APPRAISAL OF CRANE SAFETY PREPAREDNESS FOLLOWING THE INTRODUCTION OF THE NEW OCCUPATIONAL SAFETY AND HEALTH ADMINISTRATION (OSHA) CRANE RULES

by

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ABSTRACT

FRANCIS ADJEPONG BOAFO Appraisal of crane safety preparedness following the introduction of the new occupational safety and health administration (OSHA) crane rules. (Under the direction of DR. BRUCE GEHRIG)

This research investigates the impact of the new Occupational Safety and Health Administration (OSHA) Crane and Derrick Regulations 29CFR 1926 Subpart CC on the frequencies of the causes of crane related accidents and fatalities. The old and new crane rules were compared to identify the areas in the regulation which had major changes made to enhance the relevance of the new regulation in reducing crane accidents and fatalities. The comparison of the two regulations showed a comprehensive change to the old regulation. Crane related accidents and fatalities recorded between the period of 2002 and 2012 were then analyzed using chi-square test to compare relative accident and fatality levels which occurred before and after the introduction of the new regulation. The chi-square analysis showed a very little likelihood of statistically significant relationship between crane accidents injury and fatality levels and crane failure causing fatalities in relation to the change in the crane regulation. However, the chi-square analysis did show a highly likely correlation between the types of crane failures types causing injuries and the changes in regulation. Proportional analysis of the data revealed a decline in some of the causes of accidents. Areas which saw a proportional increase will need further attention to mitigate the increase. The final part of the research was to develop a checklist to ensure compliance with the new OSHA crane and derricks regulations. The checklist is intended to serve as tool to create awareness for construction site workers on any potential hazards associated with their crane operations.

DEDICATION

This Thesis is dedicated to my wife, my children, my father (Mr. Adjei Boafo) and the rest of my families in Ghana and the United States for their persistent support throughout my graduate studies. It is also dedicated to Dr. Chung-Suk Cho, and the entire faculty of the Construction and Facilities Management Program of the UNC-Charlotte College of Engineering for their esteemed guidance during my research.

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CHAPTER 1: INTRODUCTION

The need to ensure safety at construction sites while using cranes and derricks has become extremely important due to the many crane accidents and fatalities recorded in the United States and across the world (Peraza, 2009). According to Peraza (2009), the Center for Construction Research and Training (CCRT) reported that between 1992 and 2006 the Bureau of Labor Statistics documented 632 construction worker deaths resulting from 611 crane incidents. This is an average of 42 worker deaths per year. Death caused by electrocution from power lines and crane collapse accounted for approximately 158 (25%) and 89 (14%) of all fatalities respectively. While some of the causes of crane accidents were multiple factors, other single factors such as ground conditions, power lines, overloading, or shifting of the load were often responsible for the accidents. The use of cranes and derricks during lifting undoubtedly account for one of the major causes of fatalities during construction (Beaver, 2006).

Parffit (2009) opines that many modern day structural failures and the lack of prevention of these failures can be traced back to procedural flaws. Bernold et al (1997), identified safety as the most critical factor in any lift activity. Hayes et al (1998) also underscored the need to reduce industry accidents due to the billions of dollars that the nation can save through accidents preventions. It is against this backdrop that in 2010, the Occupational Safety and Health Administration (OSHA) modified the standards for cranes and derricks for the first time in 40 years. The new standards seek to address areas such as power line safety, ground conditions, assembly/disassembly, licensing of crane operators, training for riggers and signal persons, tracking key crane parts, certification requirements for crane inspection during erection and climbing, and disassembly of cranes. Other areas the new OSHA standard addresses include design of crane foundations and tiebacks by structural engineers, inspection of foundation and tiebacks, licensing of crane inspectors and approval of repairs by crane manufacturer. Although all stakeholders including the construction management team are responsible for ensuring safe crane operations at site, their lack of complete knowledge on the latest OSHA standards, regulations and best practices for planning and conducting crane operations has often resulted in fatal crane accidents. As such, this research includes developing a tool that can be used by all stakeholders responsible for the management and planning of crane operations to assess their crane safety readiness prior to and during crane operation activities.

1.1 Background

Cranes are a very significant component of construction that affects a wide scope of work at most construction sites. Cranes are widely used in agriculture, construction of buildings, bridges, dams, mining sites and shipyards Bernold et al (2007). Freight businesses also rely heavily on cranes for loading and unloading activities at the port. Industries such as oil and gas refineries and power plants rely on cranes for their operations as well. Various cranes are used for specific tasks and their selections are based on the nature of the activity, the load, the ground conditions as well as accessibility at the construction site. As an illustration of the wide variety of operations, some typical cranes used for construction are described below.

Crawler Cranes

Crawler cranes are used on firm level terrains. They have limited mobility on site and are compact and stable in nature with minimum set up. They also have the ability to rotate 360 degrees. However, due to their enormous weight, they are dismantled and transported by trucks, ship and rail, which are often costly for the project. Figure 1 below shows a typical crawler crane being used for pipe lifting and installation at a construction site.

FIGURE 1: Crawler crane
Source*:* QUY50-II Crawler crane (2013)

Research conducted by Purswell (2009) on crawler crane related accidents between the period of 1986 and 2002 revealed twenty-two (22) fatalities. These accidents were largely associated with assembly/disassembly errors. Additionally, boom collapse was mentioned as one of the major causes of accidents associated with crawler cranes. These accidents typically occur when the crane’s boom is overloaded. Purswell (2009) further identified the lack of adequate training as the major cause of these accidents. Hence, adequately training the employees will substantially reduce such accidents and fatalities.

Fixed Jib Crane

Fixed jib cranes have their main boom angles fixed. They are able to extend smaller loads over structures and can continuously remain on the main boom during operation. Some accidents associated with the fixed jib cranes are collapse due to overloading. Figure 2 shows a typical fixed jib crane used for hoisting activities.

FIGURE 2: Fixed jib crane
Source: Fixed jib crane. (2014).

Luffing Jib Crane

Luffing jibs operate differently from the fixed jibs in that they can rotate up and down with the main boom kept at a fixed angle. Figure 3 shows an example of luffing jib cranes used in a high-rise building construction. Luffing jibs can operate large loads according to their capacity. However, extensive technical knowledge is required to safely assemble and disassemble luffing jibs.

FIGURE 3: Luffing jib crane
Source: Luffing jib crane. (2012)

Telescoping Boom Crawler Cranes

This crane is used in construction of storage tanks. Its rugged nature makes it excellent equipment for rough terrain jobs. It is versatile and can be moved from one setup location to another. Figure 4 shows an example of a telescopic boom crawler crane used in tank shell erection activities.

FIGURE 4: Telescopic boom crawler crane
Source: Telescopic boom crawler crane. (2014)

Tower Crane

Tower cranes have wide reach and lifting capabilities. These cranes are utilized for extensive tasks especially where site conditions are restrictive. According to Shapira et al (2009), the tower crane is an integral part of building construction sites. They also account for a significant amount of crane accidents. A recent accident involving a tower crane occurred during the reconstruction of the World Trade Center. The cable which was being used to hoist 3 girders estimated at 40,000 lbs. around a 40 story building snapped causing the girders to crash down. Suggested possible causes included flattening of the wire ropes to 2/3rds their original diameter, as well as insufficient rope capacity to handle the load. The report recommended daily, weekly, monthly and annual inspections should be thoroughly carried out to mitigate such accidents. Figure 5 below shows a tower crane used in erecting activities.

FIGURE 5: Tower crane
Source: Construction Tower Crane QTZ63 6T (2014)

1.2 Objective

The introduction of the new OSHA crane and derricks regulation 29CFR 1926 Subpart CC has been referenced by organizations involved in crane operations as being a significant milestone in reducing the number of crane accidents and fatalities. Critical areas such as ground conditions, power lines safety, assembly/disassembly, inspection and training among other relevant issues have been addressed to guide stakeholders on how to safely operate cranes at construction sites. The following have been identified as the objective of the research:

i. Investigate the hypothesis that the new crane regulations have significantly lowered the number of crane related accidents**.**

ii. Develop a safety readiness checklist that will serve as a guide for the project team to carryout safe crane operation and to prevent accidents and avoid costly code violations

CHAPTER 2: LITERATURE REVIEW

Crane accidents remain a major issue which requires attention. In 2012, the construction industry had the highest fatality rate among the major economic sectors, including agriculture and mining, within its category. In all, 715 fatal injuries were recorded in the construction industry representing a fatality rate of almost 4 per 100,000 workers; (US Bureau of Labor Statistics 2014). Past trends of crane related fatalities which have been investigated by OSHA are presented below.

2.1 Crane Related Accidents

A review of trade and news media in 2008 by CCRT showed 54 construction worker fatalities related to crane accidents representing an approximately 30 percent increase over the annual fatalities average of 42 between 1992 and 2006 (Pareza, 2009). Figure 6 shows crane related deaths of workers between 1992 to2006.

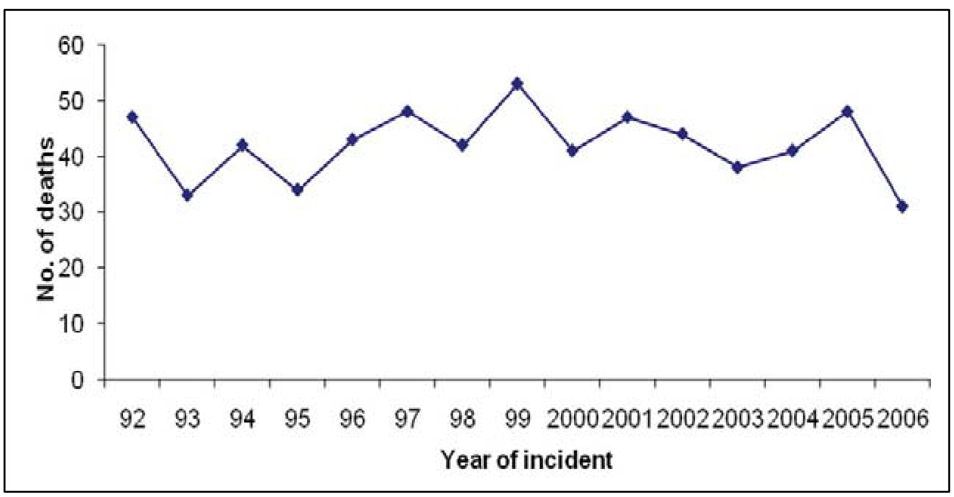


FIGURE 6: Crane-related deaths of workers, 1992-2006
Source: Pareza, (2009)

The crane fatalities recorded between 1992 and 2006 showed that power line electrocution accounted for 25% of the fatalities closely followed by contacts with crane loads and crane parts respectively. Table 1 shows the causes of the accidents. Accidents which could not be clearly categorized were defined as other causes.

TABLE 1: Causes of crane-related deaths in construction, 1992-2006

Cause of death	*# deaths*	%
Overhead power line electrocutions	157	25%
Struck by crane loads	132	21%
Struck by crane or crane parts	125	20%
Crane collapses	89	14%
Falls	56	9%
Caught in/between	30	5%
Other causes	43	7%
Total	632	*100%

*Round off to 100%.
Source: Cranes and Derricks in Construction; Final Rule. (2010)

Beaver et al. (2006) examined the major causes of crane related fatalities between 1997 and 2003 using OSHA's Integrated Management Information Systems (IMIS) database. A total of 125 cases involving crane and derricks accidents were identified during the examination and the causes of fatalities are summarized in Table 2 below.

TABLE 2: Causes of fatalities during crane hoisting activities 1997-2003

Activities	**% of fatalities**
Struck by load (other than failure of boom/cable)	32%
Electrocution	27%
Crushed during assembly/disassembly	21%
Failure of boom/cable	12%
Crane tip-over	11%
Struck by cab/counterweight	3%
Falls	2%

Source: Federal Register/Vol. 75, No. 152

Table 2 above shows that electrocution, assembly/disassembly and contact with crane remain the leading causes of crane related fatalities.

Suruda et al. (1999) similarly examined major causes of accidents between 1984 and 1994 from the OSHA IMIS database involving cranes in the construction industry. During the 11 year period, OSHA recorded 502 deaths in 479 incidents involving cranes in the construction industry. Table 3 summarizes the causes and corresponding counts and percentage of incidents.

TABLE 3: Causes of crane incidents 1984-1994

Incident caused by	No. of incidents	% of incidents
Electrocution	198	39
Crane assembly/disassembly	58	12
Boom buckling/collapse	41	8
Crane upset/overturn	37	7
Rigging failure	36	7
Overloading	22	4
Struck by moving load	22	4
Accidents related to manlifts	21	4
Working within swing radius of counterweight	17	3
Two-blocking	11	2
Hoist limitations	7	1
Other causes	32	6

Source: Federal Register/Vol. 75, No. 152

The trends above indicate that power line contacts and electrocution remain one of the highest causes of crane fatalities. Assembly/Disassembly also account for a significant number of crane accidents. Crane upset/overturn is also linked to unsuitable ground condition and this continues to pose a substantial accident risk. These categorical accident trends are relevant in guiding the focus of the research analysis.

2.2 Highlights of the New Crane Rules 29CFR 1926 Subpart CC

OSHA Act of 1970 instituted regulation 29 CFR 1926 to reduce injuries and illnesses in the American work place. The subpart N of 29 CFR 1926 was associated with cranes, derricks, hoists, elevators and conveyors and elaborated under section 29 CFR 1926.550 as the standard for Cranes and Derricks. In 1988 the 29 CFR 1926.550 was amended to include conditions under which employees on personnel platforms should be hoisted by cranes and derricks. In 1993 the 29 CFR 1 926.550 was amended to prevent all employees from getting close to lifted and suspended loads. In 2010, OSHA released new standard 29 CFR 1926 subpart CC for crane and derricks.

The revision of the OSHA Cranes and Derricks regulations is relevant in ensuring the safety of employees during the operation of cranes and derricks in construction activities by promoting industry best practices needed in mitigating crane fatalities (CFR 29 part 1926 Subpart CC Final Rule). The rules focus on wide areas such as mandating qualification requirement of crane operators and training of employees so that they are trained to identify any imminent dangers associated with crane operations. The rules also impact the design of cranes and derricks as well as modifications to any components of the crane during operation. Under the new rule, the employer is required to ascertain the ground conditions and assure that it is competent enough to support the equipment and the load being hoisted. Furthermore, it is incumbent on the employer to evaluate any forms of hazards within the vicinity of the crane that will put employees at risk. These include power lines, surrounding structures and persons who may be trapped within the area of the crane’s boom. Inspection of the crane is paramount and thoroughly addressed in the new regulation. Again, the employer is responsible to ensure that the crane meets all daily, monthly and annually inspection requirements.

The OSHA regulation 29 CFR 1926 Subpart CC which came into effect on November, 8, 2010 identifies areas where accidents and fatalities are profound. The Subpart CC is segmented from sections 1400 to 1442 with each section addressing a particular safety issue. OSHA outlined some major accidents which necessitated the introduction of the new crane and derrick regulation. Some major incidents identified by OSHA as well as the necessary standards to address and curb these accidents have been identified below.

2.2.1 Ground Conditions

Section 1926.1402 requires that an adequate and competent ground condition be provided to ensure the safe operation of the crane. Muddy ground which is unstable may cause the crane to overturn. The employer is required to ensure that ground is firm, drained and well graded prior to assembling the crane. This is a critical area which has resulted in a significant amount of crane related fatalities. In order to ensure a stable crane operation, the crane needs a competent ground which is level and engineered to support the weight of the crane and the load being lifted. Adequate ground conditions are essential for safe crane operations because the crane's capacity and stability depend on such conditions being present. An unstable ground can overturn a crane regardless of the whether it is operated within the acceptable load limits. It is therefore imperative that a crane is not assembled unless the ground conditions are determined to be firm, drained and well graded including the use of adequate supporting materials such as mats and cribbing among others (see figure 7). In the old crane rule, this issue was not addressed comprehensively resulting in crane fatalities. The new crane rule mitigates this by identifying a responsible party, also known as the controlling entity at the site, to ensure adequate ground conditions are met prior to assembling of the crane.

However, the crane operating company may discuss the adequacy of the ground conditions with the controlling entity prior to commencement of crane activities according to 29 CFR 1926.1402.

Poor ground | Competent Ground

FIGURE 7: Unstable ground vs. competent ground condition
Source: Managing mobile crane hazards. (2014)

2.2.2 Assembly/Disassembly

Fatalities resulting from workers being crushed while engaged in assembly/ disassembly activities are discussed in sections 1926.1403 to1926.1406. According to the new regulations on assembly/disassembly, it is required that an assembly/disassembly director who is qualified and competent oversees all erection and dismantling activities and ensure proper implementation of safety procedures necessary to avoid hazards associated with this activity. Assembly/disassembly errors have been identified as a major cause of fatalities associated with tower cranes and other crawler cranes. Some of the errors are improper use of the outriggers causing instability of hydraulic boom-type cranes. Tower cranes which are not assembled according to manufacturer's procedures tend to stand a high risk of causing accidents. The old crane rule did not fully address the situation resulting in many crane accidents. The new regulation 26 CFR 1926.1406 mitigates the risk of accidents by addressing the issue as follows:

- The need for all assembly/disassembly to be done according to manufacturer's procedure. Where the manufacturer procedure is not available, the regulation requires employers' procedure, which is developed by a qualified person, to be used throughout the assembly/disassembly process.
- The new rule further requires the engagement of an assembly/disassembly director (A/D Director) who is competent and qualified to oversee the erection and dismantling processes.

2.2.3 Electrocution

Electrocution hazards are covered in detail from sections 1926.1407 to 1926.1411 where hazards associated with crane operations near power lines are given much attention. It also defines the safe work procedures around existing power lines at construction sites which include de-energizing the power line or maintaining a specified tolerance distance near the power line based on the voltage running through the power line. It also recommends maintaining a 20 feet clearance distance when operating near a power line instead of the 10 feet proposed in the old regulation. Other aspects such as training of the crane operator and crew members to be able to identify hazards around the power line are contained in these sections.

2.2.4 Operator Qualification and Certification

Operator qualification and certification is discussed in section 1926.1427 where all operators are required to be certified or qualified. OSHA defines "certification as a process whereby an operator passes both written and practical tests administered by an accredited testing organization". OSHA also defines three options for an operator to receive qualification which include: (1) qualification by an audited employer program; (2)

qualification by the U.S. Military (limited to employees of the Department of Defense or members of the Armed Forces); and (3) licensing by a government entity.

2.2.5 Inspection

Section 1926.1412 discusses the types of inspection required to be performed on the crane to ensure its safe maintenance. They include shift (daily), monthly and annual inspections. Shift inspection is required to be conducted by a competent person and involves a cursory inspection of the crane each day before the equipment is used. The monthly inspection, which is a little more detailed, is also conducted by a competent person at the end of each month. The annual inspection which is more comprehensive than the monthly inspection is conducted by a qualified person.

2.3 Causes of Crane Accidents

OSHA has identified various crane related accidents which plague the construction industry on a regular basis. In reviewing and updating the new crane rule, OSHA categorized the accidents and defined the appropriate regulations required to prevent the accidents. Some of the accidents mentioned in the 29 CFR 1926 Subpart CC Final Rule document have been highlighted below.

2.3.1 Accidents Caused By Assembly/Disassembly

According to OSHA's IMIS investigation on Accident: 202086633 and Report ID: 0524700 (2004), in February 16, 2004, four fatalities and four injuries were recorded. The accident occurred when a launching gantry collapsed killing four workers and sending four other workers to the hospital. The investigation revealed that the launching gantry was being used to erect pre-cast concrete segments span by span. However, the manufacturer required that the rear legs and front legs of the launching gantry be properly anchored to resist longitudinal and lateral forces that act on the launching gantry. The legs of the launching gantry were not properly anchored hence the collapse.

