communication among the project team or subcontractors, a lack of collaboration, a lack of constructability reviews, and a poor procurement process of materials, especially long lead items, all can drastically decrease the productivity on a project.

Declining number of skilled construction workers, thus the aforementioned labor shortage of the construction industry, has also contributed to the decrease in productivity rates. The industry is currently challenged to do more with less workers and it is affecting the overall level of productivity. Project delivery methods such as design-build have been proven to increase productivity due to the high levels of early planning and collaboration. Constructability reviews and early procurement of materials have boosted the overall productivity on projects using this or similar delivery methods. BIM has also made its impact

on increasing productivity by detecting clashes among trades early in the design phase and avoiding lost time in the field during construction.

2.1.4 Safety:

Worker safety continues to be a major concern across the construction industry. Keeping workers safe and protecting them from the multitude of hazards present on a jobsite is a constant struggle. According to the U.S. Department of Labor (2019) construction continues to have the highest workplace accidents over all other industries.

In 2018, there were2.8 million workplace injuries or illnesses recorded in the United States. Of these injuries, 199,100 were recorded in the construction industry with over 39 percent of these cases resulting in lost time. This is much higher than other industries such as retail at 96,000 cases, or the automotive industry at 61,500 cases (Bureau of Labor Statistics, 2019). “Those 77,490 (39 percent) injuries and illnesses that required days away from work resulted in 21,230 sprains, strains and tears; 14,300 incidences of soreness or pain; 10,180 cuts, lacerations, and punctures; and 9,920 fractures” (Jones K. , 2019).

The first line of defense in avoiding these workplace injuries is training. Workers should all be properly trained how to use the necessary tools, safe material handling, and how to properly use all necessary safety equipment. Safety training should never be a onetime event. It is important to check up on and to

retrain workers to emphasize the importance to jobsite safety and to keep all safety related information fresh in their minds.

Accidents are easily avoidable with the proper training, access to the proper equipment and safe practices. Safety on a construction site should never be the sole responsibility of one individual on the site. It is the responsibility of all workers to prevent, report and avoid unsafe working conditions. A good safety reputation will only help a company as they express an interest in the well-being of all workers and a genuine desire for everyone to go home safely every day.

2.2 Introduction to Workplace Safety

According to the Occupational Safety and Health Administration website, we are all entitled to a safe workplace. Our employers must provide a workplace free of known health and safety hazards, which is easy to manage for most industries. In an office building or in a storefront, it can be fairly easy to mitigate potential risks, but is not the case for the construction industry.

Construction is a hazardous profession with many different hazards and risks present daily. “Climbing high off the ground, digging deep into tunnels and trenches, handling large pieces of material, operating very large equipment and working with hazardous substances put workers at risk” (Gould & Joyce, 2014). For employees working at a typical office building or a retail store, the location remains the same day to day, but in the construction industry, the location could change yearly, monthly or even

daily. Trying to mitigate these risks and hazards when the location and environment around you does not remain constant, is a challenging task.

2.2.1: Most Common Workplace Accidents

Common workplace accidents consist of muscle strain, slips, trips, falls, cuts, collisions, being struck by something, and much more. Sometimes these accidents can become fatal in the workplace, and approximately 90 percent of such fatalities in the construction industry are from just 4 different types of accidents. “These accidents are falls, being struck by something, getting caught in-between something, and being struck by electricity”. (Gould & Joyce, 2014)

2.2.1.1 Falls

“Falls are the number one cause of construction-worker fatalities, accounting for one-third of all on-the-job deaths in the industry” (CDC, 2019). The injuries that a worker sustains from a fall have a tendency to be more life threatening than most other types of injuries. Falls from surfaces as low as 6 feet high can prove to be fatal or cause serious injury. “Spinal, head, or neck injuries are a common result of falls, regardless of the height, and can leave the worker severely disabled or lead to death” (Busch, 2019). In 2018 there were a total of 5,250 work related deaths in the United States, with 1,008 total construction related deaths (U.S. Department of Labor, 2019). There were a total of 791 deaths caused by falls in the U.S during 2018 with 338 deaths in the construction industry

alone (OSHA, Occupational Safety and Health Administration Commonly Used Statistics, 2020).

There are specific requirements set forth by the Occupational Safety and Health Administration (OSHA) in regard to fall protection. OSHA mandates that fall protection must be in place for any working surface over 6 feet high, this includes full body harnesses with lanyards, guardrails, safety nets, catch platforms or other types of fall protection. According to Jones (2018), “Guardrails are the only approved fall protection method that actually prevents falls from occurring. They are ideal for unprotected edges, scaffolding work, and openings like uncovered skylights and elevator shafts”. There are strict restrictions enforced by OSHA on construction sites when it comes to guardrails. For example, guardrails must have a top rail, mid rail and toe board all placed at specific heights as stated by the 1910 Occupational Safety and Health Standards, Standard 1910.29 Fall protection systems and falling object protection-criteria and practices (U.S Department of Labor, 2020).

Other acceptable forms of fall protection include full body harnesses with shock absorbing lanyards and lifelines. These systems do not prevent falls, they protect the worker in the event of a fall and are considered personal fall arrest systems. Safety nets and catch platforms can also be used to protect workers against fall hazards and are called passive fall protection systems (Smith, 2015).

2.2.1.2 Struck By

Struck-by injuries are produced by forcible contact or impact between the injured person and an object or piece of equipment (OSHA, 2011). This includes a worker being hit by a flying object, a falling object, a swinging object, or a rolling object (Schillaci, 2018). According to the US Department of Labor (2019), in 2018 alone, there were a total of 566 deaths due to struck by accidents, with 112 of these deaths occurring in the construction industry struck by accidents make up approximately 11.1 percent of total construction industry deaths in 2018 (OSHA, Occupational Safety and Health Administration Commonly Used Statistics, 2020).

Struck by falling or flying objects usually occur when tools are knocked off the edge of a work platform, a worker drops an item from an elevated working surface, materials become loose when hoisting to elevated working platforms, or an object is propelled through the air by a worker or machinery. This is why “tools and materials should be secured when performing overhead work using toe boards or screens to prevent objects falling or debris nets and catch platforms to deflect falling objects (Jones K. , Avoiding OSHA's Fatal Four - Struck-By Hazards, 2018).

Injuries caused by swinging objects occur when a load that is being hoisted is caused to sway, striking a worker. This type of accident can be avoided by routinely inspecting the crane and rigging, keeping workers at a safe distance away from the load, and making sure all loads are secured and lifted evenly (Schillaci, 2018).

Injuries caused by rolling objects usually involve a worker being struck by a vehicle or heavy equipment while it is in motion, but also include any object that rolls, moves or slides on the same level as a worker (Jones, Avoiding OSHA's Fatal Four - Struck-By Hazards, 2018).

2.2.1.3 Caught Between

An additional danger present to workers on a construction site are caught between accidents. “The key factor in making a determination between a Caught event and a Struck event is whether the impact of the object alone caused the injury. When the impact alone creates the injury, the event should be recorded as Struck. When the injury is created more as a result of crushing injuries between objects, the event should be recorded as Caught” (OSHA, 2011). In 2018, there were 137 total caught between workplace deaths in the United States, 55 occurred in the construction industry (U.S. Department of Labor, 2019). Caught between deaths made up 5.5 percent of total construction deaths in 2018 (OSHA, 2020).

Caught between accidents occur when a worker is compressed or pinched between two or more objects. “Examples include getting your hand caught in the moving parts of an unguarded piece of machinery, being buried by trench cave-ins and getting pinned between a wall and piece of heavy equipment” (Jones K. , Avoiding OSHA's Fatal Four - Caught-In/Between Hazards, 2018).

Ways to prevent caught between accidents are to have a competent person on site to oversee activities, make sure all guards are on equipment, train workers on proper use of equipment, use safety equipment such as trench boxes or shoring, use barricades to keep workers out of the path of moving equipment, and use wheel chocks to prevent equipment from rolling (National Safety Council, 2019).

2.2.1.4 Electrical Shock

Electrical shock occurs when a worker comes into contact with a live electrical current. Electrical shock is an incident where the worker is injured but survives while electrocution is an incident where a worker is killed due to contact with a live electrical current (Feldman, 2018). In 2018 there were a total of 160 deaths due to electrocution in private industry in the United States (U.S. Department of Labor, 2019), with 86 of those deaths occurring in the construction industry. Over 50 percent of all workplace electrocutions occur in the construction industry, there by showing how inherently dangerous the construction industry may be as compared to other industries. Electrocution accounts for 8.5 percent of all construction related deaths in the united stated in 2018 (OSHA, Occupational Safety and Health Administration Commonly Used Statistics, 2020).

Electrocutions and electrical shock occurs when workers come into direct or indirect contact with power lines, when they come into contact

with an energized source, or the improper use of a flexible extension cord (American Safety Council, 2015). Some ways to prevent electrocution and electrical shock are to train workers on the proper use of power tools and teach workers to inspect extension cords. On site, workers should be aware of all overhead power lines to avoid contact, use proper lock out tag out procedures, and use ground fault circuit interrupters (GFCI) to prevent electrocution or electrical shock (American Safety Council, 2015).

2.3 Workplace Safety Policies and Regulations

Employees are entitled to a safe and healthy workplace, and should feel comfortable coming into work every day. Their work place should be free from hazards, and employees should never be put directly in harm's way. Employee safety if of the upmost importance and is regulated by law and by company policies.

