AN ASSESSMENT OF SAFETY RISK FACTORS DURING INSTALLATION AND DISMANTLING OF TOWER CRANES ON CONSTRUCTION SITES

BY

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Declaration

I declare that this dissertationentitled “An Assessment of Safety Risk Factors during Installation and Dismantling of Tower Cranes in Construction Sites” has been carried out by me in the Department of Building, Faculty of Environmental Design, Ahmadu Bello University Zaria under the supervision of Dr. S.S. Aliyu and M. Abubakar. The information sourced from existing body of knowledge has been duly acknowledged in the text and a list of references provided. No part of this dissertation was previously presented for another degree or diploma at this or any other Institution.

Salihu Abdulmutalib Adavuruku_____

Name of Student Signature Date

Certification

This dissertation entitled AN ASSESSMENT OF SAFETY RISK FACTORS DURING INSTALLATION AND DISMANTLING OF TOWER CRANES IN CONSTRUCTION SITES by Abdulmutalib Adavuruku SALIHU meets the regulations governing the award of the degree of M.Sc Construction Management of the Ahmadu Bello University, and is approved for its contribution to knowledge and literacy presentation.

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Dedication

This dissertation is dedicated to my parents Mr/Mrs Salihu Husseini Balogun, my siblings and more importantly my wife and kids for their tireless and relentless effort in praying, encouraging and supporting me through various means that saw me through this programme.

Acknowledgement

I wish to express my sincere gratitude to my team of vibrant and energetic supervisors; Dr. S.S. Aliyu and M. Abubakar for their immeasurable contribution towards the successful completion of this dissertation by way of advising, encouraging, constructive criticism and valuable input.Special thanks to Dr. S. Muhammad and all the entire staff inDepartment of Building, Ahmadu Bello University, Zaria for their relentless efforts and meaningful contributions, may the Almighty God reward you all. Not forgetting also my very good friends, Kasuwa C.M., Oyeleke F.M., B. Umar., Sani A., and Kabiru for their advice and useful contribution during the course of carrying out the research, I say thank you all. Finally, my appreciation goes to the entire students of M.Sc 2014/2015 session for their contribution and also making my stay worthwhile during my course of study.

Abstract

The process of erection, dismantling and alteration of heights in tower cranes are major safety determinants on construction sites and can result to fatal accidents if the risks involved are not properly managed. Risk factors associated with this process have been identified by some researchers but, no effort was made to scientifically analyse these factors. Hence, the research aimed at assessing safety risk factors during installation and dismantling of tower cranes with a view to establishing the most significant risk factors. A well-structured questionnaire was used to collect data from safety managers, equipment managers and team leaders of installation and dismantling operation with respect to probability/likelihood of occurrence and degree of impact for safety risk factors.Data obtained wereanalysed using descriptive statistics (mean and percentages). From the results, relative significance index score (RSIS) was obtained and evaluated on a 5x5 matrix risk rating scale to determine the criticality of safety risk factors. Results showed that “abrasion”had the highest probability of occurrence with a mean value of 3.63 and as such, the most probable factor that occur on site. The study also found that “fracture of a wire rope during dismantling” had the highest degree of impact with a mean value of 4.63 and can result to fatality on site. The latter also had the highest RSIS of 15.6 indicating a high risk factor. This research concludes that fracture of a wire rope during dismantling is a high risk factor and could result from poor maintenance culture that is generally lacking on construction sites.

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CHAPTER ONE

1.0 INTRODUCTION

1.1 Background of the Study

Tower cranes are used on construction sites as lifting equipment for their combination of height and lifting capacity. Tower crane accidents, however, are likely to be fatal because of the weight of the objects and the heights to which they are lifted (Beavers, Moore, Rinehart and Schriver, 2006). U.S. Labour statistics recorded 632 crane-related construction worker deaths from 611 crane incidents and 17 multiple death incidents resulting in 38 deaths from 1992 to 2006 (Bureau of Labour Statistics, 2008).

A crane safety analysis and recommendation report carried out in Singapore by Annex (2009) indicates that in 2008, there were 162 crane-related accidents, injuries and dangerousoccurrences, a 27% increment from 128 cases in 2007. However, most of the cases involve less serious non-fatal injuries crane accidents can undoubtedly result to big and severe damage to physical properties and human lives.

Orji, Enebe and Onoh(2016) posit that construction processes in Nigeria are characterized by unsafe practices leading to accident that leaves severe consequences on both the project and the workers. Accidents in building construction sites, whether minor or fatal could result to injuries, loss of resources, partial or permanent disability and death in case of fatalities. In an analysis of types of accident that usually occur in construction sites, injury from the use of equipment ranked first among nine (9) other types of accident examined.

Idoro (2011) asserted that although there is no reliable construction accident/incident data in Nigeriannevertheless, a study carried out on 40 contractors in 2006 showed that the rate of accidents and injuries in the Nigerian construction industry were high and the most

suitablesafety ratios were 2 accidents per 100 workers and 5 injuries per 100 workers.

Kadiri, Nden, Avre, Oladipo, Edom, Samuel, and Ananso (2014) stated that as the growth rate of construction industry increases in Nigeria, this also causes an increase in competition of projects to be executed between construction firms which are however, achieved at the expense of the workers safety and their welfare.

In this way recognizing the different causes and impact of accidents on construction sites and proposing ways and methods for decreasing these accidents ought to be recognized. Erection/climbing/disassembling of tower cranes is a possibly unsafe process including working at heights, awkward postures, lifting and adjusting parts of huge size and mass and introducing temporary support systems. These are all often performed under significant time pressure, as a result of this, the need for road closures, suitable daylight hours or short weather windows as the case maybe are pertinent (Safework, 2016).

The most unsafe process that can prompt fatalities at construction sites is the installation/dismantling of tower cranes; for example, in 2012, the fall of a tower crane amid disassembling at the University of Texas, USA claimed the lives of two workers (Occupational Safety and Health Administration, [OSHA] 2012).

There have been five lethal accidents identifying with tower crane use amid 2002– 2006 in Hong Kong, with three workers losing their lives in July 2007 alone. One of such mishap in July 2007 resulted to two fatalities and five genuine wounds. The accident occurred amid the disassembly procedure, with workers on the tower crane as it was moving down (Ting, 2007).

Also in a related development, out of the 571 incident cases of crane related accidents that happened from 2000 – 2009 in the U.S as examined by Zhao (2011), 41 cases which amounted to 7.18% occurred during assembly/disassembly. He further went ahead to say that

22 cases (23.40%) of the 94 cases that occurred from 2007-2009 resulted directly from the operations of assembly/disassembly.Recent study of tower crane accidents in Korea from 2001-2011, showed that out of the 38 fatal accident cases involving tower cranes, 68.4% of the accidents resulted from the installation/dismantling operation (Shin, 2015).

Effective safety management is to make the environment safe, to make the job safe and to make workers safety conscious. In recent years, many developed countries have considered safety as one of the important management issues of construction projects, especially, personal safety (Chen, Lu, and Huang, 2011).

Ali and Muhamad (2016) opines that without proper safety management of construction machines at construction sites, accidents could happen. Cranes are the machines that contribute to highest fatality rate in construction industry. It was concluded that cranes are machines with high risk and should be operated with safety management and strong communication between crane operator and signalman.

Hola (2010) stated that, the use of machines and equipment's are factors that generate hazards on construction sites and these hazards could cause accidents which result to injuries or even loss of lives. Safety measures at construction sites assist to prevent unforeseen incidents. Accidents at construction sites may result to loss of life and involve huge expenses in terms of cost. The occurrence of fatalities in construction sites normally leads to site closure for accident investigation, loss of man/machine hours, high labour turnover, loss of organisation reputation, loss of output, payment of burial expenses/compensation/insurance claims for the dead as the case may be (Emiedafe, 2017).

The consequences of building construction accidents are enormous and cannot be easily quantified, though inevitable but could be controlled to prevent minor or serious consequences to safety of workers (Orji *et al.,* 2016).

Identifying hazards and assessing risks in the workplace ensures safe work environment and healthy working conditions. The staff will feel well and the production and services will run easily. Hazard and risk factors coming from the workplace and working conditions ought to be assessed efficiently/systematically in the work environment. In the event that the hazards can't be wiped out totally, their noteworthiness to the health and safety of workers (magnitude of risk) ought to be evaluated and measures taken to minimize the risk to a reasonable level or to dispense it altogether (Vitharana, Subashi De Silva and Sudhira De Silva, 2015; Odeyinka and Dada, 2016; Finland Centre for Occupational Safety, (FCOS) 2017; Nordlof, Wiitavaara, Hogberg andWesterling, 2017).

Factors that influence construction site safety because of the use of tower cranes have attracted only little attention; they are normally addressed indirectly and mostly within the more extensive treatment of site safety or of crane work in general (Nunnally, 2000). Research focusing on crane safety that clearly suggests tower crane related risk factors or safety hazards is limited (Shapira and Lyachin, 2009). Hence the need to critically examine safety issues regarding the installation and dismantling operation of tower cranes.

1.2 Statement of Problem

Tam and Fung (2011) carried out a study on safety of tower cranes in Hong Kong where they discovered that the process of erection, dismantle and alteration of heights in tower cranes are major safety determinants on construction sites. In the examination, they found out that even though erection/dismantle workers were provided with the manufacturers instruction, they and their co-workers seldom have a look on it prior to implementing the stated procedures. They stated that this is so because, they have no time to do that and they can only rely on their practical experience.

However, relying on practical experience without following stated procedures by manufacturers during erection/dismantling of tower cranes lead to over confidence that brings about human errors and can result to accidents during this operation (Shin, 2015).

Occupational Safety and Health Branch [OSHB] (2012) also agreed that accidents may occur during crane erection, dismantling and height alteration operations due to failure to follow the correct procedures specified by the crane manufacturers. In order to avoid dangerous and expensive consequences a proper risk assessment is required to identify the hazards inherent in the operation and also the hazard which could result from adjacent activities.