OSHA determined that this type of accident could be prevented by compliance with the provisions of the final standard for assembling equipment. Sections of the regulation require that equipment be assembled in compliance with the manufacturer's procedures, or with alternative employer procedures, to prevent the equipment from collapsing. In addition, assembly must be conducted under the supervision of a person who understands the hazards associated with an improperly assembled crane and is well-qualified to understand and comply with the proper assembly procedures.

In another separate incident which occurred on January 30, 2006, OSHA recorded an Accident: 200355287 and Report ID: 0453710. A fatality involving an employee who was crushed by the lower end section of the lattice boom on a truck mounted crane while working from a position underneath the boom to remove the second lower pin. When the second lower pin was removed, the unsecured/uncribbed boom fell on the employee.

OSHA observed that the new OSHA crane regulation should prevent this type of accident by generally prohibiting employees from being under the boom when pins are removed. In situations in which site constraints require that an employee be under the boom when pins are removed, the employer must implement other procedures, such as ensuring that the boom sections are adequately supported, to prevent the sections from falling on the employee.

2.3.2 Accident Resulting From Inadequate Personnel Training

On July 23, 2001 OSHA investigated an Accident: 200201473 and Report ID: 0418200 which involved one fatality where the crane operator failed to extend the outriggers before extending the boom of a service truck crane to lift pipes. As the operator extended the boom, the crane tipped over on its side and another employee standing near the truck was struck on the head by the hook block.

OSHA opined that this type of accident would be prevented by compliance with the new crane standard, which contains several provisions to ensure that outriggers and stabilizers are deployed properly before lifting a load. In addition, the operator qualification and certification requirements of 1926.1427, which ensure that operators understand and follow the safety-requirements for the equipment they are operating, will help prevent this type of accident. Equally important is the training and qualification of the riggers as indicated in 1926.1404.

2.3.3 Accident Caused By Electrocution

On March 8, 1999, OSHA recorded one fatality in which employees were using a mobile crane to lift a load of steel joists. Investigation revealed that the crane contacted a 7,200-volt overhead power line, electrocuting an employee who was signalling and guiding the load. The crane operator jumped clear and was not injured.

OSHA pointed to section 1926.1408 of the new crane regulation which includes provisions that will prevent this type of accident. This section clearly defines the distance and precaution to be taken when operating near a power line. In addition to requiring employee training prior to working near or under overhead power lines, this section requires the use of ‘‘encroachment prevention’’ measures to prevent the crane from breaching a safe clearance distance from the power line. It also requires that, if tag lines are used to guide the load, the lines must be non-conductive. Finally, if maintaining the normal clearance distance is infeasible, a number of additional measures must be implemented, one of which is the use of an insulating link between the end of the load line and the load. These measures protect employees guiding the load by reducing the chance that a crane would contact a power line; and by using non-conducting tag lines to guide a load to prevent employees from being electrocuted should the load become energized.

In another incident on August 21, 2003, OSHA recorded an accident: 201320512 -- Report ID: 0317900 involving three fatalities. A crane operator and two co-workers were electrocuted when a truck crane's elevated boom contacted a 7,200 volt uninsulated primary conductor 31 feet above the ground. When the operator stepped from the cab of the truck, a conduction pathway to the ground was established through the operator's right hand and right foot, resulting in electrocution. A co-worker attempted to revive the incapacitated crane operator with cardio-pulmonary resuscitation (''CPR''), while a third co-worker contacted 911, and then returned to the incident location. When the third co-worker simultaneously touched the energized truck crane and the back of the co-worker performing CPR, the resulting pathway conducted the electrical charge through the workers, electrocuting them all.

The final standard, according to OSHA, would avoid this type of accident. Section 1926.1408 requires that a minimum safe distance from a power line be maintained as indicated in Table 4 below, which prevents equipment from becoming energized. Also, when working closer than the normal minimum clearance distance the crane must be grounded, which reduces the chance of an electrical pathway through the workers. In addition, section 1926.1408(g) requires that the operator be trained to remain inside the cab unless an imminent danger of fire or explosion is present. The operator also must be trained in the hazards associated with simultaneously touching the equipment and the ground, as well as the safest means of evacuating the equipment. The crane's remaining crew must be trained to avoid approaching or touching the equipment. The required training is reinforced by the electrocution warnings that must be posted in the cab and on the outside of the equipment.

TABLE 4: Minimum OSHA clearance distances from power lines for crane operations

Voltage (nominal, kV, alternating current)	**Minimum clearance distance (feet)**
up to 50	10
over 50 to 200	15
over 200 to 350	20
over 350 to 500	25
over 500 to 750	35
over 750 to 1000	45
Over 1000	(As established by the utility owner/operator or registered professional engineer who is a qualified person with respect to electrical power transmission and distribution)

Source: Federal Register/Vol. 75, No. 152

Power lines continue to contribute to a lot of crane fatalities. The old crane rule provided some guidance on the operation of cranes near power lines (ref: 1926.550(a)(15)(vi)). However, it recommended 10ft to be the minimum distance of operation near a power line. The rise in fatalities resulting from a crane coming into contact with a power line was an indication of the ineffectiveness of this regulation. The new crane rule on power lines (ref: 1926.1407) on the other hand proposes a minimum of 20ft as one of the options that can be considered when operating a crane near a power line. The other two options recommended are de-energizing the power line and following Table 4 above guiding the proximity to a power line based on the voltage. Figure 8 shows a diagram of the options for selection when operating near a power line. The ideal situation requires de-energizing of the power line by the employer.

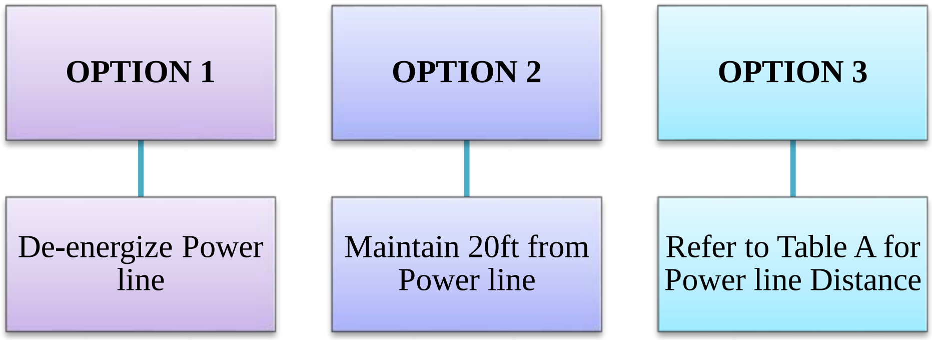


FIGURE 8: Power line options

Figure 9 shows a crane related fatality where a tower crane comes into contact with energized power line. This could be avoided by following the appropriate options above.

FIGURE 9: Crane in contact with power line
Source: Crane accidents. (2012)

2.3.4 Poor Ground Condition Causing Overturning

On September 28, 1999, a 19-year old electrical instrument helper was involved in an accident at a construction site of a manufacturing company. A contractor positioned a 50-ton hydraulic crane on an open area that consisted of compacted fill material. This area was the only location that the crane could be situated because the receiving area for the equipment was too close to the property border. The crane's outriggers were set, but matting was placed under only one of the outrigger pads. As the crane was moving large sections of piping to a new location, the ground collapsed and the crane overturned, striking the helper.

OSHA introduced section 1926.1402, Ground conditions, of the new rule as a preventive measure to this type of accident. Under this section, employers must ensure that the surface on which a crane is operating is sufficiently level and firm to support the crane in accordance with the manufacturer's specifications. In addition, 1926.1402 imposes specific duties on both entities responsible for the project (the controlling entity and the entity operating the crane) to ensure that the crane is adequately supported. It places responsibility for ensuring that the ground conditions are adequate on the controlling entity, while also making the employer operating the crane responsible for notifying the controlling entity of any deficiency in the ground conditions, and having the deficiency corrected before operating the crane.

2.3.5 Accident Caused By Wire Rope

On June 17, 2006, OSHA investigated an accident which resulted in one fatality. A spud pipe, used to anchor a barge, was being raised by a crane mounted on the barge when the hoisting cable broke, causing the headache ball and rigging to strike an employee. According to the investigation this type of accident can have various causes: an improperly selected wire rope (one that has insufficient capacity); a damaged or worn wire rope in need of replacement; or two-blocking, in which the headache ball is forced against the upper block, causing the wire rope to fail. The provisions of sections 1926.1413 and 1926.1414 address wire rope inspection, selection, and installation, and would ensure that appropriate wire rope is installed, inspected and removed from service when continued use is unsafe. Section 1926.1416, Operational aids, contains provisions to protect against two-blocking.

2.3.6 Personnel Platform Collapse

Another accident as recorded by OSHA occurred in July 13, 1999 which resulted in three fatalities. Three employees were in a personnel basket 280 feet above the ground. They were in the process of guiding a large roof section, being lifted by another crane into place. Winds gusting to 27 miles per hour overloaded the crane holding the roof section; that crane collapsed, striking the crane that was supporting the personnel basket, causing the boom to fall. All three employees received fatal crushing injuries.

According to OSHA, this type of accident would be prevented by following the section 1926.1417(n) of the new regulation, which requires the competent person in charge of the operation to adjust the equipment and/or operations to address the effect of wind and other adverse weather conditions on the equipment's stability and rated capacity. In addition, section 1926.1431, Hoisting personnel, requires that, when wind speed (sustained or gust) exceeds 20 mph, employers must not hoist employees by crane unless a qualified person determines it is safe to do so.

2.3.7 Crushing from an Outrigger

On November 7, 2005 OSHA investigated a fatality where a construction worker was crushed between the outrigger and the rotating superstructure of a truck crane. According to OSHA, the worker apparently was trying to retrieve a level and a set of blueprints located on a horizontal member of one of the outriggers when the operator began to swing the boom.

The section 1926.1424 of the new regulation, Work area control, would prevent this type of accident. This section generally requires that employers erect barriers to mark the area covered by the rotating superstructure to warn workers of the danger zone. However, workers who must work near equipment with a rotating superstructure must be trained in the hazards involved. If a worker must enter a marked area, the crane operator must be notified of the entry and must not rotate the superstructure until the area is clear.

2.3.8 Collapse by Overloading

An accident reported in OSHA's IMIS data in March 19, 2005 involved two fatalities and one injury. The unfortunate accident occurred during steel-erection operations, where a crane was lifting three steel beams for a parking garage. The crane tipped over and the boom collapsed. The boom and attached beams struck concrete workers next to the structure, killing two workers and injuring another. The accident apparently occurred because the crane was overloaded.

Overloading a crane can cause it to tip over, causing the load or crane structure to strike and fatally injured workers in the vicinity of the crane. OSHA subsequently introduced section 1926.1417, Operations in its new regulation, a provision aimed to prevent overloading. This section prohibits employers from operating equipment in excess of its rated capacity and includes procedures for ensuring that the weight of the load is reliably determined and within the equipment's rated capacity. The provisions of the final standard addressing operator training, certification, and qualification (1926.1427) would also prevent this type of accident by ensuring that operators recognize conditions that would overload the crane.

Similarly in December 7, 2005 OSHA recorded one fatality. The accident involved two cranes which were used to lower a concrete beam across a river. OSHA reported that during the lowering process, one end of the beam dropped below the other end, causing the load's weight to shift to the lower end; this shift in weight overloaded the crane lifting the lower end causing it to tip over. The lower end of the beam fell into the river, while the higher end landed on a support mat located on the bank of the river, causing a flagger to be thrown onto the beam.

According to OSHA, section 1926.1432 of the new regulation pertaining to multiple crane/derrick lifts—supplemental requirements, would prevent this type of accident. This section specifies that, when more than one crane is supporting a load, the operation must be performed in accordance with a plan developed by a qualified person. The plan must ensure that the requirements of this final standard are met, and must be reviewed by all individuals involved in the lifting operation. Moreover, the lift must be supervised by an individual who qualifies as both a competent person and a qualified person as defined by this final standard. For example, in the accident just described, the plan must include a determination of the degree of level needed to prevent either crane from being overloaded. In addition, the plan must ensure proper coordination of the lifting operation by establishing a system of communications and a means of monitoring the operation.

2.3.9 Accident of Rigger/Operator-In-Training

On May 7, 2004 OSHA investigated an accident which involved one fatality. An employee, a rigger/operator-in-training, was in the upper cab of a 60-ton hydraulic boom-truck crane to set up and position the crane boom prior to a lift. The crane was equipped with two hoists- a main line and auxiliary. The main hoist line had a multi-sheave block and hook and the auxiliary line had a 285 pound ball and hook. When the employee extended the hydraulic boom, a two-block condition occurred with the auxiliary line ball striking the auxiliary sheave head and knocking the sheave and ball from the boom. The employee was struck in the head by the falling ball.

OSHA observed that this type of accident would be prevented by 1926.1416 of the new regulation regarding Operational aids, which requires protection against two-blocking. The rule requires a hydraulic boom crane, if manufactured after February 28, 1992, to be equipped with a device that automatically prevents two-blocking. Also, the final rule under 1926.1427(a) and (f) prohibits an operator-in-training from operating a crane without being monitored by a trainer and without first having sufficient training to enable the operator-in-training to perform the assigned task safely.

2.3.10 Uncontrolled Load Lowering

On April 26, 2006 OSHA recorded one fatality. The accident occurred when a framing crew was installing sheathing for a roof. A crane was hoisting a bundle of plywood sheathing to a location on the roof. As the crane positioned the bundle of sheathing above its landing location, the load hoist on the crane free spooled, causing an uncontrolled descent of the load. An employee was under the load preparing to position the load to its landing spot when the load fell and crushed him.

OSHA Section 1926.1426 of the new regulation concerned with free fall and controlled load lowering would prevent this type of accident. This section prohibits free fall of the load-line hoist and requires controlled lowering of the load when an employee is directly under the load. From aforementioned fatal accidents involving cranes and derricks operations, it is clearly evident that the responsibility to ensure safe crane operation at site is primarily the responsibility of management. These accidents can be prevented or minimized if employers and their site management team implement the new OSHA cranes and derricks regulations in their daily execution of crane related projects.

2.4 Comparative Analysis

The significance of the comparative analysis is to offer a clear understanding of the change in regulations from old Subpart N standards to the new Subpart CC of the Cranes and Derricks in construction standards. According to Gundy et al, (2002) it is a fundamental of business project management to assess the existing state of a business and compare it with direction of the future of the business. However, comparative analysis is applicable to all sectors with the objective to identify areas that require improvement. In this research, the analyzed comparisons are intended to elaborate on the voids in the old regulation, and to show the areas of improvement opportunities that have been identified in the old regulation and subsequently updated in the new regulation.

Firstly, a literature review was thoroughly carried out on the OSHA Crane and Derrick Rules. It involved review of the OSHA regulations prior to November 2010 (i.e. the Old Crane Rules) and the new crane rules which took effect after November, 2010.

Next, the old regulation was tabulated based on the safety issues that the regulation addresses. For example, the regulation on crane operation near a power line will have a description “Power line” in the table. The new crane regulation was then obtained from the OSHA website and likewise summarized in a table to reflect the safety issues being addressed. Some categorizations include, ground conditions, power lines, assembly/disassembly and inspection among others. The two tables were then combined into a single table and the old and new rules are compared. Five scenarios have been identified as the possible outcomes of analyzing the comparison between the old and new regulation. They are:

- Covered: Sections of the old regulation which fall in this category imply that they are similar to the provisions in the new regulation albeit minor changes.
- Moderately Covered: This is used to categorize the old regulations that are nearly the same as the new regulations but had some additional modification.
- Partially Covered: This identifies portions of the old regulations that have seen major changes as indicated in the updates of the new regulations.
- Slightly covered: This section refers to aspects of the old regulations that are barely similar in the new regulation.
- Not Covered: This section refers to entirely new additions which otherwise was not at all mentioned in the old regulation.

Since the new regulation is an update of the old regulation, the old regulation is matched to the new regulation in each category for comparison. The comparative analysis is conducted between the new and old crane rule to ascertain the relevant changes that have been made to the old rules that are expected to yield the desired safety impact during the operation for cranes and derricks at construction sites. Details of the comparative analysis are discussed below.

2.5 Comparing New and Old OSHA Crane Regulations

A comparative analysis of the old and new crane regulations assesses the significant changes made to the old crane regulations as well as other additional information in the new regulations addressing causes of crane related accidents.A comparison of the new

OSHA 1926 Subpart CC, Cranes and Derricks in Construction; Final Rule. (2010).and old OSHA Rule 1926.550, Code of Federal Regulations. (2010) for crane and derricks revealed that, though some of the areas covering crane activities were addressed in the old regulation, most of the critical issues which resulted in fatalities were conspicuously missing. Table 6 highlights the overarching differences between the old and new regulations which served as basis of this research study.

TABLE 5: Comparing old and new OSHA regulations for cranes and derricks

	Description	New Rule 1926 Subpart CC	Old Rule 1926.550
1	Ground conditions	Covered	Not Covered
2	Assembly/Disassembly	Covered	Partially Covered
3	Power Lines Safety	Covered	Partially Covered
4	Inspections	Covered	Slightly Covered
5	Wire Rope	Covered	Moderately Covered
6	Crane Signaling and Safety Devices	Covered	Partially Covered
7	Authority to Stop Operation	Covered	Not Covered
8	Operator and Signal Person Qualifications	Covered	Not Covered
9	Training	Covered	Not Covered
10	Personnel Platform	Covered	Moderately Covered

2.6 Detailed Comparative Analysis of New and Old OSHA Crane Rules

The process involved the tabulation and pairing of the aspect of the old and new crane regulations that addresses specific accident causes generating the results shown in Table 5. For instance, Assembly/Disassembly shown in Item No.2 of Table 6 requires that the employer complies with the crane manufacturers' procedures and restrictions. This is found in the new regulation 1926.1403. However, the old crane rules 1926.550(a) also mentioned the need for the employer to comply with crane manufacturer's specifications and limitations. By comparing the details of the two regulations it is shown that whiles this item is fully discussed in the new crane rules, the information was only partially mentioned in the old crane regulation. A comprehensive pairwise comparison of the two regulations is shown in Appendix B.

TABLE 6 : Comparing old and new OSHA regulations for cranes and derricks

COMPARATIVE ANALISYS OF THE NEW AND OLD OSHA CRANE & DERRICK REGULATION						
ITEM	TOPIC	ACTIVITY	NEW RULE	OLD RULE	SUMMARY DESCRIPTION - NEW RULE	SUMMARY DESCRIPTION - OLD RULE
1	Ground Conditions 1926.1402	Ability of the ground to support the equipment	Yes	No	Ground Conditions 1926.1402 § Ability of the ground to support the Crane equipment § A/D director or the operator must assess ground condition. § Controlling Entity or Employer to remedy unsuitable ground prior to hoisting	
		Adequate Supporting materials	Yes	No		
		Adequate ground preparations by controlling entity	Yes	No		
		Adequate information from controlling entity on ground conditions	Yes	No		
		A/D Director and Operator capable of assessing ground conditions.	Yes	No		
2	Assembly/ Disassembly 1926.1403	Compliance with Manufacturer's procedure	Yes	Yes	Ground Conditions 1926.1402 § Ability of the ground to support the Crane equipment § A/D director or the operator must assess ground condition. § Controlling Entity or Employer to remedy unsuitable ground prior to hoisting Assembly/Disassembly 1926.1403	1926.550(a) employer shall comply with the manufacturer's specifications and limitations. 1926.550(a) (2) § Rated load capacities, and recommended operating speeds shall be visible to the operator at his control. § Attachments used with
		Supervision by a competent and qualified person (A/D Director)	Yes	No		
		Knowledge of procedures as A/D director	Yes	No		
		Review of assembly/disassembly procedures by A/D director	Yes	No		
		Clear safety instruction to crew by AD Director	Yes	No		

CHAPTER 3 METHODOLOGY AND DATA COLLECTION

As discussed in the research objectives in Chapter 1, the following chart shown in Figure 10 summarizes the process and methodology of the research.

