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Hazard Identification, Risk Assessment and Risk Control (Hirarc) for Lifting Operation at Condominium Construction in Sabah.

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Abstract: A construction is a high-risk industry that encompasses a wide range of construction, alteration, and repair activities. Construction workers are exposed to a variety of risks such as falling from rooftops, falling from scaffolding, unprotected machinery, being struck by heavy construction equipment, electrocutions, silica dust, and asbestos. One of the high-risk activities is operation of lugging tower crane. The aim of this study was to conduct hazard identification, risk assessment and risk control (HIRARC) for lifting operation at condominium construction in Sabah. The first objective was to investigate occupational hazard that contributes to the increased number of reported occupational accidents, injuries and diseases related to lifting operation of tower crane at Condominium Construction in Sabah. Workplace inspection was implemented by using Hazard identification checklist. Based on the inspection, the work activities were identified, and hazard were also being identified. The second objective was to assess hazards and associated risks related to Lifting operation of tower crane at Condominium Construction in Sabah by conducting risk assessment on the hazard identified using risk matrix. It was found that there were four hazards involving four activities categorized under high level of risk. Based on risk assessment conducted, the third objective was achieved by recommending control measures using Hierarchy of Control. The risk control proposed were presented to the safety team for further improvement.

Keywords: Tower Crane Accident, HIRARC, High-rise construction.

1. Introduction

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A condominium is a big property complex made up of individual apartments, each of which is individually owned. A nonexclusive stake in certain "community property" owned by the condominium management is frequently included in ownership. Condominium management is often comprised of a board of unit owners who oversee the complex's day-to-day operations, such as lawn maintenance and snow removal [1]. The complexity of condominium construction poses many hazards and risks.

A construction is a high-risk industry that encompasses a wide range of construction, alteration, and/or repair activities. Construction workers are exposed to a variety of risks, including falling from rooftops, falling from scaffolding, unprotected machinery, being struck by heavy construction equipment, electrocutions, silica dust, and asbestos [2]. The current scenario in high-rise development is that the project manager failed to identify the specific risks associated with tower crane operation. Even though danger identification is a critical procedure in construction, many managers fail to do so properly because they rely primarily on safety personnel. When a risk assessment is not carried out, the project team will not be able to detect the hazard that occurred during tower crane operation, and the hazard will continue to exist until an accident occurs [3]

In line with the Department approach of preventive measures as a way of enforcing the law on Occupational Safety and Health (OSH), it seems that HIRARC has become extremely important. With HIRARC, one will be able to identify hazard, analyze and assess its associated risk and then apply the suitable control measures [4].

2. Tower Crane Accidents in Malaysia

Department of Occupational Safety and Health (DOSH) have published the accident cases related to tower crane accident that occurred during 2014 to 2018 [5]. Table 2 shows the cases of tower crane accident which caused casualty at construction site in Malaysia. From the statistics, it can be showed that the likelihood of accidents was frequent, and the impact of the accidents were severe.

Table 1: Type of accident involving tower crane operation [5].

Item	Date	Title Case	Location	Summary Case
1	2018-10-21	Died, crushed by brick wall	Construction site, Selangor	The tower crane operator died after a brick wall collapse and crushed the victim while on the way to the 7th floor 'resting area'.
2	2017-07-11	Died being struck by hook block	Construction site, Johor	Tower crane's hook block has broken and fell onto workers on the ground. During the incident, he was doing housekeeping under the crane operation area.
3	2016-10-15	Died being struck by falling hook block and load	Construction site, Kuala Lumpur	The victim died due to a breakage of the wire rope of a tower crane causing the hook

				block to fall and strike the victim.
4	2015-10-26	Died being struck by tower crane bucket	Construction sites, WPKL	Incident happened as the 1.2 tone bucket filled with sand was lifted by tower crane. During the process, suddenly bucket fell down and struck the victim.
5	2015-06-26	Falling from height	Construction sites, Johor	The victim fell due to working platform collapsed as a result of the concrete bucket lifted by crane tower fell on the scaffolds structure.

As a result of these issues, the present hazard identification and risk assessment on the lifting operation will need to be reviewed immediately to ensure inherent safety is fulfilled and the risk of an undesirable event is controlled at all safety crucial points to avoid a disastrous occurrence.

2.1 Factors contribute to the cause of an accident in Malaysia.

Tower crane accidents occur most frequently during operation and handling because crane movement increases the chance of an accident [6]. Operational and technical factors are the leading causes of accidents, followed by safety management, human factors, and the environment. [7]

Factors that contribute to crane accidents in Malaysia. As show in Figure 1, the most common cause of crane accidents in Malaysia is structural failure, which accounts for 28 of the likely reasons. Environmental influences are the least influential, accounting for only two possible reasons. Figure 2 demonstrates that the largest peak of that time period occurred in 2017, which can be attributed to six different human variables. The comparison between crane accidents in Malaysia and around the world is shown in Table 2. In Malaysia, structural failure elements account for the highest percentage of potential causes, at 35%. Structure failure ranked first in the global category, with 57 percent of the overall percentage value [8].