If risk levels could be anticipated reliably and easily, construction workers and managers (company safety manager, site engineer, project manager, superintendents, etc.) could better mitigate the risks in numerous ways to ensure safety (Rozenfeld, Sacksand Rosenfeld, 2009; Umeokafor*et al.*,2014).

Chi, Sangwon, Dae and Yoonjung (2015) opines that, risk identification and cautioning can improve the safety of workplaces. By organizing high recurrence risk factors to viably control accident occurence and deal with the probability of lethal injuries on construction sites when an accident is unavoidable, enables/helps safety managers to comprehend the nature of construction accidents and plan for key risk mitigation.

However, Jannadi and Almishari (2003) having concerted to the fact that assessment of risk is crucial for improving safety, they went ahead to say that precise evaluation is not really necessary and that an estimated predicted level of risks will suffice for the safety managers to take necessary actions.

In construction sector, the percentage of work accidents is more extended as compared with other areas. In this context, it might be considered as necessary and useful for an extended

analysis of risk factors and even more identification of risk factors in construction as related to work safety on sites (Bogdan and Alina, 2017).

Yu, Ding, Zhou and Luo (2014) in his study, found that failure to carry out identification and analysis of safety risk is a major factor that causes accidents in China metro construction as it ranked 8th amongst the 40 factors identified as accident causal factors.

Practically, it is impossible for a project manager to focus attention on managing all identified risk factors hence, the reason to carry out a proper analysis to help prioritize those identified (Odeyinka and Dada, 2016).

Researchers have not done much in scientifically addressing safety issues pertaining to tower crane erection/dismantling operations which has been stated by Neitzel, Seixas and Ren (2001); Beavers *et al.*(2006); Zhao(2011); OSHB(2012); Shin(2015)as a dangerous operation that could hamper safety on construction sites.

Although, Shin (2015) was able to identify some factors affecting safety during installation and dismantling of tower cranes, but no attempt was done to systematically analyse these factors to measure qualitatively or quantitatively the level of risk these factors poses to safety or their degree of influence on safety so as to establish the most significant ones where the limited resources for safety can be utilized to minimize the inherent risk.

1.3 Justification of the Study

The essence of this research cannot be overemphasized as our construction sites would continue to be a potential death trap if proper measures are not taken to manage the risk involved especially with tower crane usage whose accidents may not occur frequently but very disastrous when they do occur. Proper identification and analysis of all the risk factors involved during installation and dismantling operations would help us to determine the individual and combined effect as they affect safety which would aid in the accurate

measurement of risk and development of adequate risk response with respect to tower crane safety on our construction sites. On the other hand this would also help in the better allocation and utilization of limited resources. It is anticipated that the result of this research if implemented would help minimize accident occurrence on our construction sites especially with respect to tower crane usage.

1.4 Aim and Objectives

1.4.1 Aim

The aim of this research is to assesssafety risk factors during installation and dismantling of tower cranes with a view to enhancing safety on site.

1.4.2 Objectives

i. To identifythe safetyrisk factors during installation and dismantlingof tower cranes in construction sites.
ii. To determine theprobability of occurrence for each safety risk factor.
iii. To determine the degree of impact of the safety risk factors.
iv. To evaluate the safety risk factors based on established risk rating scales.

1.5 Scope and Limitations

1.5.1 Scope

This research is limited to opinions of safety managers, team leaders and equipment managers practicing in Abuja, Lagos and Kaduna. This is so because their nature of work have exposed them to the use of tower cranes and they would have gained the requisite experience needed to give correct insight about the information required. Abuja, Lagos and Kaduna were chosen because they are known with high rate of construction activitiesinvolving the use of tower cranes. Safety risk factors during the operation of tower cranes were not considered for the research, only those associated with the process of installation and dismantling of tower cranes were considered.

1.5.2 Limitations

i. The fewer number of research so far carried out on installation and dismantling of tower cranes made it difficult to draw up inferences for the study.

ii. The study could not cover all the states in Nigeria which could have made the findings more generalized.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Overview of Safety Issues in Construction Industry

The construction industry is often considered as a risky business due to its complexity and strategic nature. It requires various project stakeholders, internal and external factors which will prompt huge dangers. Sadly, the construction industry has a poor notoriety in hazard investigation or risk analysis when compared to other industries (Laryea, 2008). Construction projects are initiated in perplexing and dynamic conditions bringing about conditions of high vulnerability and risk, which are aggravated by requesting time limitations. Construction industry has changed essentially in the course of recent years, it is now an industry driven primarily by private investors; the presence of securitized real estate has increased considerably. It is vulnerable to the numerous technical & business risks that often represent greater exposures than those that are traditional. Thus risk assessment need arises (Jayasudha and Vidivell, 2016).

Guo, Heng and Vera (2013) however posits that construction safety is a serious problem in the construction industry worldwide, especially in large-scale construction projects. In order to improve the safety management performance, there is need to properly identify the causes of accident occurrence in any construction project.

2.1.1 Safety risk assessment in construction

The general approach to risk assessment in construction as in other industries, as presented in the professional literature and standards (Hinze, 1997; Polish Standardization Committee [PN-N] 2000; Holt, 2001; Manuele, 2005), is to identify the risks and then evaluate them by multiplying the likelihood of an accident by the potential severity of that accident. The troublesome piece of this approach is to assess the probability of any potential accident.

The very first step is to identify and assess risks for each specific kind of activity. Recognizing hazards can be a difficult choreon the ground that, there are many different kinds of factors, and determining the relevance of each one is right around an unthinkable mission. In principle, statistical analysis of historical construction workrelated accident data, seeking the numerical probabilities and severity levels for each type of accident, would be a direct method to evaluate the risks. Be that as it may, this approach is dangerous for two reasons: the likelihood of occurrence for most potential accidents is extremely small, and, as Gyi, Gibb and Haslam (1999) pointed out, there is a high rate of under reporting of accidents and near-misses. Thus very large sample sizes would be required to achieve statistical significance of the distributions obtained. Yet detailed information for assessing any kind of risk is rarely available (Warszawski and Sacks, 2004). Indeed, accident reports are becoming increasingly unavailable to researchers as a result of privacy protection laws. Luckily, although assessment of risks is vital for improving safety management, exact assessment isn't generally necessary (Jannadi and Almishari, 2003); an estimated predicted level of the risks will just be fine for the safety manager to take the right actions. A drawback of existing methods for risk assessment in construction (Jannadi and Almishari, 2003; Yi and Langford, 2006; Wang and Boukamp, 2007) is that they don't unequivocally represent the fact that on construction sites, workers not only endanger themselves or others in their immediate working environment,they likewise jeopardize other personnel who may be in the path of danger above, below or in the same vicinity. Falling objects, for example, are a particular hazard that is relatively unique to construction environments.

2.2 Accidents in the Nigerian Construction Industry

Accidents frequently occur on building construction sites. These accidents could be in the form of workers falling from heights, excavation accidents, the risk of falling debris or

equipment's etc. Researchers have shown that accidents and injuries in developing countries are by and large high when contrasted with other European nations (Idoro, 2008).

Kadiri *et al.* (2014) expressed that as the development of construction industry blooms in Nigeria, this additionally makes an expansion in rivalry of activities to be executed between construction firms which are anyway accomplished to the detriment of the workers welfare and their safety. Accordingly recognizing the different causes and impact of accidents on construction sites and proposing ways and means of minimizing these accidents ought to be recognized. These accidents result in bodily injury or even death. Loss of income, psychological effects is also experienced by such workers.

2.3 Tower Cranes and their Safety Issues

As one of the most noticeable objects on construction sites and a symbol of modern construction operations, cranes possess the capacity of lifting heavy loads and manoeuvring the loads over long spans. When properly situated on a site, cranes can deliberately lift and lower loads to essentially any coveted area on a building site. Shockingly, when large numbers of cranes have been dispatched to a construction site, the hazard exposure also increases for construction workers who work with, around or under these cranes (Zhao, 2011).The wellbeing of building construction workers on site is vital to making progress in any project, when these workers are healthy, work can go on easily as essentially all works on site are reliant on the workers for implementation (Kolo, 2015).

Adnan (2001) posits that safety and health improvement brings about reduced accidents costs, increased productivity, enhances human relation and raises firm image. Operating a tower crane is a modern occupation that requires broad aptitudes and experience, as well as more essentially a complete comprehension of the states of the crane and its encompassing condition all through the task (Fang, 2016).

Tower cranes are unpredictable and impressive installations. When cranes collapses for instance, to gusts of wind this inevitably hits the regional and/or national news headlines and gets into the trade press (Health and Safety Laboratory, (HSL) 2010). Strangely, scientific literature devotes relatively little attention regarding breaking down the reasons for crane accidents and considering how they could be avoided (Swuste, 2005; Shapira and Lyachin, 2009).

Given that collapse of tower cranes could result in genuine dangers to the wellbeing of site work force and members of the public, organisation and individuals responsible for safety of tower cranes should take fitting measures to guarantee their safety and wellbeing (Construction Industry Council, (CIC) 2010).

Crane accident causes are most at times seen as operator errors on the part of crane operators. The risk appended to cranes are particular which is the reason why planning must be linked to specific hazards and to crane-centred risks such as those pertaining to its load, its location and its environmental conditions.In the event that these are disregarded, the risk will quickly increase and will create conditions of independent errors and management decisions consequently prompting accidents (Schexnayder, 2003; McDonald, Ross and Carnahan, 2011).

2.4 Installation and Dismantling Operation in Tower Cranes

Tower cranes are utilized broadly in construction sites to lift and move heavy materials. Despite the fact that they contrast in type, the primary parts are the same. A tower crane is fixed to the ground on a concrete slab anchor, sometimes it is additionally joined to the sides of structures.