2.3.1 Occupation Safety and Health Administration (OSHA)

On December 29th, 1970, the United States Congress passed the Occupational Safety and Health (OSH) Act to ensure safe and healthy working conditions for men and women. With the passing of the OSH Act, two different organizations were developed. One of these organizations is the National Institute for Occupational Safety and Health (NIOSH). NIOSH is a research agency focused on studying worker safety and health, and empowering employers and workers to create safe and healthy workplaces (CDC, 2020). The other of the two

agencies that were a product of the OSH Act is the Occupational Safety and Health Administration (OSHA). This organization ensures safe and healthy working conditions for working men and women by setting and enforcing standards and by providing training, outreach, education, and assistance (OSHA, Occupational Safety and Health Administration, 2020)

2.3.1.1: OSHA Inspections

OSHA, being a government agency, has the authority to make unannounced inspections to construction job sites and typically will not inform any of the construction project parties prior to their inspection. An inspection can be conducted in the event there is an imminent danger situation present, there has been a serious injury or death, if there is a worker complaint, if there is a referral, a targeted inspection, or if they are conducting a follow up inspection (OSHA, 2020). According to the OSHA Standard Industry Code (SIC) search, in 2019, there were a total of 37,372 OSHA inspections in the construction industry alone across the United States. The following are the various types of OSHA inspections that could be made to a construction site:

Imminent danger situation: An inspection that occurs when there is a hazard present to some or all workers on the construction site that could cause serious harm or death. The OSHA compliance officers will request that the situation be corrected immediately and may remove workers from the harmful situation.

Severe injuries or Illness inspection: This inspection will be conducted if there has been a job site fatality and will be conducted within 8 hours of the incident. This type of inspection will also be conducted if a worker is severely injured on the job and has been hospitalized.

Worker complaint inspection will occur if there have been allegations of hazardous situations on a job site or if any OSHA violations exist.

Referral inspection: This inspection will be conducted if there have been any referrals of hazards on a construction site from other federal, state, or local agencies.

Target inspection: This is an inspection conducted on a job site that falls into a high hazard industry or an inspection of a workplace with a history of high injury rates.

2.3.1.2 OSHA Violations and Fines

There are different types of OSHA violations with differing severities. According to the OHSA Website, each of these violations has an associated dollar amount for fines that would be issued to the violator. The five types of violations are willful, serious, repeated, other than serious and failure to abate. A willful violation occurs when an "employer knowingly failed to comply with a legal requirement (purposeful disregard) or acted with plain indifference to employee safety" (OSHA, Occupational Safety and Health Administration, 2020). A serious violation

occurs when a hazard is present that could cause serious physical harm or death. A repeated violation happens when an entity has been cited for a particular violation in the past and is being cited for the same violation or an extremely similar violation. An other-than-serious violation occurs when a "violation that has a direct relationship to job safety and health, but is not serious in nature" (OSHA, Occupational Safety and Health Administration, 2020). A failure to abate violation occurs when an employer fails to correct the hazardous situation by the date specified by OSHA. This results in a daily charge past the abatement date, compared to the lump sum penalties issued by OSHA. OSHA also has posting requirements for violations. Upon receiving an OSHA notice, the employer must post the notice at the location of the violation, so all workers are made aware of the hazards. According to OSHA, the notice must remain posted for 3 working days or until the hazard is abated, whichever is longer (OSHA, 2020). If the employer fails to post the violation, the employer is eligible to be fined.

Type of Violation	**Penalty**
Serious Other-Than-Serious Posting Requirements	$13,494 per violation

Failure to Abate	$13,494 per day beyond the abatement date
Willful or Repeated	$134,937 per violation

Table 2.3.1.2: OSHA violations and Penalties (OSHA, 2020)

2.3.2: Safety Policies

To establish a safety standard within a company, a safety policy must be drafted, distributed, and always made available to all employees. The purpose of most safety policies is to reduce the risk to employees so that they can carry out their day-to-day duties in a safe working environment (Fielder, 2019).

A well-written company safety policy will protect both the worker and the company. The worker will be protected if the employer fails to provide the necessary safety equipment for the tasks or intentionally places the worker in harm's way. The safety policy will show the employers' responsibilities in keeping the worker safe. The safety policy will also protect the company from the negligent worker that holds no regard for workplace safety. Failure to follow the company safety policy can result in termination for the worker and the elimination of a major liability for the company.

Some of the standard components of a company safety policy are incident reporting, a drug and alcohol policy, Personal Protective

Equipment policy, distracted and defensive driving policy, a seatbelt policy, emergency evacuation, workplace violence policy, and more.

2.3.2.1: Construction Company Safety Plan

Construction sites differ significantly from most other industries and professions because of the increased number of hazards present and a constantly evolving work environment. Therefore a construction safety plan tends to be relatively more robust and detailed. As the project evolves, so do the hazards to the workers, making it essential for construction companies to have well-written safety policies. A construction safety plan is a document that outlines the procedures, rules, and regulations that are or will be put in place to protect workers over the course of a construction project (Safeopedia, 2020). A construction company safety plan will have all the same categories as a standard safety policy for other industries such as the drug and alcohol policy, workplace violence, and incident reporting, but where it will differ significantly is the emphasis on personal protective equipment use, tool and equipment safety, excavation and trenching, lead and asbestos abatement, ladder safety, and scaffolding safety. Construction safety plans will also address things such as electrical safety, considering all workers will be working with temporary power supplied during construction, and respiratory safety policies due to an abundance of dust and airborne particles. A construction company safety plan is a living, breathing document as it needs constant

attention to address an ever-changing industry with an overwhelming number of hazards.

2.3.2.2: Site-Specific Safety Plans

Every construction company should further the development of its safety plan to encompass the specific hazards associated with each job site. A Site-Specific Safety Plan outlines how the contractor or subcontractor will manage the risk on a specific project site and the health and safety requirements for that project (Randle, 2018). Parts of the overall company safety plan will be edited to make it specific to a particular project. The evacuation plan, and the jobsite orientation will be tailored to fit the project and to address any hazards that are unique to the jobsite. The evacuation plan will always need to be adapted to establish the muster point for all workers to gather, and to establish a flow of personnel if the site needs to be evacuated for any reason.

Each new project for a company should be analyzed to determine what activities are specific to that site. A Job Hazard Analysis (JHA) and site-specific training requirements must be outlined in the site-specific safety plan. A JHA must be completed by each subcontractor and the general contractor on a regular basis to identify hazards specific to their trades and identify a procedure for mitigating the risks involved. “The system observes the connections between worker, task, tools and environment. After identifying hazards, the user takes steps to reduce or

eliminate them" (Trotto, 2016). This is typically done on a weekly basis or even daily basis as the tasks and hazards are rapidly changing with the progression of the project.

2.4: Advances in Workplace Safety

2.4.1: New Construction Safety Technologies

Construction is typically an industry that lags when it comes to integrating new technologies, but the construction industry has displayed some significant advances when it comes to safety. There are new wearable technologies that monitor worker status and location, new designs in hard hats to better protect the worker while keeping ergonomics in mind, and there have been some extraordinary advances in simple safety equipment such as high visibility vests. With these latest advances in construction safety, there are plenty of equipment options and other resources which can help to minimize the risks associated with an on-site accident (Rouse, 2019).

2.4.1.1: Wearable Technologies

Wearable technology is relatively new to the job site. Wearable technology typically refers to a small sensor that a construction worker wears either on a belt, or vest. These wearables can detect signs of danger, such as lack of movement, gas, and heat. Co-workers and contractors can be automatically alerted if a problem is detected

(Raphaelson, 2018). Some wearables come equipped with a call button to send a signal when a worker needs help. With the aid of software, the construction management team can locate the worker in danger and quickly send help.

Wearable technologies are slowly becoming integrated into the construction industry but have received some pushback from workers. Many workers do not like the idea of being tracked throughout the workday and feel it is an invasion of privacy. According to the 2018 USG Corporation and the U.S. Chamber of Commerce Commercial Construction Index, only about six percent of polled contractors used wearable technology. Still, it was expected to see an increase up to 23 percent by 2021 (USG Corporation & U.S. Chamber of Commerce, 2018).

2.4.1.2: Hardhat Design

Hard hats have made great advancements in both design and ergonomics. The creation of smart hardhats is one example of the great strides in construction worker safety that have been made within the past five years. These hard hats, similar to the wearable sensors, monitor workers and detect signs of fatigue or other impairments (Rouse, 2019). Newly designed hardhats look more like a rock-climbing helmet as compared to the traditional hardhat. This is all an effort to better protect the worker from all angles and to keep the hard hat on the workers head in the event of a fall, they are struck by something, or even from just bending

over. Being required on all construction sites across the United States, the hard hat industry is expected to hit $3.19 billion in sales by 2025 (Hexa Research, 2017). The hard hat has made some significant advancements since its invention in 1919, but no matter the style or added equipment the focus remains the same, and that is the safety of construction workers.

2.4.1.3: Safety Vests

The commonly seen high visibility vest is intended for one purpose and one purpose only, and that is to make workers more visible to equipment operators and more visible in low light settings. There have been advancements in improving the safety vest by including LED light strips to increase visibility, and the incorporation of wearable sensors to detect the workers status and changes to the work environment that would be potentially hazardous to the workers' health. Smart vests and similar garments utilize a wide range of features which could play a key role in creating and maintaining a safer work environment (Rouse, 2019).