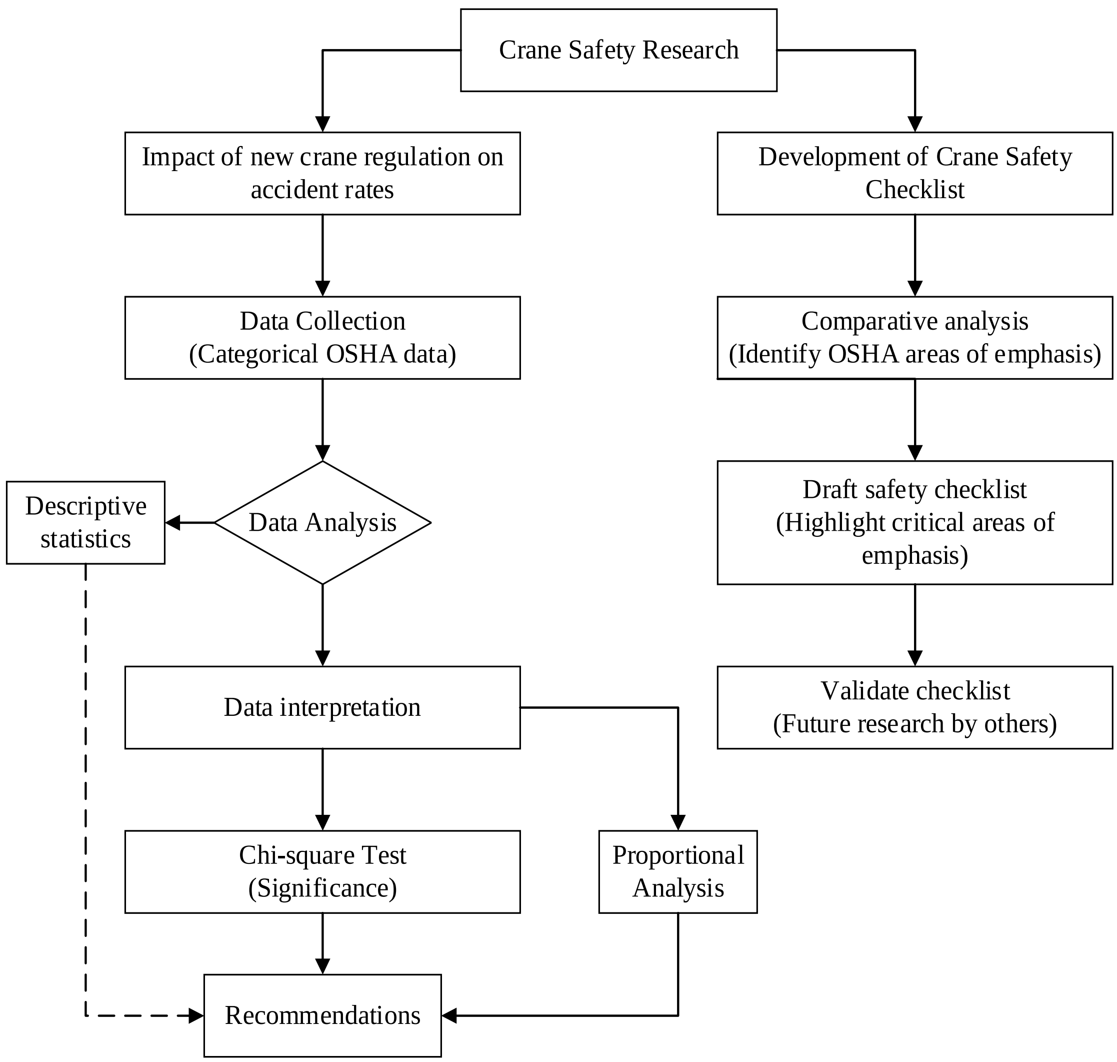


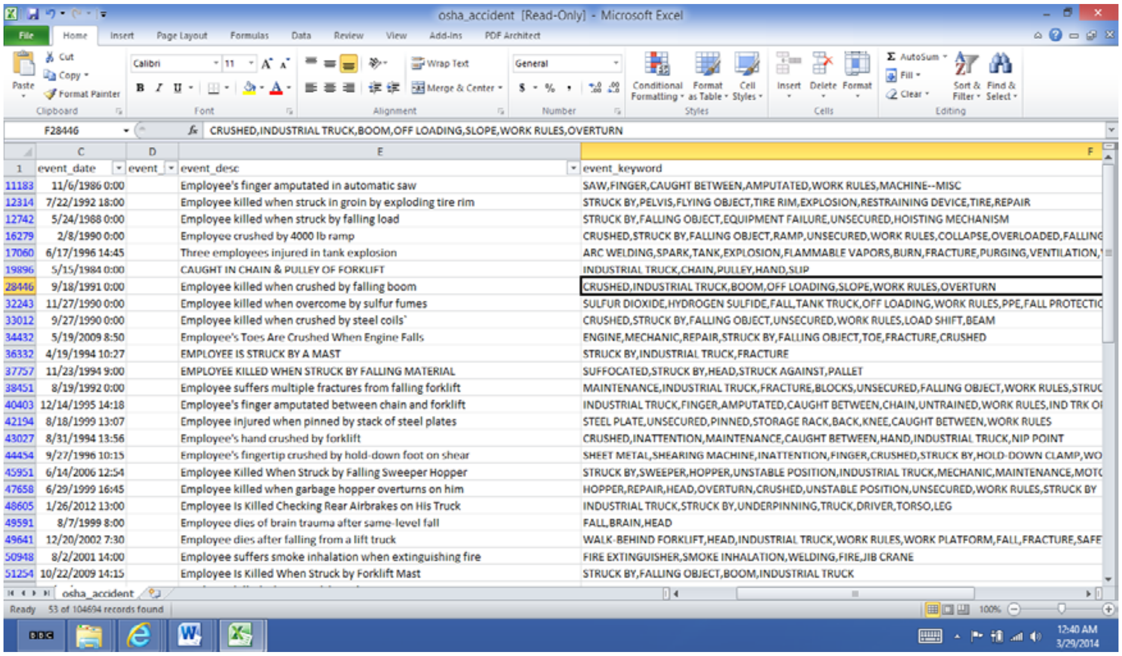
FIGURE 10: Hierarchy of project methodology

3.1 Data Collection

In order to investigate and analyse the accident data and frequencies, accident data from the OSHA website were collected and analysed. The first group of data collected was the OSHA Enforcement Data obtained from the US Department of Labor, Data Enforcement website http://ogesdw.dol.gov/views/data_catalogs.php.

The web page includes the data catalog for accidents and inspections conducted by OSHA and compiled annually. It also includes information regarding the reason for conducting the inspection and details on citations and penalty assessments resulting from violations of OSHA standards. Additionally, accident investigation information is provided including textual descriptions of the accident and details regarding the injuries and fatalities which occurred. The study focuses primarily on the accident investigation information as well as the textual description of the various crane related accidents and the details of the injuries and fatalities recorded by the OSHA under the data enforcement center.

The OSHA Accident data was downloaded into Excel format which is the software used in the data analysis. A sample of the raw data is shown in Figure 11 below.



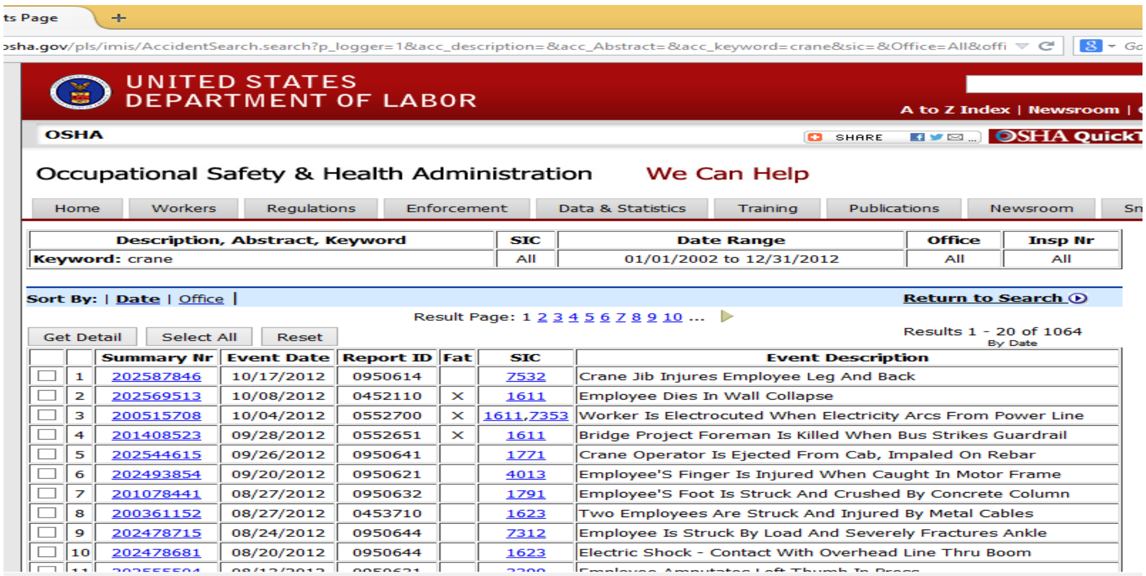
	event_date	event_	event_desc	event_keyword
11183	11/6/1986 0:00		Employee's finger amputated in automatic saw	SAW,FINGER,CAUGHT BETWEEN,AMPUTATED,WORK RULES,MACHINE--MISC
12314	7/22/1992 18:00		Employee killed when struck in groin by exploding tire rim	STRUCK BY,PELVIS,FLYING OBJECT,TIRE RIM,EXPLOSION,RESTRAINING DEVICE,TIRE,REPAIR
12742	5/24/1988 0:00		Employee killed when struck by falling load	STRUCK BY,FALLING OBJECT,EQUIPMENT FAILURE,UNSECURED,HOISTING MECHANISM
16279	2/8/1990 0:00		Employee crushed by 4000 lb ramp	CRUSHED,STRUCK BY,FALLING OBJECT,RAMP,UNSECURED,WORK RULES,COLLAPSE,OVERLOADED,FALLING
17060	6/17/1996 14:45		Three employees injured in tank explosion	ARC WELDING,SPARK,TANK,EXPLOSION,FLAMMABLE VAPORS,BURN,FRACTURE,PURGING,VENTILATION,
19896	5/15/1984 0:00		CAUGHT IN CHAIN & PULLEY OF FORKLIFT	INDUSTRIAL TRUCK,CHAIN,PULLEY,HAND,SLIP
28446	9/18/1991 0:00		Employee killed when crushed by falling boom	CRUSHED,INDUSTRIAL TRUCK,BOOM,OFF LOADING,SLOPE,WORK RULES,OVERTURN
32243	11/27/1990 0:00		Employee killed when overcome by sulfur fumes	SULFUR DIOXIDE,HYDROGEN SULFIDE,FALL,TANK TRUCK,OFF LOADING,WORK RULES,PPE,FALL PROTECTIO
33012	9/27/1990 0:00		Employee killed when crushed by steel coils`	CRUSHED,STRUCK BY,FALLING OBJECT,UNSECURED,WORK RULES,LOAD SHIFT,BEAM
34432	5/19/2009 8:50		Employee's Toes Are Crushed When Engine Falls	ENGINE,MECHANIC,REPAIR,STRUCK BY,FALLING OBJECT,TOE,FRACTURE,CRUSHED
36332	4/19/1994 10:27		EMPLOYEE IS STRUCK BY A MAST	STRUCK BY,INDUSTRIAL TRUCK,FRACTURE
37757	11/23/1994 9:00		EMPLOYEE KILLED WHEN STRUCK BY FALLING MATERIAL	SUFFOCATED,STRUCK BY,HEAD,STRUCK AGAINST,PALLET
38451	8/19/1992 0:00		Employee suffers multiple fractures from falling forklift	MAINTENANCE,INDUSTRIAL TRUCK,FRACTURE,BLOCKS,UNSECURED,FALLING OBJECT,WORK RULES,STRUC
40403	12/14/1995 14:18		Employee's finger amputated between chain and forklift	INDUSTRIAL TRUCK,FINGER,AMPUTATED,CAUGHT BETWEEN,CHAIN,UNTRAINED,WORK RULES,IND TRK OI
42194	8/18/1999 13:07		Employee injured when pinned by stack of steel plates	STEEL PLATE,UNSECURED,PINNED,STORAGE RACK,BACK,KNEE,CAUGHT BETWEEN,WORK RULES
43027	8/31/1994 13:56		Employee's hand crushed by forklift	CRUSHED,INATTENTION,MAINTENANCE,CAUGHT BETWEEN,HAND,INDUSTRIAL TRUCK,NIP POINT
44454	9/27/1996 10:15		Employee's fingertip crushed by hold-down foot on shear	SHEET METAL,SHEARING MACHINE,INATTENTION,FINGER,CRUSHED,STRUCK BY,HOLD-DOWN CLAMP,WO
45951	6/14/2006 12:54		Employee Killed When Struck by Falling Sweeper Hopper	STRUCK BY,SWEEPER,HOPPER,UNSTABLE POSITION,INDUSTRIAL TRUCK,MECHANIC,MAINTENANCE,MOTO
47658	6/29/1999 16:45		Employee killed when garbage hopper overturns on him	HOPPER,REPAIR,HEAD,OVERTURN,CRUSHED,UNSTABLE POSITION,UNSECURED,WORK RULES,STRUCK BY
48605	1/26/2012 13:00		Employee Is Killed Checking Rear Airbrakes on His Truck	INDUSTRIAL TRUCK,STRUCK BY,UNDERPINNING,TRUCK,DRIVER,TORSO,LEG
49591	8/7/1999 8:00		Employee dies of brain trauma after same-level fall	FALL,BRAIN,HEAD
49641	12/20/2002 7:30		Employee dies after falling from a lift truck	WALK-BEHIND FORKLIFT,HEAD,INDUSTRIAL TRUCK,WORK RULES,WORK PLATFORM,FALL,FRACTURE,SAFE
50948	8/2/2001 14:00		Employee suffers smoke inhalation when extinguishing fire	FIRE EXTINGUISHER,SMOKE INHALATION,WELDING,FIRE,JIB CRANE
51254	10/22/2009 14:15		Employee Is Killed When Struck by Forklift Mast	STRUCK BY,FALLING OBJECT,BOOM,INDUSTRIAL TRUCK

FIGURE 11: Raw OSHA enforcement crane accident data

The event date, which shows the recorded date for the accident, was then sorted from old accidents to current accidents. The data was obtained for crane and derrick related accidents which occurred between years 2002 to 2012. This was conducted by using the "event description" column and the "event keyword" columns respectively. By searching for the texts "*crane*" and "*derrick*", the accidents associated with these key words were filtered.

The second group of data, which is known as OSHA IMIS data was obtained from the website: https://www.osha.gov/pls/imis/accidentsearch.html. The page provides a summary of the complete accident description and the factors which caused the accident. The search is narrowed down using key words, accident description, and date of the event among others (US DOL website). The word "*crane*" was inserted into the keyword section and the dates from January 2002 and 2013 were used as the event dates to narrow the search of crane related accidents to those between January 2002 and December 2012.

The search results consist of the summary numbers, event dates, report id, fatality identification and the event description among other. Figure 12 shows the search results with the summary numbers and event dates etc.



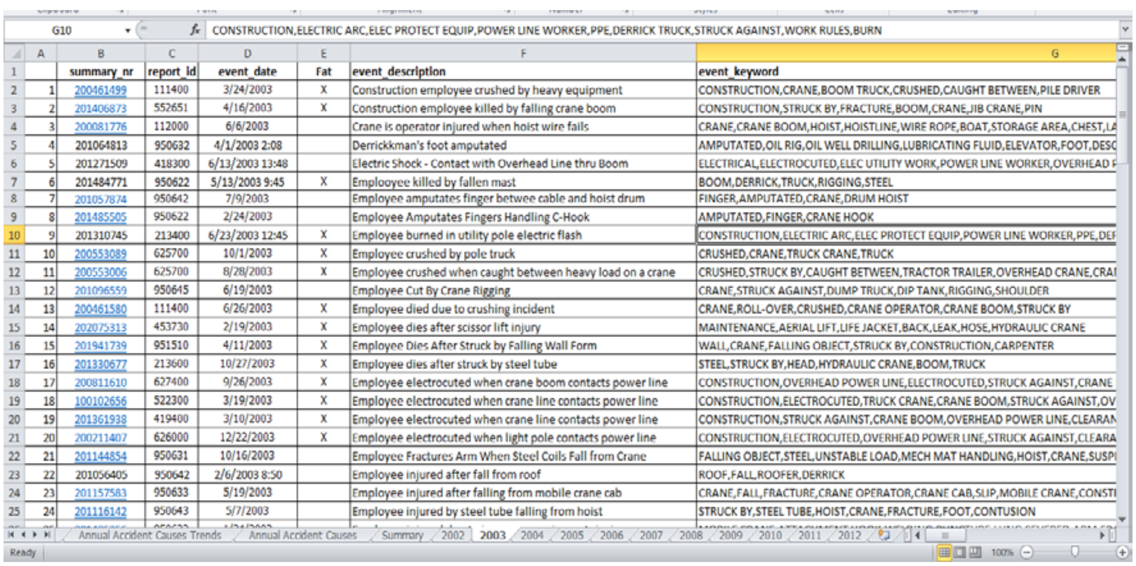
	Summary Nr	Event Date	Report ID	Fat	SIC	Event Description
1	202587846	10/17/2012	0950614		7532	Crane Jib Injures Employee Leg And Back
2	202569513	10/08/2012	0452110	X	1611	Employee Dies In Wall Collapse
3	200515708	10/04/2012	0552700	X	1611,7353	Worker Is Electrocuted When Electricity Arcs From Power Line
4	201408523	09/28/2012	0552651	X	1611	Bridge Project Foreman Is Killed When Bus Strikes Guardrail
5	202544615	09/26/2012	0950641		1771	Crane Operator Is Ejected From Cab, Impaled On Rebar
6	202493854	09/20/2012	0950621		4013	Employee'S Finger Is Injured When Caught In Motor Frame
7	201078441	08/27/2012	0950632		1791	Employee'S Foot Is Struck And Crushed By Concrete Column
8	200361152	08/27/2012	0453710		1623	Two Employees Are Struck And Injured By Metal Cables
9	202478715	08/24/2012	0950644		7312	Employee Is Struck By Load And Severely Fractures Ankle
10	202478681	08/20/2012	0950644		1623	Electric Shock - Contact With Overhead Line Thru Boom

FIGURE 12: Crane accidents from OSHA IMIS database

The summary numbers are hyperlinked to the crane accident report where the accident reports were obtained and analysed as shown in Figure 13 below.

FIGURE 13: Example of OSHA IMIS Crane accident description

The two data sources were combined into a single Excel table in order to retrieve all relevant information from the search of the crane accident data on the two websites. This process was done by placing the two data sets in such a way that the “summary numbers” and dates were aligned in one columns. As shown in figure 14.