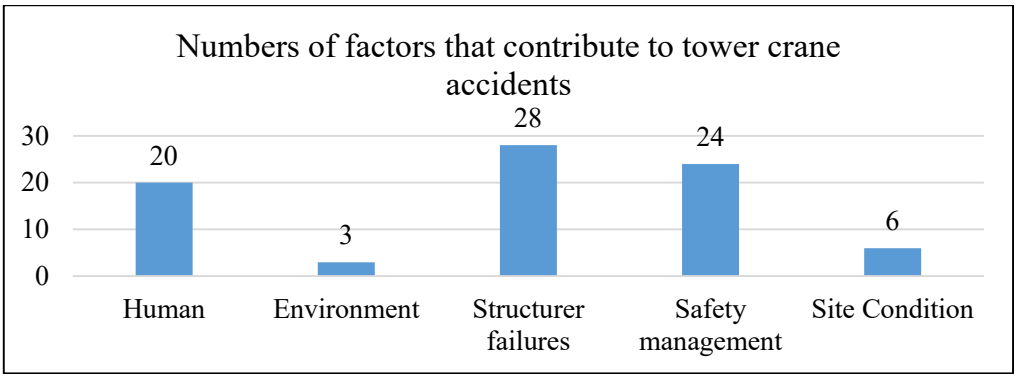

Figure 1: The numbers of factors that contributes to tower crane's accident from 2012 to 2019 [8].

Table 2: The numbers of probable causes by tower crane's accident from 2012 to 2019 [8].

Item	Factors	Years/Cases							
		2012	2013	2014	2015	2016	2017	2018	2019
1	Human	0	1	2	3	5	6	1	2
2	Environmental	0	0	1	0	1	0	0	0
3	Structural Failures	3	0	4	3	4	6	6	2
4	Safety Management	0	1	5	4	2	8	2	1
5	Site Condition	0	0	1	3	1	0	1	1

2.2 Methodology

The methodology is divided into three sections: inspection hazard identification, risk assessment and risk control method. To complete the above parameters, this study shall adopt HIRARC form that helps to identify, collect and analyze the data. The research study also included primary and secondary data collection. Primary data collection which was applied by implemented field observation (Workplace Inspection) by using checklist and focus group discussion also were conducted with experts and operator. Meanwhile for secondary data, archived documents used to collect secondary data to identify hazards, risk matrix ranking applied to evaluate and assess risks along with the control recommendations. Some steps are designed according to above sections in order to carry out the research. To achieve data collection, several studies on the similar industry were implemented. The research framework illustrated in Figure 2 below.

