

Crane Failure and Accident in Construction

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Abstract. The role of the construction industry in moving the nation's economy forward cannot be underestimated as it grows rapidly in each year. Even when the global economy faces uncertainties, property sector still relatively stable. The construction industry extensively linked with many other sectors of the economy. Therefore, construction industry acts as an economic engine in Malaysia. However, 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. The aim of this project is to identify safe practices to be implemented for crane machine in order to reduce hazards in constructions in Malaysia. All information and data were collected through questionnaire surveys from professionals, interview with expert panels and case studies of crane accident cases in Malaysia. The paper concluded that cranes are machines with high risk and should be operated with safety management and strong communication between crane operator and signalman.

Introduction

Every construction projects need machinery and equipment. Lifting and hoisting are important construction process tasks that require meticulous planning [4]. Material handling and lifting equipment now dominates building construction sites more than ever before and constitutes the critical element in achieving productivity [2]. Cranes are the most conspicuous machines on site, owing not only to their size but also to the vital role they have in transporting materials and elements vertically and horizontally [2]. Many kinds of projects, such as high-rise construction, the cranes are critical and one of the most commonly shared resources at the site. Therefore, efficient and safe operation of cranes is of the utmost importance in the safety, schedule, and overall success of the project [5]. Crane is generally equipped with a hoist rope, wire ropes or chains, and sheaves. Usually this machine is used to lift materials vertically or horizontally. Cranes can be on onshore or offshore, making lifting works of huge ton of materials possible. It uses one or more simple machines to create mechanical advantages and move loads beyond human capabilities [1]. Cranes are usually been used in transport industry to load and unload freight, in the construction industry to move materials and in manufacturing industry to assemble heavy equipment. As construction project grows, especially in high-rise building projects, it is impossible for the works to run smoothly without the aid of cranes. However, cranes are a central component of many construction operations and are associated with a large fraction of construction deaths. Estimates suggest that cranes are involved in up to one-third of all construction and maintenance fatalities. Failure to maintain safety during handling cranes can lead to serious accidents that can injure operators or damage equipment and buildings or even kill surrounding workers.

Previous Studies

Construction industry is often been subjected with the terms like “accidents”, “hazards”, “high-risky” and others. Safe operation of construction equipment is essential to successful delivery of construction projects, as most construction processes require equipment, and, furthermore, the need for equipment continues to increase [9]. It is true that as engineers that work at a site, they have

high potential on hazards and accidents. Generally, construction risk can be classified to 3 main factors, which can be categorized into three classes: due to client, due to contractor (the builder) and due to designer. Cranes are involved in up to one-third of all construction and maintenance fatalities [3]; [8] crane. Cranes, which come in numerous configurations and are a critical component of most construction work, contribute to as many as one-third of all construction and maintenance fatalities and injuries resulting in permanent disability [3] ; [6].

Using machines have their own hazards especially tower crane machines. One of the major causes of fatalities during construction is in the use of cranes or derricks during lifting operations [10]. Tower crane is the largest machine that been use in construction sites, yet it provide the biggest risk to site workers. Although been equipped with advance safety technologies, accidents like blind lifting and poor communication can lead to machine failure and fatality [7]. Cases like tower crane fell from 11-storey high at construction site near Damansara on 15 April 2014 that killed Mohd Hafadz Sanip, the operator for the crane have open engineers' eyes on taking safety seriously.

For every type of crane, they have different type of failure. For example, mobile crane fails because of poor stability during lifting and tower crane fails because of fail of crane steel support structure. These crane failures are dangerous, as it can lead to permanent disabilities or even death. Occupational Health and Safety (OSHA) had come with many standards of safety at site to minimize hazards and accidents during construction works in order to cope with the potential risks on the site. The site workers have to follow these regulations to increase safety level in their construction.

Methodology

The methodology used in this research is shown in Figure 1. The objectives were achieved through the questionnaire survey, case study and interview with expert panels in order to compile the information related to crane safety in construction industry.

In this study, the primary data have been collected from the questionnaire surveys which have been sent to all professionals at selected organizations, case studies of selected cases on crane accident and failure in Malaysia and interview with expert panels. Meanwhile, the secondary data have been gathered from several sources such as journals, articles, books, internet and previous researches.

The questionnaire consists of 3 sections which correspond to the objectives of the study. The first section is background respondents; the second section is to obtain information on the main cause of crane accident in terms of mobile crane and tower crane; the third section to identify the recommendations to minimize crane failure in construction.

After collecting the data obtained from questionnaire, data analysis will be carried out by using Microsoft Office Excel 2010. The data then will be analyzed by using frequency distribution analysis and chart diagram such as bar chart will be used to visualize the result from the analysis.

$$\text{Formula for percentage frequency analysis} = \frac{\text{number of respondents} \times 100\%}{\Sigma \text{total number of respondents}}$$

The classification of the rating scales proposed by Majid and Mc Caffer (1997) is used. The classification of the rating scales are as follows:

Likert scale	Range
1 = Strongly Disagree	(1.00 ≤ Average Index < 1.50)
2 = Disagree	(1.50 ≤ Average Index < 2.50)
3 = Slightly Agree	(2.50 ≤ Average Index < 3.50)
4 = Agree	(3.50 ≤ Average Index < 4.50)
5 = Strongly Agree	(4.50 ≤ Average Index ≤ 5.00)