A tower crane is installed at a construction site by assembling the primary components which are; the mast, slewing unit, operating cabin, jib, and counterweight. The base isconnected to

the mast, which gives the crane its height. The mast is then attached to the slewing unit (gear and motor) that makes the crane to rotate. On top of the slewing unit are three other vital parts: the long horizontal jib (working arm), the shorter counter-jib, and the operator's cab. A tower crane used to construct skyscrapers is typically assembled and climbed by putting frames inside the telescoping cage; this is known as a telescopic job. Prior to the installation of a tower crane, a constructor readies a lifting plan to include types, numbers, and capacities of the tower cranes to be operated. A decision to install tower cranes also must secure space for installation work in places where the tower cranes will stand and operate at the construction site. Figure2.1 shows the installation process (erecting and climbing) of a tower crane assembly: base anchor, assembling mast, tower crane coping cage, slewing unit, front jib, counter jib, front jib(2–3), counterweight, hoist winch, front jib(4–10), and telescoping. A dismantling procedure is generally inverse to the procedure of installation, however might be more difficult than the installation. The Guide for Installation/Dismantling of Tower Cranes describes the complete process (Shin, 2015).

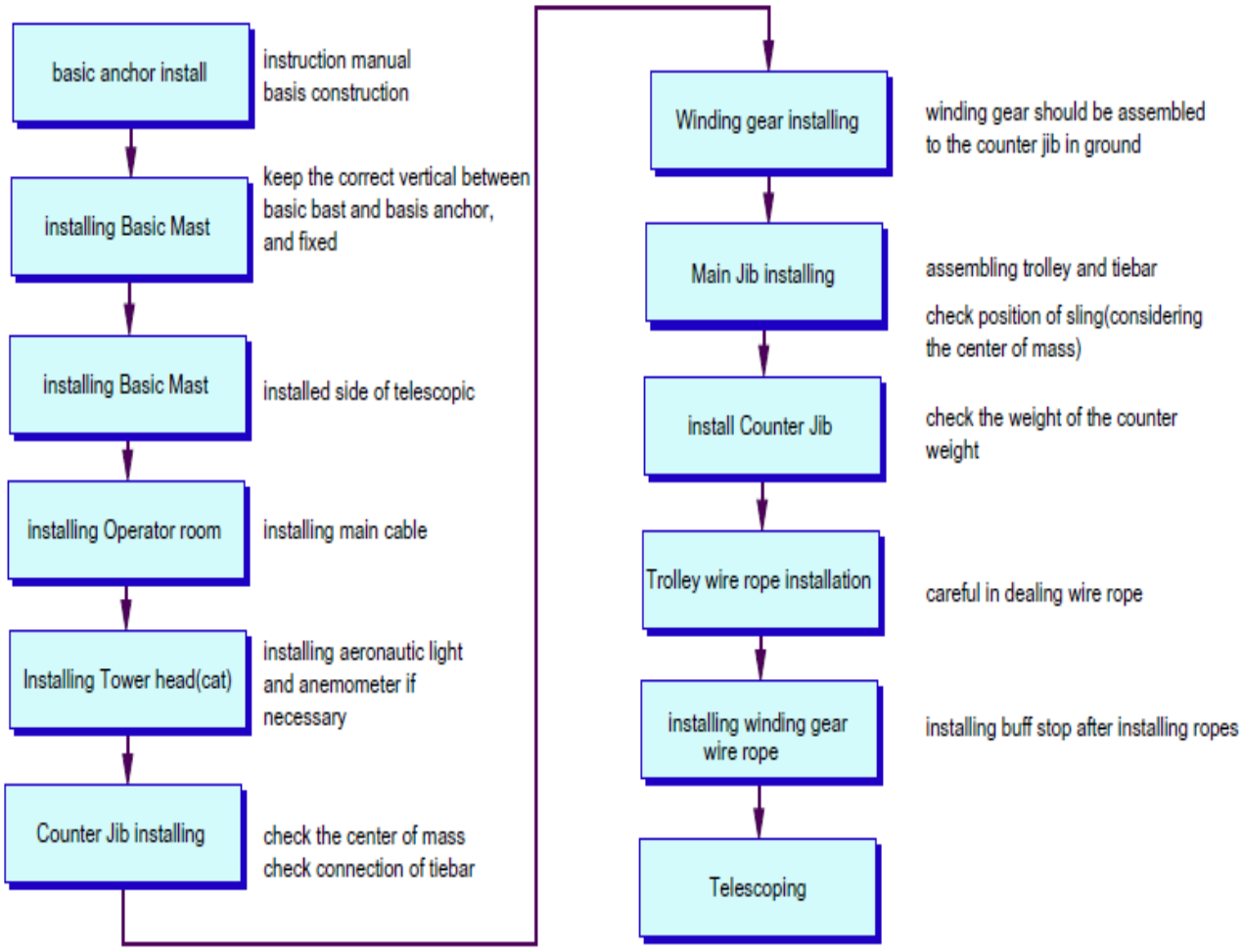


Figure 2.1:Tower crane installation and dismantling process

Source: Shin(2015)

2.5 Risk Assessment

The Health and Safety Executive [HSE] (1998) defined risk assessment/appraisal as a procedure that identifies the dangers related with specific activities/tasks, evaluates the effects of exposure to these hazards and actualizes the measure expected to control the risk of injury/ill health to as low a level as could reasonably be expected.

Risk assessment/appraisal includes recognizing potential dangers, assessing their probability, and estimating the consequences. The combination of these estimates signifies the risk associated with the activity being evaluated. More realistically, risk is perceived as a

collection of all possible pairs of likelihoods and outcomes [Li, Oi;i = 1,2,. . . ,n], where Oi and Li denote an outcome and its likelihood respectively. (Khanzode, Maitiand Ray, 2012).

The assessment of risks informs risk control choices, the usageof which is checked and reviewed to guarantee that risk is controlled and stays within tolerable limits (Lingardand Rowlinson, 2005). Assessing risks enables one to prioritize the action to be taken to control them. At the end of the day, risk assessment is about deciding who may be harmed and afterwardmaking a decision about how likely it is something turns out badly, and how genuine the consequences could be (Sarah, 2012).

Distribution pattern of a given likelihood-outcome pair is known as risk profile. Occupational injury risk is the probability of getting injured whencarrying out a particular job. Phases in assessment of injury risk incorporate identification of hazards, assessment of risk, and categorization of risks based on risk index (Maiti, 2005). Risk assessment methodologies are classified as qualitative methods and quantitative methods.These categories can additionally be classified as deterministic, probabilistic, and combinatorial approaches. Quantitative risk assessment requires the estimation of frequency and consequence severity in quantitative terms. This method is viable when the risks are high, costs of detailed analyses are justified, and significant information is accessible. The results are represented in the form of risk profiles. Qualitative risk assessment/appraisal is more reasonable when risks are low and modest number of categories can cover whole range of consequences and likelihoods. The outcomes are represented in the form of risk matrices where occurrence probability and consequence severity represent the two axis.Risk assessment process involves two choices thus;

(i) Selection of criterion variables and,

(ii) Selection of modelling techniques.

As expressed before, the modelling techniques can be subjective utilizing scoring system to measure risk such as low, medium or high or quantify objectively the values of likelihood and consequences using probability distributions. Utilization of probability models likewise helps in developing risk intervals rather than a point value (Tixier, Dusserre, Salvi and Gaston, 2002; Arunraj and Maiti, 2007).

2.5.1 Risk identification

Canadian Centre for Occupational Health and Safety [CCOHS] (2017) defines risk identification as the way toward discovering, listing, and characterizing hazards. Generally speaking, the goal is to find and record conceivable hazard that might be available in your working environment. It might help to work as a team and incorporate both people who are familiar with the work area, as well as those who are not,by so doing you have both the experienced and fresh eye to carry out the inspection. In either case, the individual or group ought to be capable to conduct the assessment and have great knowledge about the hazard being assessed, any circumstances that may likely happen, and protective measures fitting to that hazard or risk.

To be sure that all hazards are found:

i. *Look at all aspects of the work.*
ii. *Include non-routine activities such as maintenance, repair, or cleaning.*
iii. *Look at accident / incident / near-miss records.*
iv. *Include people who work off site either at home, on other job sites, drivers, teleworkers, with clients, etc.*
v. *Look at the way the work is organized or done (include experience of people doing the work, systems being used, e.t.c).*
vi. *Look at foreseeable unusual conditions (for example: possible impact on hazard control procedures that may be unavailable in an emergency situation, power outage, etc.).*
vii. *Determine whether a product, machine or equipment can be intentionally or unintentionally changed (e.g., a safety guard that could be removed).*
viii. *Review all of the phases of the lifecycle.*
ix. *Examine risks to visitors or the public.*
x. *Consider the groups of people that may have a different level of risk such as young or inexperienced workers, persons with disabilities, or new or expectant mothers. (CCOHS, 2017).*

Dziadosz and Rejment (2015) and Odeyinka and Dada (2016) called attention to the different techniques that has been developed for risk identification. These includes brainstorming among project stakeholders, interviews, the internal audit in a company, the periodic document reviews, Delphi method, and the use of checklist and risk register.

> *Ways to find out if an identified factor poses a risk*
> *Each hazard should be studied to determine its' level of risk. To research the hazard, you can look at:*
>
> i. *Product information / manufacturer documentation.*
> ii. *Past experience (knowledge from workers, etc.).*
> iii. *Legislated requirements and/or applicable standards.*
> iv. *Industry codes of practice / best practices.*
> v. *Health and safety material about the hazard such as safety data sheets (SDSs), research studies, or other manufacturer information.*
> vi. *Information from reputable organizations.*
> vii. *Results of testing (atmospheric or air sampling of workplace, biological swabs, etc.).*
> viii. *The expertise of an occupational health and safety professional.*
> ix. *Information about previous injuries, illnesses, near misses, incident reports, etc.*
> x. *Observation of the process or task. (CCOHS, 2017).*

2.5.2 Risk analysis

Risk analysis is the primary component of risk management that enables experts to quantify and analyse risks that may present potential threats to project performance regarding cost, quality, safety, and time (Choudhry, Aslam, Hinze and Arain, 2014).