2.4.2: Research and Development in the Construction Industry

The definition of research and development is "the studies and tests that are done in order to design new or improved products" (Merriam-Webster, 2021). Construction companies typically do not take part in very many research and development activities, and the construction industry as a whole does not spend

much if its annual income on research and development. Research and development is mainly conducted by the manufacturers and the designers of materials, heavy equipment, safety equipment, tools and new technologies that all support the construction industry. There are a host of technology-based changes which have occurred – or at the very least, increased – in construction machinery over the last five years: automation, different power sources and telematics (Brown, 2019). Tools have made great advancements in design as well. Major tool manufacturers have been altering their designs to make tools lighter and easier on the human body to use. Companies such Fiskars has redesign the hammer, making it more shock absorbent and fits more comfortable in the hand. Other companies, including Milwaukee Tool and Bosch Power Tools, have begun introducing power tools with better ergonomic design as well, allowing users to ease up on the grip and use the equipment in a way that has the least impact on the body's most vulnerable areas (Construction Executive, 2017).

There is a tendency to conduct more research than development in the construction industry. There has been an abundance of research conducted on various aspects of the construction industry including safety, labor productivity, logistics, economics of the construction industry, and current issues that the construction industry is facing. This research as brought forward new methods of doing business, has led to the development of new and improved safety equipment, and has provided possible solutions to major problems such as the current labor shortage.

2.5 Emergency Action Plans

Within the site specific safety plan, there is a designated emergency action plan. Figure 2.5.1. shows how OSHA standards are taken and refined down to a company safety plan, then to a site specific safety plan and then to the emergency action plan. The emergency action plan outlines the company procedure in the event of a jobsite emergency, national emergency, or natural disaster. This plan must be in writing, unless the company has ten or fewer employees, and must be made kept in the workplace and made available for employee review (OSHA, Occupational Safety and Health Administration, 2020). An emergency can occur in an instant, causing injury or illness and the employer and workers must be prepared to handle the situation. A poorly prepared plan may lead to a disorganized evacuation or emergency response, resulting in confusion, injury, illness (due to chemical, biological and/or radiation exposure), and/or property damage (OSHA, 2020). The emergency action plan will map out the necessary steps that both the employer and workers must take to maintain a level of safety and order on the jobsite.

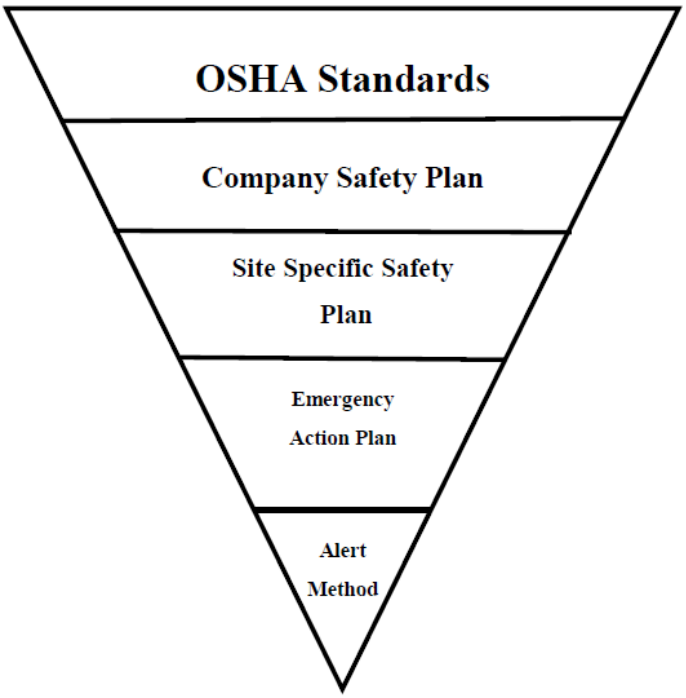

Figure 2.5.1: Safety Plan Refinement Funnel (Pulver, 2021)

2.5.1: Emergency action Plan Components

When preparing an emergency action plan, some sections to include are General Disasters, Natural Disasters, Toxic Chemical Release, Civil Disorder, and the News Media (Kirchoff-Consigli Construction Management Inc., 2013). An emergency preparedness plan also provides all evacuation and or shelter in place procedures depending on the type of disaster.

The "General Disasters" section of the plan explains in detail the necessary procedures in the event there is a medical emergency, fire or an explosion on the construction site. This section clearly designates the duties of each member the management team to avoid any confusion, and to ensure all

procedures are carried out properly and thoroughly. This section also provides the location of the posted phone numbers and addresses for the fire department, police department, and the nearest hospital.

The “Natural Disasters” section of the plan covers the necessary procedure in the event of a flood, tornado, severe thunderstorm, sever snowstorm, hailstorms, hurricanes, and earthquakes. This part of the plan covers operating procedure if there is or is not advanced warning of the disaster, lists the duties of the management staff, and describes how the workers should conduct themselves during the incident.

The “Toxic Chemical Release” section refers to an airborne release or a spill. This section covers the necessary evacuation procedure and provides the phone number to an environmental emergency agency to assist in the cleanup of the release. Spills or releases that travel outside or have the potential to travel outside the jobsite property lines must also be addressed in this section. Toxic chemical spills that leave or threaten to leave the jobsite must be reported to the appropriate stated department of environmental protection (Kirchoff-Consigli Construction Management Inc., 2013).

Within an emergency action plan, the section on “Civil Disorder” refers to union demonstrations, bomb threats, vandalism, or public protests / demonstrations. This section of the plan first directs the management team to contact the local authorities, then outlines the necessary steps that must be taken to maintain safety and order on the jobsite. Proper evacuation procedures are explained in this section for events such as bomb threats, and expectations for

worker conduct during demonstrations is also clearly stated as to avoid agitating any protestors or vandals. The overall impacts of civil disorder can be difficult to predict, so a well written and clearly communicated plan is of the upmost importance. Site management should identify known and anticipated risks, taking into consideration the nature and duration of the civil unrest event (Travelers Risk Control, 2020). Site security must be addressed in this section, to prevent damage to the project, theft of tools and materials, and harm to the workers. This section must also place an emphasis on communication procedures, as during one of these events, communication is extremely important to maintain safety and order on the jobsite.

In today's environment, the media can be extremely persuasive and must be handled appropriately. The emergency action plan must address the proper procedure for handling the arrival and presence of news media. This section should designate an individual spokesperson to communicate with the media to avoid misinformation being released and to protect the privacy of any individuals involved in an incident. This section should instruct employees that all media inquiries should be directed to the spokesperson and to resist commenting about the situation on their personal social media profiles (Reimer, 2019). Site security is another topic that must be addressed in this section, to prevent reporters or other media personnel from entering the jobsite and potentially placing themselves in harm's way or inciting some sort of civil unrest on the project.

2.5.2: OSHA Requirements

For businesses that have 10 employees or more, it is required by OSHA to have a written emergency action plan. If the business has less than 10 employees, it can be a verbal plan and does not have to be a written plan. No matter the business size, an emergency action plan is still required under OSHA standards 29 CFR 1910.38(a) and 29 CFR 1926.35) and is required to be available to all employees in the workplace (OSHA, 2020). OSHA states that the emergency action plan shall cover those designated actions employers and employees must take to ensure employee safety from fire and other emergencies. These OSHA standards establish the minimum requirements as to what must be included in an emergency preparedness plan.

Section 1926.35(b) of the OSHA standards labeled "Elements" describes all the components that shall be included in the plan, starting with escape routes, then evacuation procedures, employee duties and the preferred means of reporting the emergencies. OSHA mandates that the emergency action plan includes emergency escape procedures along with the emergency escape routes for all employees on the project. Section 1926.35(d) of the OSHA standard further describes the necessary evacuation procedures and states that "the employer shall establish in the emergency action plan the types of evacuation to be used in emergency circumstances" (OSHA, 2020). If the construction site needs to be evacuated, OSHA requires the emergency action plan to have a method or plan in place to account for all workers that have been evacuated.

A major component of the emergency action plan focuses on training. Before implementing the emergency action plan, the employer shall designate and train a sufficient number of persons to assist in the safe and orderly emergency evacuation of employees (OSHA, 2020). OSHA also states that the employer needs to review the plan with each employee that has a designated duty in the event of an evacuation or emergency when the initially come to the project if their responsibilities change or if the plan changes. The employer also must review the emergency action plan with all employees that do not have designated duties as well, and the employer must also make all employees aware of the printed copy location.

2.5.3: Emergency Alerting

One of the most important sections of the emergency action plan is the section on alerting. OSHA standard 1926.35(c)(1) states that the employer shall establish an employee alarm system. The standard does not specify any particular type of alerting method. It only states that there must be a means of alerting workers in the event of an emergency. OSHA also states in standard 1926.35(c)(2) that if the alerting method is also used to contact emergency services or for other purposes, there must be a different signal for each purpose.

It is the responsibility of the employer to make sure that the alert is a distinctive and recognizable sound, and paired with training, is understood by all present workers to evacuate the project and to meet at the designated meeting or muster point. If there is an alarm system present that requires power, it is

mandated by fire codes to have a form of pack up power. This will enable the alert to function with a lack of primary power. There are a wide variety of emergency alerting methods and products on the market for employers to choose from. Section 2.6 explores emergency alert systems in more detail.