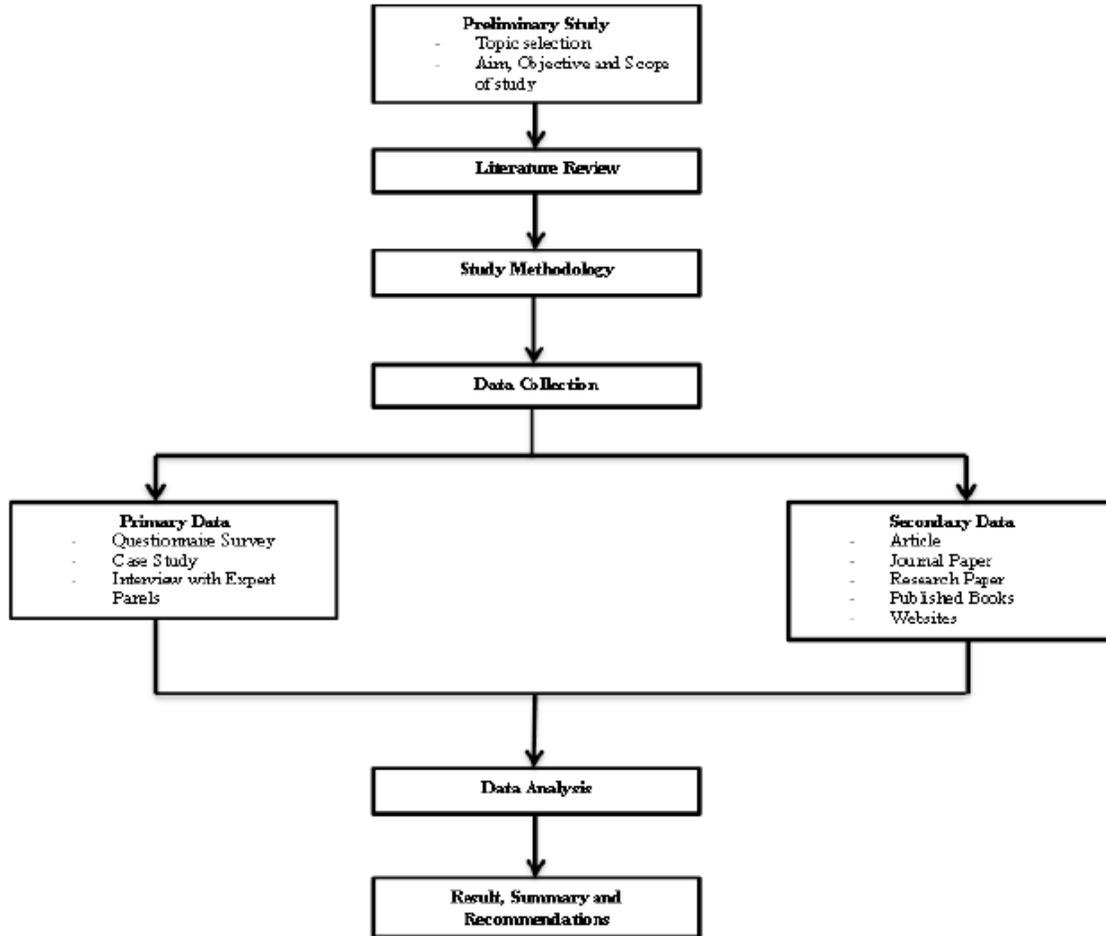


Figure 1: Flow Chart of Methodology

Data Analysis

In this research, the method been used to collect the data are questionnaire survey, interview with expert panels and case studies.

Questionnaire Survey A total of 30 sets of questionnaire was then distributed to the contractors and engineers at the selected site, 30 responses were received within the desired period which is equal to 100% of the total rate of responses. The data obtained can provide effective information to achieve the objectives of this study.

Respondents Information. These surveys have identified several numbers of personal information in order to help interpret the results. Figure 2 and 3 shows the gender and range of age target respondents. This survey only select professional members at site construction with different or variety of their job sectors as shown in Figure 4. This question also include respondents' experience in managing site and crane in construction with type of involvement with crane and type of crane involved as in Figure 5, 6 and 7.

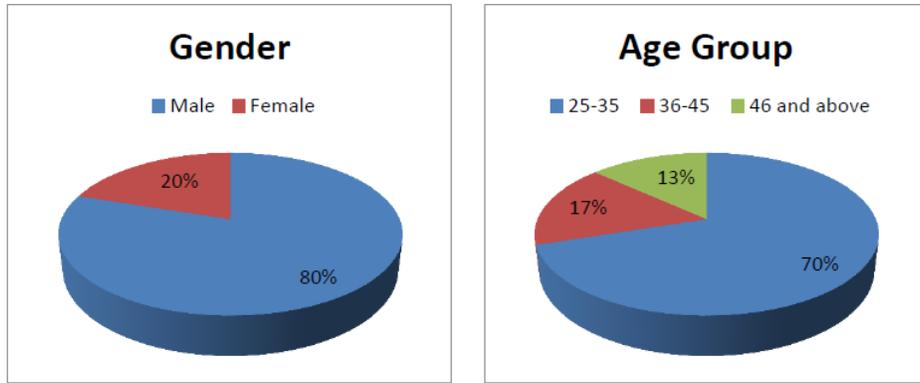


Figure 2 and 3: Age and gender breakdown of respondents

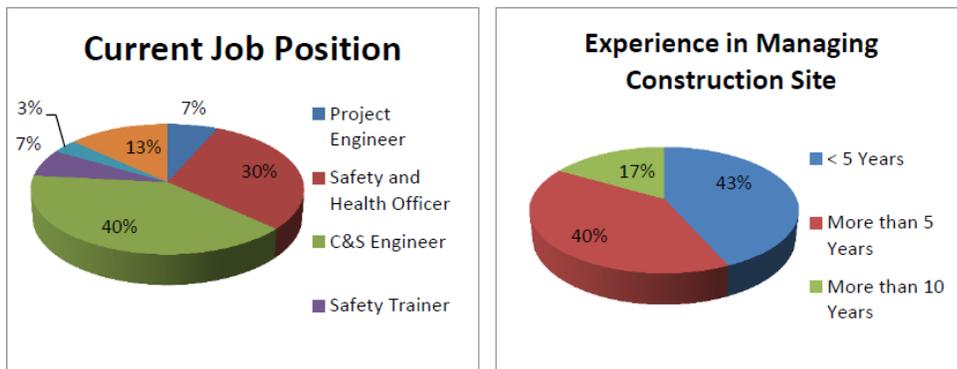


Figure 4 and 5: Respondents' current job position and experience in managing construction site