Risk analysis can likewise be said to be a procedure for comprehending the nature of hazards and determining the level of risk. It gives a basis for risk evaluation and choices about risk control. Likewise data can include present and chronicled data, theoretical analysis, informed opinions, and the worries of stakeholders. Risk analysis incorporates risk estimation. (CCOHS, 2017).

Risk analysis includes the qualitative and quantitative valuation of the identified risks the project managers and the team need to compute the likelihood of an incidence of the risk factors and the risk’s probable impact. Theypresumed that risk quantification model help in

gauging the likely outcome in terms of costs, schedule and quality.Consequently,gives motivator to the project team to correct these weaknesses (Walkerand Topkar, 2012).

2.5.2.1 Methods

Qualitative risk analysis

Qualitative risk analysis examines and prioritizes risk in light of the likelihood/probability of occurrence and the effect on the project that happens unexpectedly. Thus, recommends that mental suggestions to organising and prioritizing risks are the premise of qualitative risk analysis (Project Management Institute, (PMI) 2013).

De Marco and Thaheen (2014) opines that it is abroad approach to ranking risks by priority, which at that point controls the risk reaction process and furthermore helps in determining the end result of quantitative risk analysis or move directly into risk response planning. Getting ready for qualitative risk analysis requires the risk management plan as the first input which coordinates the process, the methodologies in use and the scoring model for identified risks. Qualitative methods create a list of risks, and risk ranking in order to prioritize risks for further analysis by evaluating and searching thoroughly the risks probability of occurrence and impact.

PMI (2013), established that project type have some significant relationship with the process especially when a new project has little or no historical background. Some of the qualitative techniques are; brainstorming, causes and effect diagram or Ishikawa diagram and checklists. Others are Delphi, Event and tree analysis, Risk breakdown matrix and Risk quality assessment. In qualitative analysis the following processes are achieved thus;

i. The analysis of the risk probability.
ii. Determine the risk impact on the project objectives
iii. The identification of root causes of the risks.
iv. The confirmation of the risk's importance.

v. Provision of prioritized risks according to PMI requirements.

Quantitative risk analysis

Quantitative technique is a numerical process of assessing the probability/likelihood and impact of identified risks on the project. Thus, it makes a widely inclusive risk score for the project (PMI, 2013; De Marco and Thaheen, 2014).

Galway (2004) expressed that there is no uncertain arrangement of criteria for deciding when to utilize quantitative techniques, yet it can't be completed before qualitative and semi-quantitative analyses. Quantitative risk analysis is more grounded than qualitative risk analysis as achievement of the project goals relies on utilization of numerous tools.

Some of the important quantitative techniques are; decision tree analysis and expected monetary value. Others are expert judgment, Fault tree analysis, fuzzy logic, probability distribution and sensitivity analysis according to (De Marco and Thaheen, 2014; Touran, 2006). In quantitative risk analysis the following processes are carried out. Thus;

i. Creation of numerical models.
ii. Achievement of combined results.
iii. Determine the confidence level on the project.
iv. Carry out sensitivity analysis.
v. Update the prioritized risk lists.

Monte Carlo simulations and system dynamics application utilizes computer-based tools in that way they are considered derivative concept of quantitative techniques. Perhaps, because of the prolonged use of numerical past data for such analysis (PMI, 2009).

2.5.2.2 Techniques

According to Baloi (2012) some of the risk analysis techniques available to include preliminary risk analysis, faulty trees, event trees, sensitivity analysis, probability analysis, certainty factors, Dempster-Shaffer Theory of Evidence and Fuzzy Logic. He chosefour of

these methods, probability analysis, certainty factors, Dempster-Shaffer Theory of Evidence and Fuzzy Logic and discussed them with regard to their application to risk analysis in engineering projects. The main reason for considering these four techniques is their potential to effectively handle uncertainty inherent in construction projects. He concludes the study by proposing probability analysis as the best technique to address risks factors that are organisation related such as;

i. Material
ii. Labour
iii. Equipment
iv. Estimator
v. Management
vi. Construction
vii. Finance

2.5.3 Risk components

Anonymous (2016) classified risk into three essential components. These components should be considered independently when decidingon the most proficient method tomanage the risk. Risk Components are:

i. The event that could occur – the risk,
ii. The probability that the event will occur – the likelihood,
iii. The impact or consequence of the event if it occurs – the penalty (the price you pay).

2.5.4 Risk matrix and scales

The Risk Matrix is additionally prevalently known as the Probability and Impact Matrix. The risk matrix is utilized during risk assessment and is born during qualitative risk analysis in the risk management process. It is an exceptionally powerful tool that could be utilized effectively with Senior Management to raise awareness and increase visibility of risks so that

sound decisions on specific risks can be made in context. A risk is “rated” for its Probability and Impact on a scale to comprehend where on the risk matrix it lies, which risks in the process push ahead into the risk management process is dependent on the industry, company, project and people. Some are naturallymore risk tolerant than others (Chittoor, 2013).

2.5.5 Importance of risk assessment

Risk assessments are vital as they form an integral part of an occupational health and safety management plan. They help to:

i. Create awareness of hazards and risk.
ii. Identify who may be at risk (e.g., employees, cleaners, visitors, contractors, the public, etc.).
iii. Determine whether a control program is required for a particular hazard.
iv. Decide if existing control measures are sufficient or if more ought to be done.
v. Prevent injuries or illnesses, particularly when done at the design or planning stage.
vi. Prioritize hazards and control measures.
vii. Meet legal requirements where applicable (CCOHS, 2017).

2.6 Review of Tower Crane Studies

An accident investigation by Beavers *et al.* (2006) found that inadequate performance of crane operators and riggers was the fundamental purpose behind crane accidents, in light of the high likelihood of accidents shown by examination of fatalities happening amid the years 1997– 2003 in the USA. Research indicates that the prevalent causes of crane-related accidents include human error such as carelessness because construction safety largely depends on worker performance (Shapiro *et al.,* 2000; Beavers *et al.,* 2006).

Aneziris *et al.* (2008) utilized Netherlands accident information to build up a measuring model for the risk of crane collapse, overturning, or dropping loads/objects. Work environment safety is influenced by different factors and crane accidents have a tendency to

be under-reported in the construction industry therefore, accident investigation may not uncover every single related factor (Shapira and Lyachin, 2009). They used interview and survey studies to investigate factors that affect safety of tower crane operation at construction sites and identified 21 factors, categorized into four groups: project conditions, environment, human factors, and safety management. However, their study excluded the installation/dismantling of tower cranes.

Sertyesilisik, Tunstall and Mcloughlin(2010) investigated lifting operations from the planning stage to operation in the United Kingdom and found that the experience and knowledge of crane teams needed improvement and that training issues regarding inspection and maintenance required careful monitoring. Tam and Fung (2011) pointed out the importance of underlying conditions for tower cranes in a Hong Kong case study. Inadequate safety training and unsafe working conditions are other factors responsible for tower crane collapse (Sertyesilisik *et al.*, 2010; Tam and Fung, 2011).

A model development study by Li, Chan and Skitmore (2012) proposed a virtual safety training system for tower crane dismantlement work. Shapira, Simcha and Goldenberg (2012) developed an integrative model for quantitative evaluation for safety on construction sites with tower cranes. Other research has concentrated on upgrading the performance of cranes and their operation (Rosenfeld and Shapira, 1998; Kim and Singhose, 2010; Kim, Kim, Lee and Ryu, 2011; Chi, Chen, Kang and Hsieh, 2012).

Kim (2013) overviewed the working states of tower crane operators and found that workers experienced more challenges related to the climate, physiological and psychological elements when dealing with elevated structures than while doing general building jobs.Swuste (2013) studied fatal tower crane accidents in the Netherlands and portrayed accidents involving tower cranes as 'ordinary mischances' because of their capabilities and the complexity of

installation. Examination of tower crane collapse found these reasons to be due to errors by the builders and operators in identifying and interpreting crane capacity and operation (McDonald *et al.,* 2011; Zrnic, Bosnjak, Gasic, Arsic and Petkovic, 2011; Frendo, 2013; Marquez, Venturino and Otegui, 2014).

In Korea, Shin (2015) in his research analysed accident reports related to tower cranes on construction sites, especially accidents happening during tower crane installation/dismantling and then identified some factors affecting safety during installation/dismantling of tower cranes, and concludes that 68.4% of the accidents resulted from the installation and dismantling operation.

2.7Review of Factors Affecting Safety during Installation/Dismantling of Tower Cranes

Not much has been done by researchers to clearly identify various factors affecting safety during installation and dismantling operation of tower cranes especially in Nigeria where construction site safety is very poor and accidents on construction sites are rarely reported nor documented for use as contractors are simply concerned with making maximum profit (Odeyinka and Dada, 2016).

However, according to OSHB (2012) accidents may occur during crane erection, dismantling and height alteration operations due to failure to follow the correct procedures specified by the crane manufacturers, use of incorrect parts, the wrong size or type of bolt, the incorrect assembly or sequence of assembly, or taking apart of components.