G10 CONSTRUCTION,ELECTRIC ARC,ELEC PROTECT EQUIP,POWER LINE WORKER,PPE,DERRICK TRUCK,STRUCK AGAINST,WORK RULES,BURN

	A	B	C	D	E	F	G
1		summary_nr	report_id	event_date	Fat	event_description	event_keyword
2	1	200461499	111400	3/24/2003	X	Construction employee crushed by heavy equipment	CONSTRUCTION,CRANE,BOOM TRUCK,CRUSHED,CAUGHT BETWEEN,PILE DRIVER
3	2	201406873	552651	4/16/2003	X	Construction employee killed by falling crane boom	CONSTRUCTION,STRUCK BY,FRACTURE,BOOM,CRANE,JIB CRANE,PIN
4	3	200081776	112000	6/6/2003		Crane is operator injured when hoist wire fails	CRANE,CRANE BOOM,HOIST,HOISTLINE,WIRE ROPE,BOAT,STORAGE AREA,CHEST,LA
5	4	201064813	950632	4/1/2003 2:08		Derrickkman's foot amputated	AMPUTATED,OIL RIG,OIL WELL DRILLING,LUBRICATING FLUID,ELEVATOR,FOOT,DESC
6	5	201271509	418300	6/13/2003 13:48		Electric Shock - Contact with Overhead Line thru Boom	ELECTRICAL,ELECTROCUTED,ELEC UTILITY WORK,POWER LINE WORKER,OVERHEAD F
7	6	201484771	950622	5/13/2003 9:45	X	Emplooyee killed by fallen mast	BOOM,DERRICK,TRUCK,RIGGING,STEEL
8	7	201057874	950642	7/9/2003		Employee amputates finger betwee cable and hoist drum	FINGER,AMPUTATED,CRANE,DRUM HOIST
9	8	201485505	950622	2/24/2003		Employee Amputates Fingers Handling C-Hook	AMPUTATED,FINGER,CRANE HOOK
10	9	201310745	213400	6/23/2003 12:45	X	Employee burned in utility pole electric flash	CONSTRUCTION,ELECTRIC ARC,ELEC PROTECT EQUIP,POWER LINE WORKER,PPE,DEF
11	10	200553089	625700	10/1/2003	X	Employee crushed by pole truck	CRUSHED,CRANE,TRUCK CRANE,TRUCK
12	11	200553006	625700	8/28/2003	X	Employee crushed when caught between heavy load on a crane	CRUSHED,STRUCK BY,CAUGHT BETWEEN,TRACTOR TRAILER,OVERHEAD CRANE,CRAI
13	12	201096559	950645	6/19/2003		Employee Cut By Crane Rigging	CRANE,STRUCK AGAINST,DUMP TRUCK,DIP TANK,RIGGING,SHOULDER
14	13	200461580	111400	6/26/2003	X	Employee died due to crushing incident	CRANE,ROLL-OVER,CRUSHED,CRANE OPERATOR,CRANE BOOM,STRUCK BY
15	14	202075313	453730	2/19/2003	X	Employee dies after scissor lift injury	MAINTENANCE,AERIAL LIFT,LIFE JACKET,BACK,LEAK,HOSE,HYDRAULIC CRANE
16	15	201941739	951510	4/11/2003	X	Employee Dies After Struck by Falling Wall Form	WALL,CRANE,FALLING OBJECT,STRUCK BY,CONSTRUCTION,CARPENTER
17	16	201330677	213600	10/27/2003	X	Employee dies after struck by steel tube	STEEL,STRUCK BY,HEAD,HYDRAULIC CRANE,BOOM,TRUCK
18	17	200811610	627400	9/26/2003	X	Employee electrocuted when crane boom contacts power line	CONSTRUCTION,OVERHEAD POWER LINE,ELECTROCUTED,STRUCK AGAINST,CRANE
19	18	100102656	522300	3/19/2003	X	Employee electrocuted when crane line contacts power line	CONSTRUCTION,ELECTROCUTED,TRUCK CRANE,CRANE BOOM,STRUCK AGAINST,OV
20	19	201361938	419400	3/10/2003	X	Employee electrocuted when crane line contacts power line	CONSTRUCTION,STRUCK AGAINST,CRANE BOOM,OVERHEAD POWER LINE,CLEARAN
21	20	200211407	626000	12/22/2003	X	Employee electrocuted when light pole contacts power line	CONSTRUCTION,ELECTROCUTED,OVERHEAD POWER LINE,STRUCK AGAINST,CLEARA
22	21	201144854	950631	10/16/2003		Employee Fractures Arm When Steel Coils Fall from Crane	FALLING OBJECT,STEEL,UNSTABLE LOAD,MECH MAT HANDLING,HOIST,CRANE,SUSPI
23	22	201056405	950642	2/6/2003 8:50		Employee injured after fall from roof	ROOF,FALL,ROOFER,DERRICK
24	23	201157583	950633	5/19/2003		Employee injured after falling from mobile crane cab	CRANE,FALL,FRACTURE,CRANE OPERATOR,CRANE CAB,SLIP,MOBILE CRANE,CONSTI
25	24	201116142	950643	5/7/2003		Employee injured by steel tube falling from hoist	STRUCK BY,STEEL TUBE,HOIST,CRANE,FRACTURE,FOOT,CONTUSION

FIGURE 14: Table of combined OSHA crane accident sources.

The conditional formatting tool in excel was used to select all duplicate accidents. This process was used to remove duplicate accident and avoid double counting.

CHAPTER 4: DATA ANALYSIS AND INTEPRETATION

Once a comprehensive list of crane accident data was compiled, the data was analysed in three categories being:

i. Causes of Fatalities and Injuries,

ii. Causes of Crane Accidents, and

iii. Chi-square test of the accidents before and after 2010

Causes of Crane Fatalities and Injuries - Definitions

A review of previous research on OSHA crane accidents by Peraza (2009) was used as a guide to categorize the causes of the crane fatalities and injuries. The identified causes for the fatalities and injuries are defined below:

- Electrocution: This is a fatality or injury sustained by a worker when a crane comes into contact with a live power line.
- Struck by and against: Fatality or injury sustained by a worker when they are hit by the load or the crane during operation.
- Caught by or in-between: Fatality or injuries sustained by a worker which results from the worker being trapped by either the load or parts of the crane.
- Fall: Fatality or injuries which occur when a worker falls from an elevation (mostly when hoisted with the crane).
- Crush: Fatality or injury sustained by a worker which results in the worker being pressed under a load or parts of the crane.

- Other causes: Fatalities or injuries which are crane related but are not clearly categorized among the identifiable causes of accidents.

Causes of Crane Accidents - Definitions

- Overturn/ tips: This refers to accidents that result from the crane overturning or tipping over.
- Collapse: This is an accident which results from the collapse of the crane members or parts.
- Ground conditions: Refers to accidents associated with the poor ground conditions within the area of the crane operation.
- Power line contact: Refers to accidents which occur when the crane comes into contact with a live power line (mostly overhead).
- Overloading: Refers to crane related accidents caused be overloading of the crane during operations.
- Wire rope/hoist/sling: Refers to crane accidents caused by failure of wire rope, hoists or slings.
- Signal/ communication error: Refers to crane accidents resulting from signal or communication errors
- Other: Refers to accidents which are crane related but are not clearly categorized among the identifiable causes of accidents.

The data was analysed using Microsoft Excel as a tool. The steps used to carry out the analysis are as follows:

Step 1- The data was sorted according to the date of the accident, starting from year 2002 to 2012. See Appendix Cand D.

Step 2. The details of each accident were accessed using the hyperlink of the summary number in column B of the accident data as shown in Figure 14, shown previously.

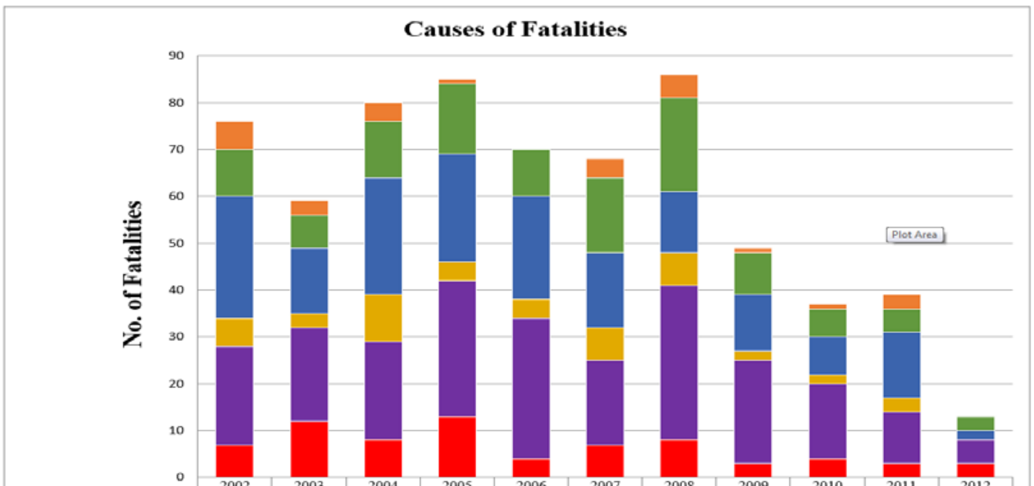
Accidents which could not be accessed with the hyperlinks were examined using the event description and the event keywords recorded in columns F and G respectively. The cause or causes of the crane accidents was identified for each incident. Also, the number of fatalities and/or injuries associated with each incident were also tabulated. This was done for all accidents recorded from 2002 to 2012. Once all crane accidents were analysed, aggregate totals for each category of accident causes as well as total numbers of injuries were calculated for each year.

4.1 Data Interpretation

TABLE 7: Summary of crane fatalities causes, 2002 to 2012

Year	Electrocution	Struck By and Against	Caught By and Between	Fall	Crush	Other causes of fatalities	Total	%
2002	7	21	6	26	10	6	76	11.5%
2003	12	20	3	14	7	3	59	8.9%
2004	8	21	10	25	12	4	80	12.1%
2005	13	29	4	23	15	1	85	12.8%
2006	4	30	4	22	10	0	70	10.6%
2007	7	18	7	16	16	4	68	10.3%
2008	8	33	7	13	20	5	86	13.0%
2009	3	22	2	12	9	1	49	7.4%
2010	4	16	2	8	6	1	37	5.6%
2011	3	11	3	14	5	3	39	5.9%
2012	3	5	0	2	3	0	13	2.0%
Total	72	226	48	175	113	28	662	100.0%
%	10.9%	34.1%	7.3%	26.4%	17.1%	4.2%	100%	

Table 7 above shows the summary of the causes of crane-related fatalities which occurred between the period of 2002 and 2012. In all an estimated 662 fatalities were recorded with year 2008 accounting for most of the fatalities at 13%. 2012 recorded the least number of fatalities at 2%. The analysis showed that “struck by and against” accounted for the most fatalities causes with 34%. It was followed closely by falls and crushes with 26% and 17% respectively. In Figure 15 below, the same data has been plotted as color coded bar graphs to indicate the causes of fatalities distribution and variation. A comparison with the previous data analysis on crane fatalities recorded between 1992 and 2006, showed that electrocutions decreased from about 25% to 10%. Fatalities caused as a result of workers being struck by crane load or part also reduced by nearly 10%. However, fatalities resulting from falls increased from 9% to nearly 27%.



	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Other causes of fatalities	6	3	4	1	0	4	5	1	1	3	0
Crush	10	7	12	15	10	16	20	9	6	5	3
Fall	26	14	25	23	22	16	13	12	8	14	2
Caught By and Between	6	3	10	4	4	7	7	2	2	3	0
Struck By and Against	21	20	21	29	30	18	33	22	16	11	5
Electrocution	7	12	8	13	4	7	8	3	4	3	3

FIGURE 15: Number of crane related fatalities by causes from 2002 to 2012

A trend analysis (shown in Figure 16) from year 2002 to 2012 indicates a general decline. Most significantly there was nearly a 23% decline in fatalities from year 2002 to 2003. Moreover, the period between 2008 and 2012 saw a steep decline in the fatality numbers and recorded approximately 85% decline in fatalities. The recession that occurred after 2008 may have accounted for the sharp decline due to a lower number of construction activities being undertaken during this period. Moreover, the introduction of the new crane rule effective January, 2011 may also have contributed to the decline in the number of fatalities recorded from 2011 and 2012.

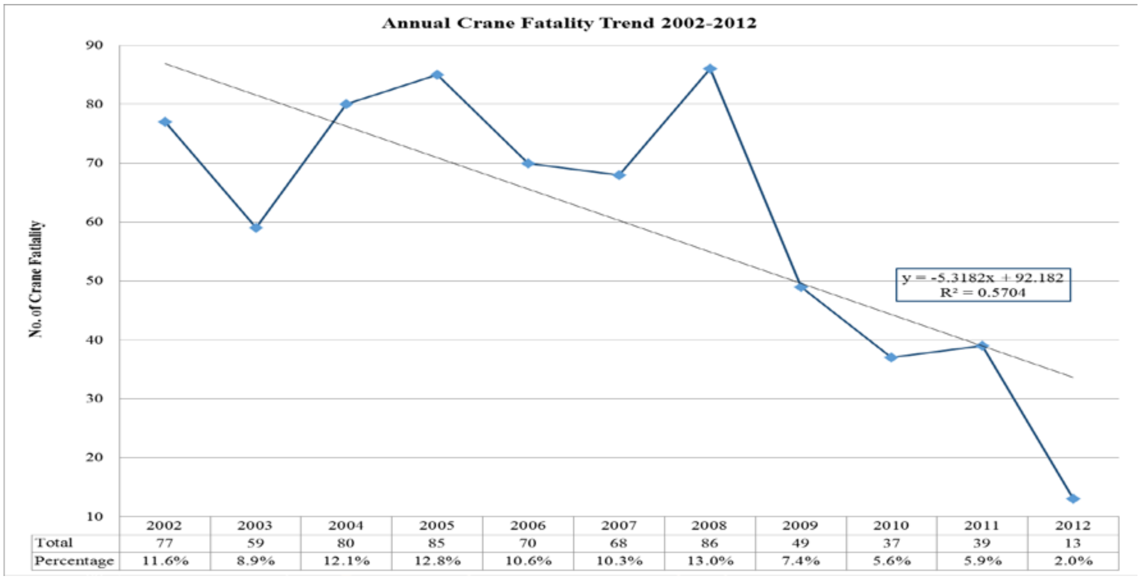


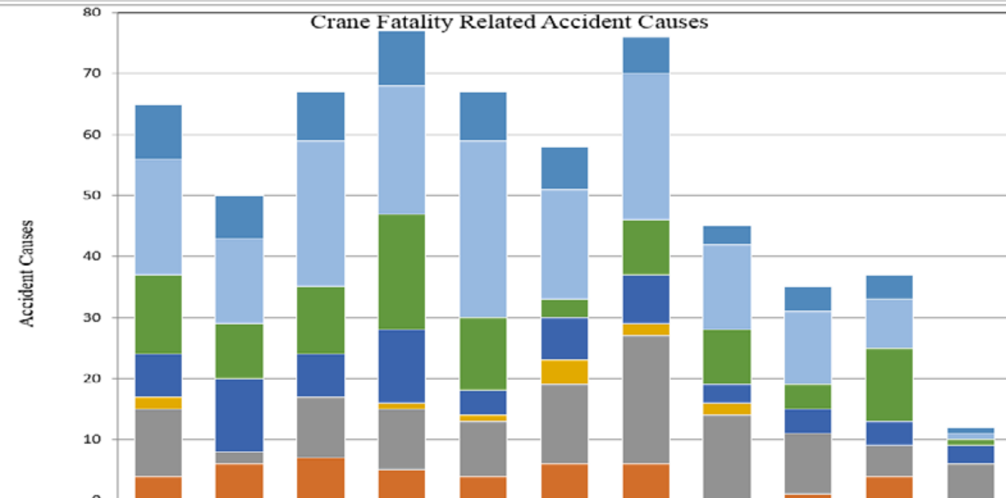
FIGURE 16: Crane related fatalities, 2002 to 2012

The negative slope of the trend line in Figure 16 above, is an indication of a significant decline in crane fatalities. It is observed that the R^2 value is near 0.6 suggesting that there is some degree of correlation between the frequency of fatalities and the years the deaths occurred.

TABLE 8: Types of crane failures causing fatalities, 2002 to 2012

Year	Overturn / tips	Collapse	Ground conditions	Power line contact	unstable/ Overload	Wire rope/ hoist/ sling	Signal/ communic-ation error	Other	Total
2002	4	11	2	7	13	19	11	9	76
2003	6	2	0	12	9	14	9	7	59
2004	7	10	0	7	11	24	13	8	80
2005	5	10	1	12	19	21	8	9	85
2006	4	9	1	4	12	29	3	8	70
2007	6	13	4	7	3	18	10	7	68
2008	6	21	2	8	9	24	10	6	86
2009	0	14	2	3	9	14	4	3	49
2010	1	10	0	4	4	12	2	4	37
2011	4	5	0	4	12	8	2	4	39
2012	0	6	0	3	1	1	1	1	13
Total	43	111	12	71	102	184	73	66	662
%	6.5%	16.8%	1.8%	10.7%	15.4%	27.8%	11.0%	10.0%	100%

Table 8 above is the summary of the causes of the crane fatalities recorded between year 2002 and 2012. The results show that “Wire rope/hoisting errors” accounted for the most causes of the crane fatalities related accidents with nearly 28%, representing 184 fatalities. Collapse and overloading recorded almost 17% and 16% respectively. Power line contact and signaling errors accounted for nearly 11% each of the crane fatalities related accidents.



Years	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Other	9	7	8	9	8	7	6	3	4	4	1
Wire rope/hoist/ sling	19	14	24	21	29	18	24	14	12	8	1
unstable/ Overload	13	9	11	19	12	3	9	9	4	12	1
Powerline contact	7	12	7	12	4	7	8	3	4	4	3
Ground conditions	2	0	0	1	1	4	2	2	0	0	0
Collapse	11	2	10	10	9	13	21	14	10	5	6
Overturn/ tips	4	6	7	5	4	6	6	0	1	4	0

FIGURE 17: Type of crane failure causing fatalities

Figure 17 above represents the same data plotted in bar chart format to illustrate the distribution and variation of the various crane fatalities related accident causes against the number of recorded accidents over time. In all, crane collapse represented almost 13% of all recorded causes of the fatalities related accidents. Similar percentage was recorded in previous research on crane fatalities recorded between 1992 and 2006 suggesting a marginal crane failure rate in this category over time.