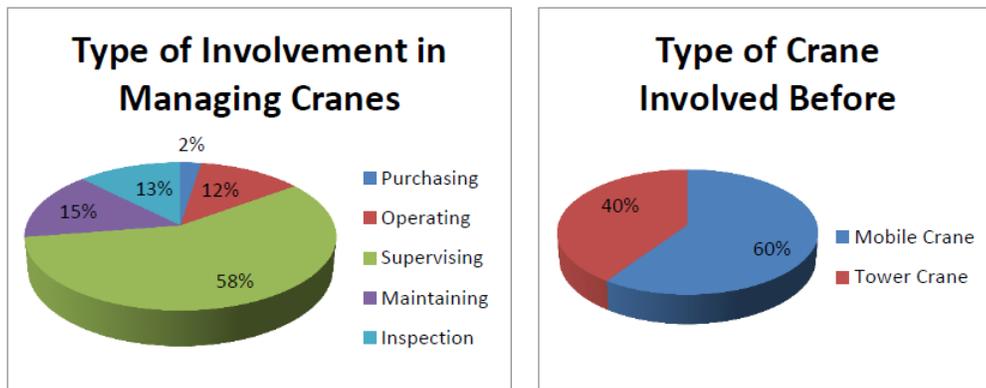


Figure 6 and 7: Type of involvement in managing cranes and type of crane involved by respondents

Objective 2: To Investigate Main Cause of Crane Accident This section consist of three parts, which are factor that leads to crane failure, human error that lead to crane failure and mechanical failure that lead to crane failure. This question is further divided into two parts which are for mobile cranes and for tower cranes. All respondents have to answer all questions for mobile and tower crane parts.

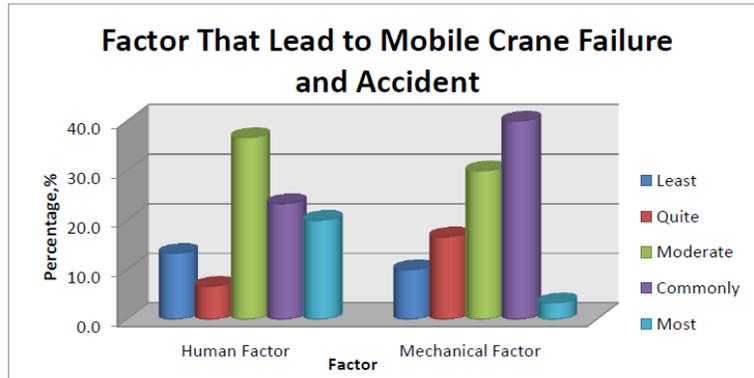


Figure 8: Factor that lead to mobile crane failure and accident in construction

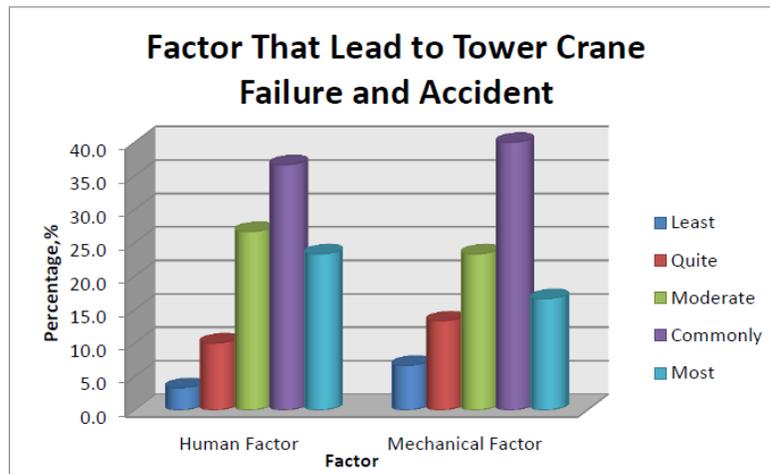


Figure 9: Factor that lead to tower crane failure and accident in construction

From Figure 8 above, we can see that majority of respondents agree that human factor is the main cause of mobile crane failure and accident in construction with average index of 3.30. Figure 9 shows that majority of respondents agree that human factor is the main cause of tower crane failure and accident in construction with average index of 3.67.