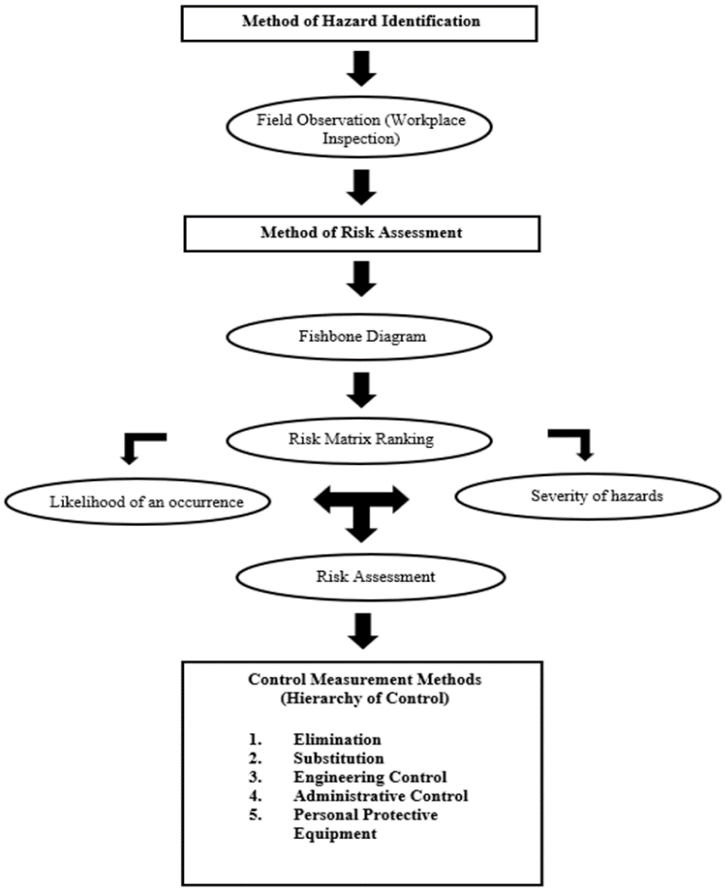

Figure 2: Framework of the methodology

In purpose of workplace hazard identification, checklist was used to list known hazards drawn from past experience which may be in the form of previous risk assessment of similar operations or systems, or actual incidents that have happened previously. There are several checklists available depending on the type of area being inspected. In this study, Hazard Identification Checklist type are used. This checklist included a detailed list of items to inspect. However, it is better if the checklist is specific on a certain area to be inspect. These techniques involved the systematic use of an appropriate checklist and considering whether each of the items on the checklist could possibly apply to a particular system [10].

Field observation was conducted in purpose to observe the risk occupational accident in the workplace and the management of OSH especially for the tower crane in the company. For this study, short interview was conducted first to crane's operator, and followed by field observations of tower crane in the workplace. The objective of the short interview is to find further overview of the management's perspective in managing safety and health issue regarding the luffing crane in the workplace. The surrounding of an area of the tower crane are carefully analyzed for reference during the development of HIRARC procedures.

To study the potential causes of an occupational occurrence among the workers that involving of tower crane operation at Condominium Construction in Sabah, an Ishikawa fishbone diagram or known as cause-and-effect analysis was further analyzed after conducting Hazard Identification, Risk Assessment and Risk Control or known as HIRARC risk matrix. A fishbone diagram is a cause-and-effect discovery tool that helps to figure out the reason(s) for defects, variations or failures within a tower crane operation. In addition, it helps break down, in successive layers, root causes that potentially contribute to an effect. A fishbone diagram is one of the tools used in a root cause analysis [10].

The the risk assessment was conducted. The purpose of risk assessment is to provide an objective and systematic approach to assessing hazards and their associated risks that will provide an objective measure of an identified hazard at the certain area/ workplace as well as provide a method to control the risk. It is one of the general duties as prescribed under the Occupational and Safety and Health Act 1994 (Act 514) for the employer to provide a safe workplace to their employees and other related person [11].

3. Results and Discussion

The data analysis is divided into three (3) parts. The (1st) first part is Checklist. This checklist is consisting into one (1) section which is "Hazard Identification Checklist". The checklist is divided into fifteen (15) subsections respectively. This checklist was conducted during the time of Field Observation (Workplace Inspection) or Walkthrough Survey. Then the data gather from checklist would be used together with other part of analysis for compilation then used in HIRARC method form later for the result. The third (2nd) part is HIRARC by using HIRARC. This technique would be used to identify the dangers of specific tasks in order to reduce the risk of injury to workers. The last (3rd) part is Ishikawa fishbone diagram method. This part of the study was conducted at the next day of the assessment were in place. This method would be used to discover the causes and effect relationship of an underlying problem detected from Hazard identification Checklist by combines brainstorming and mind mapping.

3.1 Hazard Identification

This study was conducted by assessing the hazard that is related to day to day working activity specifically by tower crane operation at Condominium Construction in Sabah. The work activities was classified for this activity was illustrated in Figure 3 below.

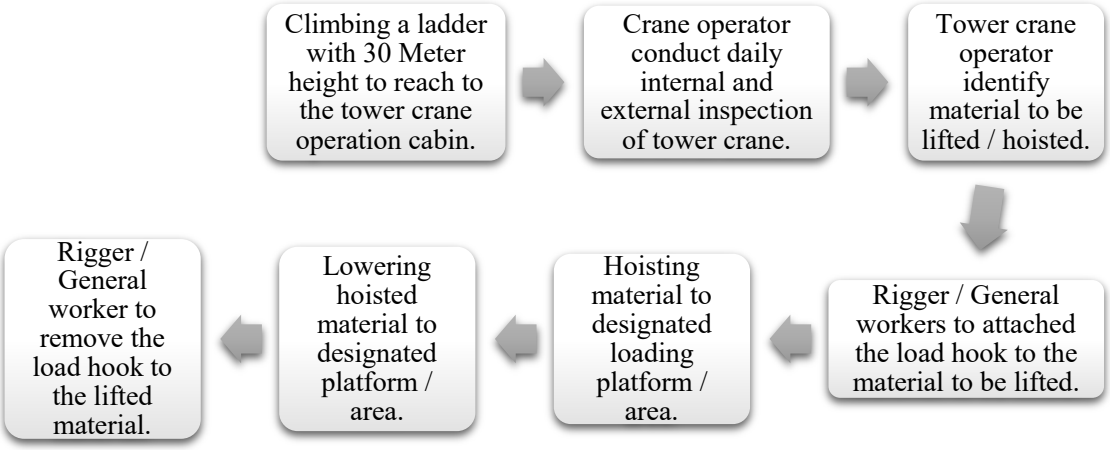

Figure 3: Classification of work activity related to tower crane operation.

