A Review of Risk Factors Affecting Safety During Installation and Dismantling Operation of Tower Cranes

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Abstract

The construction industry plays a central and significant role in the economy of any nation. One of the major reasons for ineffective project delivery in the Nigerian construction industry is the improper assessment of risk factors. The effect of cost overrun and schedule overrun not only influence the construction industry but the overall economy as well. The industry however is currently facing a lot of challenges to include constant increase in the rate of accidents on construction sites which could be due to ineffective safety management as construction companies are usually interested in maximizing their profit in order to secure funds for new investments, and cover possible expenses associated with the occurrence of risk factors during construction. Installation and dismantling of tower crane is a dangerous activity on construction sites that can result to fatal accidents if not properly managed. The first step to managing any risk process is to clearly identify the risk associated with the process. It is in view of this that this research aimed at reviewing relevant literatures on risk factors affecting safety during installation and dismantling of tower cranes with a view to establishing a list of safety risk factors upon which further studies can be carried out to complete the risk management cycle. These safety risk factors where validated through the opinion of stakeholders (Safety managers, Equipment managers and Installation/dismantling worker) engaged in the installation and dismantling of tower cranes on site. Their input helped to narrow down the list of safety risk factors to 21 amongst all the risk factors reviewed. It is recommended that a complete risk management process be carried out on this factors so as to help control the risk and eventually reduce the accidents as a result of installation and dismantling operation.

Keywords: *Accident, Hazard, Risk, Safety, Tower crane, Construction industry.*

Introduction

Construction industry is an important part of the economy in many countries and often seen as a driver of economic growth especially in developing countries. Typically, construction industry contributes to 11% of gross domestic products (GDP) in most developing countries (Giang and Pheng, 2010). In Nigeria, it contributed about 5-7% in the GDP growth, and over 42% of fixed capital growth over the last four (4) decades. (Dye *et al.*, 2010 as cited in Kolo, 2015). In construction sector, the percentage of work accidents is more extended as compared with other areas (Bogdan and Alina, 2017). The safety of building construction workers on sites is key to achieving success in any project, when these workers are healthy, work can go on smoothly as virtually all works on site are dependent on the workers for implementation (Kolo, 2015).

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 generally high when compared to other European countries (Idoro, 2008).

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 *et al.*, 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 signal man.

Factors that affect construction site safety due to the work of tower cranes have attracted only moderate attention; they are commonly addressed indirectly and partially within the broader treatment of site safety or of crane work in general (Nunnally, 2000). Literature addressing crane safety that explicitly 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/dismantling operation of tower cranes.

Background

Hola (2010) stated that, the use of machines and equipments 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 help to prevent unforeseen accidents. Accidents at construction sites may lead to loss of life and involve huge cost. The occurrence of fatalities in construction sites usually leads to site closure for accident investigation, loss of man/machine hours, loss of output, high labour turnover, loss of corporate reputation, payment of burial expenses/compensation/insurance claims for the dead (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).

Tower cranes are used on construction sites as lifting equipment for their combination of height and lifting capacity. Tower crane incidents, however, are likely to be fatal due to the weights of the objects and the heights to which they are moved (Beavers *et al.*, 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 fatalities, injuries and dangerous occurrences, a 27% increase from 128 cases in 2007. While most of the cases involve less serious non-fatal injuries, crane incidents can potentially lead to massive and severe damage to both physical properties and human lives.

Orji *et al.* (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 his 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 Nigeria. However, a study of 40 contractors in 2006 revealed that accident and injury rates were high in the Nigerian construction industry and the best safety ratios were 2 accidents per 100 workers and 5 injuries per 100 workers.

Kadiri *et al.* (2014) stated that as the growth rate of construction industry increases in Nigeria, this also causes an increase in competition of projects to execute between construction firms which are however achieved at the expense of the workers welfare and their safety. Therefore, identifying the various causes and effect of accidents on construction sites and proposing ways and

means of reducing these accidents should be acknowledged.

Erection/climbing/dismantling of tower cranes is a potentially hazardous process involving working at heights, awkward postures, lifting and aligning components of significant size and mass and installing temporary support systems. These are all often performed under significant time pressure due to the need for road closures, suitable daylight hours or short weather windows as the case maybe (Safework, 2016).