2.6: Emergency Alert Systems

An emergency alert system can be as big as the president alerting the country of a national emergency or as small as an alarm notifying someone of equipment failure. Typically, across many industries an emergency alert system will notify employees of a fire, gas leak, natural disaster, national emergency or anything that will place them in immediate danger. As mandated by OSHA, all employers must have a method of alerting their employees in the event of an emergency, and there are a wide variety of different methods that can be adopted. Alert systems can be as simple or as complex as the employer would like ranging from a simple loud speaker system to integrated fire alarm systems that automatically contact the local fire department.

2.6.1 Methods of Emergency Alerting

There are a wide variety of different methods of alerting employees or the public of an emergency. Some examples of these methods are discussed in the following sections.

2.6.1.1 Mass Notification Systems

Mass notification systems are fairly basic platforms that will send text messages, emails or recorded messages out to individuals to inform them of an emergency and give instruction as to what needs to be done or to stand by for more information. This is a one way system that will send these notifications out, but the individuals cannot send any messages or information requests back to the system. These types of systems are best suited to be used by local, state and the federal governments, police departments, fire departments, emergency management organizations. Some examples of types of messages sent from a mass notifications systems would be tornado warnings, flash flood warnings, and severe thunderstorm alerts. These systems can also be used to send out amber alerts or silver alerts, also to notify the public if there is an active shooter or a dangerous criminal that has escaped police custody. This system relies on a database of names, phone numbers, and emails to distribute information, but this database needs to be set up and maintained. Any organization that decides to use a mass notification system must have the communications infrastructure and the bandwidth available to deliver hundreds or even thousands of messages to everyone within the database.

2.6.1.2 Wireless Emergency Alerts (WEA)

The Wireless Emergency Alert (WEA) System is considered an essential part of America's emergency preparedness (Federal

Communications Commission, 2021). WEA systems send out text like messages to compatible mobile devices that are targeted to specific geographic regions. Recipients do not need to subscribe or sign up to receive these messages as they are automatically sent out via network providers to all compatible devices. Established in 2008 with the Warning Alert and Response Network (WARN) Act, and launched in 2012, WEA has been used nearly 56,000 times to warn the public about dangerous weather, missing children, and other critical situations (Federal Communications Commission, 2021). As a form of mass notification, the U.S. Government has relied on the WEA system to keep citizens informed through all types of emergencies.

2.6.1.3 SMS Text

Similar to the Wireless Emergency Alert systems, the SMS text system sends out alerts, messages or notifications to mobile devices and emails using a large database of contact information. The primary difference between SMS Test Systems and the WEA system is that recipients must sign up or subscribe to receive messages or alerts. This type of system allows employers to send urgent and non-urgent messages to employees. SMS Text systems can be used to send public safety announcements, including police activity, fires, or natural disasters. SMS text systems can also be used as a backup means of communication if phone lines or other forms of primary communication are disabled.

SMS systems can be used for notifications other than emergency alerts. SMS notification systems also have a pivotal role in logistics which can include sending event updates, keeping participants apprised of shifting schedules, and coordinating complex operations involving multiple individuals, facilities, or supplies (twilio, 2021).

SMS text systems also have the capability to send out coupons and marketing advertisements to recipients, further showing the capabilities of these systems, and they are not only used for emergency alerts. The negative side to using this system for more than emergency alerts is that workers may ignore the alert if they are inundated with notifications from the system all day. If a company uses this system for more than just emergency alerts or urgent messages workers may read the messages later or disregard the message all together. SMS systems are a great way to rapidly disperse information over all employees with increased technology and cellphone use, but the overuse of these systems can lower their effectiveness.

2.6.1.4 Application Based Systems

Application or "App" systems are web based systems that use apps on mobile devices or on computers to send emergency notifications. These web-based applications involve a particular type of software that allows users to interact with a remote server through a web browser interface (Lvivity, 2018). This allows users of an app based system to access the

server from anywhere in the world as long as there is cellular phone service or an internet connection. The user just needs to have the app downloaded to their computer or mobile device and allow notifications from that particular application. An example of this app is product called Alert Media and a sample of their app can be seen in figure 2.6.1. This type of system can also be used for other services than just emergency alerts, such as tracking and storing company information, sending documents to large groups of people, and providing one location for documentation to be accessed by anyone given permission at any time of day.

App systems allow companies to overall reduce operating costs because they will not need to spend large amounts on initial software purchase, set up and maintenance. Since web-based apps can run on any platform, there is no need to pay developers to create multiple versions of the program (i.e. for Mac OS and Windows, or for Android and iOS) (Lvivity, 2018).

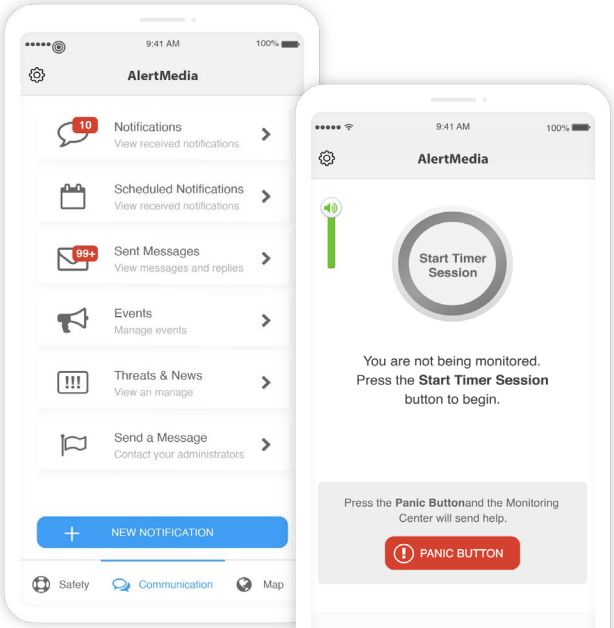

Figure 2.6.1 Alert Media App (Alert Media, 2021)

2.6.1.5 Outdoor Public Warning Systems

Outdoor Public Warning systems are used to warn the public in the event of severe weather or a public hazard. These systems consist of stationary sirens/speakers strategically placed throughout the community, may be activated individually or in groups, can signal via alert tone or broadcast a specific message. (Villwock, 2019). Examples of outdoor public warning systems would include tornado sirens, lightning strike, and severe thunderstorm sirens. These warnings are not limited to natural disasters or hazards. Outdoor public warning systems can be used to notify the community to evacuate or shelter in place for any type of hazard from

an active shooter to a nuclear meltdown. There is typically one sound for each different emergency, which means that the agency using the outdoor public warning system must inform its workers or the community what each different alert means, and what action needs to be taken.

2.6.2: Construction Industry Emergency Alert Products / Methods

The construction industry has a select few alert methods that are typically used, due to the temporary nature of the project and effectiveness of the alert. Some alert methods used on jobsites range from simple air horns to major high tech remote alert systems. An alert method is vital to a construction project so all workers can be notified as fast as possible in the event of a jobsite emergency, national emergency, natural disaster, or impending severe weather conditions. This emergency alert signals worker to stop what they are doing and to gather at a designated muster point for further instruction.

2.6.2.1: Air Horn

Some construction companies opt to use the traditional method of informing workers of an emergency, and that is the air horn. Explained to all workers during their jobsite orientation, three blast of the air horn means to stop what you are doing and to evacuate the jobsite and gather at the designated muster point. Each blast must be long enough to be heard, and the pause between must be long enough so workers can hear three distinct blasts. This will ensure the emergency alert is heard and

understood across the jobsite. An air horn should be kept in the project field office and should also be made available at multiple locations within the project. Easy access to the air horn is important, so the signal can be sent quickly rather than losing valuable time looking for the air horn. For small projects and small businesses the air horn is the best method available for emergency alerts because of its simplicity, effectiveness, and low cost.

Figure 2.6.2.1: Typical air horn found on a construction site.

(Tornado Studios, 2021)

2.6.2.2: Mass Notification Systems, or SMS text Alerts

Construction companies may choose to use a mass notification system or an SMS text alert system to notify workers of an emergency. These types of systems prove to be more useful on large multi-story

construction projects where a simple air horn may not be audible to all workers on the project. A mass notification system or SMS text alert system will effectively notify all workers via their mobile devices at any location of the construction site. The negative side of these types of systems is that workers must be able to hear the notifications or to be able to feel the vibration of their mobile device. During normal construction activities, this could prove difficult due to the noise level on a construction site, and the vibrations of tools and equipment. These systems typically have a high cost associated with them, and the contact names, emails and phone numbers all need to be entered into the system. The system needs to be maintained, and updated periodically. Systems like these typically have a limited number of contacts that can be entered into the database, and come with a relatively high price for the company.

2.6.2.3 Application based systems

Construction companies may choose to use an app based system for emergency alerts and documentation transfer. These systems can come at a lower upfront cost compared to the mass notification system or the SMS text systems as the software does not have to be purchased by the company, and the app does not need to be created. There are existing apps and systems on the market such as Alert Media (as seen in figure 2.6.2.3) and Rave Mobile Safety that companies pay to use. Some systems require licenses to be purchased, while others charge based on the number of

contacts that are required by the company using the system. The contact lists and notifications can be managed on a job by job basis by the project engineers and project managers. A downfall to using this system for notifications other than emergency alerts is that if workers are inundated with notifications, they may start to ignore the notifications and read them at a later time. A distinct sound would need to be used for emergency alerts so workers know the difference between an emergency and when a document is uploaded. There is also the issue of wireless network connections and overall reliability of the systems. If the project is located in an area with limited wireless network connection, worker may receive notifications late or not at all. Latency is inevitable for any web or cloud based system, and can create a delay between when the initial alert is sent, and the message is received. This can reduce valuable time that workers have to evacuate the jobsite.