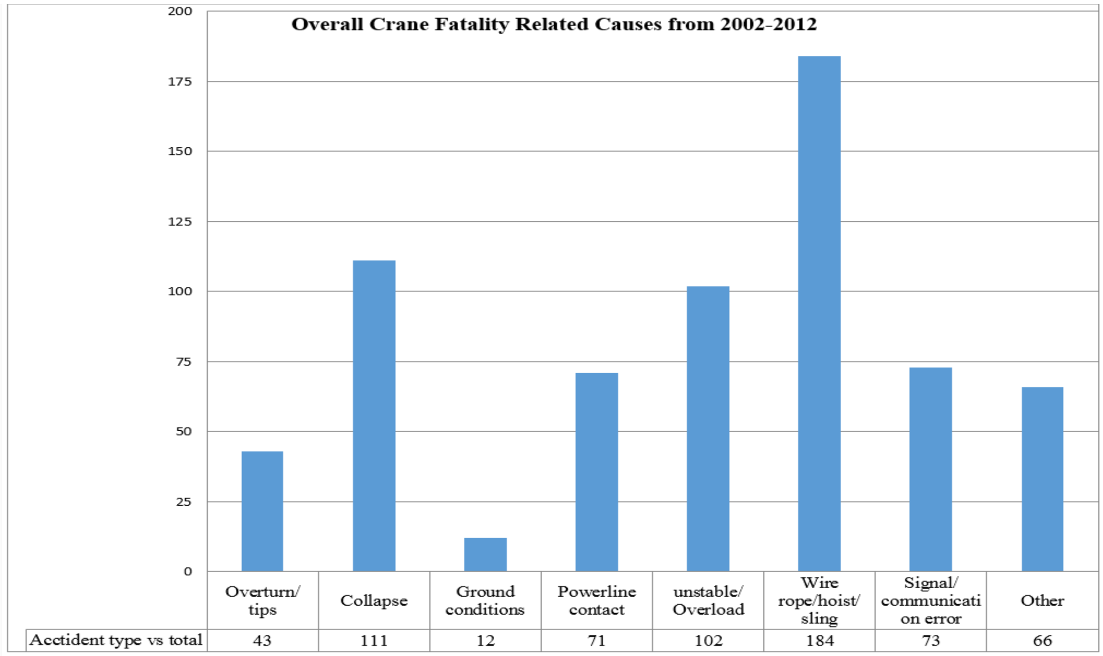


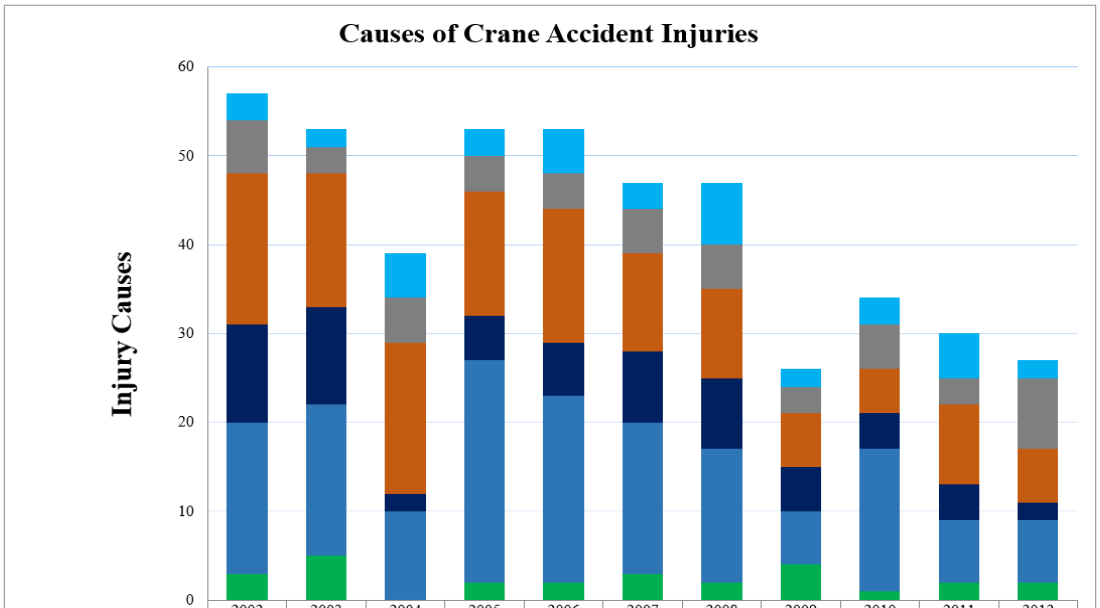
FIGURE 18: Fatality-related accidents by crane failure type from 2002-2012

Figure 18 above shows the overall crane fatalities related accidents causes for 2002 to 2012. The graph shows that Hoisting errors accounted for the most accident causes with 184 fatalities associated with the accidents. This brings to light the alarming accidents associated with rigging errors, the finding from this data show that this category is a significant factor in most crane fatalities recorded between 2002 and 2012

TABLE 9: Summary of crane injuries causes, 2002-2012

Year	Electrocution	Struck By and Against	Caught By and Between	Fall	Crush	Other injury causes	Total
2002	3	17	11	17	6	3	57
2003	5	17	11	15	3	2	53
2004	0	10	2	17	5	5	39
2005	2	25	5	14	4	3	53
2006	2	21	6	15	4	5	53
2007	3	17	8	11	5	3	47
2008	2	15	8	10	5	7	47
2009	4	6	5	6	3	2	26
2010	1	16	4	5	5	3	34
2011	2	7	4	9	3	5	30
2012	2	7	2	6	8	2	27
Total	26	158	66	125	51	40	466
Percentage	5.6%	33.9%	14.2%	26.8%	10.9%	8.6%	100%

Table 9 shows analysis of injuries related causes of crane accidents. The analysis is relevant as it serves to address the causes of crane related injuries during construction activities. There were a total of 466 injury related crane accidents between year 2002 and 2012. Year 2002 recorded the most crane injuries related accident. An average of 39 injuries were recorded per year during the period. Also, 2009 to 2012 recorded relatively lower number of injuries compared to the previous years. It was observed that "struck by and against" accounted for the highest cause of injuries at 32% followed by falls and sling/hoist breaks with approximately 25% and 16% respectively.



	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Other injury causes	3	2	5	3	5	3	7	2	3	5	2
Crush	6	3	5	4	4	5	5	3	5	3	8
Fall	17	15	17	14	15	11	10	6	5	9	6
Caught By and Between	11	11	2	5	6	8	8	5	4	4	2
Struck By and Against	17	17	10	25	21	17	15	6	16	7	7
Electrocution	3	5	0	2	2	3	2	4	1	2	2

FIGURE 19: Number of crane related injuries by cause from 2002-2012

Figure 19 above represents the same data plotted in a bar chart format to illustrate the distribution and variation of the various crane injuries related accident against the number of accidents recorded between years 2002 to 2012. Electrocution was the lowest cause of injuries with an average of 2 electrocutions per year. The fewer number of injury related electrocutions indicates that most electrocutions resulted in fatality.

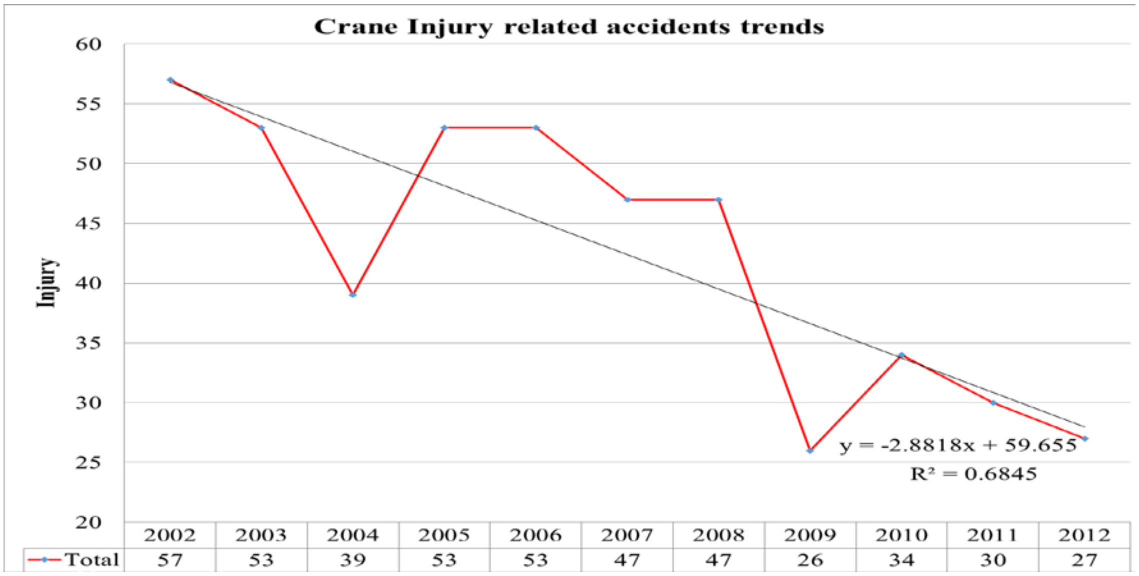


FIGURE 20: Crane injury-related accidents trends from 2002-2012

Figure 20 above shows the overall crane injuries observed yearly from 2002 to 2012. The graph shows a general decline from year 2002 to 2012.

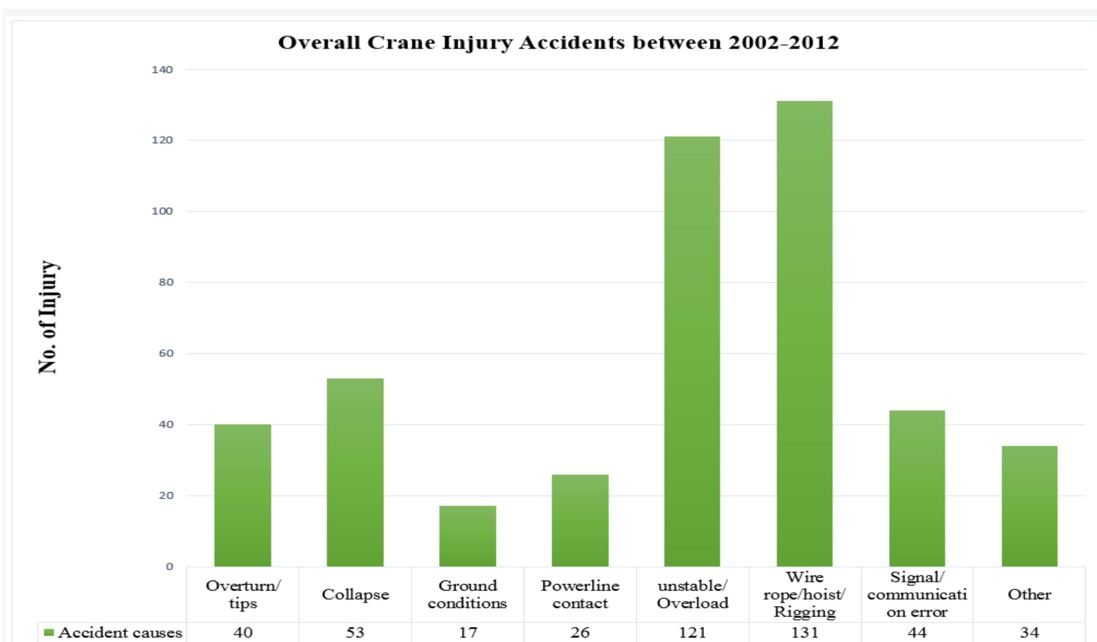


FIGURE 21: Over all injury-related accidents by crane failure type from 2002 - 2012

Figure 21 above shows the overall injury-related accidents by crane failure types. In all, the most observed injuries were caused by "hoisting errors" with 131 injuries. "Overloading and unstable loads" followed closely with 121 injuries. 53 of the injuries were caused by crane collapse whiles electrocution caused 25 injuries. Whereas previous research in the literature review did not include injuries related crane accidents, the findings from this data shows the causes of fatalities also led to the cause injuries.

TABLE 10: Types of crane failure causing injuries, 2002 to 2012

Year	Overturn / tips	Collapse	Ground conditions	Power line contact	unstable/ Overload	Wire rope/hoist/ Rigging	Signal/ communication error	Other
2002	8	6	4	4	7	14	7	7
2003	7	2	1	5	7	21	5	5
2004	2	5	1	0	14	12	3	2
2005	3	9	1	2	15	13	8	2
2006	5	3	1	2	11	22	5	5
2007	8	3	2	3	14	10	5	2
2008	3	6	3	2	9	17	4	3
2009	2	3	0	3	7	7	2	2
2010	0	5	2	1	9	11	4	2
2011	1	4	2	2	17	1	1	2
2012	1	7	0	2	11	3	0	2
Total	40	53	17	26	121	131	44	34
Percentage	8.6%	11.4%	3.6%	5.6%	26.0%	28.1%	9.4%	7.3%

Table 10 shows an analysis of types of crane failure causing injuries 2002 to 2012. Signal and communication errors caused 44 injuries related crane accidents. Power line contact also accounted for nearly 6% of all injuries related crane accidents. Crane collapse and crane overturn averaged 8% each during the same period. Ground conditions accounted for nearly 4% of all injuries related accidents.

4.2 Chi-Square Analysis

The data was sorted by various causes of crane related accidents and grouped into two categories. One group shows the number of accidents occurring between year 2002 and 2010 representing accidents recorded under the old crane rules. The other groups include accidents recorded between 2011 and 2012, representing accidents recorded under the new crane rules

The hypothesis of the study is that there is a significant correlation in the number of crane related accidents and the changes in the crane regulations. This hypothesis is tested by using the chi-square to compare the cumulative frequencies of accident data recorded between 2002 and 2010 with those between 2011 and 2012. Research shows that chi-square analysis is used when there is a need to examine the similarities between two or more populations or variables on some characteristics of interest. In this case, the comparison is between accidents frequencies before the introduction of the new OSHA crane regulation and the frequency of similar accidents recorded after the introduction of the new OSHA crane regulation. Since chi-square can handle more than one variable or population in a statistical analysis, it is useful in this scenario involving different accidents types and causes.

If the null hypothesis is true, then there is no significant relationship between the frequency of accidents before and after the introduction of the new crane regulations. Consequently, if the chi-square value is greater than the critical value then the null hypothesis will be rejected. This implies that there is a possibility of a significant relationship between the frequencies of the crane related accidents occurring before and after the introduction of the new crane regulations.

From the Chi-square Analysis (2013) the methodology for analyzing the data is as follows:

1. Categorization of the data by grouping them according to the type of accident and aggregating the frequencies based on their similarity in respect of the period in which they occurred.
2. The null hypothesis is that there is no significance relationship between the observed and expected frequencies of the accidents before and after the introduction of the new crane rule.
3. In determining the Chi-square, the degree of freedom will be determine and the confidence level will assumed as P=0.05 indicating 95% significance that the data is accurate.
4. The Chi-square (x) will be calculated as follows:

$$\chi^2 = \sum \frac{(O-E)^2}{E}$$

$$E = \frac{\text{(Row total) x (Column total)}}{\text{Grand total}}$$

Where E = Expected Frequency

And O = Observed frequency,

5. The degree of freedom, *df*, is a parameter used to look up chi-square values from the chi-square table.

   The degree of freedom (*df*) is determined by *df = (r-1)(c-1),*

   Where *r* = number of rows and *c* = number of columns of the frequency data table being analysed.
6. The Chi-square value is compared with the critical value on Chi-square table.

7. If the Chi-square value is greater than the critical value then the null hypothesis will be rejected. This implies that there is a significant difference in the frequencies of the crane related accidents occurring before and after the introduction of the new crane regulation. However, if the Chi-square test is less than the critical value, the null hypothesis will be retained, meaning that there is no significant relationship between the frequencies of the crane related accidents occurring before and after the introduction of the new crane regulation.

4.2.1 Chi-Square Analysis for Type of Crane-related Fatalities

Step1: The frequencies of the causes of crane related fatalities was summarized according the cause of the fatalities and the year of occurrence. These figures were tabulated and grouped under the two categories. The first group were the fatalities recorded prior to the change in regulations and the second group were the fatalities recorded after the change in crane regulations as shown in Table 11 below.

TABLE 11: Observed frequency of causes of crane fatalities

Period of Change in regulations	Year	Electrocution	Struck By and Against	Caught By and Between	Fall	Crush	Other causes
Before Bew Crane Regulations (2002 To 2010)	2002	7	21	6	26	10	6
	2003	12	20	3	14	7	3
	2004	8	21	10	25	12	4
	2005	13	29	4	23	15	1
	2006	4	30	4	22	10	0
	2007	7	18	7	16	16	4
	2008	8	33	7	13	20	5
	2009	3	22	2	12	9	1
	2010	4	16	2	8	6	1
	Total	66	210	45	159	105	25
Bew Crane Regulations (2011 To 2012)	2011	3	11	3	14	5	3
	2012	3	5	0	2	3	0
	Total	6	16	3	16	8	3

Step 2: The data was summarized into accidents fatalities recorded from 2002-2010 and those recorded from 2011-2012 representing the periods before and after the introduction of the new crane regulation respectively as shown in Table 12 below.

TABLE 12: Observed frequency of causes of crane related fatalities

Year	Electrocution	Struck By and Against	Caught By and Between	Fall	Crush	Other causes	Total
Before (2002 To 2010)	66	211	45	158	105	25	610
After (2011 To 2012)	6	16	3	16	8	3	52
Total	72	227	48	174	113	28	662

Step 3: The expected frequency is determined as shown in Table 13 below.

TABLE 13: Expected frequency of causes of crane related fatalities

Year	Electrocution	Struck By and Against	Caught By and Between	Fall	Crush	Other causes	Total
Before (2002 To 2010)	66.3	208.2	44.2	161.3	104.1	25.8	610
After (2011 To 2012)	5.7	17.8	3.8	13.7	8.9	2.2	52
Total	72	226	48	175	113	28	662

Sample Calculation of Expected Frequency for electrocution before 2011

i. (72x610)/662=66.3

Step 4: Determination of chi-square as shown in Table 14 below

TABLE 14: Determination of chi-square value for causes of crane related fatalities

Year	Electrocution	Struck By and Against	Caught By and Between	Fall	Crush	Other causes	Total
Before (2002 To 2010)	0.002	0.015	0.013	0.032	0.007	0.025	0.094
After (2011 To 2012)	0.021	0.173	0.157	0.370	0.086	0.291	1.099
Total	0.023	0.188	0.171	0.401	0.094	0.316	1.192

Calculating Chi-Square from the equation

$$\chi^2 = \sum \frac{(O-E)^2}{E}$$

Sum ($(66-66.3)^2/66.3$+……...) = 1.192

Calculating degree of Freedom from the equation df =(r-1)(-c1)

Degree of Freedom = (2-1) x (6-1) = 5

With a significant level of P=0.05 and a degree of freedom of 5, the chi-square value of 11.07 is obtained from the chi-squared table.

Comparing the critical value to the calculated chi-square value of 1.192 indicate that the calculated value is less than the critical value and the null hypothesis should be accepted. Or in other words, the calculated chi-square is associated with a significance level of p=0.947. This would indicate that there is very little likelihood that a correlation exist between the change in crane regulations and the number of crane related fatalities occurring over the period.

4.2.2 Chi-Square Analysis for Type of Crane-Related Injuries

A similar Chi-square analysis was conducted for injuries related crane accidents to investigate the relationship between the accidents frequencies and the changes in the crane regulations. Below is the chi-square analysis.

TABLE 15: Observed frequency of causes of crane injuries

Change in regulation	Year	Electro cution	Struck By and Against	Caught By and Between	Fall	Crush	Other causes
Before New Regulation (2002 To 2010)	2002	3	17	11	17	6	3
	2003	5	17	11	15	3	2
	2004	0	10	2	17	5	5
	2005	2	25	5	14	4	3
	2006	2	21	6	15	4	5
	2007	3	17	8	11	5	3
	2008	2	15	8	10	5	7
	2009	4	6	5	6	3	2
	2010	1	16	4	5	5	3
	Total	22	144	60	110	40	33
After New Regulation (2011 To 2012)	2011	2	7	4	9	3	5
	2012	2	7	2	6	8	2
	Total	4	14	6	15	11	7

TABLE 16 Observed frequency of causes of crane related injuries

Year	Electrocution	Struck By and Against	Caught By and Between	Fall	Crush	Other causes	Total
Before (2002 To 2010)	22	144	60	110	40	33	409
After (2011 To 2012)	4	14	6	15	11	7	57
Total	22	144	60	110	40	33	409

TABLE 17: Expected frequency of causes of crane related injuries

Year	Electrocution	Struck By and Against	Caught By and Between	Fall	Crush	Other causes	Total
Before (2002 To 2010)	22.8	138.7	57.9	109.7	44.8	35.1	409
After (2011 To 2012)	3.2	19.3	8.1	15.3	6.2	4.9	57
Total	26	158	66	125	51	40	466

Sample Calculation of Expected Frequency for electrocution before 2011

i. (22x409)/466=22.8

TABLE 18: Determination of chi-square value for causes of crane related injuries

Year	Electrocution	Struck By and Against	Caught By and Between	Fall	Crush	Other causes	Total
Before (2002 To 2010)	0.029	0.205	0.074	0.001	0.507	0.126	0.942
After (2011 To 2012)	0.211	1.468	0.532	0.005	3.635	0.908	6.759
Total	0.241	1.672	0.606	0.006	4.141	1.034	7.701

Calculating Chi-Square from the equation

$$\chi^2 = \sum \frac{(O-E)^2}{E}$$

Sum $((22-22.8)^2/24+\ldots\ldots..)= 7.701$

Calculating degree of Freedom from the equation df =(r-1)(-c1)

Degree of Freedom = (2-1) x (6-1) = 5

With a significant level of P=0.05 and a degree of freedom of 5, the chi-square value of 11.07 is obtained from the chi-squared table.