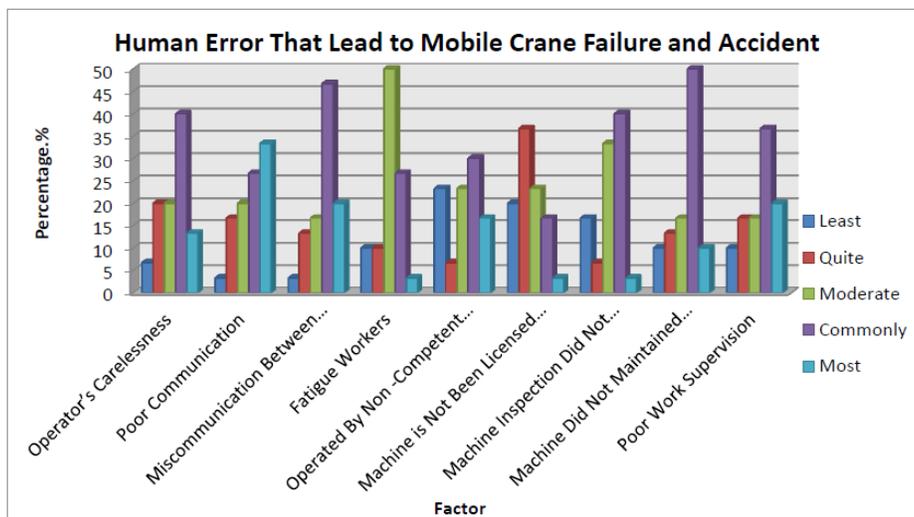


Figure 10: Human error that lead to mobile crane failure and accident

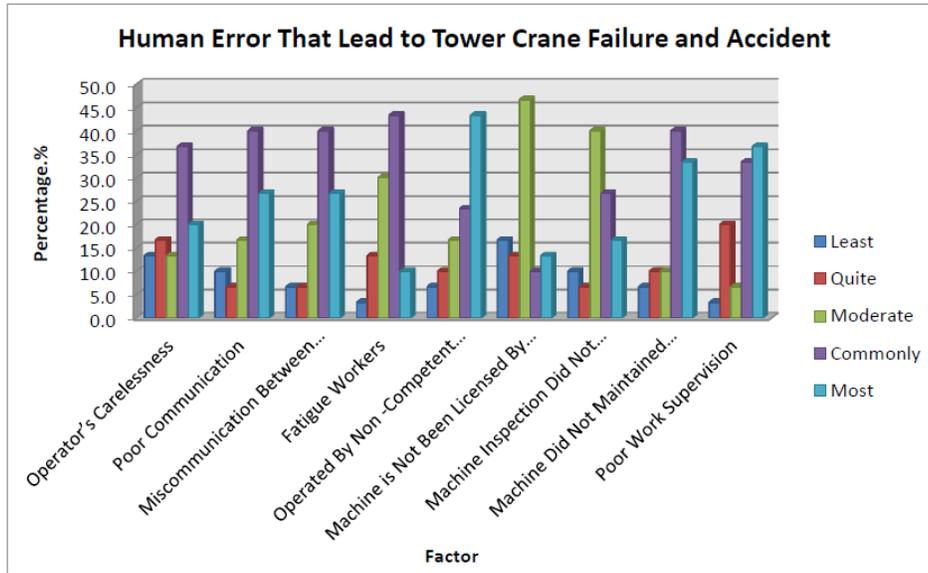


Figure 11: Human error that lead to tower crane failure and accident

From Figure 10 above, we can see that majority of respondents agree that poor communication is the main human factor that causes mobile crane failure and accident in construction with average index of 3.70. Figure 11 shows that majority of respondents agree that crane operated by a non-competent person is the main human factor that cause tower crane failure and accident in construction with average index of 3.87.