Figure 2.6.2.3: Alert Media App and Computer Software

(Alert Media, 2021)

2.6.2.4: Remote Emergency Alert Systems

Remote systems are the construction industries solution to the temporary nature of the business. Remote emergency alert systems are totally self-contained, portable and even have the ability to be programed to contact the local fire department or police department. These systems are operated from a main control panel, or base station, that would be located in the construction project trailer. This panel is very similar to the main panel of a fire alarm system in a building. There are variety of remote devices that communicate with the main control panel. These systems typically offer smoke detectors, heat detectors, horn strobes and call stations. The construction manager can choose which devices they would like to use on the project. Each device is programed with the main panel and assigned a location within the project, very similar to fire alarm devices within a finished building. The call stations are devices that are located throughout the building and are similar to a fire alarm pull switch. These call stations can either set off the fire alarm or send a signal for medical help. The location is displayed on the main panel, making it easier for medical help or fire fighters to get to the location of the emergency. Companies such as Ramtech with their WES system (as seen in figure 2.6.2.4) and the First Response Group with their SmatSite Fire Solutions systems are pioneering this type of technology. A negative to these systems is the overall cost of initial purchase, and the cost of replacement batteries for the devices and panel. Multiple devices are needed on each

floor of a project to effectively notify all workers of an emergency. The cost of the WES3 base station is approximately $700, and each additional device such as the smoke detector, heat detector, and call points come in at a cost of $450 (Kyle, 2019). These systems can be cumbersome to use as well with multiple units to be programed, installed and maintained. The call points also provide workers the opportunity to signal false alarms, delaying productivity on the project for the day.

Figure 2.6.2.4: Ramtech Wes3 System. From left to right, the WES3 base station, call point and smoke detector. (Ramtech Electronics Limited, 2020)

2.6.3: Emergency Alert Methods in Other Industries

Unlike the construction industry, most other industries do not have the temporary and nomadic environment. Most other industries set up in a finished

building to conduct business and are not constantly moving their operations from job to job. These industries may choose to utilize wireless emergency alerts, or SMS text systems to inform their employees of an emergency, but typically the building they occupy will be equipped with a permanently installed fire alarm system and possibly a loudspeaker system to communicate with all employees in emergency situations.

Fire alarm systems are usually integrated with sprinkler systems in commercial buildings, and automatically send a signal to the local fire department. Codes, requirements, and components for these systems to be used in each different building type are governed by the National Building Code, National Fire Code, and the National Fire Protection Association. Fire alarm systems typically consist of a main control panel for the system, horn strobe devices, heat detectors, and or smoke detectors. All devices work simultaneously to identify a fire and locate the hazard within the building via programed device locations. The locations are relayed to the main panel so the fire department can mitigate the hazard in less time.

Some industries set up a code system to notify workers of a situation, and they follow a protocol they have been trained to follow for each different code. These emergency alerts are typically broadcast over a loudspeaker system that has been installed throughout the building. These codes can have a color system or a numerical system to notify workers of the severity of the situation and the necessary steps that must be immediately taken to ensure their safety and the

safety of other workers within the facility. For example, all hospitals have at least three different color codes that they use to notify all workers.

In the manufacturing industry, there are a wide variety of products that are used to notify workers in the event of an emergency. Fixed fire alarm systems and overhead speaker systems will convey emergency information to workers fast and efficiently, but there are high tech systems available as well. For example, a product named InformaCast for Manufacturing can tie into existing sensors and devices to alert employees when emergencies happen (Singlewire Software, 2021). If equipment is disrupted by an accident or by simple malfunction, management and employees are informed so proper steps can be taken to rectify the situation. Informacast can be tied into safety devices such as eyewash stations, so when activated, a signal can be sent to the health and safety department notifying them a worker used the station and needs medical attention. This system can also send out a notification to all workers via phones, computers and wireless devices to notify workers of impending severe weather such as tornadoes. This integrated system provides a variety of benefits to the manufacturing industry and keeps all levels of management informed of events.

Chapter 3: Methodology

The methodology for this research consists of an extensive literature review and an anonymous survey that explores emergency alert systems used in the construction industry today. The literature review began with the exploration of issues that the construction industry faces today, with one of these issues being jobsite safety. The current safety issues then lead the literature review into workplace safety to discuss the most common types of injuries that occur in the construction industry. This brought the research to the question of how can these accidents be prevented? In order to mitigate these accidents, employers create workplace safety policies and plans. The literature review goes on to explain what OSHA is, how it sets forth standards that shape company safety plans, and how these standards are enforced. This section also explains the difference between a company safety plan and a site specific safety plan. After a brief exploration of the current advances in construction safety that help to maintain these safety policies, the literature review moved into emergency preparedness plans. Embedded within the site specific safety plan is the emergency preparedness plan. The research identified the key components of the emergency preparedness plan, and explains that within the emergency preparedness plan for any construction project you will find a section on emergency alerts. The research investigated various types of emergency alerts both within the construction industry and within other industries to identify the most common types of alert methods available to employers.

A survey was created with the intent of identifying the construction industries familiarity with high tech emergency alert systems, and to understand their perception of the systems. This 15 question survey was created using Qualtrics survey software and was distributed through an

anonymous link to approximately 400 construction industry professionals in the northeast via email and Linked In. The survey questions and their logic within the research can be seen in the following tables.

Demographic Questions		
Question Number	**Question**	**Logic / Intent of the Question**
1	What is your title within your company?	To sort the responses by higher vs lower management and field vs office staff, and to explore if there is any correlation between different groups, and the responses to later questions in the survey.
2	How long have you worked for your company?	Explore any correlations between employment longevity with a company and some of the questions in regards to emergency alert methods and willingness to pay for safety related equipment.
3	How many full time employees does your company have?	Understand the respondents' company size, and identify any correlations with company size and questions asked later in the survey.
4	What sector of the construction industry does your company specialize in?	Sort data by industry sector, and identify any correlations with answers to later questions when compared to their industry sector.

5	What is the average typical contract value of a single project for your company?	Explore contract volumes and to identify any correlations between contract value and some of the later questions in the survey.

Table 3.1: Demographic Questions and Logic

Emergency Alert Questions		
Question Number	**Question**	**Logic / Intent of the Question**
6	What do you currently use to notify workers on your jobsites in the event of an emergency? Choose all that apply.	Determine the most commonly used emergency alert system among all the respondents, and the distribution among use of different alerting methods.
7	Have you heard of any app-based emergency alert systems for jobsites where a company can purchase software to send emergency alerts and notifications to workers via their cellphones or mobile devices?	Determine familiarity of the respondents with particular type of emergency alert systems.

8	Are you currently using or ever have used an App-based emergency alert system?	Determine if the respondents have ever used this type of emergency alert system prior.
9	Do you think using cell phones as a method for your workers to receive emergency alerts may have any negative impact on daily productivity?	Determine a potential hurdle against app based systems: If workers have their cell phones with them all the time to receive emergency alerts, they would be more apt to have their phones out for non-work related use, impacting overall productivity.
10	Have you ever heard of a remote emergency alert system where devices such as call stations, smoke detectors, and horn strobes are installed on a job site, and are all connected to a main operation panel via a remote signal?	Determine familiarity of the respondents with particular type of emergency alert systems.
11	Are you currently using or have ever used a remote emergency alert system?	Determine if the respondents have ever used this type of emergency alert system prior.
12	Would you consider using an App based or remote emergency alert systems on your next project?	Provide insight into the respondent's willingness to use one of these systems, and if not, allow respondents to provide feedback as to why they would not consider using one of these systems.

13	What would deter you from using one of these high-tech emergency alert systems on a project?	Determine if there is any room in the market for an improved high tech emergency alert system, or if the existing products could be altered to make them more appealing to construction companies.
14	If you have used one of these high-tech emergency alert systems, do you think they could be improved?	Identify if those who used these systems before believe that these systems could be improved or if they believe the system is acceptable as is.
15	What percentage of your project safety budget would you be willing to devote to either a remote or app based emergency alert system?	Determine the willingness to invest into these safety systems, and compare the responses of this question, to the responses of the demographic questions, and identify any correlations that may exist.

Table 3.2: Emergency Alert Questions and Logic

Further development of this survey lead to moving question six to the end of the survey. Based on the Qualtrics survey logic, for those respondent that said they would not consider using

either the app-based system or the remote system, they were then directed to question 6 to finish their survey. This was deemed a more appropriate ending question and allowed for a better flow from question to question during the survey.

Distribution of the survey began at the end of April 2020, and the data to be analyzed was collected on March 1st 2021. IBM SPSS 26 statistical data software, and the Qualtrics survey software were used to analyze the data, find correlations and key results, and form conclusions about construction jobsite emergency alert systems.

Chapter 4: Findings and Analysis

The Jobsite Emergency Alert survey that was distributed for this research produced a total of 34 responses, an 8.5% response rate. Of these thirty four responses, 38 percent were project managers, 12 percent were project superintendents, 0 percent were project executives, and 50 percent of the respondents chose the "other" option, and listed their job titles. The titles of the 50 percent include 2 field engineers, 2 project engineers, 2 assistant project managers, an estimator, assistant estimator, safety manager, vice president, senior vice president, president, owners project manager, preconstruction manager, director of operations, and a director of scheduling and lean services.