The Construction Plant-Hire Association (CPA) (2011) outlines the following as the risks/hazards associated with tower crane assembly and disassembly. Thus;

a) **Assembly & Disassembly of sections on Ground**
    i. Pinched fingers
    ii. Tools slipping

iii. Misalignment

iv. Re-arrangement of strops

v. Sledge hammer work

vi. Working platforms

b) **Assembly & disassembly of sub items**

i. Falling items

ii. Falling men

iii. Falling tools

iv. Misalignment

v. Incompatibility

vi. Missing items

In a more recent development a research carried out by Shin (2015) identified the following as factors affecting safety of tower crane installation/dismantling in construction sites. Thus he stated that;

a. It is a dangerous, dirty, and difficult job that people avoid
b. A contract of tower crane installing/dismantling is generally a sub-contract between the lessor and the tower crane installation/dismantling employer (team leader, subcontractor) following an agreement between a constructor (principal contractor) and the lessor for leasing the tower cranes.
c. The tower crane installation and dismantling firms are quit small, with insufficient capital to invest in tower crane safety
d. Incomplete numbers of workers to execute the work correctly and safely

i. The work is done by a highly-skilled and small team of construction workers

ii. The team leader (employer) faces some challenges from recruiting the required workers (need at least more than 5 skilled persons for installing or dismantling one tower crane)

iii. Young workers who are ready to do the work are lacking

iv. Lack of qualified persons who are well trained and have good experience for the job

v. Workers (erector, dismantler) are quitting the job very often, due to unbearable working conditions

vi. Always working on weekends and holidays, for example, on Saturday and Sunday

vii. Time constraintsdemanded from principal contractors or employer

viii. Trying to complete the work earlier than the ample time for safe work

ix. Frequently omitting necessary safety procedures or rules for numerous reasons

e. Lack of worker competence

i. They have just little knowledge of the characteristics of variouskinds of tower cranes

ii. Erectors and dismantlers have the tendency to just work based on previous experience and not from the stated manual of specifications for the tower crane

iii. There isn't any precise training centreto add knowledge to tower crane workers

iv. Manuals are written in foreign languages which makes it difficult for workers to comprehend.

f. Instruction and supervising at construction sites are not sufficient

i. Only a few qualified and experienced supervisors and trainers work at construction sites to educate workers

ii. No training materials are usable for the work in the sites

iii. The chief manager, safety officer, and supervisors at the construction sites of the principal contractor do not see the need to ensure the safety of tower crane installation and dismantling

g. Unreasonable site conditions
   i. Lack of working space, miss-arrangement of materials, conflicts with other construction processes
   ii. Ground conditions not well prepared, narrow roads, soft ground, and no way for the crane to reach the site.
   iii. Not securing work space by restricting access of other people to the area
   iv. The principal contractor isn't interested in the work, abandoning the work to the hands of the lessor.

h. Deterioration of tower crane parts (components)
   i. Pins, bolts, and other parts are not fixed properlyreasons been that they have been used for a long time
   ii. Workers have to work forcefully because bolts, nuts, or frames are not correctly fixed
   iii. The lessor tends to bye-passregular maintenance or inspections
   iv. The lessor suffers from low cost on the contract

i. Objects that ought to be hoisted and moved in construction sites are heavier than before such as PC, FORM, H-BEAM and so on.
   i. Overloading with objects exceeding the tower crane load limit
   ii. For time savings, some operators in construction sites might ignore the safety device (overload protective devices) which cause fatigue in components of the tower crane, leading to fracture.

j. Inexperienced tower crane operators

k. Not following work procedures in manuals for the installation, climbing, and dismantling of tower cranes

Shin (2015) further listed some factors that could easily result to accidents as a result of tower crane installation/dismantling based on each work phase as shown in Table 2.1.

Table 2.1: Dangers of accidents related to tower crane installation/dismantling

Work phases	Dangers of accidents
Erecting work	Asymmetric load caused by wrong setting of the foundation anchor, which inclined to one side Insufficient installation of a telescopic shoe (incomplete of fixing or mounting) Poor supporting/fastening of a brace/block to a mast Not using safety belts Working without a scaffold and work plates
Climbing work	Imbalance of each jib while telescoping by not using a counterweight Unlocking or missing of fixing pins at both ends of the sides (not clapping and fastening all bolts) Insufficient loading conditions in the mast bogie rails Derailment of a mast from bogie rails Imbalance due to failure to use a balance mast Buckling of a telescopic cage Fracture of clamped bolts supporting a circle ring
Dismantling work	Unsafe removal of pins on the telescopic supporter Jib fracture/inappropriate selection of the position for raising the main jib Fracture of a wire rope during dismantling Imbalance due to failure to use a balance mast
Common	Abrasion (wear and tear of components such as bolts, nuts, or pins) Incorrect stability of the slewing platform by not completing the connection or omitting bolts on the surrounding circle ring Inappropriate sling work or operation (incompetence of slingers) Errors of a crane operation or malfunction of a tower crane

Source: Shin (2015)

2.8 Reviewed Safety Risk Factors

There had been no previously established safety risk factors during installation and dismantling of tower cranes especially with respect to our own construction environment. However, attempts have been made by some researchers such as (Shin, 2015; OSHB, 2012; CPA, 2011) to identify some risk factors associated with installation and dismantling operation of tower cranes which can result into accidents that could range from minor injury to multiple fatality. All these factors were carefully reviewed and this research came up with a list of safety risk factors as shown in Table 2.3. The identified and reviewed safety risk

factors was used as basis for assessing the probability/likelihood of occurrence and impact of each factor identified.

Table 2.2: Safety risk factors

S/No.	Safety risk factors during installation and dismantling
1	Insufficient number of workers to perform the work correctly and safely.
2	Workers (erector, dismantler) are leaving the work often due to hard working condition).
3	Time constraints requested from employer/principal contractor.
4	Trying to finish the work earlier than the time required for safe work.
5	Frequently omitting required safety procedures or rules for various reasons.
6	Lack of workers competence.
7	Instruction and supervision at construction sites are insufficient.
8	Contractors do not recognise the need to ensure the safety tower crane installation/dismantling.
9	Unreasonable sites condition (working space, ground conditions and restrictions).
10	Deterioration of tower cranes part (components).
11	Workers attitude (installation/dismantling workers).
12	Overloading with objects exceeding the tower crane load limit.
13	Inexperienced tower crane operators.
14	Not following work procedures in manuals for the installation/climbing/dismantling of tower cranes.
15	Malfunction of a tower crane.
16	Buckling of a telescopic cage.
17	Fracture of a wire rope during dismantling.
18	Failure of working platforms.
19	Incompatibility of components.
20	Falling items.
21	Abrasion (wear and tear of components such as bolts, nuts, or pins)

Source: CPA (2011); OSHB (2012); Shin (2015)

CHAPTER THREE

3.0 RESEARCH METHODOLOGY

3.1 Research Design

Research design according to Walliman (2011) helps to provide a frame work for the collection and analysis of data and subsequently indicates which research methods are appropriate. This research adopted a quantitative research method through the use of a survey to achieve the desired objectives. This method was adopted because, the research seeks to describe the status of identified variables in a systematic order. Quantitative research includes the generation of data in quantitative form that can be subjected to rigorous quantitative analysis in a formal and rigid fashion (Kothari, 2004).

Figure 3.1 clearly explains how the research was conducted including the process followed and methods adopted to realize the set objectives of the research.

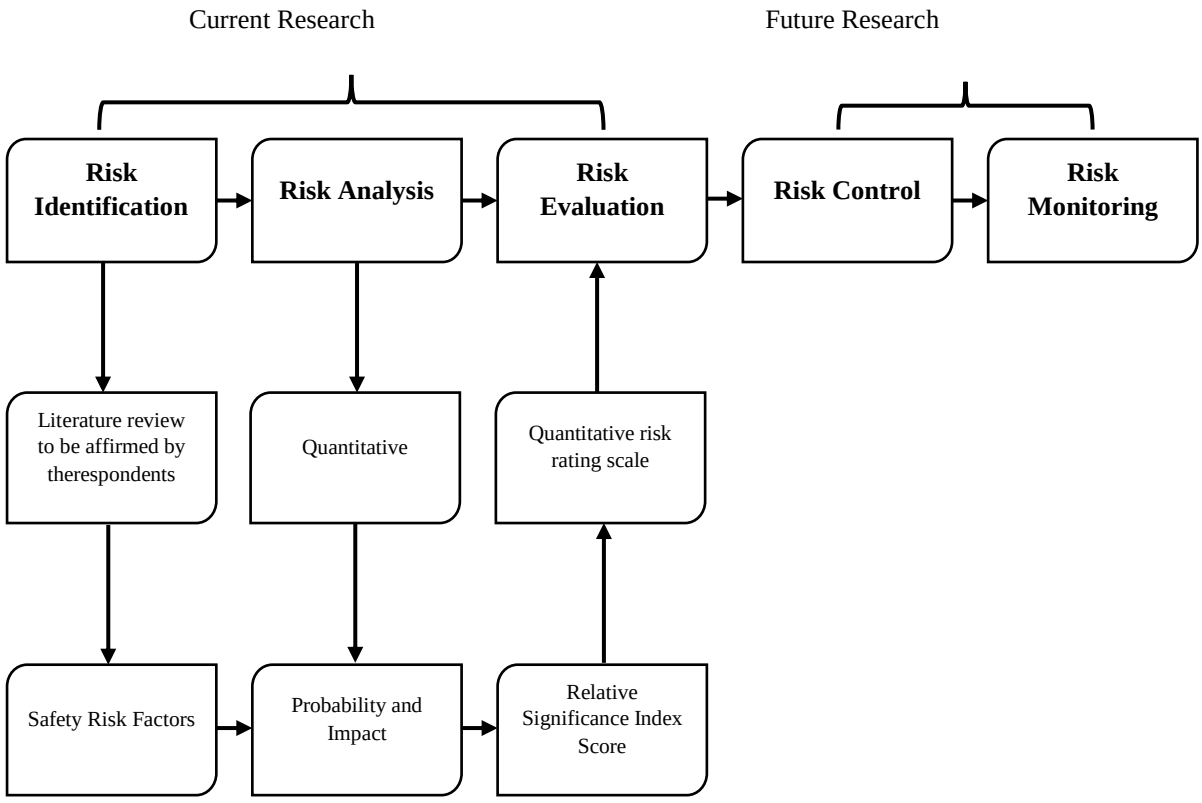


Figure 3.1: Flow process chart for the currentresearch and future study

3.2 Population, Sample Size and Sampling Technique

3.2.1 Population

The population for this study consisted ofsafety managers, team leaders and equipment managers.These practitioners were selected because, they are directly involved in the process and must have gotten the requisite knowledge to make precise judgement. The population size therefore for the research is unknown as no data is available on exact number of these practitioners.

3.2.2 Sample size

The sample size for this research wasobtained from Table 3.1developed by Louangrath (2014) that the minimum sample size for an unknown population for 95% confidence interval with 5% error level is approximately 34 counts.