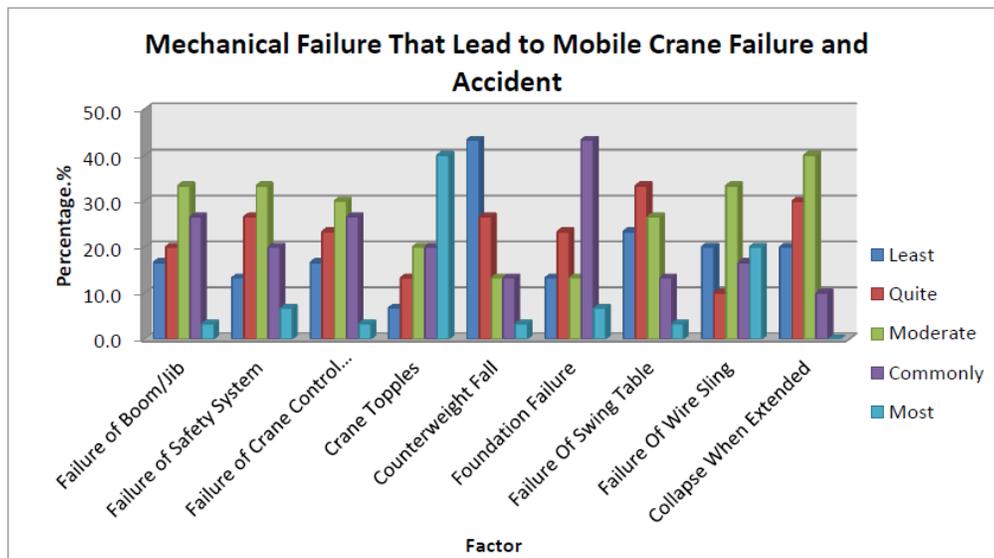


Figure 12: Mechanical failures that lead to mobile crane failure and accident

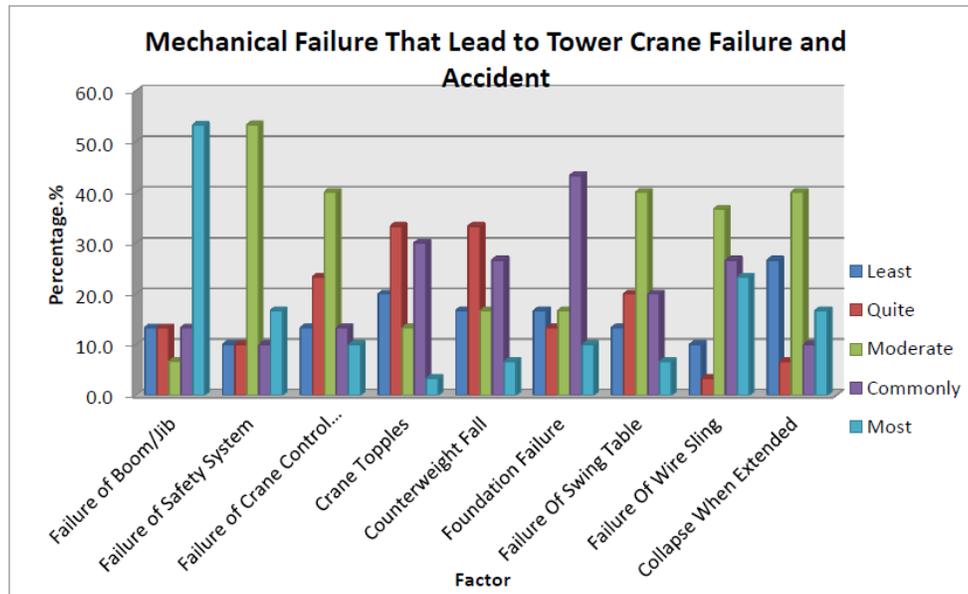


Figure 13: Mechanical failures that lead to tower crane failure and accident

From Figure 12 above, we can see that majority of respondents agree that crane topples is the main mechanical failure that cause mobile crane failure and accident in construction with average index of 3.73. Figure 13 shows that majority of respondents agree that failure of boom/jib is the main mechanical failure that cause tower crane failure and accident in construction with average index of 3.80.

Objective 3: To Propose Recommendation to Minimize Crane Failure In Construction This section consist of four parts, which are impact of crane failure and accident to construction, recommendations based on human error to minimize crane failure and accident in construction, recommendations based on mechanical failure to minimize crane failure and accident in construction and open ended question on the respondents' opinion based on the recommendations to minimize crane failure and in construction. This question is further divided into two parts which are for mobile cranes and for tower cranes. All respondents have to answer all questions for mobile and tower crane parts.

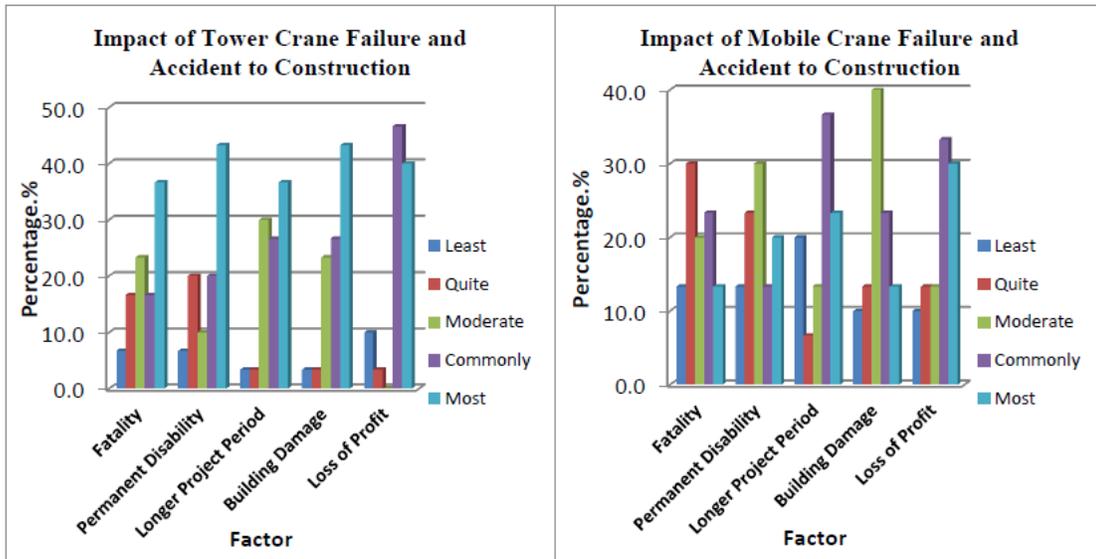


Figure 14, 15: Impact of mobile and tower crane failure and accident to construction

From Figure 14 above, we can see that majority of respondents agree that loss of profit is the main impact of mobile crane failure and accident in construction with average index of 3.60. Figure 15 shows that majority of respondents agree that building damage and loss of profit are the main impact of tower crane failure and accident in construction with average index of 4.03.

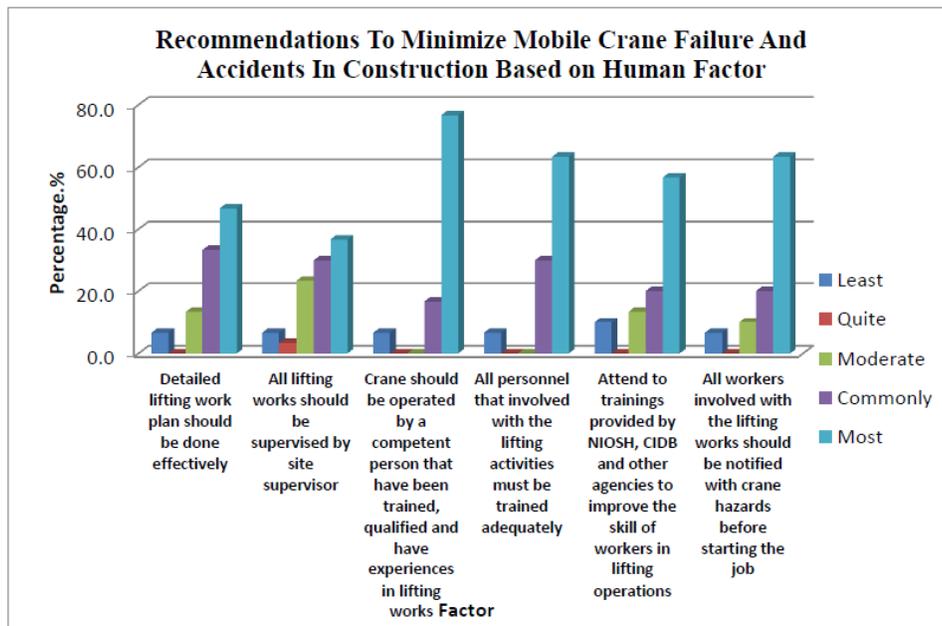


Figure 16: Recommendations to minimize mobile crane failure and accidents in construction based on human factor