The survey shows that 50 percent of these individuals have been with their company for less than 5 years. A total of 24 percent of the respondents have been with their company between 5 and 9 years, 18 percent have been with their company for 10 to 19 years, and 9 percent said they have been with their company for 20 to 29 years. The survey showed that there weren't any respondents that have been with their company for 30 or more years.

The results of the survey show that a significant percentage of respondents came from large or mid-sized companies. Figure 4.1 shows the percentage of respondents for companies that have 1 to 49 employees, 50 to 99 employees, 100 to 499 employees, 500 to 999 employees and 1000 or more employees. The two largest categories that respondents chose were the 1000 or more employees and the 100 to 499 employees.

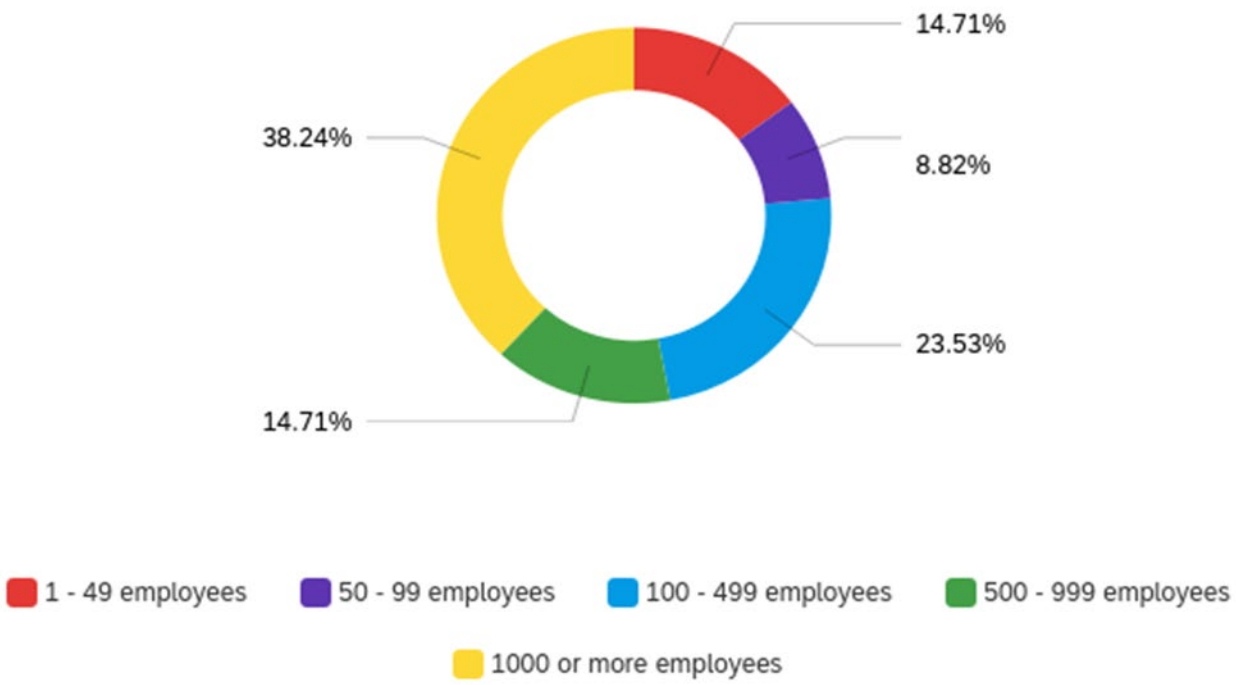

Figure 4.1: Number of full time employees at respondent companies.

The results also show that a majority of the respondents work in the commercial sector of the construction industry. The survey showed 57 percent of the respondents work in commercial construction. This can be seen in figure 4.2 below, along with the number of respondents in other sectors of the construction industry. There were four respondents more specific when answering this question, and selected the “other” option in the survey and listed the sector they work in,

accounting for a total of 9 percent of the respondents. These individuals listed the sector their company focusses on as all sectors, commercial architecture, healthcare, and higher education.

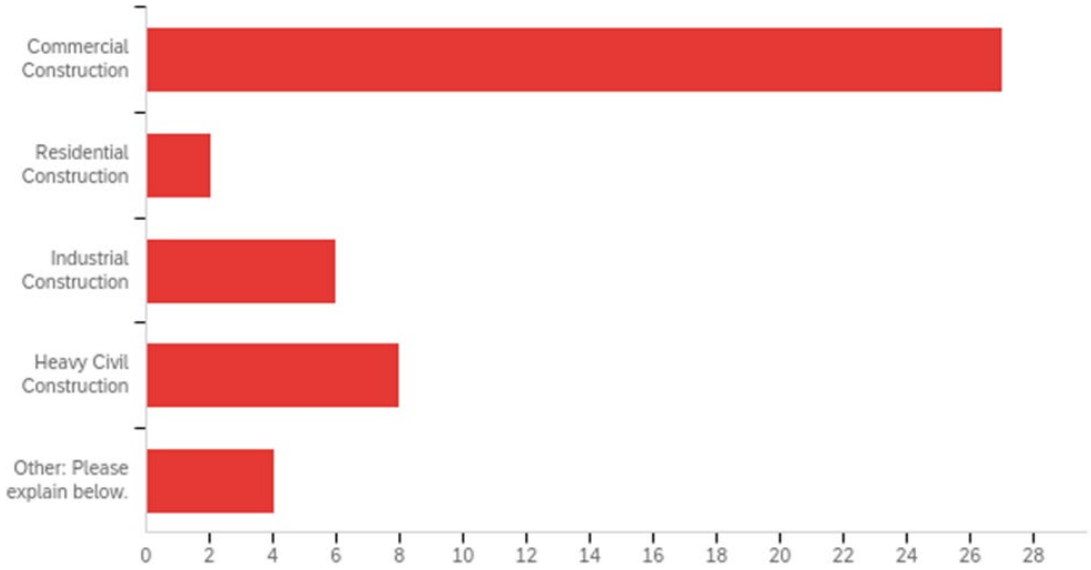

Figure 4.2: Construction Industry Sectors

Respondents were asked about the average typical contract value for a single project for their company. The results show that 44 percent of the respondent's companies held average contract values in the 1 to 9 million dollar range, closely followed by the 20 to 99 million dollar range with 41 percent of the respondents. These two ranges account for just over 85 percent of all responses to the survey. This can be seen in figure 4.3, which shows the number of respondents per typical average contract value.

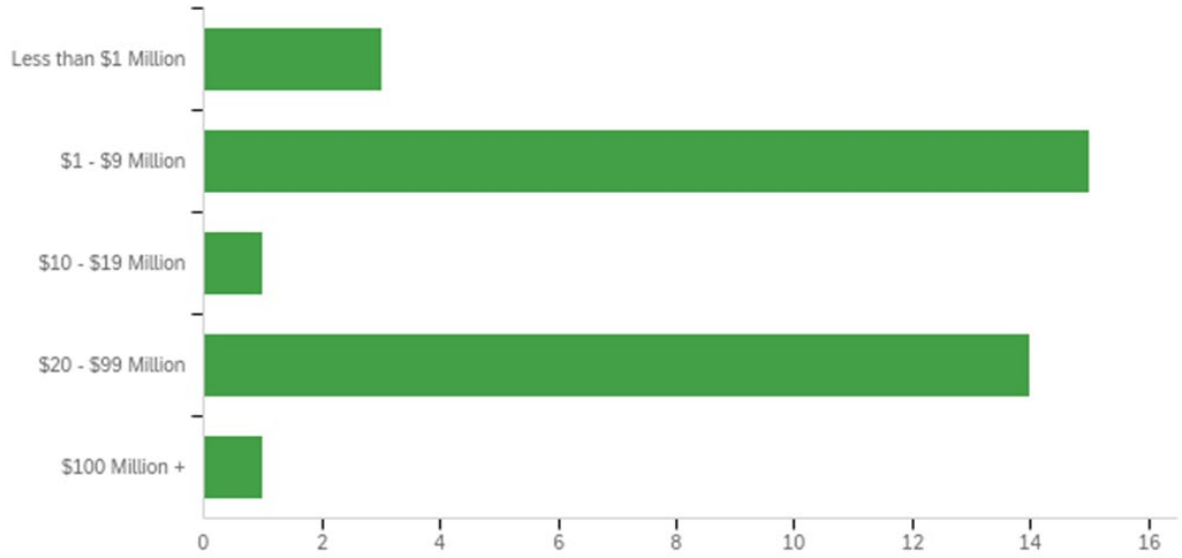

Figure 4.3: Typical average contract value.

This demographic information shows that a majority of the respondents have been with their current mid-sized or large commercial construction companies for 9 years or less, holding a wide variety of positions within these companies from entry level field and office positions, up to vice presidents and presidents of the company. These Companies typically hold contract values from 1 to 9 million and 20 to 99 million dollar ranges.

The results of the survey show that 59 percent of the respondents have heard of app-based emergency alert systems, and of this percentage, only 40 percent are currently using one or have used one in the past. Since this system relies on workers having cell phones to receive the alerts, the respondents were asked if they thought using cell phones as a method of receiving emergency alerts could have a negative impact on daily productivity. Out of the 34 responses, 30 said they didn't think that this cell phone use would impact daily productivity, and can be seen below in figure 4.4.