Comparing the critical value to the calculated chi-square value of 7.701 indicate that the calculated value is less than the critical value and the null hypothesis should be accepted. Or in other words, the calculated chi-square is associated with a significance level of p=0.173. This would indicate that there is very little likelihood that a correlation exist between the change in crane regulations and the number of crane related injuries occurring over the period.

4.2.3 Chi-Square Analysis for Injury-related Accidents by Crane Failure Type

TABLE 19: Observed frequency of crane failure types causing injuries

Change in regulation	Year	Overturn / tips	Collaps-e	Ground condition-s	Power line contact	Overloadin-g	Wire rope /hoist/ sling	Signal/ communica-tion error	Other
Before New Regulation (2002 To 2010)	2002	8	6	4	4	7	14	7	7
	2003	7	2	1	5	7	21	5	5
	2004	2	5	1	0	14	12	3	2
	2005	3	9	1	2	15	13	8	2
	2006	5	3	1	2	11	22	5	5
	2007	8	3	2	3	14	10	5	2
	2008	3	6	3	2	9	17	4	3
	2009	2	3	0	3	7	7	2	2
	2010	0	5	2	1	9	11	4	2
	Total	38	42	15	22	93	127	43	30
After New Regulation (2011 To 2012)	2011	1	4	2	2	17	1	1	2
	2012	1	7	0	2	11	3	0	2
	Total	2	11	2	4	28	4	1	4

TABLE 20: Observed frequency of causes of crane failure types causing injuries

Year	Overturn/ tips	Collapse	Ground conditions	Power line contact	unstable/ Overload	Wire rope/hoist / sling	Signal/ communication error	Other	Total
Before (2002 To 2010)	38	42	15	22	93	127	43	30	410
After (2011 To 2012)	2	11	2	4	28	4	1	4	56
Total	40	53	17	26	121	131	44	34	466

TABLE 21: Expected frequency of crane failure type causing injuries

Year	Overturn/ tips	Collapse	Ground conditions	Powerline contact	unstable/ Overload	Wire rope/hoist/ sling	Signal/ communication error	Other	Total
Before (2002 To 2010)	35.2	46.6	15.0	22.9	106.5	115.3	38.7	29.9	410.0
After (2011 To 2012)	4.8	6.4	2.0	3.1	14.5	15.7	5.3	4.1	56.0
Total	40.0	53.0	17.0	26.0	121.0	131.0	44.0	34.0	466.0

Sample Calculation of Expected Frequency for overturn/tip before 2011

ii. (40x410)/466=35.2

TABLE 22: Determination of chi-square value for crane failure types causing injuries

Year	Overturn/ tips	Collapse	Ground conditions	Powerline contact	Overload	Wire rope/hoist/ sling	Signal/ communication error	Other	Total
Before (2002 To 2010)	0.22	0.46	0.00	0.03	1.70	1.20	0.47	0.00	4.09
After (2011 To 2012)	1.64	3.37	0.00	0.25	12.46	8.76	3.48	0.00	29.95
Total	1.86	3.83	0.00	0.28	14.16	9.96	3.95	0.00	34.04

Calculating Chi-Square from the equation

$$\chi^2 = \sum \frac{(O-E)^2}{E}$$

Sum $((22-22.8)^2/24+\ldots\ldots..)= 34.04$

Calculating degree of Freedom from the equation df =(r-1)(-c1)

Degree of Freedom = (2-1) x (8-1) = 7

With a significant level of P=0.05 and a degree of freedom of 7, the chi-square value of 14.07 is obtained from the chi-squared table.

Comparing the critical value to the calculated chi-square value of 34.04 indicate that the calculated value is bigger than the critical value and the null hypothesis should be rejected. Or in other words, the calculated chi-square is associated with a significance level of $p=1.69\times10^{-5}$. This would indicate that there is high likelihood that a correlation exist between the change in crane regulations and the number of crane failure type causing injuries occurring over the period.

4.2.4 Chi-Square Analysis for Fatality-related Accidents by Crane Failure Type

TABLE 23: Observed frequency of crane failure types causing fatalities

Change in regulation	Year	Overturn/ tips	Collapse	Ground conditions	Power line contact	Overloading	Wire rope/ hoist/ sling	Signal/ communication error	Other
Before New Regulation (2002 To 2010)	2002	4	11	2	7	13	19	11	9
	2003	6	2	0	12	9	14	9	7
	2004	7	10	0	7	11	24	13	8
	2005	5	10	1	12	19	21	8	9
	2006	4	9	1	4	12	29	3	8
	2007	6	13	4	7	3	18	10	7
	2008	6	21	2	8	9	24	10	6
	2009	0	14	2	3	9	14	4	3
	2010	1	10	0	4	4	12	2	4
	Total	39	100	12	64	89	175	70	61
After New Regulation (2011 To 2012)	2011	4	5	0	4	12	8	2	4
	2012	0	6	0	3	1	1	1	1
	Total	4	11	0	7	13	9	3	5

TABLE 24 Observed frequency of crane failure types causing fatalities

Year	Overturn / tips	Collapse	Ground conditions	Power line contact	unstable/ Overload	Wire rope/hoist/ sling	Signal/ communica-tion error	Other	Total
Before (2002 To 2010)	39	100	12	64	89	175	70	61	610
After (2011 To 2012)	4	11	0	7	13	9	3	5	52
Total	43	111	12	71	102	184	73	66	662

TABLE 25: Expected frequency of crane failure types causing fatalities

Year	Overturn / tips	Collapse	Ground conditions	Power line contact	unstable/ Overload	Wire rope/hoist/ sling	Signal/ communica tion error	Other	Total
Before (2002 To 2010)	39.6	102.3	11.1	65.4	94.0	169.5	67.3	60.8	610.0
After (2011 To 2012)	3.4	8.7	0.9	5.6	8.0	14.5	5.7	5.2	52.0
Total	43.0	111.0	12.0	71.0	102.0	184.0	73.0	66.0	662.0

Sample Calculation of Expected Frequency of overturn/tips before 2011

iii. (43x610)/662=39.6

TABLE 26: Determination of chi-square value for crane failure types causing fatalities

Year	Overturn/ tips	Collapse	Ground conditions	Power line contact	Overload	Wire rope/ hoist/ sling	Signal/ communication error	Other	Total
Before (2002 To 2010)	0.01	0.05	0.08	0.03	0.26	0.18	0.11	0.00	0.72
After (2011 To 2012)	0.11	0.60	0.94	0.36	3.11	2.06	1.30	0.01	8.49
Total	0.12	0.65	1.02	0.39	3.37	2.23	1.41	0.01	9.21

Calculating Chi-Square from the equation

$$\chi^2 = \sum \frac{(O-E)^2}{E}$$

Sum ((39-39.6)^2/39.6+……..)= 9.21

Calculating degree of Freedom from the equation df =(r-1)(-c1)

Degree of Freedom = (2-1) x (8-1) = 5

With a significant level of P=0.05 and a degree of freedom of 7, the chi-square value of 14.07 is obtained from the chi-squared table.

Comparing the critical value to the calculated chi-square value of 9.21 indicate that the calculated value is less than the critical value and the null hypothesis should be accepted. Or in other words, the calculated chi-square is associated with a significance level of p=0.0.238. This would indicate that there is very little likelihood that a correlation exist between the change in crane regulations and the number of crane failure type causing fatalities occurring over the period.

Out of the four analysis on with the chi-square test, only one result suggested a high correlation between the new regulation and the number and type of crane accidents resulting in injury or death occurring over the period. However, a proportional analysis has been performed below on the relationship between accidents recorded before the new regulation and those recorded after the new regulation in order to explore other possible impacts from the new regulations.

4.3 Proportional Analysis

The data was also compared to ascertain the proportional trends of crane related accidents which occurred between 2002 and 2012.

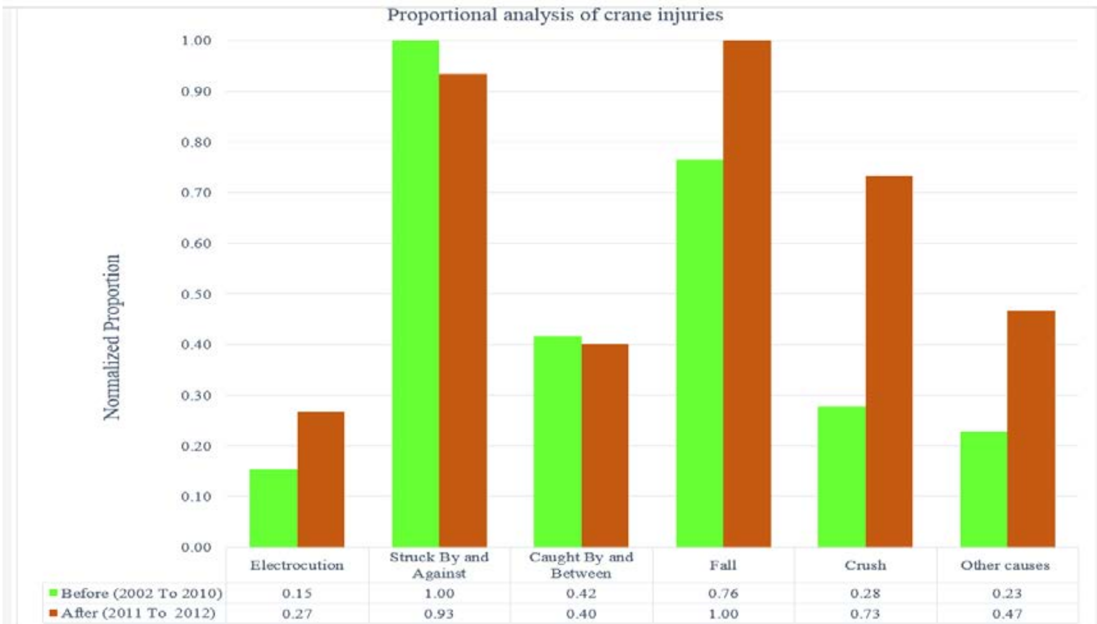


FIGURE 22: Proportion of crane related injuries and change in regulation

The proportional analysis was used to compare the crane injuries recorded from 2002 to 2010 and 2011 to 2012 representing accidents before and after the change in crane regulations respectively. While injuries caused as a result of workers being “struck”, and “caught between” showed a decline by proportions, injuries caused by electrocution, fall, and crush showed an increase in the proportions with the change in the regulations as shown in Figure 22. This may be an indication that the regulation is impacting the areas that saw the decline by proportions. Hence suggesting that crane operators and crew may be focusing on avoiding accidents resulting from being “struck by” and “caught by” whiles paying less attention to areas such as electrocution, falls and crushes.

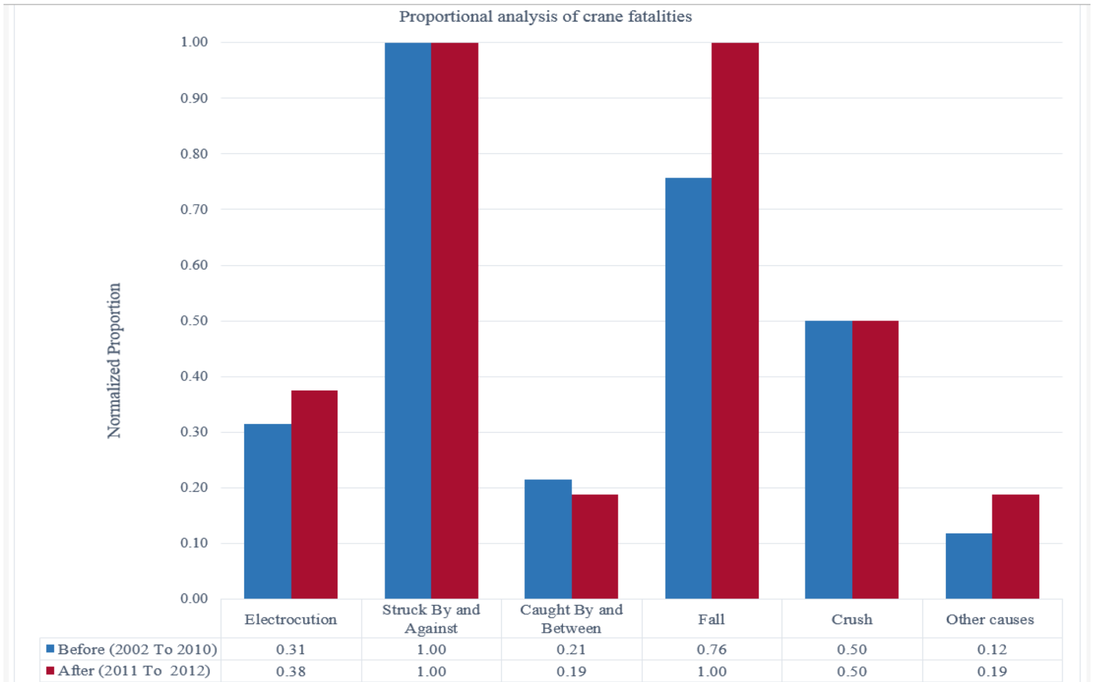
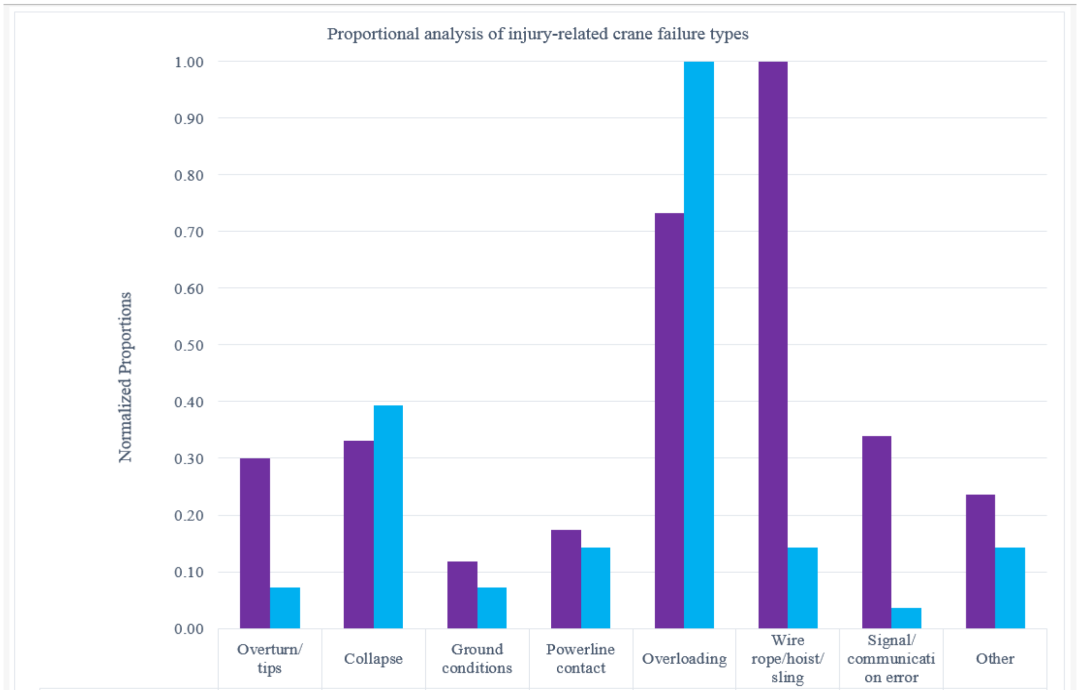


FIGURE 23: Proportion of crane related fatalities and change in regulation

Figure 23 shows proportional analysis used to compare the crane fatalities recorded from 2002 to 2010 and 2011 to 2012 representing accidents before and after the change in crane regulations respectively. While fatalities caused as a result of workers being “struck”, “caught between” and “crush” showed a marginal decline by proportions, fatalities caused by electrocution, fall, and other causes showed a proportional rise with the change in the regulations. This could be an indication that the new regulation has been able to halt fatalities resulting from crane workers being “crushed”, “struck by” and “caught by”. There is also the possibility that crane workers on construction sites may be paying more attention to the areas that saw the proportional decline than other fatalities causes such as Electrocutions and falls.



	Overturn/ tips	Collapse	Ground conditions	Powerline contact	Overloading	Wire rope/hoist/ sling	Signal/ communication error	Other
Before (2002 To 2010)	0.30	0.33	0.12	0.17	0.73	1.00	0.34	0.24
After (2011 To 2012)	0.07	0.39	0.07	0.14	1.00	0.14	0.04	0.14

FIGURE 24: Proportion of crane failure types causing injury and change in regulation

Figure 24 shows a normalized proportional analysis used to compare crane failure types that were associated to injuries and recorded from 2002 to 2010 and 2011 to 2012 representing accidents before and after the change in crane regulations respectively. It was observed that crane failures resulting from "overturning", "poor ground conditions", "power lines contacts", "wire ropes/hoists" and "signaling error" showed a decline by proportions, but on the other hand crane failures associated to "collapse, and overloading showed a proportional rise. This is an indication of the crane regulation impacting the areas with proportional decline. It can be inferred that the crane workers and management may be focusing more attention to reducing accidents in these categories. This observation buttresses the chi-square analysis for injury-related crane accidents by crane failure type. Where the results show a correlation in the crane regulation and the crane failure frequency.

It is also important that categories such as overloading and collapse are given such needed attention to reduce accidents.

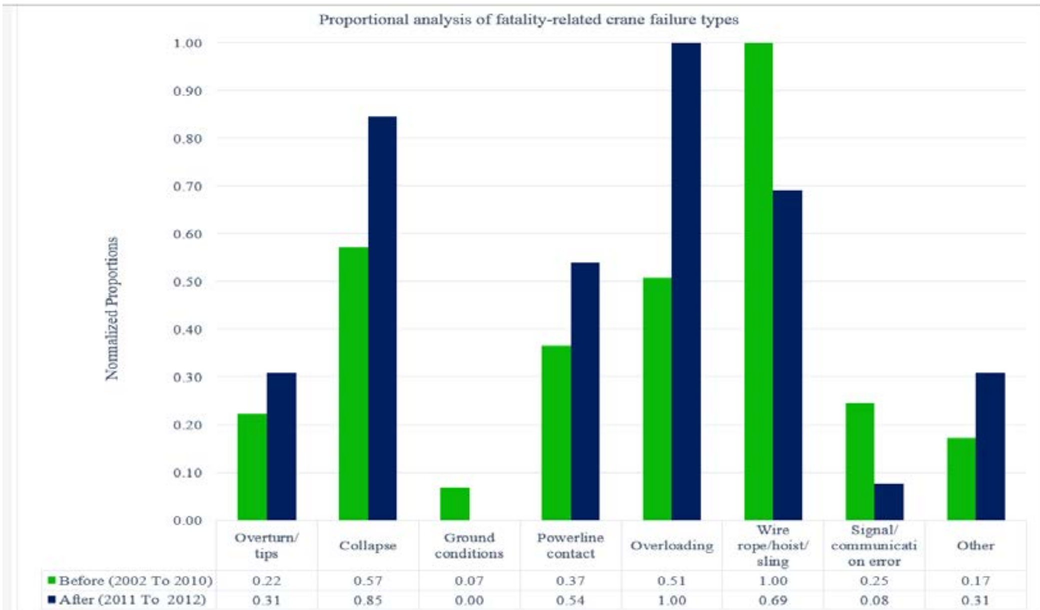


FIGURE 25: Proportion of crane failure types causing fatality and change in regulation

Figure 25 shows a normalized proportional analysis used to compare crane failure types causing fatalities and recorded from 2002 to 2010 and 2011 to 2012 representing accidents before and after the change in crane regulations respectively. While crane failures resulting from “wire ropes/hoists” and “signaling error” showed a decline by proportions, crane failures associated to “overturning”, “ground condition”, “collapse”, “power line contact”, and “overloading” showed a proportional rise with the change in the regulations. The analysis suggests that crane workers and management may be paying a lot of attention to hoisting/rigging activities as well as signaling whiles the other categories lack attention. It is recommended that site management will begin to focus on the areas where proportional increase was observed.