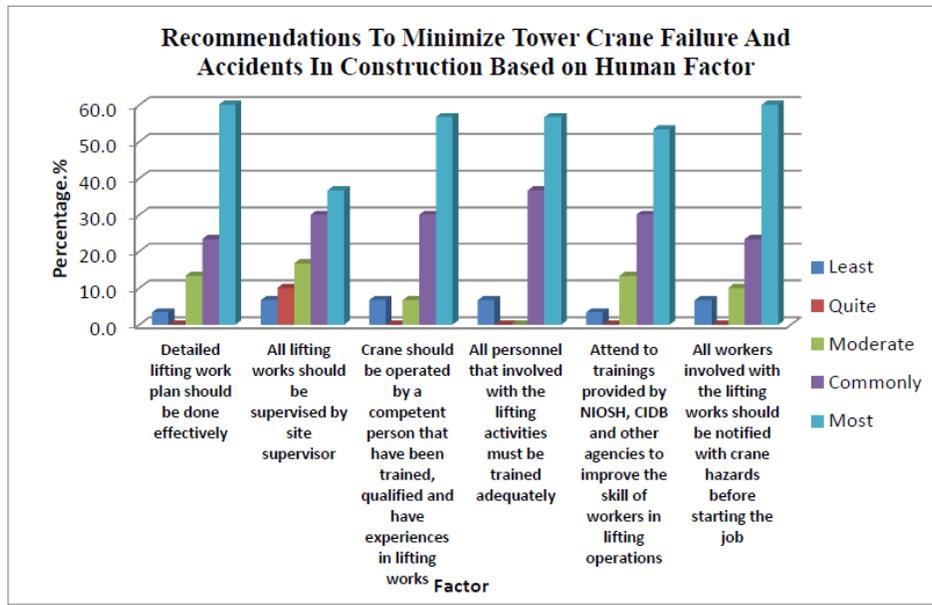


Figure 17: Recommendations to minimize tower crane failure and accidents in construction based on human factor

From Figure 16 above, we can see that majority of respondents agree that crane should be operated by a competent person that have been trained, qualified and have experiences in lifting works is the main recommendation to minimize mobile crane failure and accident in construction based on human error with average index of 4.57. Figure 17 shows that majority of respondents agree that detailed lifting work plan should be done effectively and all personnel that involved with the lifting activities must be trained adequately are the main recommendations to minimize tower crane failure and accident in construction based on human error with average index of 4.37.

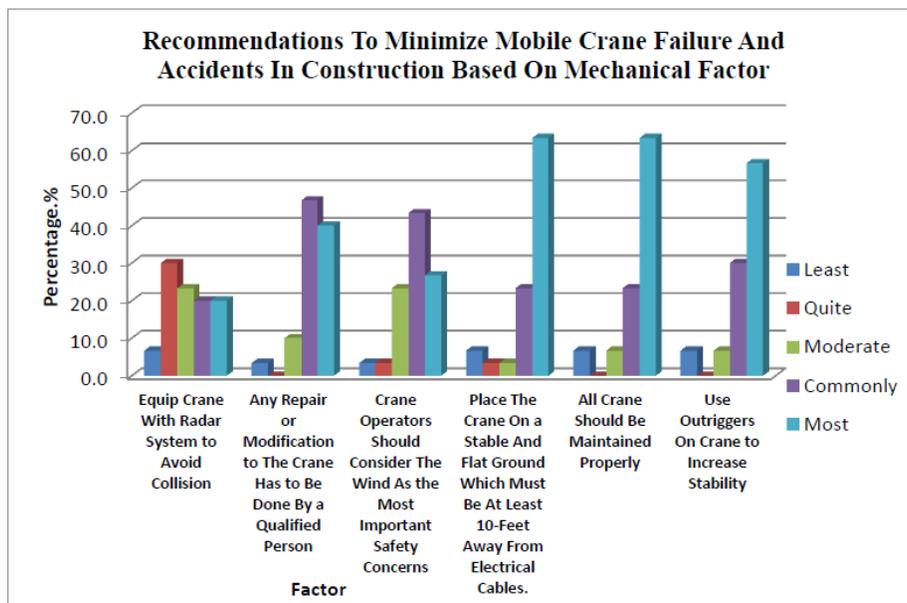


Figure 18: Recommendations to minimize mobile crane failure and accidents in construction based on mechanical factor

From Figure 18 above, we can see that majority of respondents agree that all crane should be maintained properly is the main recommendation to minimize mobile crane failure and accident in construction based on mechanical failure with average index of 4.37. Figure 19 shows that majority of respondents agree that all crane should be maintained properly is the main recommendation to minimize tower crane failure and accident in construction based on mechanical failure with average index of 4.17.

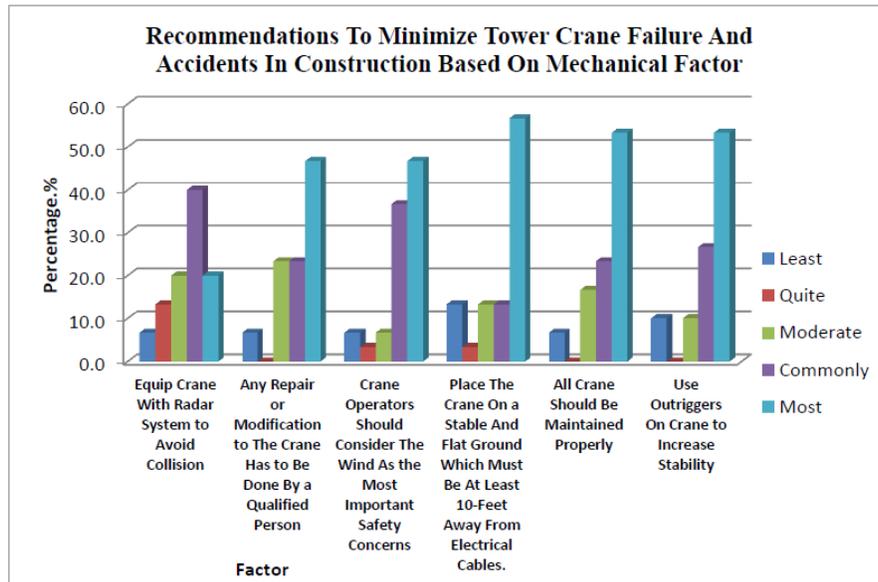


Figure 19: Recommendations to minimize tower crane failure and accidents in construction based on mechanical factor