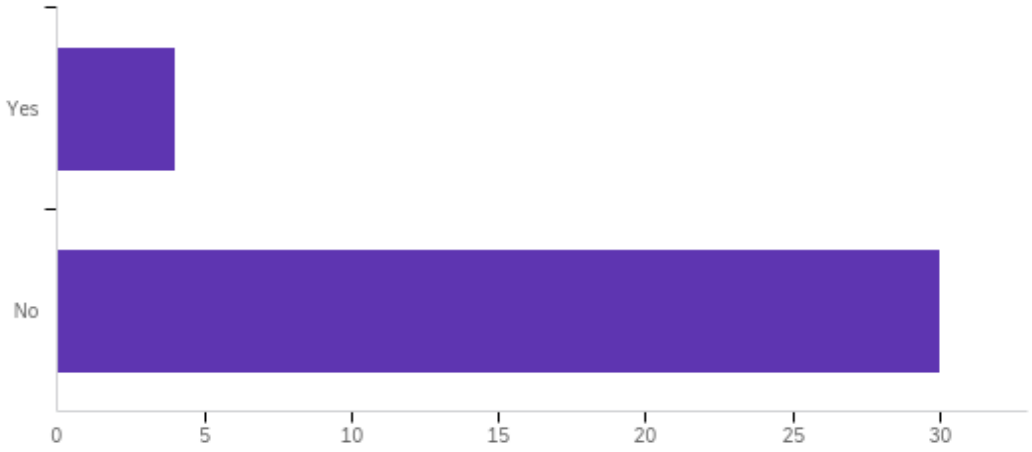

Figure 4.4: Cell Phones and daily productivity

According to this survey, fewer individuals have heard of remote emergency alert systems. Of the 34 respondents, 47 percent of the individuals have heard of this type of system, and 31 percent of these individuals have actually used this type of system or are currently using it. The respondents were then asked if they would consider using either an app-based emergency alert system or a remote emergency alert system on their next project. The results of the survey show that 21 out of the 34 respondents would consider using either system on their next project, which is 62 percent. One respondent said they would consider using a remote emergency alert system on their next project, 10 respondents said they would consider using an app-based emergency alert system on their next project, and 2 respondents said they would not consider using either system. Of the two that said they would not consider either system, the reasoning behind their answers was that it seems too cumbersome to use for the slim chance that it is needed, and it seems as if there may not be a way to follow protocol with these systems.

Figure 4.5: Question 13 most frequently used words.

The survey asked the respondents about the factors that may deter them from using one or both of these systems on a project. When the results were checked by the qualtrics survey software, the most common word found in the responses was cost, this can be seen in figure 4.5 which is the word cloud generated through the survey report. This means that to the respondents, cost is the biggest deterrent from using either of these emergency alert systems. Another major concern was the overall reliability of the systems.

Three other individuals responded with the common theme of concern with the system failing. This consisted of the system being underdeveloped and not well thought out, software outages, lack of wifi or inadequate wireless connectivity, and technical glitches to disrupt daily functions. Two of the respondents discuss the potential for false alarms and the possible loss of productivity, two other respondents feel the systems would not be necessary, two respondents feel there would be issues with employees buying into the system and forcing employees to carry

a cell phone, and one individual said the project size and site location may be a deterrent for using one of these systems. Two other respondents said this would not be their decision and it would need to be made by the appropriate level of management within the company.

Based on the logic of this survey, some of the respondents were asked if they have used one of these two systems, and if they think that the systems could be improved. Out of the 9 respondents to this question, 7 said that the systems could be improved and 2 said that they couldn't be improved. This can be seen in figure 4.6.

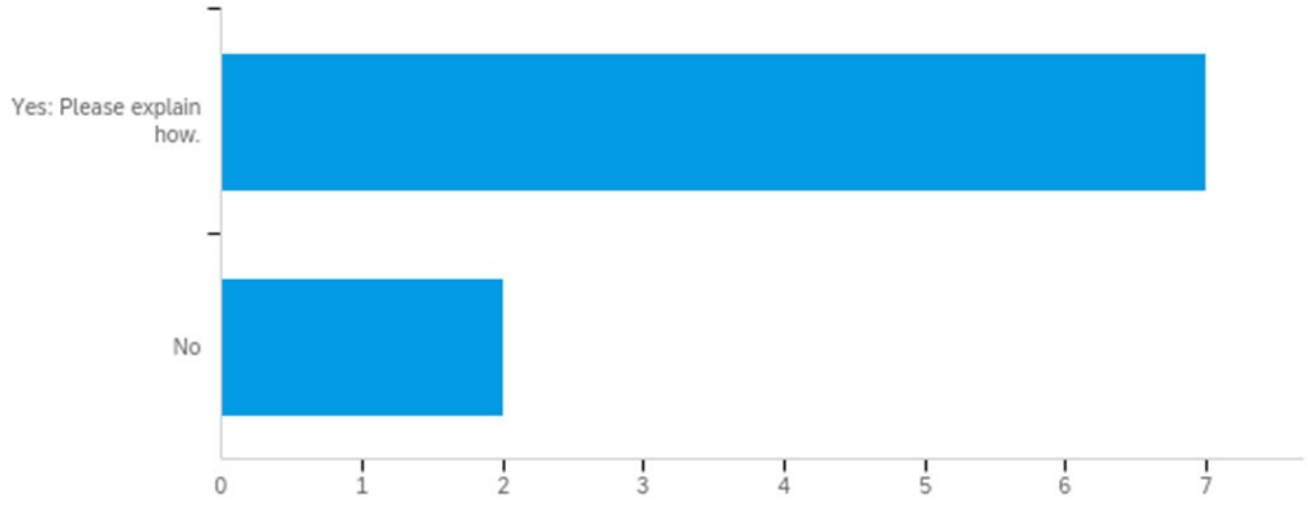

Figure 4.6: The systems can or can't be improved.

Respondents were then asked how much of their safety budgets they would be willing to spend on an app-based emergency alert system, and a remote emergency alert system. Of the 34 respondents, 27 answered the question for the app-based emergency alert system. The minimum percentage for this question was 1 percent of the project safety budget, and the maximum was 30

percent of the project safety budget. As for the remote emergency alert system, 25 respondents answered the question and the minimum percentage for this question was 0 percent of their project safety budget, and the maximum was 21 percent of their project safety budget. Figure 4.7 shows the mean for each separate emergency alert system.

Figure 4.7: Mean percentage of the safety budget to be allocated.

The final question of the survey asked respondents what they currently use on jobsites for emergency alerts, and to choose all that may apply. This question produced a total of 40 responses, which indicated that some companies use at least a couple different alert methods. The first choice to this question was air horn. This made up 58 percent of the responses for this question, showing it is the most common method of emergency alerting on construction jobsites. The app-based emergency alert option and the remote emergency alert option both received 4 responses each. The option for "no alert used" received 5 responses, and the final option of "other: please explain" received 4 responses. One individual said that they do not have a program in place, but phone calls go out in the event of an emergency. Another respondent said they use group texts sent to cell phones and ipads, and the final two respondents said they use existing

building alert systems or temporary alert systems, or have to follow strict existing building protocols for emergency alerts. The results of this question can be seen in figure 4.8.

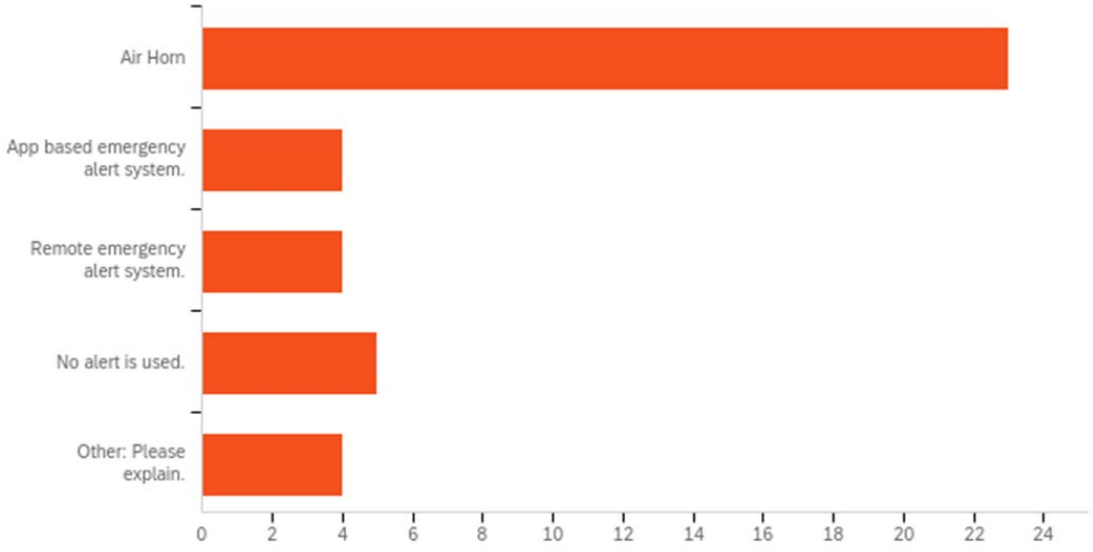

Figure 4.8: Systems currently used for emergency alerts.