Ejohwomu, Oshodi and Onifade (2016) sought the opinion of construction professionals in their research and got a 46% response rate. In a related development Kadir and Shittu (2015) who also got responses from construction professionals had a response rate of 73.68%. Aje (2012) also used questionnaire addressed to construction practitioners and got a response rate of 55.53%. Considering the above mentioned response rate from previous researches the anticipated response rate for this research was then derived from their average. Thus;

Average response rate = 46 + 73.68 + 55.53/3 = 58.4% ≈ **60%.**

Applying an anticipated response rate of 60%, the sample size would be;

Sample size = 34/0.60 = 56.67counts ≈ **57 counts**

Table 3.1:Minimum Sample Table Using Multistage Non-finite Population Method

%	$1-\alpha$	$\sigma_{N(0,1)}$	E	n_1	n_2	n_3	$\omega_{\max}$	$\omega_{\min}$	n
0.80	0.840	1.00	0.05	16.80	282.24	11.52	1,152.04	11.64	**23.88**
0.85	1.040	1.00	0.05	20.80	432.64	14.35	1,434.99	14.49	**26.65**
0.90	1.280	1.00	0.05	25.60	655.36	17.74	1,774.49	17.92	**29.64**
0.95	**1.650**	**1.00**	**0.05**	**33.00**	**1,089.00**	**22.98**	**2,297.83**	**23.21**	**33.72**
0.96	1.750	1.00	0.05	35.00	1,225.00	24.39	2,439.26	24.64	**34.75**
0.97	1.880	1.00	0.05	37.60	1,413.76	26.23	2,623.13	26.50	**36.03**
0.98	2.050	1.00	0.05	41.00	1,681.00	28.64	2,863.56	28.92	**37.65**
0.99	2.320	1.00	0.05	46.40	2,152.96	32.45	3,245.43	32.78	**40.08**
0.995	2.550	1.00	0.05	51.00	2,601.00	35.71	3,570.71	36.07	**42.04**
0.999	3.000	1.00	0.05	60.00	3,600.00	42.07	4,207.14	42.50	**45.63**
0.9999	3.291	1.00	0.05	65.82	4,332.27	46.19	4,618.69	46.65	**47.81**
1.00	5.500	1.00	0.05	110.00	12,100.00	77.43	7,742.74	78.21	**61.91**

(Louangrath, 2014)

3.2.3 Sampling techniques

Purposive sampling technique was used for carrying out this research. This technique was adopted because, the population size is unknown which makes it difficult to use any of the random sampling techniques.

3.3 Data Collection Method

Primary source of data collection was used for this researchas it involves knowledge elicitation from practitioners who are involved in the process of tower crane installation and dismantling in construction sites.

3.4 Description of Instrument

A well-structured questionnaire was used to elicit knowledge from the respondents about the subject matter.The questionnaire used was designed in three sections as indicated below;

Section A: Detail of the respondent.

Section B: Probability of occurrence forsafety risk factors.

Section C: Impact of safety risk factor during installation and dismantling of tower cranes.

The probability of occurrence and impact for each safety risk factor were assessed using a five point Likert scale. The Likert scale is as clearly explained for easy understanding in Tables 3.2 and 3.3 respectively.

Table 3.2: Likert scale for probability/likelihood of occurrence

Score	Probability of Occurrence	Description
1	Rare	This will probably never happen or recur
2	Unlikely	Do not expect it to happen or recur but it is possible it may do so
3	Possible	Might happen or recur occasionally
4	Likely	Will probably happen or recur, but it is not a persisting issue
5	Almost Certain	Will undoubtedly happen or recur, possibly frequently.

Source: CPA(2011)

Table 3.3: Likert scale for degree of impact

Score	Degree of Impact	Description
1	Negligible	Minor injury, no medical treatment, insignificant property or equipment damage
2	Minor Injury	Non reportable injury, requires medical treatment, temporary impairment, minor loss of process or slight property damage
3	Major Injury (RIDDOR)	Reportable injury, requires hospital admission, moderate loss of process, limited property damage.
4	Fatality	Major injury single fatality, injuries result in permanent impairment, critical process loss, critical property damage
5	Multiple Fatality	Multiple fatalities, catastrophic business loss

Source: CPA(2011)

Details of the questionnaireis as seen in Appendix 1. A total of 57 questionnaireswere administered.

3.5 Data Analysis

This research used descriptive statistics to analyse the data which was done with the aid ofstatistical tools such as SPSS and Microsoft Excel package. The mean scores were gotten for the probability of occurrence and impact after which the risk scores (RS) which is a function of the probability of occurrence and degree of impact was determined for each factor leading to the computation of their relative significance index score (RSIS) and then ranked

in descending order. A 5X5 matrix risk rating scale was then used to evaluate each risk factor based on their determined RSIS to establish the most significant ones. Thus;

$\mathrm{RSIS}^{i} = \frac{\sum_{j=1}^{N} RS_j^i}{N}$ ………………………………………… (Shen, George, & Catherine, 2001)

RSIS^{i} is the relative significance index score for risk i

RS_j^i is the risk score for risk i, as acknowledge by respondent j

N is the number of the respondent

But RS_j^i is a function of the probability of occurrence and the degree of impact therefore;

$RS_j^i = \alpha_j^i \beta_j^i$

α_j^i is the probability of occurrence for risk i, as acknowledge by respondent j

β_j^i is the degree of impact for risk i as acknowledge by respondent j

The relative significance index score is an analytical tool that helps to assess the probability and impact of a risk by quantifying it in numerical value which aid in the evaluation process as shown in Figure 3.1. The RSIS could have values that are not directly represented on the rating scale such as 7, 11, 13, 14, 17, 18, 19, 21, 22, 23 and 24. Hence, the need to modify the scale to incorporate these values by setting intervals to the prescribed colour representation.

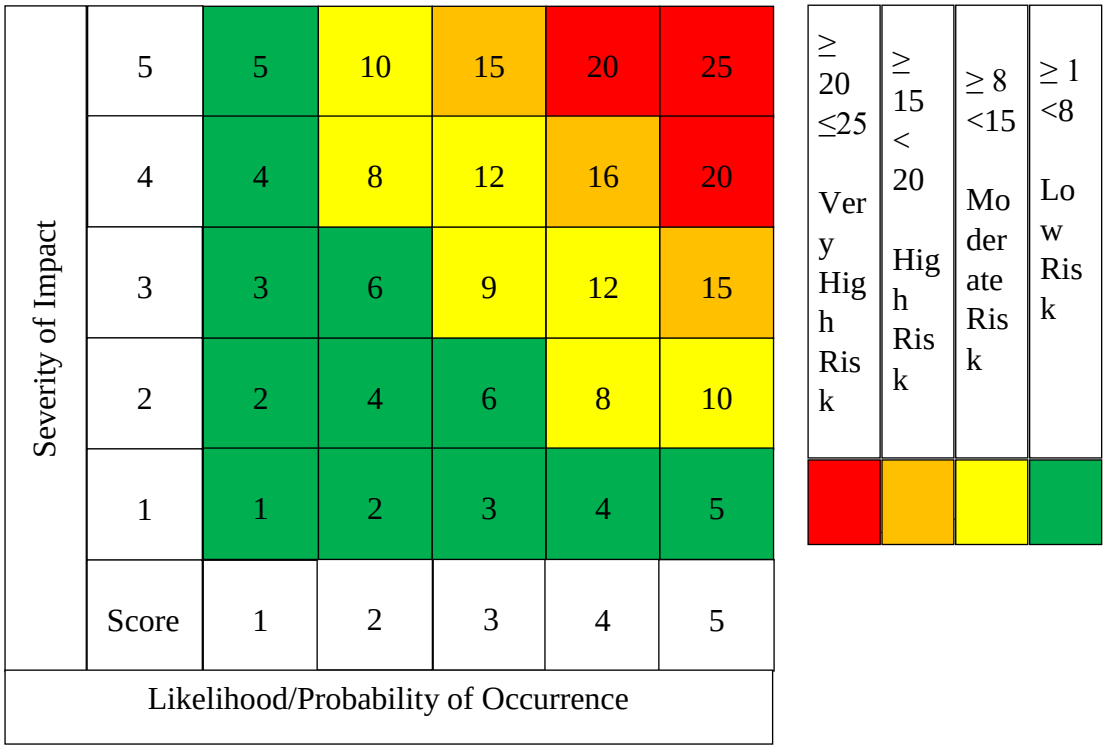


Figure 3.1: Quantitative risk rating scale for evaluating risk factors

Source: CPA(2011) and modified by the researcher to suit its purpose.

CHAPTER FOUR

4.0 DATA PRESENTATION, ANALYSIS AND DISCUSSION

4.1 Questionnaire Administered

The population of the study consisted ofsafety managers, equipment managers and team leaders of installation and dismantling work handling projects in Kaduna, Abuja and Lagos as at the time of carrying out the research. A total of 57 questionnaires were administered to the respondents.The completed questionnaire were checked to ascertain that they have been duly ticked/answered before they were analysed. The response rate is presented in Table 4.1.

Table 4.1:Response Rate of Administered Questionnaire

Questionnaires	Frequency (No)	Percentage (%)
Total administered	57	100
Total recovered	46	80.7
Total analysed	38	66.7

Source: Field survey (2018)

Table 4.1 shows that 80.7% of thequestionnaires were filled and returned but, only 66.7% were analysable. This is more than the minimum sample size of 34 (60%) required for a valid analysis.

4.2 Respondents Profile

This section presents the personal details of the respondents to include; their nature of job, educational qualification and years of experience as presented in Table 4.2.