The most dangerous process that can lead to fatalities at construction sites is the installation/dismantling of tower cranes; for instance, in 2012, the collapse of a tower crane during dismantling at the University of Texas, USA claimed the lives of two workers (OSHA, 2012).

There have been five fatal accidents relating to tower crane use during 2002–2006 in Hong Kong, with three workers being killed in July 2007 alone. One such accident in July 2007 caused two fatalities and five serious injuries. The accident happened during the dismantling process, with workers on the tower crane as it was climbing 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. It was further noted 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).

Review of Literature

Hazard and Risk Identification

A hazard is the potential for harm. In practical terms, a hazard is often associated with a condition or activity that, if left uncontrolled, can result in an injury or illness. HSE (2004) define hazard as any source of potential damage, harm or adverse health effects on something or someone under certain conditions at work. Basically, a hazard can cause harm or adverse effects (to individuals as health effects or to organizations as loss of property or equipment).

A hazard can also be seen as a specific situation connected with a production process or a work process and is characterised by such a configuration or state of factors of this process, which may result in an accident at work or an occupational disease (Carter and Smith 2006; Hoła 2008). Thus a hazard is any factor which can cause loss of life or health.

Risk has been traditionally defined as a measure of the probability and severity of adverse effects (Haimes, 2009). Valsamakis et al (2004) define risk as a variation in actual outcome from the expected one, which implies the presence of uncertainty. Risk is the chance or probability that a person will be harmed or experience an adverse health effect if exposed to a hazard. It may also apply to situations with property or equipment loss, or harmful effects on the environment (CCOHS, 2017). The general concept of all definitions of risk provides that risk is a danger of unwanted and unfortunate events.

CCOHS (2017) defines risk identification as the process of finding, listing, and characterizing hazards. Overall, the goal is to find and record possible hazard that may be present in your workplace. It may help to work as a team and include both people familiar with the work area, as well as people who are not, this way you have both the experienced and fresh eye to conduct the inspection. In either case, the person or team should be competent to carry out the

assessment and have good knowledge about the hazard being assessed, any situations that might likely occur, and protective measures appropriate to that hazard or risk.

Dziadosz and Rejment (2015); Odeyinka and Dada (2016) pointed out the various 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.

Yu *et al.* (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.

Chi *et al.* (2015) opines that, risk identification and warning can enhance the safety of working environments. By prioritizing high frequency risk factors to effectively control accident occurrence and manage the likelihood of fatal injuries on construction sites when an accident is unavoidable, enables/assists safety managers to understand the nature of construction accidents and plan for strategic risk mitigation.

Tower Crane Studies

An accident analysis by Beavers *et al.* (2006) found that inadequate performance of crane operators and riggers was the main reason for crane accidents, based on the high probability of accidents indicated by analysis of fatalities occurring during the years 1997–2003 in the USA. Aneziris *et al.* (2008) used Netherlands accident data to develop a quantifying model for the risk of crane collapse, overturning, or dropping loads/objects. Swuste (2013) studied fatal tower crane accidents in the Netherlands and described accidents involving tower cranes as 'normal accidents' due to 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 *et al.*, 2011; Frendo, 2013; Marquez *et al.*, 2014). Workplace safety is affected by various factors and crane accidents tend to be under-reported in the construction industry; consequently, accident analysis may not reveal all related factors (Shapira and Lyachin, 2009). Shapira and Lyachin (2009) 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 *et al.* (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. Kim (2013) surveyed the working conditions of tower crane operators and found that workers encountered more difficulties related to the climate, physiological and psychological elements when working on high-rise buildings than when doing general building jobs. A model development study by Li *et al.* (2012) proposed a virtual safety training system for tower crane dismantlement work. Shapira *et al.* (2012) developed an integrative model for quantitative evaluation for safety on construction sites with tower cranes. Other research has focused on enhancing the performance of cranes and their operation (Rozenfeld and Shapira, 1998; Kim and Singhose, 2010; *Kim et al.*, 2011; Chi *et al.*, 2012). 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). Inadequate safety training and unsafe working conditions are other factors (Sertyesilisik *et al.*, 2010; Tam and Fung,

2011). 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 as would be discussed in the next heading. He concludes that 68.4% of the accidents resulted from the installation/dismantling operation.