CHAPTER 5 SAFETY READINESS CHECKLIST

The safety readiness checklist is an important tool intended to guide the project site management team in ensuring that employees work in a safe environment during crane operations. By ensuring safe working environment, the company may be able to attract and retain qualified workforce in the company, minimize accident compensations claims and reduce potential citations by OSHA inspectors. The safety checklist is intended to be a guide that can be referenced by site management to remind them of possible accidents associated with their crane operations.

A crane safety readiness checklist was developed after a comparative analysis of the old and new crane rules revealed a significant addition of regulations to the new crane rules. Also, the analysis of accidents helped to identify areas of the regulation which requires management attention on planning and conducting crane operation. Some of the critical issues observed with accidents data analysis includes signal/communications, power line contacts, unstable loads/overloading and collapse among others. Hence the checklist was compiled using the new crane regulation as the resource guide emphasizing the significant hazards identified in the data analysis. The initial draft checklist is included in Appendix A.

The initial draft of the checklist was submitted to a member of the Crane Institute of the American Society of Civil Engineers who volunteered to share his opinion on the checklist and provide a review based on his practical knowledge of crane operation. A letter of invitation together with the draft safety readiness checklist was submitted for review and comments. The scope of the review comprised the following:

i. A review of the entire safety readiness checklist and an evaluation of the extent to which it covers all significant crane related accidents causes.

ii. Evaluate the relevance of the checklist to be used at site with respect to the level of details and clarity of the checklist to avoid confusion and misinterpretation of the contents.

iii. Identification of the responsible parties who should be the administrators of the checklist and the target group that may be positively impacted by the checklist.

The reviewer's response gave a very clear direction and focus for the checklist. Below are the comments from the review committee member:

1. It is too long

2. The question needs to be asked- "Who will be using this checklist?" It seems to me that too many entities at different levels would be involved. For effective use, different checklists would be needed for different levels of management.

3. There is really no need for any columns other than the first one- labeled "yes" in this case.

4. You should mention that this is for the federal OSHA- as several states have their own that equal or exceed federal OSHA rules.

5. There are a few grammatical errors that need to be corrected.

6. Any checklist for use in the field or elsewhere should contain items related to OSHA, the site specific requirements, and what is considered good practice. In other words, you would need access to these other documents to establish a checklist and many site specific

documents have their own checklist. However, not all owners or general contractors have such rules.

7. As this may sound confusing and difficult, you might redo your goal and make your checklist a guide- only for those trying to formulate a site specific crane and lifting procedures document.

8. It would be good to reference each question to the specific paragraph in the standard.

Based on the comments above the safety checklist was modified to reflect the changes and is shown in Table 27.

TABLE 27: Modified crane safety readiness checklist based on new crane regulations

New Crane Rule	Crane Operation Checklist	Yes	No
1926.1401	Employer Responsibilities		
	Do you have a comprehensive lift plan available for the lifting activities?		
1926.1402	Ground Conditions		
	Is the controlling entity (employer) aware of ground conditions?		
	Is ground condition adequate to support equipment operation?		
	Is your A/D director able to assess ground condition?		
	Is your spotter/rigger/signal person able to assess ground condition?		
	Is your crane operator able to assess ground condition?		
1926.1403	Assembly and Disassembly (A/D)		
	Do you have crane manufacturer's procedure for the A/D activity?		
	Is your procedure for A/D activities developed by qualified person?		
1926.1404	Assembly and Disassembly (A/D) Director		
	Is there an A/D Director assigned to the activity?		
	Is the A/D Director competent and qualified for the activity?		
	Are crew members trained to alert the operator any imminent danger?		
	Do you have a qualified rigger A/D rigging activities?		
1926.1407	Power Lines		
	Have your work zone been established for the crane activity?		
	Have you identified any power lines within or near the work zone?		
	Can the power line be de-energized and grounded by the owner?		
	Are you able to maintain a minimum of 20ft distance from power line?		
	Do you use Table A as alternative to keeping a 20ft off the power line.		
	What measures have you taken to prevent encroachment and electrocution (tag lines, erected barricades, dedicated spotter, proximity alarm, operator warning and crane limiting devices etc.)?		

TABLE 27: Modified crane safety readiness checklist based on new crane regulations

New Crane Rule	Crane Operation Checklist	Yes	No
1926.1412	Inspections		
	Do you have an up to date records for monthly and annual crane inspections by a qualified person?		
	Are there daily inspections carried out by a competent person prior to crane operation?		
	Prior to operating an assembled crane, has a qualified person inspected and certified the assembly according to manufacturer's criteria?		
	Do you know of any modification done on the crane?		
	Has the modification been approved by the manufacturer or qualified registered professional engineer?		
1926.1413	Wire Rope Inspection		
	Do you have up to date records for monthly and annual wire rope inspections by a qualified person?		
	Is there any observed or known defect on the wire rope?		
	Are the synthetic slings protected from abrasive or sharp edges?		
	Are wire ropes being selected and used according to manufacturer or qualified person's recommendation?		
1926.1415	Safety Devices & Operational Aids		
	Are safety devices installed and in good working condition		
	Are operational aids installed and in good working condition		
1926.1417	Operation		
	Is the rated capacity (load chart) of the crane visible to the operator?		
	Is manufacturer's procedure being applied to the crane operation?		
	Is operator trained to comply with rated capacity of the crane?		
	Is operator trained to avoid activities that will divert his attention during operation?		
	Are the crew trained to tag equipment out of service when it is malfunctioning?		
1926.1418	Authority to Stop Operation		
	Is the crane operator aware of his authority to stop crane activities if he suspect any safety issues at site?		
1926.1419	Signals		
	Has a signal person been designated to guide the crane operator?		
	Has the signal person been trained in any of the approved signaling methods (hand, voice, audible etc.)?		
1926.1423	Fall Protection		
	Are crew members trained to use proper harness to ensure fall protection?		
1926.1424	Work Area Control		
	Are site employees trained to avoid hazardous areas where crane operation is carried?		
	Are warning and control lines in place to stop encroachment within the swing /crush zone?		
1926.1425	Keeping Clear of the Load		
	Are the hoisting team trained to avoid exposure to hoisted loads?		

TABLE 27: Modified crane safety readiness checklist based on new crane regulations

New Crane Rule	Crane Operation Checklist	Yes	No
	Is the hoisting team trained to properly rig hoisted loads within the fall zone?		
1926.1426	Free Fall and Controlled Load Lowering		
	Is the supervisor aware that free fall cranes must be not be used to hoist workers or loads whiles workers are in the fall zone?		
	Does the crane have a backup protection against free fall?		
1926.1427	Operator Qualification and Certification		
	Is operator qualified and certified by an authorized body?		
	Is operator certification valid and current (renewable every 5years)?		
1926.1428	Signal Person Qualifications		
	Is the signal person qualified and able to use hand signals?		
	Has the signal person been trained on basic operation and limitations?		
1926.1429	Qualifications of Maintenance & Repair Employees		
	Is the maintenance person qualified to carryout repair works on the crane?		
	Is the maintenance person familiar with hazards related to the crane repair?		
1926.1430	Training		
	Has operator been trained on manufacturer’s emergency procedure for halting an unintended crane movement?		
	Has the operator, crew and maintenance person been trained on tag-out procedures?		
	Do you evaluate your crew to check their knowledge of the crane standards?		
	Do you conduct refresher training for your crew or evaluate their knowledge for retraining?		
	Do you provide or sponsor crane safety training at no cost to the employees?		
1926.1431	Hoisting Personnel		
	Is the crane being used to hoist personnel (normally this is prohibited)?		
	Is the personnel platform designed by qualified structural engineer?		
	Is the personnel platform installed according to approved standard?		
	Is the personnel platform equipped with guard and crab rails?		
	Has the load criteria of personnel platform been considered?		
	Is a trial lift of the personnel platform carried out prior to performing the actual lift?		

CHAPTER 6: DISCUSSION, CONCLUSION AND RECOMMENDATIONS

Construction remains one of the leading industries with high risk of injuries and fatalities (Yilmaz et al, 2009). Construction and industrial activities involving cranes and derricks account for many accidents recorded in the US and other nations. These accidents can be minimized, if not completely prevented, if adequate measures are put in place before, during and after the construction activities to prevent these accidents. Proper planning of crane related activities prior to construction is very important in exposing any potential risks that may result from the use of the crane. Training of the crew, the assembly/disassembly director and the crane operator is relevant in ensuring that the team understands the risks involved in their operations and the necessary action required to prevent such accidents. The new OSHA crane rule 1926.1430 requires among others, that management must provide sufficient training for the workers and periodically evaluate their knowledge in order to identify any specific training needs for the workers.

Indeed, the new OSHA Crane and Derricks regulation 1926 Subpart CC is an important tool that addresses the crane accidents. Although the chi-square analysis of the relation between the change in regulations and the frequency of fatalities and injuries showed no relationship, it was observed that there were proportional decline in some of the injuries and fatalities after the new regulation was introduced. Although additional research would be required, this could be preliminary evidence that the new regulations have had a positive impact on reducing some types of fatalities and injuries associated with crane operations.

The chi-square analysis of the relationship between the change in crane regulations and the frequency of accident causes resulting in injuries, on the other hand, showed a significance in the relationship. Furthermore, there was a decline by proportions in some of the accident causes after the introduction of the new regulations. Again, additional research would be required by this would suggest that the new regulations have had an impact in reducing the causes of crane accidents. However, it should be noted that the period of the regulation change coincided with the peak of the recession when the construction industries and other sectors of the economy saw decline in activities. This could have had an impact on the results, as well.

It may be useful to carry a further investigation in the future to establish the relationship between the frequency of accidents and the new regulations. The results of the findings will help streamline the crane activities to ensure a safe construction.

Recommendations

The proportional analysis of the fatalities frequencies showed a decline in some of the causes which suggests that the new regulations implementation may be yielding positive results. This, however, could not be confirmed with the Chi-square analysis which showed no relationship existing between the accident frequencies and the introduction of the new regulation. It is, therefore, recommended that future research be conducted to verify whether or not the new regulations have had an impact on reducing crane related injuries and accidents.

The accident data analysis revealed that communications errors caused a significant amount of accidents. To reduce such accidents it is recommended that effective training of riggers and operators to communicate very well during crane activities be conducted. Also, the crew need to be trained to avoid work zones which expose them to potential safety hazards. Site management should ensure that work zones are properly demarcated with adequate signs installed to prevent any encroachment within the construction zone.

With the introduction of the Assembly/Disassembly Director being a qualified and a competent person, it is expected that crane activities be supervised well to prevent accidents. It is recommended that management must always ensure they have a qualified person to manage the crane activities.

Certification of the crane operator is one of the new additions to the regulation and it is recommended that management regularize the training process of all crane operators. This training will classify the operator with the type of crane and the load the operator can work with. This is a good step to ensuring that the operators do not operate cranes for which they have inadequate or insufficient knowledge. This will go a long way to reducing the errors that may result in accidents.

It is recommended that daily, monthly and annual inspections on the crane by a qualified and competent person in order to identify any problems with the crane and correcting them before operating it. Also significant is the wire rope inspections for synthetic slings which should be thoroughly carried out by a competent person in order to remove all damaged slings from site. The accident analysis showed a number of accidents occurred due to damage of sling wires.

Finally, the crane safety checklist is intended to serve as a source of information which can be included in the site safety program by management to help them prepare for any crane activities. It is expected that by using certain parts or all of the checklists the contractor may be able to identify potential crane safety hazards and ultimately prevent accidents and / or citations due to errors in their operations.

Research Limitation

There are limitations to this research which have been identified below as follows;

i. Crane readiness checklist: Only one of the targeted number of participants reviewed the safety readiness checklist. Since one reviewer cannot constitute experts opinion, it is recommended that a future survey involve a considerable number of reviewers in order to obtain a comprehensive view of the checklist.

ii. The data used for the chi-square analysis may be affected by the decline in construction activities due to the recession which occurred around the period when the new regulation was introduced. Since the recession might have caused a decline in construction activities and possible decline in crane related accidents, it is recommended further studies to be conducted to verify whether or not the changes in crane regulations has had an impact in reducing the frequency of crane accidents.

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APPENDIX A: DRAFT CRANE SAFETY CHECKLIST

Crane Operation Checklist	Yes	No	N/A	Cost Implication	
				Yes	No
Employer Responsibilities					
Is a comprehensive lift plan available for the lifting activities?					
Is the craned leased/rented for the project?					
Does the employer own the crane?					
Ground Conditions					
Is the controlling entity (employer) aware of ground conditions?					
Are there known documented hazards beneath the equipment set-up?					
Is ground condition adequate to support equipment operation?					
Is the A/D director able to assess ground condition?					
Is the spotter/rigger/signal person able to assess ground condition?					
Is the crane operator able to assess ground condition?					
Assembly and Disassembly (A/D)					
Is the crane manufacturer's procedure available for the A/D activity?					
Does the manufacturer's prohibition apply to the A/D activity?					
Is the Employer's procedure for A/D developed by qualified person?					
Is the A/D procedure made to prevent collapse, provide adequate stability and prevent employees' exposure danger during A/D?					
Assembly and Disassembly (A/D) Director					
Is the A/D Director present at site?					
Is the A/D Director competent and qualified for the activity?					
Is the A/D Director competent but assisted by Qualified person(s)?					
Can the A/D Director confirm that site and ground condition are suitable prior to the activity?					
Is the A/D Director able to assign safe tasks to crew members and prevent hazards?					
Does the A/D Director implement procedures to minimize exposure to danger under the boom?					
Are crew members trained to alert the operator any imminent danger?					
Is the operator trained to communicate with a crew who is located within an unsafe zone of the crane activity?					
Is the A/D rigging done by a qualified rigger?					
Are the synthetic slings protected from abrasive, sharp or acute edge?					
Power Lines					
Has the work zone been established for the crane activity?					
Is there any power lines identified within or near the work zone?					
Can the power line be de-energized and grounded by owner?					
Can a 20ft or 50ft distance be maintained from power line whose voltages is below or above 350KV respectively?					
Table A referred to as being alternative to keeping a 20ft off the power line.					

Crane Operation Checklist	Yes	No	N/A	Cost Implication	
				Yes	No
Are there any steps to prevent encroachment and electrocution (tag lines, erected barricades, dedicated spotter, proximity alarm, operator warning and crane limiting devices etc.)?					
Has the operator and crews been trained on how to avoid electrocution?					
Inspections					
Is the crane's annual and monthly inspection records up to date?					
Are the daily and monthly inspections carried out by a competent person prior to crane operation?					
Are there any observed or known defects?					
Have the defects been fixed prior to the start of crane the operation?					
Has an annual/comprehensive inspection been carried out by a qualified person?					
Is there any observed or known defect that creates unsafe conditions?					
Is the Defect fixed prior to starting the crane operation?					
Has inspection document been thoroughly checked off, signed and dated?					
Prior to operating an assembled crane, has a qualified person inspected and certified the assembly according to manufacturer's criteria?					
Has any modification been done on the crane?					
Has the modification been approved by the manufacturer or qualified registered professional engineer					
Wire Rope Inspection					
Are the annual and monthly inspection records of the wire rope up to date?					
Are the daily and monthly inspections of wire rope being carried out by a competent person prior to crane operation?					
Is there any observed or known defect on the wire rope?					
Is the defect fixed prior to using wire rope crane operation?					
Is the annual/Comprehensive inspection being carried out by a qualified person?					
Is there any observed or known defect on de wire rope that creates unsafe conditions?					
Is the defect fixed prior to the start of the crane operation?					
Has inspection document been thoroughly checked off, signed and dated?					
Are wire ropes being selected and used according to manufacturer or qualified person's recommendation?					
Safety Devices & Operational Aids					
Are safety devices installed an in good working condition					
Are operational aids installed and in good working condition					
Operation					
Is the rated capacity (load chart) of the crane visibly displayed in the cab and known to the operator?					
Is manufacturer's procedure being applied to the crane operation?					

Crane Operation Checklist	Yes	No	N/A	Cost Implication	
				Yes	No
Is operator trained to comply with rated capacity of the crane?					
Is operator trained to avoid activities that will divert their attention during operation?					
Are the crew trained to tag equipment out of service when it is malfunctioning?					
Are operator and crew trained to take the necessary precaution during start of crane and ensuing bad weather?					
Authority to Stop Operation					
Is the crane operator aware of their authority to stop crane activities if they suspect any safety issues at site?					
Signals					
Is the operator's line of sight obstructed during operation?					
Has a signal person been designated to guide the crane operator?					
Has the signal person been trained in any of the permitted signaling methods (hand, voice, audible etc.)?					
Fall Protection					
Are crew members trained to use proper harness to ensure fall protection?					
Work Area Control					
Are site employees trained to avoid hazardous areas where crane operation is carried?					
Are warning and control lines in place to ward off encroachment within the swing /crush zone?					
Keeping Clear of the Load					
Are the hoisting team trained to avoid exposure to hoisted loads?					
Are hoisting team trained to properly rig all hoisted loads while guiding or receiving load within the fall zone?					
Free Fall and Controlled Load Lowering					
Is the supervisor aware that free fall cranes must be not be used to hoist workers or loads whiles workers are in the fall zone?					
Does the crane have a backup protection against free fall?					
Operator Qualification and Certification					
Is operator qualified and certified by an authorized body?					
Is operator certification valid and current (renewable every 5years)?					
Signal Person Qualifications					
Is the signal person qualified and able to understand and use the standard method of hand signals?					
Does signal person have basic understanding of equipment operation and limitations?					
Qualifications of Maintenance & Repair Employees					
Is the maintenance/repair personnel qualified to carry out the repair works on the crane?					
Is the maintenance/repair personnel familiar with the operation, limitations and characteristics and hazards related to the crane?					

Crane Operation Checklist	Yes	No	N/A	Cost Implication	
				Yes	No
Training					
Has operator been trained on manufacturer’s emergency procedure for halting an unintended crane movement?					
Are competent persons and qualified persons trained to apply the crane standards when performing their duties on the crane?					
Has Crew been trained to avoid hazardous areas around the crane and loads?					
Has the operator, crew and maintenance personnel been trained on tag-out procedures etc.?					
Does employer evaluate each worker to confirm their understanding of the crane standards?					
Does employer conduct refresher training for employees or evaluate their knowledge for retraining?					
Does employer provides or sponsors crane safety training at no cost to the employees?					
Hoisting Personnel					
Is the crane used to hoist personnel (normally this is prohibited)?					
Is the personnel platform or boatswain chair used to hoist employees?					
Is the personnel platform designed by qualified structural engineer?					
Is the personnel platform installed according to approved standard?					
Is the personnel platform equipped with guard and crab rails?					
Is the hoisting of personnel platform according to approved standard?					
Has the load criteria of personnel platform been considered?					
Is a trial lift of the personnel platform carried out prior to performing the actual lift?					