Table 4.2: Respondents profile

Items	Frequency (No)	Percentage (%)
Job description		
Safety managers	14	36.8
Equipment managers	11	29.0
Installation and dismantling workers	13	34.2
Total	**38**	**100**
Educational qualification		
ND	12	31.6
HND	7	18.4
Bachelors	13	34.2
MSc.	6	15.8
Total	**38**	**100**
Years of experience		
0-5	13	34.3
6-10	20	52.6
11-15	4	10.5
16-20	1	2.6
>20	0	0
Total	**38**	**100**

Source: Field survey(2018)

Table 4.2 indicates that all the categories of respondents are adequately represented having at least ≈ 30% representation each with safety managers having a higher representation of 36.8% and equipment managers having the least representation of 28.9%. All the respondents had at least a post-secondary education with 13(34.2%) of them having a bachelors and 6(15.8%) had MSc. Table 4.2 also shows that 34.2% of the respondents had between 0-5 years of experience. A cumulative of 65.8% of the respondents have at least 6years of experience working in tower crane environment and were therefore able to make correct and valid judgement.

4.3 Probability of Occurrence for Safety Risk Factor

The probability of occurrence for each safety risk factor were scored by the respondents based on a five point Likert scale. Mean values were determined and standard deviation also determined to help rank the factors that have the same mean value as shown in Table 4.3.

Table 4.3:Probability of occurrence for Safety Risk Factors

S/No	Safety Risk Factors	Mean	SD	Rank
1	Abrasion (wear and tear of components such as bolts, nuts, or pins).	3.63	1.19	1st
2	Fracture of a wire rope during dismantling.	3.37	0.88	2nd
3	Deterioration of tower cranes part (components).	3.29	0.98	3rd
4	Inexperienced tower crane operators.	3.18	1.04	4th
5	Lack of workers competence.	3.13	1.10	5th
6	Trying to finish the work earlier than the time required for safe work.	3.05	0.96	6th
7	Buckling of a telescopic cage.	2.95	0.87	7th
8	Frequently omitting required safety procedures or rules for various reasons.	2.92	0.94	8th
9	Failure of working platforms.	2.92	1.05	9th
10	Falling items.	2.92	1.1	10th
11	Not following work procedures in manuals for the installation/climbing/dismantling of tower cranes.	2.89	0.92	11th
12	Contractors do not recognise the need to ensure the safety of tower crane installation and dismantling.	2.89	1.03	12th
13	Workers (erector, dismantler) are leaving the work often due to hard working condition.	2.74	1.13	13th
14	Insufficient number of workers to perform the work correctly and safely.	2.71	1.06	14th
15	Unreasonable sites condition (working space, ground conditions and restrictions).	2.61	0.82	15th
16	Time constraints requested from employer/principal contractor.	2.61	1.05	16th
17	Malfunction of a tower crane.	2.50	1.22	17th
18	Workers attitude (installation/dismantling workers).	2.47	0.89	18th
19	Instruction and supervision at construction sites are insufficient.	2.34	1.12	19th
20	Overloading with objects exceeding the tower crane load limit.	2.21	0.70	20th
21	Incompatibility of components.	2.16	1.08	21st

Source: Field survey(2018)

Table 4.3 presents the assessment of the probability of occurrence of each factor which shows that the most probable factor is “Abrasion (wear and tear of components such as bolts, nuts or

pins)" with a mean value of 3.63 and the least probable factor is "Incompatibility of components" with a mean value of 2.16. However, the first six (6) factors as seen in Table 4.3 had mean values ≥ 3.0 which means these factors have a possibility of occurring and may recur occasionally. The factors from 8th position to 21st had mean values ≥ 2.0 which means these factors are unlikely to recur but, have the possibilityof occurring. We can conclusively say that these results implies that all the identified factors have the possibility of occurring on our construction sites.

Researchers that previously looked at safety issues associated with tower crane installation and dismantling concluded that failure to follow work procedure is the most likely factor that can result to accidents on construction sites as stated by (OSHB, 2012; Shin, 2015). However, the results presented in Table 4.3 has proved otherwise by ranking "not following work procedure in manuals" as 12th position with a mean value of 2.89. This could imply that there have been an increased awareness and recognition of safety issues during installation and dismantling of tower cranes over the years which has made the users more safety conscious by implementing work procedures as stated in the manuals. Although, much still need to be done to reduce the likelihood of occurrence of the stated safety risk factor to its barest minimum.

The most probable factor been "abrasion (wear and tear of components such as bolts, nuts, or pins)" has affirmed previous research finding that maintenance management is a highly affecting factor on safety when using tower cranes as stated by (Shapira & Lyachin, 2009). This implies that this factor yet plays a great influence on safety during installation and dismantling and/or during operation.

It is also interesting to note that operator proficiency or experience of the tower crane operator which has been widely accepted as the major safety determinant on site as cited by (Shapira and Lyachin, 2009; Beavers *et al.,* 2006; Shapiro, 2000) was ranked 4th with a mean

value of 3.18. This implies that although it remains a probable factor according to this study however, it has a greater influence on safety during the operation of tower crane. Another likely reason for this factor been ranked 4th could be that operators had gained experience over the years thereby reducing its influenceon safety as tower cranes are now widely used and becoming a culture in every construction environment.

Incompatibility of components ranked the least amongst all other factors assessed which implies that tower crane manufacturers have continuously improved on the compatibility of itstower crane components. More efforts is still required to completely eliminate this factor as it's still a probable factor although not recurring frequently.

4.4 Degree of Impact for Safety Risk Factors

The impact of each factor were assessed using a five point Likert scale so as to establish their various levels of severity/degree of impact if they eventually occur on construction sites. The mean values were then calculated as shown in Table 4.4.

Table 4.4: Degree of impact for safety risk factors

S/No.	Safety Risk Factors	Mean	Rank
1	Fracture of a wire rope during dismantling.	4.63	1st
2	Not following work procedures in manuals for the installation/climbing/dismantling of tower cranes.	4.24	2nd
3	Overloading with objects exceeding the tower crane load limit.	4.18	3rd
4	Frequently omitting required safety procedures or rules for various reasons.	4.11	4th
5	Lack of workers competence.	4.03	5th
6	Unreasonable sites condition (working space, ground conditions and restrictions).	4.00	6th
7	Trying to finish the work earlier than the time required for safe work.	3.92	7th
8	Inexperienced tower crane operators.	3.89	8th
9	Deterioration of tower cranes part (components).	3.71	9th
10	Abrasion (wear and tear of components such as bolts, nuts, or pins).	3.63	10th
11	Malfunction of a tower crane.	3.61	11th
12	Incompatibility of components.	3.53	12th
13	Buckling of a telescopic cage.	3.47	13th

14	Falling items.	3.32	14th
15	Contractors do not recognise the need to ensure the safety of tower crane installation and dismantling.	3.26	15th
16	Failure of working platforms.	3.24	16th
17	Instruction and supervision at construction sites are insufficient.	3.05	17th
18	Insufficient number of workers to perform the work correctly and safely.	2.92	18th
19	Time constraints requested from employer/principal contractor.	2.76	19th
20	Workers attitude (installation/dismantling workers).	2.74	20th
21	Workers (erector, dismantler) are leaving the work often due to hard working condition).	2.34	21st

Source: Field survey(2018)

From the Table, fracture of a wire rope during dismantling had the highest degree of impact with a mean value of 4.63 which implies that the resultant effect of this safety risk factor if it occur is fatality, major injury/injuries, permanent impairment, critical process loss and critical property damage. The factor "workers (erectors, dismantlers) are leaving the work often due to hard working condition" had the lowest degree of impact with a mean value of 2.34 which therefore implies that it's resultant effect if it occur can only lead to minor injury. All the factors however has degree of impact that range from minor injury to fatality as shown in Table 4.4. There is a need to pay serious attention on the first six factors as they have mean values ≥ 4.0 which means if they occur, their resultant impact would lead to fatality on site.

Overloading tower cranes with objects exceeding its load limit is the 20th probable factor to occur on site as seen from Table 4.3. However, results for degree of impact in Table 4.4 showed that it has a high degree of impact if its accident does happen on site as it was ranked 3rd position amongst other factors with a mean value of 4.18. The latter is in line with previous findings that exceeding tower crane load limit results to accident on site that could be very fatal involving multiple injuries in most cases. From a careful observation of this factor, one would notice a sharp distinction between its probability of occurrence and degree of impact. The reason for this could be linked to the previous assertion that there has been a significant improvement in the level of safety awareness on site as a result of continuous

research on safety challenges associated with tower crane working environment thereby, reducing the probability of occurrence.

4.5 Evaluation of Safety Risk Factors

The safety risk factors were evaluated by first determining their relative significant index score which is a function of the probability of occurrence and the degree of impact. The result of this was then measured against a standard risk rating developed by CPA(2011) so as to come up with their risk levels as shown in Table 4.5.