Further analysis of the data showed a majority of the respondents from large companies with 1000 or more employees were willing to spend 10 percent of their safety budget or more on remote emergency alert systems, but were only willing to spend 10 percent or less on app-based emergency alert systems. This data can be seen in the cross tabulations tables below.

Q3 * Q15_1 Cross tabulation

		Q15_1											Total
		1	3	4	5	8	9	10	12	15	16	30	
Q3	1	0	0	0	0	0	1	1	0	1	0	1	4
	2	0	0	0	1	0	1	0	0	0	0	0	2
	3	1	1	1	0	0	0	1	1	0	1	0	6
	4	1	0	0	0	1	0	2	0	0	0	0	4
	5	0	1	0	2	0	1	4	0	3	0	0	11
Total		2	2	1	3	1	3	8	1	4	1	1	27

Table 4.1 Question 3, and 15-1 analysis

Q3 * Q15_2 Cross tabulation

		Q15_2									Total
		0	1	2	4	5	10	15	20	21	
Q3	1	0	0	0	0	0	1	1	0	1	3
	2	0	0	0	0	0	2	0	0	0	2
	3	1	0	1	1	1	1	0	0	0	5
	4	0	1	0	0	1	2	0	0	0	4
	5	0	0	0	0	2	5	2	2	0	11
Total		1	1	1	1	4	11	3	2	1	25

Table 4.2: Question 3 and 15-2 analysis

With this information, a statistical analysis was completed to see if there was a correlation between the company size and if using cell phones as a means of sending alerts would affect daily productivity. Considering larger companies are willing to spend more on remote emergency alert systems, it was suspected that larger companies would think using cell phones as a method of emergency alert delivery may impact the daily productivity. This analysis showed that respondents who work for larger companies, did not think there would be a negative impact on daily productivity if cell phones were used as a method of receiving emergency alerts. All respondents from companies with 1000 or more employees selected no for question 3.

Statistical analysis showed a correlation between the average typical contract value and the individuals familiarity with app-based emergency alert systems $R=-.470$, $N= 33$, $P=0.006$. The data shows that the larger the average typical contract value a company has, the less likely they have heard of app based emergency alerts systems.

Further analysis of the data shows a correlation between the respondents opinion on if the systems can be improved or not, and the willingness to pay for each system $R=0.641$, $N=9$, $P=0.063$ Those respondents that said the systems could not be improved were willing to spend more on app based systems over the remote systems, and those that said the systems could be improved, were willing to spend more on the remote systems.

No correlations were found between the length of time an individual has spent with their current company, job title, or the sector of the construction industry they work in and any of the questions asked in regard to the emergency alert systems.

Chapter 5: Conclusions and Recommendations

Among the current issues that the construction industry is facing today, worker safety is of the upmost importance. In the event of an emergency, an alert system or method is necessary to inform workers on a construction site to evacuate and gather at the muster point for further instruction. This can be for a jobsite emergency, impending severe weather, natural disaster or national emergency. An alert method is required at a minimum by OSHA and should be identified within the company emergency action plan. There are a wide variety of systems available on the market today ranging from simplistic to high tech. Research shows that there are primarily three types of emergency alert methods used in the construction industry. These include a simple air horn, app–based alert systems that require the use of software and applications downloaded to mobile devices, and remote alert systems that rely on battery powered devices located throughout the project, connected to a main control panel in the field office..

Through the use of an in-industry survey, with more than half of its respondents from the commercial sector of the construction industry, this study determined that the industry primarily uses an air horn for emergency alerts. The findings of this study present that the construction industry is more critical towards the app-based emergency alert systems rather than the remote emergency alert systems, while finding faults in both systems. One of the largest deterrents for the construction industry to utilize either the remote alert system, or the app-based system is cost, followed by concerns for false alarms, and technology issues. The construction industry is currently willing to spend more on the remote emergency alert systems over the app-based systems, but if the weaknesses of these systems can be addressed there would be a shift in

preference, and the construction industry may be willing to spend more on the app-based emergency alert systems. Further advertising of these systems should take place in order to make companies with high dollar projects aware of the app-based systems, and the overall benefits they can provide to project safety. Based on the data analysis, there is limited room in the market for a new emergency alert product. Given the number of individuals that have heard of these types of systems, introducing a new product would not be beneficial to the industry, instead a better marketing effort should be made to promote these systems and make them well known in the industry. The current systems need their faults analyzed and addressed, which may urge companies to be more willing to integrate these types of systems into their next projects.

For future research, it is recommended to conduct a study that explores the number and types of safety incidents that have been caused by the lack of an emergency alert system. It is also recommended to further explore the system faults, and to develop a strategy of addressing these faults and testing the updated systems to see if the perception of the industry can be changed. Furthermore, studies should look into impacts of these systems on the overall safety performance of the projects paving the way to offer emergency alert systems that are not just convenient and reliable, but also effective.

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Appendices

Appendix A: Jobsite Emergency Alert Survey

Start of Block: Default Question Block

Q18 My name is Steven Pulver and I am a masters student in the construction management program at Roger Williams University. I am working with Dr. Bilge Gokhan Celik to conduct this survey for my graduate thesis research project of jobsite emergency alert systems. I can be reached via email with any questions regarding this survey at spulver@rwu.edu, and Dr. Celik may be reached at bcelik@rwu.edu. This survey is completely anonymous and all data recorded will only be used in the aggregate form. No names will be recorded, or used during the course of the survey and research project. Please indicate whether you do or do not consent to taking this survey. Thank you very much for your time.

- ○ I consent (1)
- ○ I do NOT consent (2)

Skip To: End of Survey If My name is Steven Pulver and I am a masters student in the construction management program at Rog... = I do NOT consent

Page Break

Q1 What is your title within your company?

- ○ Project Manager (1)
- ○ Project Superintendent (2)
- ○ Project Executive (3)
- ○ Other: Please describe your title below. (4)

_____

Q2 How long have you worked for your company?

- ○ Less than 5 years (1)
- ○ 5 - 9 years (2)
- ○ 10 - 19 years (3)
- ○ 20 - 29 years (4)
- ○ 30 + years (5)

Q3 How many full time employees does your company have?

- ○ 1 - 49 employees (1)
- ○ 50 - 99 employees (2)
- ○ 100 - 499 employees (3)
- ○ 500 - 999 employees (4)
- ○ 1000 or more employees (5)

Q4 What sector of the construction industry does your company specialize in?

- ☐ Commercial Construction (1)
- ☐ Residential Construction (2)
- ☐ Industrial Construction (3)
- ☐ Heavy Civil Construction (4)
- ☐ Other: Please explain below. (5) _____

Q5 What is the average typical contract value of a single project for your company?

- ○ Less than $1 Million (1)
- ○ $1 - $9 Million (2)
- ○ $10 - $19 Million (3)
- ○ $20 - $99 Million (4)
- ○ $100 Million + (5)

Q7 Have you heard of any app-based emergency alert systems for jobsites where a company can purchase software to send emergency alerts and notifications to workers via their cellphones or mobile devices?

- ○ Yes (1)
- ○ No (2)

Skip To: Q9 If Have you heard of any app-based emergency alert systems for jobsites where a company can purchase... = No

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Q8 Are you currently using or ever have used an App-based emergency alert system?

- ○ I have used one (1)
- ○ I have never used one. (3)

Q9 Do you think using cell phones as a method for your workers to receive emergency alerts may have any negative impact on daily productivity?

- ○ Yes (1)
- ○ No (2)

Q10 Have you ever heard of a remote emergency alert system where devices such as call stations, smoke detectors, and horn strobes are installed on a job site, and are all connected to a main operation panel via a remote signal?

- ○ Yes (1)
- ○ No (2)

Skip To: Q12 If Have you ever heard of a remote emergency alert system where devices such as call stations, smoke... = No

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Q11 Are you currently using or have ever used a remote emergency alert system?

- ○ I have used one (1)
- ○ I have never used one. (3)

Q12 Would you consider using an App based or remote emergency alert systems on your next project?

- ○ I would consider an app based emergency alert system. (1)
- ○ I would consider a remote emergency alert system. (2)
- ○ I would consider using either app based or remote emergency alert systems. (3)
- ○ I would NOT consider using either of these systems. Please explain. (4)

_____

Q13 What would deter you from using one of these high-tech emergency alert systems on a project?

_____

Display This Question:

If Are you currently using or ever have used an App-based emergency alert system? = I have used one

Or Are you currently using or ever have used an App-based emergency alert system? =

Or Are you currently using or have ever used a remote emergency alert system? = I have used one

Or Are you currently using or have ever used a remote emergency alert system? =

Q14 If you have used one of these high-tech emergency alert systems, do you think they could be improved?

- ○ Yes: Please explain how. (1) _____
- ○ No (2)

Display This Question:

If Would you consider using an App based or remote emergency alert systems on your next project? != I would NOT consider using either of these systems. Please explain.

Q15 What percentage of your project safety budget would you be willing to devote to either a remote or app based emergency alert system?

0 10 20 30 40 50 60 70 80 90 100

App based system ()	
Remote System ()	

Q6 What do you currently use to notify workers on your jobsites in the event of an emergency? Choose all that apply.

- ☐ Air Horn (1)
- ☐ App based emergency alert system. (2)
- ☐ Remote emergency alert system. (3)
- ☐ No alert is used. (4)
- ☐ Other: Please explain. (5) _____

End of Block: Default Question Block