APPENDIX B: PAIRWISE COMPARISON OF OLD AND NEW CRANE RULES

COMPARATIVE ANALISYS OF THE NEW AND OLD OSHA CRANE & DERRICK REGULATION						
ITEM	TOPIC	ACTIVITY	NEW RULE	OLD RULE	SUMMARY DESCRIPTION - NEW RULE	SUMMARY DESCRIPTION - OLD RULE
1	Ground Conditions 1926.1402	Ability of the ground to support the equipment	Yes	No	Ground Conditions 1926.1402 § Ability of the ground to support the Crane equipment § A/D director or the operator must assess ground condition. § Controlling Entity or Employer to remedy unsuitable ground prior to hoisting	
		Adequate Supporting materials	Yes	No		
		Adequate ground preparations by controlling entity	Yes	No		
		Adequate information from controlling entity on ground conditions	Yes	No		
		A/D Director and Operator capable of assessing ground conditions.	Yes	No		
2	Assembly/ Disassembly 1926.1403	Compliance with Manufacturer's procedure	Yes	Yes	Ground Conditions 1926.1402 § Ability of the ground to support the Crane equipment § A/D director or the operator must assess ground condition. § Controlling Entity or Employer to remedy unsuitable ground prior to hoisting Assembly/Disassembly 1926.1403 § employer must comply with manufacturers	1926.550(a) employer shall comply with the manufacturer's specifications and limitations. 1926.550(a) (2) § Rated load capacities, and recommended operating speeds shall be visible to the operator at his control. § Attachments used with cranes shall not exceed
		Supervision by a competent and qualified person (A/D Director)	Yes	No		
		Knowledge of procedures as A/D director	Yes	No		
		Review of assembly/disassembly procedures by A/D director	Yes	No		
		Clear safety instruction to crew by AD Director	Yes	No		
		Rated capacity limits for loads not to be exceeded	Yes	Yes		

COMPARATIVE ANALISYS OF THE NEW AND OLD OSHA CRANE & DERRICK REGULATION							
ITEM	TOPIC	ACTIVITY	NEW RULE	OLD RULE		SUMMARY DESCRIPTION - NEW RULE	SUMMARY DESCRIPTION - OLD RULE
		Manufacturer's guide if unavailable, should be prepared by a qualified PE familiar with the equipment.	Yes	Yes		procedure and prohibition Assembly/Disassembly 1926.1403 § A competent person and a qualified person to supervise Assembly/disassembly. § Crew member must inform the operator when going to location where operator's view is obstructed. § During assembly/disassembly, rated capacity limits for loads must not be exceeded. § Employer procedures must be developed by a qualified person	manufacture's recommendation
3	Power line safety 1926.1407	Determination of any part of equipment, load line or load closer than 20ft to a power line	Yes		Partially	Power line safety 1926.1407 If any part of the equipment or load could get closer than 20 feet to a power line, the employer must satisfy any of the following: § Option (1) De-energize and ground. § Option (2) Maintain 20 foot clearance or § Option (3) follow Table A	§ 1926.550(a)(15)(i) For lines rated 50 kV. Or below, minimum clearance between the lines and any part of the crane or load shall be 10 feet; § 1926.552(a)(15)(ii) For lines rated over 50 kV., minimum clearance between the lines and any part of the crane or load shall be 10 feet plus 0.4
		Option (1) - Confirmation that power line is De-energized and grounded.	Yes	Yes			
		Option (2)- Maintain 20 foot clearance	Yes		Partially		
		Determine the line's voltage and the minimum clearance (Table A)	Yes		Partially		

COMPARATIVE ANALISYS OF THE NEW AND OLD OSHA CRANE & DERRICK REGULATION

ITEM	TOPIC	ACTIVITY	NEW RULE	OLD RULE	SUMMARY DESCRIPTION - NEW RULE	SUMMARY DESCRIPTION - OLD RULE
		Use a dedicated spotter	Yes	Yes	clearance Power line safety 1926.1407 § If the operator is unable to see the elevated warning line, a dedicated spotter must be used § A proximity alarm set alert operator of encroachment § If employer requests voltage information power line has two days to provide it. § The employer must train each operator and crew member on procedures and dangers of power lines.	inch for each 1 kV. Over 50kV., or twice the length of the line insulator, but never less than 10 feet; 1926.550(a)(15)(vi) § Any overhead wire is deemed energized line until electrical utility authorities indicate otherwise and it has been visibly grounded equipment clearance shall be a minimum of 4ft for voltage less than 50 kV., 10ft for voltage over 50 kV up to 345kV, and 16 ft. for voltage up 750 kV.
		Use of automated warning devices	Yes	No		
		Precautionary Measures while operating under power line	Yes	No		
		Adequate training for crane activity workers around power line	Yes	No		
4	Inspection 1926.1412	Modified equipment must be inspected by a qualified person.	Yes	No	Inspection 1926.1412 § Equipment that has had modifications must be inspected by a qualified person	126.550(a)(6) § A thorough, annual inspection of the hoisting machinery shall be made by a competent person. § The employer shall
		A repaired equipment must be inspected by a qualified person	Yes	No		

COMPARATIVE ANALISYS OF THE NEW AND OLD OSHA CRANE & DERRICK REGULATION

ITEM	TOPIC	ACTIVITY	NEW RULE	OLD RULE	SUMMARY DESCRIPTION - NEW RULE	SUMMARY DESCRIPTION - OLD RULE
		Inspection required after assembly by a qualified person	Yes	No	§ Equipment that has had a repair or adjustment must be inspected by a qualified person § Upon completion of assembly, the equipment must be inspected by a qualified person § A competent person must begin a visual inspection prior to each shift the equipment will be used. Inspection 1926.1412 § Each month the equipment is in service it must be inspected a competent person § At least every 12 months the equipment must be inspected by a qualified person	maintain a record of the dates and results of inspection
		Shift Inspection to be carried out by a competent person.	Yes	No		
		Monthly equipment inspection to be conducted by a competent person	Yes	No		
		Annual thorough equipment inspection to be conducted by a competent person	Yes	Yes		
		wire rope inspection and repair/replacement	Yes	Yes		
5	Wire Rope 1926.1413					
		Daily, Monthly and Annual Inspection of wire rope	Yes	Yes		
		Wire rope selection and replacement must be in accordance with manufacturer's specification.	Yes	Yes		
		Wire rope must comply with section 5-1.7.1 of ASME B30.5-2004	Yes	Yes		

COMPARATIVE ANALISYS OF THE NEW AND OLD OSHA CRANE & DERRICK REGULATION						
ITEM	TOPIC	ACTIVITY	NEW RULE	OLD RULE	SUMMARY DESCRIPTION - NEW RULE	SUMMARY DESCRIPTION - OLD RULE
		Wire rope must be designed to prevent sudden rope failure	Yes	No		
6	Crane Signaling & Safety Devices 1926.1415/1419				Wire Rope 1926.1413 § Wire Rope must be inspected before each shift by a competent person. § Deficiency of wire rope must be examine by a competent person and removed if it's a safety hazard. § Monthly and Annual Comprehensive inspection of wire ropes by qualified person Crane Signaling 1926.1404(q)(4) Each outrigger or stabilizer must be visible to the operator or to a signal person during extension and setting. 1926.1441(f) Signal person qualifications. The employer must train each signal person in the proper use of signals applicable to the use of the equipment. 1926.1419(a)	1926.550(a)(7) Wire rope shall be taken out of service if : § Broken § Worn or distorted § Reduced diameter 1926.550*a)(4) § Hand signals to crane and derrick operators shall be per ANSI standard § An illustration of the signals shall be posted at the job site. § 1926.550(d)(3) Crane with power travel mechanism shall have an effective audible warning signal 1926.550(a)(15)(iv) A person shall be designated to observe clearance of the equipment and give timely warning
		Crane lever indicator on the equipment shall be either built-in or installed	Yes	No		
		Built-in or installed horn on the equipment shall be available to operator	Yes	Yes		
		Safety devices must be fully functional prior to start of operation	Yes	Yes		
		Boom stop indicators and hoist limiting devices	Yes	Yes		
		Jib stop indicators and limiting devices	Yes	Yes		
		Automatic overload prevention devices installed in modern equipment	Yes	No		
		Outrigger/stabilizer position sensor/monitor installed on equipment	Yes	No		
		A load rating chart with clearly , legible letters and figures and visible to operator	Yes	Yes		

COMPARATIVE ANALISYS OF THE NEW AND OLD OSHA CRANE & DERRICK REGULATION

ITEM	TOPIC	ACTIVITY	NEW RULE	OLD RULE	SUMMARY DESCRIPTION - NEW RULE	SUMMARY DESCRIPTION - OLD RULE
					A signal person must be provided in each of the following situations: § The point of operation, meaning the load travel or the area near or at load placement, is not in full view of the operator. § When the equipment is traveling in the direction of obstructed view. § Due to site specific safety concerns, either the operator or the person handling the load determines that it is necessary. 1926.1419(b) Types of signals. Signals to operators must be by hand, voice, audible, or new signals.	
7	Authority to stop operation 1926.1418	Operator must have the authority to stop operation whenever safety concerns exist.	Yes	No		
8	Operator & Signal Person Qualification 1926.1427/1428	Employer must ensure that crane operator is duly trained and qualified.	Yes	No	Authority to stop operation 1926.1418 Whenever there is a concern as to safety, the operator must have the authority to stop and refuse to handle	
		Option (1): Certification by an accredited crane operator testing organization	Yes	No		

COMPARATIVE ANALISYS OF THE NEW AND OLD OSHA CRANE & DERRICK REGULATION						
ITEM	TOPIC	ACTIVITY	NEW RULE	OLD RULE	SUMMARY DESCRIPTION - NEW RULE	SUMMARY DESCRIPTION - OLD RULE
		Option (2): Qualification by an audited employer program	Yes	No	loads until a qualified person has determined that safety has been assured Operator Qualification 1926.1427(a) § The employer must ensure that, prior to operating any equipment the operator is qualified or certified to operate the equipment. § Exceptions: Operator qualification or certification is not required when manufacturer-rated hoisting/lifting capacity is 2,000 pounds or less § The employer must provide the qualification or certification at no cost to operators employed on November 8, 2010. Operator Qualification Options § Option (1): Certification by an accredited crane operator testing organization. § Option (2): Qualification by an audited employer program § Option (3): Qualification by the U.S. military. § Option (4): Licensing by a government entity.	
		Option (3): Qualification by the U.S. military.	Yes	No		
		Option (4): Licensing by a government entity.	Yes	No		
		Employer must ensure that signal person is duly trained and qualified.	Yes	No		
		Option (1) The signal person has documentation from a third party qualified evaluator	Yes	No		
		Option (2)-Employer's qualified evaluator	Yes	No		

COMPARATIVE ANALISYS OF THE NEW AND OLD OSHA CRANE & DERRICK REGULATION						
ITEM	TOPIC	ACTIVITY	NEW RULE	OLD RULE	SUMMARY DESCRIPTION - NEW RULE	SUMMARY DESCRIPTION - OLD RULE
9	Training 1926.1430	Overhead power lines: The employer must train each employee	Yes	No	Training 1926.1430 The employer must provide training as follows: § Workers near Overhead power lines § each operator § Each assigned signal person. § Each competent person and each qualified person § each operator and employee authorized to start/energize equipment § refresher training § Training at no cost to the employee.	
		Signal persons: The employer must train each signal person	Yes	No		
		employer must train each operator-in-training	Yes	No		
		The employer must train each competent person and each qualified person	Yes	No		
		The employer must evaluate each employees	Yes	No		
		The employer must provide refresher training in relevant topics for employees	Yes	No		
10	Personnel Platform 1926.1431	The use of equipment to hoist employees is prohibited except where other choices are not feasible	Yes	Yes	Personnel Platform 1926.1431 § Hoist of employees on personnel platform is prohibited except when personnel hoist, ladder, etc. are more hazardous, or is not possible. Platform must meet the following: § Uniformly level § Outriggers extended and	1926.550(g) § Hoist of employees on personnel platform is prohibited except when personnel hoist, ladder, etc. are more hazardous, or is not possible. § Hoisting of the personnel platform shall be a slow, controlled activity.
		The equipment must be uniformly level	Yes	Yes		
		Equipment with outriggers or stabilizers must have them all extended and locked.	Yes	Yes		
		total load of suspended personnel platforms < 50% of rated capacity	Yes	Yes		

COMPARATIVE ANALISYS OF THE NEW AND OLD OSHA CRANE & DERRICK REGULATION							
ITEM	TOPIC	ACTIVITY	NEW RULE	OLD RULE		SUMMARY DESCRIPTION - NEW RULE	SUMMARY DESCRIPTION - OLD RULE
		A qualified person familiar with structural design to design personnel platform	Yes	Yes		locked § The total load must not exceed 50% of design load capacity § Equipment must have functional safety devices § A trial lift with the unoccupied personnel platform required	
		Rigging hardware must support platform without failure.	Yes	Yes			
		Trial lift and inspection is required	Yes	Yes			
		Personnel platform must not be used under severe weather conditions.	Yes	Yes			
		Fall arrest system must be provided	Yes	Yes			
		Hoisting personnel within 20 feet of a power line <350 kV, and within 50 feet of a power line > 350 kV, is prohibited	Yes	No			

APPENDIX C: SAMPLE-CRANE FATALITYACCIDENTS ANALYSIS

2002 CRANE FATALITY CAUSES										
summary_nr	report_ id	event_date	event_desc	Electro-cution	Struck By and Against	Caught By and Betwe-en	Fall	Cru -sh	Other causes	Tot al
202023305	316100	12/17/2002	Employee killed when crushed by tire guard of crane			0.5		0.5		1
201173234	950621	12/12/2002	Employee Crushed and Killed by Falling Crane		0.5		0.5			1
200525848	751910	12/5/2002	Construction employee killed in crane boom accident		1					1
201406725	552651	12/3/2002	Employee killed in fall from concrete form				1			1
201342656	729700	11/29/2002	Employee killed when pinned between crane and roof truss					1		1
200800589	523300	11/26/2002	Employee killed in fall from derrick boom				1			1
170667810	111500	11/26/2002	Employee died after being struck by falling trailers		0.5		0.5			1
201853744	452110	11/21/2002	Employee killed in fall from aerial lift		0.5		0.5			1
201056942	950642	11/19/2002	Employee Burned in Fire						1	1
202369211	105532 0	11/16/2002	Oil rig fire kills one Employee and injures another						1	1
200376028	454510	11/15/2002	Employee Killed When Struck by Crane Boom		1					1
200570547	316700	11/11/2002	Employee died when struck by steel tube		0.5		0.5			1
201103496	950624	11/5/2002	Employee Is Burned by Contact with Energized Conductor	1						1
200352847	453710	10/30/2002	Two employees killed, two injured in tower collapse				1			1
200211142	626000	10/23/2002	Employee fatally injured when struck by rebar		1					1
200901163	418400	10/23/2002	Employee killed after being struck by a crane's bucket		1					1
200642627	627700	10/21/2002	Employee electrocuted when crane boom strikes power line	1						1
200372688	454510	10/4/2002	Employee killed when crane boom falls		0.5		0.5			1

2002 FATALITY RELATED CAUSES OF CRANE ACCIDENTS												
summary_ nr	report_id	event_date	event_desc	Overt -urn /tips	Collap -se	Ground condi- tions	Power line contact	Over- loading	Wire rope/ hoist /sling	Other- Signal/ communicat -ion error	Tot al
202023305	316100	12/17/2002	Employee killed when crushed by tire guard of crane							1	1
201173234	950621	12/12/2002	Employee Crushed and Killed by Falling Crane							1	1
200525848	751910	12/5/2002	Construction employee killed in crane boom accident							1	1
201406725	552651	12/3/2002	Employee killed in fall from concrete form							1	1
201342656	729700	11/29/2002	Employee killed when pinned between crane and roof truss							1	1
200800589	523300	11/26/2002	Employee killed in fall from derrick boom							1	1
170667810	111500	11/26/2002	Employee died after being struck by falling trailers							1	1
201853744	452110	11/21/2002	Employee killed in fall from aerial lift							1	1
201056942	950642	11/19/2002	Employee Burned in Fire							1	1
202369211	1055320	11/16/2002 15:00	Oil rig fire kills one Employee and injures another							1	1
200376028	454510	11/15/2002	Employee Killed When Struck by Crane Boom							1	1
200570547	316700	11/11/2002	Employee died when struck by steel tube						1		1
201103496	950624	11/5/2002	Employee Is Burned by Contact with Energized Conductor				1				1
200352847	453710	10/30/2002	Two employees killed, two injured in tower collapse		1						1
200211142	626000	10/23/2002	Employee fatally injured when struck by rebar							1	1
200901163	418400	10/23/2002	Employee killed after being struck by a crane's bucket							1	1
200642627	627700	10/21/2002	Employee electrocuted when crane boom strikes power line				1				1
200372688	454510	10/4/2002	Employee killed when crane boom falls		1						1

APPENDIX D: SAMPLE-CRANE INJURIES RELATED ACCIDENTS ANALYSIS

2002 ANALYSIS OF CRANE INJURY CAUSES

summary_ nr	report_ id	event_date	event_desc	Electro-cution	Struck By and Against	Caught By and Between	Fall	Crush	Other causes Sling/ hoist break	Total
200052017	728900	12/29/2002	Employee injured by chemical burn from potassium hydroxide						1	1
201155843	950633	12/21/2002 7:20	Employee Struck in Leg By Broken Survey Line		1					1
201143401	950631	12/18/2002	Employee Suffers Facial Lacerations and Fractures						1	1
202313409	950612	12/15/2002	Employee Injured When Struck by Steel Plate		0.5		0.5			1
201172871	950621	11/12/2002	Employee struck by falling jib boom		0.5		0.5			1
201056959	950642	11/11/2002	Employee injured when struck by rail car		1					1
201065463	950632	11/8/2002	Employee sustains broken leg after being struck by rebar		0.5		0.5			1
201056967	950642	11/6/2002	Employee Suffers Crushing Injury To Thumb			0.5		0.5		1
201124013	950613	11/5/2002	Employee injured in fall from truck mounted crane				1			1
201156643	950633	11/4/2002	Employee's finger amputated while positioning metal coil			1				1
201034428	950635	11/2/2002	Employee injured when struck by wooden cribbing		1					1
201103363	950624	10/21/2002	Employee's thumb amputated in clamps of pallet stacker						1	1
952176	355116	10/17/2002 10:45	Electric shock - contact with overhead line thru boom	1						1
201633237	1054111	10/14/2002	Employee injured after 23 foot fall				1			1
201096211	950645	10/14/2002	Employee injured after boom collapses						1	1
202339438	352430	10/11/2002	Employee not injured when crane overturned						1	1
201633005	1054112	10/8/2002	Employee's Fingers Amputated by Chain			0.5		0.5		1

2002 ANALYSIS OF CRANE ACCIDENT CAUSES (INJURY RELATED)

summary_ nr	report_id	event_date	event_desc	Over -turn /tips	Coll-apse	Ground condi-tions	Power line contact	Over-loading	Wire rope /hoist /sling	Other-Signal/comm-unication error	Total
200052017	728900	12/29/2002	Employee injured by chemical burn from potassium hydroxide							1	1
201155843	950633	12/21/2002 7:20	Employee Struck in Leg By Broken Survey Line							1	1
201143401	950631	12/18/2002	Employee Suffers Facial Lacerations and Fractures							1	1
202313409	950612	12/15/2002	Employee Injured When Struck by Steel Plate							1	1
201172871	950621	11/12/2002	Employee struck by falling jib boom					1			1
201056959	950642	11/11/2002	Employee injured when struck by rail car							1	1
201065463	950632	11/8/2002	Employee sustains broken leg after being struck by rebar					1			1
201056967	950642	11/6/2002	Employee Suffers Crushing Injury To Thumb							1	1
201124013	950613	11/5/2002	Employee injured in fall from truck mounted crane			1					1
201156643	950633	11/4/2002	Employee's finger amputated while positioning metal coil						1		1
201034428	950635	11/2/2002	Employee injured when struck by wooden cribbing						1		1
201103363	950624	10/21/2002	Employee's thumb amputated in clamps of pallet stacker							1	1
952176	355116	10/17/2002 10:45	Electric shock - contact with overhead line thru boom				1				1
201633237	1054111	10/14/2002	Employee injured after 23 foot fall							1	1
201096211	950645	10/14/2002	Employee injured after boom collapses		1						1
202339438	352430	10/11/2002	Employee not injured when crane overturned	1							1
201633005	1054112	10/8/2002	Employee's Fingers Amputated by Chain							1	1