Table 4.5Safety risk evaluation

S/No.	Safety Risk Factors	RSIS	Rank	Risk Level
1	Fracture of a wire rope during dismantling.	15.6	1st	High
2	Abrasion (wear and tear of components such as bolts, nuts, or pins).	13.2	2nd	Moderate
3	Lack of workers competence.	12.6	3rd	Moderate
4	Inexperienced tower crane operators.	12.4	4th	Moderate
5	Not following work procedures in manuals for the installation/climbing/dismantling of tower cranes.	12.3	5th	Moderate
6	Deterioration of tower cranes part (components).	12.2	6th	Moderate
7	Frequently omitting required safety procedures or rules for various reasons.	12.0	7th	Moderate
8	Trying to finish the work earlier than the time required for safe work.	12.0	8th	Moderate
9	Unreasonable sites condition (working space, ground conditions and restrictions).	10.4	9th	Moderate
10	Buckling of a telescopic cage.	10.2	10th	Moderate
11	Falling items.	9.7	11th	Moderate
12	Failure of working platforms.	9.5	12th	Moderate
13	Contractors do not recognise the need to ensure the safety of tower crane installation and dismantling.	9.4	13th	Moderate
14	Overloading with objects exceeding the tower crane load limit.	9.2	14th	Moderate
15	Malfunction of a tower crane.	9.0	15th	Moderate
16	Insufficient number of workers to perform the work correctly and safely.	7.9	16th	Low
17	Incompatibility of components.	7.6	17th	Low
18	Time constraints requested from employer/principal contractor.	7.2	18th	Low
19	Instruction and supervision at construction sites are insufficient.	7.1	19th	Low

20	Workers attitude (installation/dismantling workers).	6.8	20th	Low
21	Workers (erector, dismantler) are leaving the work often due to hard working condition).	6.4	21st	Low

Source: Field survey(2018)

From the Table, fracture of a wire rope during dismantling had the highest RSIS of 15.6 and implies a high risk factor which requires a high level of control put in place to forestall danger and make the working environment safer. The factors ranked from 2nd to 15th as shown in Table 4.5 had RSIS of 13.2 -9.0 respectively and as such implies that they are moderate risk factors that is acceptable but, requires suitable controls to maintain a safe working environment.Those ranked from 16th to 21st had RSIS of 7.9 – 6.4 respectively which implies low risk factors that are acceptable with no further action required. The factor "workers (erectors, dismantler) are leaving the work often due to hard working condition" had the lowest RSIS of 6.4 and does not really pose any treat to safety. This could be attributed to the high rate of unemployment in the country as reported by NBS (2017) thereby making the assertion in the factor false because, those who managed to be gainfully employed instead of leaving would rather do everything possible to keep their jobs so as to continue sustaining themselves. The fear that losing their job might make them become unemployed for the rest of theirlives makes people stick to the ones they have irrespective of the working condition. It is widely recognised that poor maintenance culture is lacking in both private and public sectors in Nigeria as stated by (Mbamali, 2003). This could therefore be the reason why "fracture of a wire rope during dismantling" closely followed by "Abrasion (wear and tear of components such as bolts, nuts or pins) had high RSIS of 15.6 and 13.2 respectively. Routine maintenance of the tower cranes could help to minimize the risk level.

CHAPTER FIVE

5.0 SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.1 Summary of Findings

From the results of the data analysed, these are the summary of the key findings. Thus;

i. The following were assessed as the most probable safety risk factors with mean values ≥ 3.0 “abrasion (wear and tear of components such as bolts, nuts, or pins); fracture of a wire rope during dismantling; deterioration of tower cranes part (components); inexperienced tower crane operators; lack of workers competence; trying to finish the work earlier than the time required for safe work.” Although not persistently, these factors occur and recur occasionally on site during installation and dismantling of cranes.

ii. Incompatibility of components ranked the least with mean value of 2.16 amongst all the factors assessed although, still a probable factor but not likely to recur often.

iii. The following factors were assessed to have a high degree of impact with mean values ≥ 4.0 “fracture of a wire rope during dismantling; not following work procedures in manuals for the installation/climbing/dismantling of tower cranes; overloading with objects exceeding the tower crane load limit; frequently omitting required safety procedures or rules for various reasons; lack of workers competence; unreasonable sites condition (working space, ground conditions and restrictions).”

iv. It was found that fracture of a wire rope during dismantling ranked 1st with RSIS of 15.6 closely followed by abrasion (wear and tear of components such as bolts, nuts, or pins) with RSIS of 13.2.

v. The following were evaluated as low risk factors with RSIS < 8 “insufficient number of workers to perform the work correctly and safely; incompatibility of components;

time constraints requested from employer/principal contractor; instruction and supervision at construction sites are insufficient; workers attitude (installation and dismantling workers); workers (erector, dismantler) are leaving the work often due to hard working condition".

5.2 Conclusion

The following conclusions were drawn from the findings of the study;

i. In assessing the probability of occurrence, the research concluded that all identified safety risk factors had the possibility of occurring even though they are not persistent or frequently occurring issues.

ii. Abrasion (wear and tear of components such as bolts, nuts, or pins) which could be seen as a maintenance management issue as looked at by previous research is a highly affecting factor on safety during installation and dismantling of tower cranes just as it affects safety during its operation.

iii. In assessing the degree of impactit was concluded that all safety risk factors assessed had degree of impact that range from minor injury to fatality with "fracture of a wire rope during dismantling" having the highest degree of impact that could result to fatality, major injury/injuries, permanent impairment, critical process loss and critical property damage.

iv. In evaluating the safety risk factors, the research concluded that fracture of a wire rope during dismantling is a high risk factor and therefore requires high level of control put in place to forestall any danger and make the working environment safer. This could be as a result of poor maintenance culture and lack of regular or routine check carried out by the users of the tower cranes.

v. It was concluded that, the factors evaluated as low risk are acceptable safety risk factors only to be noted, they do not require any form of control or further action carried out on them.

5.3 Recommendations

Based on the findings of the study, the following recommendation were made;

i. Adoption of a preventive maintenance strategy or routine check on the tower crane parts and components could help minimize the probability of occurrence of the safety risk factors such as “abrasion (wear and tear of components such as bolts, nuts, or pins)” and “fracture of a wire rope during dismantling”.

ii. The results of this research should be used by construction firms who engage in the use of tower cranes as a decision making tool to help control these safety risks.

iii. Installation and dismantling of tower crane is a dangerous operation as such, only competent workers should be allowed to do the job in line with stated work procedures.

5.4 Contribution to Knowledge

The study has established the following contributions to knowledge;

i. That abrasion (wear and tear of components such as bolts, nuts, or pins) has been established as the factor with the highest probability of occurrence on site during installation and dismantling of tower cranes with a mean value of 3.63.

ii. This research has also established that fracture of a wire rope during dismantling operation had the highest degree of impact with mean value of 4.63.

iii. That fracture of a wire rope during dismantling is a high risk factor with RSIS of 15.6 and requires high level of control.

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APPENDICES

Appendix A: Questionnaire

SAFETY RISK FACTORS DURING TOWER CRANE INSTALLATION AND DISMANTLING

Dear respondent,

This questionnaire is part of an MSc research aimed at **'Assessing the safety risk factors during installation and dismantling of tower cranes in construction sites'.** You are kindly requested to provide the relevant information that will help in achieving the set objectives of the research. The information provided will be treated confidentially and used strictly for the purpose of the research.

An average of 15minutes is required to fill the questionnaire.

Your participation will be highly appreciated.

Thank you.

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Section A: Please tick as appropriate

Personal details of respondents.

1. Nature of job: ( ) Safety manager ( ) Equipment manager ( ) Installation and dismantling worker
2. Highest educational qualification: ( ) Secondary school ( ) ND ( ) HND ( ) Bachelors ( ) MSc ( ) Others (please specify)……...
3. Any training certification obtained (please specify)……
4. Years of experience: ( ) 0-5 years ( ) 6-10 years ( ) 11-15 years ( ) 16-20 years ( ) 21-25 years ( ) Above 25 years

Section B: Probability/Likelihood of occurrence of risk factors during installation and dismantling of tower cranes.

Please indicate the extent to which each risk factor is likely to occur during installation and dismantling using a scale of 1 to 5 where the meaning to the scales are indicated below for better understanding.

Score	Probability of Occurrence	Description
1	Rare	This will probably never happen or recur
2	Unlikely	Do not expect it to happen or recur but it is possible it may do so
3	Possible	Might happen or recur occasionally
4	Likely	Will probably happen or recur, but it is not a persisting issue
5	Almost Certain	Will undoubtedly happen or recur, possibly frequently.

S/No.	Risk Factors	1	2	3	4	5
1	Insufficient number of workers to perform the work correctly and safely.					
2	Workers (erector, dismantler) are leaving the work often due to hard working condition).					
3	Time constraints requested from employer/principal contractor.					
4	Trying to finish the work earlier than the time required for safe work.					
5	Frequently omitting required safety procedures or rules for various reasons.					
6	Lack of workers competence.					
7	Instruction and supervision at construction sites are insufficient.					
8	Contractors do not recognise the need to ensure the safety tower crane installation/dismantling.					
9	Unreasonable sites condition (working space, ground conditions and restrictions).					
10	Deterioration of tower cranes part (components).					
11	Workers attitude (installation/dismantling workers).					
12	Overloading with objects exceeding the tower crane load limit.					
13	Inexperienced tower crane operators.					
14	Not following work procedures in manuals for the installation/climbing/dismantling of tower cranes.					
15	Malfunction of a tower crane.					
16	Buckling of a telescopic cage.					
17	Fracture of a wire rope during dismantling.					
18	Failure of working platforms.					
19	Incompatibility of components.					
20	Falling items.					
21	Abrasion (wear and tear of components such as bolts, nuts, or pins.					
If others, please specify						
22						
23						
24						
25						
26						

Section C: Impact of risk factors during installation and dismantling of tower cranes.

1. Please indicate the extent to which each risk factor impact on safety during installation and dismantling using a scale of 1 to 5 where the meaning to the scales are indicated below for better understanding.

Score	Degree of Impact	Description
1	Negligible	Minor injury, no medical treatment, insignificant property or equipment damage
2	Minor Injury	Non reportable injury, requires medical treatment, temporary impairment, minor loss of process or slight property damage
3	Major Injury (RIDDOR)	Reportable injury, requires hospital admission, moderate loss of process, limited property damage.

4	Fatality	Major injury single fatality, injuries result in permanent impairment, critical process loss, critical property damage
5	Mutiple Fatality	Multiple fatalities, catastrophic business loss

S/No.	Risk Factors	1	2	3	4	5
1	Insufficient number of workers to perform the work correctly and safely.					
2	Workers (erector, dismantler) are leaving the work often due to hard working condition).					
3	Time constraints requested from employer/principal contractor.					
4	Trying to finish the work earlier than the time required for safe work.					
5	Frequently omitting required safety procedures or rules for various reasons.					
6	Lack of workers competence.					
7	Instruction and supervision at construction sites are insufficient.					
8	Contractors do not recognise the need to ensure the safety tower crane installation/dismantling.					
9	Unreasonable sites condition (working space, ground conditions and restrictions).					
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20	Falling items.					
21	Abrasion (wear and tear of components such as bolts, nuts, or pins.					
If others, please specify						
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Please suggest ways in which these risk factors during installation/dismantling can be effectively managed.

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Thank you.