The results of the last part are as the table below:

Table 1: Recommendations to minimize tower crane failure and accidents in construction

Recommendation	Factor (Human/Mechanical)
Tower crane operator must eligible and have license (competent)	Human
Every 4 hrs opt need to be chaged	Human
Enforcement on crane operator competent (no pr) and lifting plan at all time	Human
The loading of certain materials or stuff must be checked with the limitation of the tower crane.	Human
To add camera which can zoom in so that the operator can see signal men	Mechanical
All crane must inspected by dosh/jkkp and safety officer before use	Human
Take serious whatever you are doing because it's involving life.	Human
Competency in all aspects not just crane operator, but the rigger and lifting supervisor + compulsory in lifting plan	Human
Do weekly mobile cren inspection and fully supervise	Human
Take into accounts the speed of wind.	Human
Pay extra attention when working	Human
Competency personnel including lifting supervisor & lifting plan for each lifting operation	Human

Interview with Expert Panels Interview with expert panels had been done with 4 individuals from position of safety and health supervisor and NIOSH staff. The information of the respondents is as follows:

Number	Name	Position
Respondent 1	En Zahrudin Ruskam	Safety and Health Supervisor
Respondent 2	Mr Syed	NIOSH Staff
Respondent 3	En Haris	Safety and Health Officer
Respondent 4	En Amir	Safety and Health Officer

The results of the interview for all respondents are as follows:

Table 2(a): Result from interview with expert panels

Question	Respondent 1	Respondent 2
1 To evaluate the hazard level associates with crane usage in construction		
What is the common crane type used in construction?	- Type of crane used is based on the level of the construction project - For big projects, Mobile and Tower crane will be used - For small projects, only mobile crane will be used for lifting processes	- Mobile crane is the common crane used in construction
What are the risks/hazards of using crane in construction?	- Workers fatality, permanent disability, injuries	- Operator fall from tower crane - Crush by falling object from crane - Crane overload
Which type of crane is more prone to accident and failure? Why?	- Mobile crane is more prone to accident and failure - Can involve in collision with other mobile crane	- Mobile crane is more prone to accidents because it involves citizen when traveled top construction site
2 To investigate main cause of crane accident		
Between human factor and mechanical factor, which one lead to more accident and failure of cranes in construction?	Tower Crane - Human factor is the main cause because Human Factor can lead to mechanical failure of the crane	Mobile Crane - Human factor is the main cause because Human Factor can lead to mechanical failure of the crane
What are the common human mistakes that lead to crane failure?	Tower Crane - Operated by a non-competent person - Maintenance of the machine did not been done properly - Poor work supervision	Mobile Crane - Operated by a non-competent person - Crane is not registered - Operator did not aware about maximum allowable lifting weight
What are the common mechanical failures that lead to crane accidents?	Tower Crane - Failure of boom jib - Safety system did not function properly	Mobile Crane - Failure of swing table - Wire sling broke off
3 To propose recommendation to minimize crane failure in construction		
In terms of risk, what are the impacts of the crane failure to the construction project?	Tower Crane - Damage to construction and nearby building - Fatality	Mobile Crane - Waste money and time to repair machine
What are the recommendations to minimize crane accidents and failure in construction in terms of mobile and tower crane?	Tower Crane/ Mobile Crane - All workers involved with lifting operations should have good attitude in ensuring working safety - Identify risk before starting work - Inspect machine according to schedule - Engineer should play role to avoid accidents	Tower Crane/ Mobile Crane - Penalty to the company of the construction - Delay of project completion time - Cost for accident and failure investigation - Unforeseen cost Tower Crane/ Mobile Crane - Get special training on rigging, slinging - Follow the acts and rules

Table 2 (b): Result from interview with expert panels

Question	Respondent 3	Respondent 4
1 To evaluate the hazard level associates with crane usage in construction		
What is the common crane type used in construction?	- Mobile crane is commonly used as it been used in small and big construction projects	- Mobile crane is the common crane used in construction
What are the risks/hazards of using crane in construction?	- Hit my moving crane - Hit by load lifted by crane	- Struck by falling load from crane - Hit my moving crane
Which type of crane is more prone to accident and failure? Why?	- Mobile crane as accidents and failure can easily occurred if the machine handled carelessly	- Mobile crane are more prone to accident and failure as carelessness can easily occurred