Factors Affecting Safety during Installation and Dismantling of Tower Crane

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 OSHLD (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**

1. Pinched fingers
2. Tools slipping
3. Misalignment
4. Re-arrangement of strops
5. Sledge hammer work
6. Working platforms

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

1. Falling items
2. Falling men
3. Falling tools
4. Misalignment
5. Incompatibility
6. 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 industry. Thus he stated that;

1. It is a difficult, dirty, and dangerous job that people avoid
2. A contract of tower crane installing/dismantling is a generally a sub-contract between a lessor and a tower crane installation/dismantling employer (team leader, subcontractor) following a contract between a constructor (principal contractor) and the lessor for leasing the tower cranes on the construction site
3. The tower crane installation/dismantling firms are too small, with insufficient money to invest in tower crane safety
4. Insufficient numbers of workers to perform the work correctly and safely

– The work is carried out by a highly-skilled and small team of construction workers
– The team leader (employer) suffers from recruiting necessary workers (need at least more than 5 skilled persons for installing or dismantling one tower crane)
– Young workers who are willing to do the work are lacking
– Lack of qualified persons who have well trained and good experience for the job
–Workers (erector, dismantler) are leaving the job very often, due to hard working conditions
–Frequently working on weekends and holidays, for example, on Saturday and Sunday
–Time constraints: requested from principal contractors or employer
–Trying to finish the work earlier than the time required for safe work
–Frequently omitting required safety procedures or rules for various reasons

5. Lack of worker competence

– They have a little knowledge of the characteristics of different types of tower cranes

– Erectors and dismantlers tend to just work based on previous experience not from the manual of specifications of the tower crane
– There is no specific training centre to educate tower crane workers
– Manuals are written in foreign languages so that it is difficult for workers to understand

6. Instruction and supervising at construction sites are insufficient
– Few qualified and experienced supervisors and trainers work at construction sites to educate workers
– No training materials are suitable for the work in the sites
– The chief manager, safety officer, and supervisors at the construction sites of the principal contractor do not recognize the need to ensure the safety of tower crane installation/dismantling

7. Unreasonable site conditions
– Lack of working space: mis-arrangement of materials, conflicts with other construction processes
– Ground conditions not prepared well: narrow roads, soft ground, and no way for the crane to approach the site
– Not securing work space by restricting access of other people to the area
– The principal contractor is not interested in the work, leaving the work to the hands of the lessor

8. Deterioration of tower crane parts (components)
– Pins, bolts, and other parts are not fixed correctly because they have been used for a long time
– Workers have to work by force because bolts, nuts, or frames are not correctly fixed
– The lessor tends to avoid periodic maintenance or inspections due to the cost
– The lessor suffers from low cost on the contract

9. Objects that should be hoisted and moved in construction sites are heavier than before (PC, FORM, H-BEAM, etc.)
– Overloading with objects exceeding the tower crane load limit
– For time savings, some operators in construction sites may ignore the safety devices (overload protective devices) that cause fatigue of components of the tower crane, leading to fracture of the component

10. Inexperienced tower crane operators

11. 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 1.

Table 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)

Table 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.

(Review, 2017)

Findings

All the risk factors identified by past literature after carefully been reviewed, brought the list of safety risk factors to 21 with special attention paid to those that affect our construction environment where no research has previously identified risks associated with installation and dismantling of tower cranes on construction site. These factors where then validated by sorting the opinion of safety managers, equipment managers and installation and dismantling workers because of their direct involvement in tower crane activities on site. The motive for this was to get more factors to be captured or remove irrelevant factor amongst the list already prepared. The concluded list of safety risk factors is as presented in table 2.

Conclusion and Further Research

Construction industry no doubt contributes to the economic growth of any country. However the industry is currently facing a lot of challenges to include constant increase in the rate of accidents on construction sites. Ineffective safety management has been said to be a major cause of accidents as contractors are after maximizing profit and pay little or no attention to safety issues on site. Installation and dismantling of tower

crane has been tagged a dangerous activity on construction site that can result to fatal accidents if not properly managed. In view of this, risk factors affecting safety during installation and dismantling operation were reviewed and a list of safety risk factors established from them. The research concludes that there are 21 safety risk factors during installation and dismantling operation of tower cranes on site.

Researchers can now perform an extensive analysis on all the identified safety risk factors to establish the most significant ones where the limited resources for safety can be utilized to control the risks by reducing accident occurrence on site as a result of these factors.

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