2 To investigate main cause of crane accident			
Between human factor and mechanical factor, which one lead to more accident and failure of cranes in construction?	Tower Crane/ Mobile Crane - Human error lead to mechanical failure		Tower Crane/ Mobile Crane - Human error is the main factor as it can lead to mechanical failure
What are the common human mistakes that lead to crane failure?	Tower Crane - Machine inspection did not been done according to schedule - Operator did not take weather into account - Fatigue operator handling the crane	Mobile Crane - Machine inspection did not been done according to schedule - Poor communication between signalman and crane operator - Outrigger did not completely released - Fatigue operator handling the crane	Tower Crane - Safety device been cut off - Operator did not inform site management about machine defect - Machine operated by non-competent person - Ground inspection did not been done properly Mobile Crane - Outrigger did not completely released - Crane used on not proper ground - Operator carelessly handling the crane - Operator did not inform site management about machine defect
What are the common mechanical failures that lead to crane accidents?	Tower Crane - Failure of swing table - Boom jib broken	Mobile Crane - Failure of swing table - Crane topples	Tower Crane - Boom/ Jib collapse and fall - Counterweight fall - Failure of crane foundation Mobile Crane - Crane topples - Broken wire sling - Swing table failure
3 To propose recommendation to minimize crane failure in construction			
In terms of risk, what are the impacts of the crane failure to the construction project?	Tower Crane/ Mobile Crane - Iceberg cost (Indirect, direct) - Delay of time - Fatality		Tower Crane/ Mobile Crane - Penalty to the company of the construction - Delay of construction time
What are the recommendations to minimize crane accidents and failure in construction in terms of mobile and tower crane?	Tower Crane/ Mobile Crane - Crane should be operated by competent person - Crane inspection should be done according to schedule - Check the environment before doing lifting works - Signalman should be trained		Tower Crane/ Mobile Crane - Site management should care about crane parts defect - Operator should know the crane's load lifting capacity - Before installing crane, inspect the ground to know the soil's strength - Crane operator should inform site management when lifting operation is not safe - Inspect crane according to schedule - Crane operator should have competency

Case Study Two case studies have been done to collect data for objectives 1, 2 and 3. One case involves mobile crane accident and one case involves tower crane accident in construction. The scope of this case study is cases in Malaysia only. The result of the case study is as follow:

Table 3: Result from case studies

No	Description	Case Study 1	Case Study 2
1	Details	- Place of accident: Ara Damansara, Petaling Jaya, Malaysia - The victim, Mohd Hafadz had come in for work at 7.50am after finishing his previous shift at around 4am on the same morning - His colleague witnessed the crane plunging to the ground at around 8.50am as he was walking to the site office - He was only on his second week into the job	- Place of accident: Damansara, Petaling Jaya, Malaysia - Date : 12 January
1	Type of Crane Used	- Tower Crane	- Mobile crane
2	Type of Failure	- Tower Crane fell from 11 story high	- Mobile crane they were using overturned at a flyover construction site
5	Human Factor	- Mohd Hafadz had been working from 7.30am on Monday until 4am Tuesday before coming in for the ill-fated morning shift - Mohd Hafadz had already started operating the machine while his other colleagues were still attending the morning briefing	- Result of inadequate planning, unclear responsibilities or unsafe use - The hazards which increase the risk of an overturning event are many and include unstable working platforms, subsurface voids, high winds, poor maintenance, inexperienced crane operators and supervisors, excessive loads, underrated crane capacity and poor use of outriggers and bearing plates,
6	Mechanical Factor	- It appears as if the top of the crane broke free from the tower, as the slew ring bolts or other component failed.	- Mobile crane was overly-loaded, when it overturned at 4.50pm - Failure to maintain crane stability is one of the key factors associated with serious crane

			incidents - The main factors that affect crane stability include, operating the crane near its maximum rated capacity, ground conditions and the means of supporting the crane's outrigger pads, tyres or tracks, the slope of the ground, wind conditions
7	Effect of Accident/Failure	- Fatality of 26 years old crane operator, Mohd Hafadz Sanip - Killed on the spot - Tower crane damaged	- Li Yi Jia, 50 was killed, while three others were injured - Victims being thrown on the ground as the crane overturned. - When the crane suddenly collapsed, the victim was trapped in between the steel frame and concrete pillar.
8	Recommendations	- The Appointed Person has overall control of the lifting operation and their duties should include: - assessment of the lifting operation including planning, choice of crane and equipment, and liaison with other parties affected by the lift - ensuring inspection and maintenance has been carried out - organisation and control of all lifting operations - briefing the Crane Supervisor on the contents of the method statement and Lifting Plan - ensuring there is an effective procedure for reporting defects and incidents and taking any necessary corrective action - The Appointed Person should consult with other experts including temporary works engineers and crane suppliers.	- A safe system of work should be in place for all lifting operations and should include: planning of the operation, selection of a suitable crane and equipment, maintenance of the crane and equipment, preparation of the site, provision of properly trained and competent supervisory personnel, ensuring all test certificates and thorough examination reports are available, preventing unauthorised movement or use of the crane, provision for the safety of all those involved or affected by the operation. The safe system of work could usefully be embodied within a lifting plan.

Conclusion

Aim and objectives have been achieved and the following is the conclusion of each objective that can be drawn out.

Objective 1: To evaluate the hazard level associates with crane usage in construction The first objective of this study has been achieved through interview with expert panels and case study to know what type of crane is prone to more hazards during construction and the main hazard for the crane. From the findings it can be concluded that mobile crane contribute to more hazard to workers in construction as it is more used in construction sites in Malaysia. The main hazard for this type of crane is crane overloads.

Objective 2: To investigate main cause of crane accident From findings of questionnaire survey, interview with expert panels and case studies, we can see that for both type of cranes, human error is the main factor that lead to crane failure and accident in construction. For mobile crane, the most common human error that lead to mobile crane failure and accident in construction is poor communication between crane operator and signalman. The most common mechanical failure that lead to mobile crane failure and accident in construction is crane topples or overturned. For tower crane, the most common human error that lead to tower crane failure and accident in construction is tower crane operated by a non-competent person. The most common mechanical failure that lead to tower crane failure and accident in construction is failure of boom/jib.

Objective 3: To propose recommendation to minimize crane failure in construction Based on results obtained, the best recommendations to minimize mobile crane failure and accident in construction are crane should be operated by a competent person that have been trained, qualified and have experiences in lifting works based on human factor and all crane should be maintained properly based on mechanical factor. The best recommendations to minimize tower crane failure and accident in construction are all personnel that involved with the lifting activities must be trained adequately based on human factor and all crane should be maintained properly based on mechanical factor.

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