The identification of hazards was conducted by observing the work activities each workstation throughout the line and the hazards associated with the work activities were listed in Table 3 below.

Table 3: Hazard Identification at workplace

Item	Work Activity	Hazard	Effect
1	Climbing a ladder with 30 Meter height to reach to the tower crane operation cabin.	a) Trips and falls due to lack of body harness. b) Exert force with their hands while climbing tower crane ladder.	a) Sprains or strains [12] b) Musculoskeletal Disorders (MSDs) [13]
2	Crane operator conduct daily internal and external inspection of tower crane.	a) Fall from height. b) Dealing with tiring works tasks such as daily inspection of tower crane.	a) Fall from height that can lead to major injuries such as broken limbs and fractured skulls [14]. b) Work-related stress, burnout or depression [15].
3	Tower crane operator identify material to be lifted / hoisted.	a) Flying object b) Narrow cabin space c) Sit for too long	a) Cuts, abrasions or blindness [16]. b) Discomfort due to feelings of confinement. c) Metabolic syndrome, heart disease and poor mental health [17].
4	Rigger / General workers to attached the load hook to the material to be lifted.	a) Exposed to sharp object b) Pinch point c) Unproper sling angle	a) Cuts (laceration, puncture) or an amputation [17]. b) Amputation and death (Pinch Points

Item	Work Activity	Hazard	Effect
			Safety Toolbox Talk [18]. c) Falling object that can lead to bruises, fractures, strains and sprains [19].
5	Hoisting material to designated loading platform / area.	a) Falling object due to unproper sling angle and hook sling lock. b) Blind spot and miscommunication c) Insecure rigging d) Unstable load e) Old loading platform	Can lead to injuries such as serious concussions, brain injuries, debilitating neck or back injuries, paralysis, broken bones, and even death [19].
6	Lowering hoisted material to designated platform / area.	a) Blind spot and miscommunication b) Falling object due to defective sling. c) Insecure rigging	Can lead to injuries such as serious concussions, brain injuries, debilitating neck or back injuries, paralysis, broken bones, and even death [19]
7	Rigger / General worker to remove the load hook to the lifted material.	a) Pinch point b) Exposed to sharp object c) Falling / flying object.	a) Amputation and death (Pinch Points Safety Toolbox Talk [18]. b) Cuts (laceration, puncture) or an amputation [17] c) Cuts, abrasions or blindness [16].

3.2 Risk Assessment

Risk assessment matrix were designed for each hazard at workplace. Through this matrix, all hazards that had identified above during the workplace inspection by using risk assessment method were then weighted by their elements through respective data, tables and their possible occurrences and risk involved. Table 4 shows the result of risk assessment for tower crane operation.

Table 4: Risk Assessment of Tower Crane operation.

Type of Hazards	Hazard	Severity	Likelihood	Risk	Value
Ergonomic Hazard	Exert force with their hands while climbing the unsecure tower crane ladder	3	5	15	HIGH
	Sit for too long	1	4	4	LOW

Psychological Hazard	Dealing with tiring works tasks such as daily inspection of tower crane.	2	5	10	MEDIUM
	Trips and falls	3	5	15	HIGH
	Fall from height				
	Dangerous machinery	3	4	12	MEDIUM
	Flying object	2	4	8	MEDIUM
	Narrow cabin space	1	4	4	LOW
	Exposure to sharp object	3	4	12	MEDIUM
	Pinch point	2	5	10	MEDIUM
	Unproper sling angle	3	4	12	MEDIUM
Safety Hazard	Falling object due to unproper sling angle and hook sling lock.	4	5	20	HIGH
	Defective sling, equipment	4	3	12	MEDIUM
	Blind spot and miscommunication	3	4	12	MEDIUM
	Insecure rigging	3	4	12	MEDIUM
	Unstable load	4	3	12	MEDIUM
	Old loading platform	3	3	9	MEDIUM

Based on the risk assessment conducted at Condominium Construction in Sabah, there were four (4) most critical hazards which is in HIGH risks category, the risk score of an abovementioned i.e. exert force with their hands, trips and falls, fall from height and falling object during the tower crane operation are determined to be 15, 15, 15 and 20, respectively. Meanwhile, 11 hazards were categorized as medium risk and 2 hazards identified as low risk.

3.3 Cause-and-effect analysis

Based on the Hazard Identification and Assessment in the Risk Assessment, the hazard was further analysis by using cause-and-effect analysis for ergonomic hazard, falling object and fall from height since the risk score of these hazards determined to be 15, 15, and 20, respectively in high risks score category.

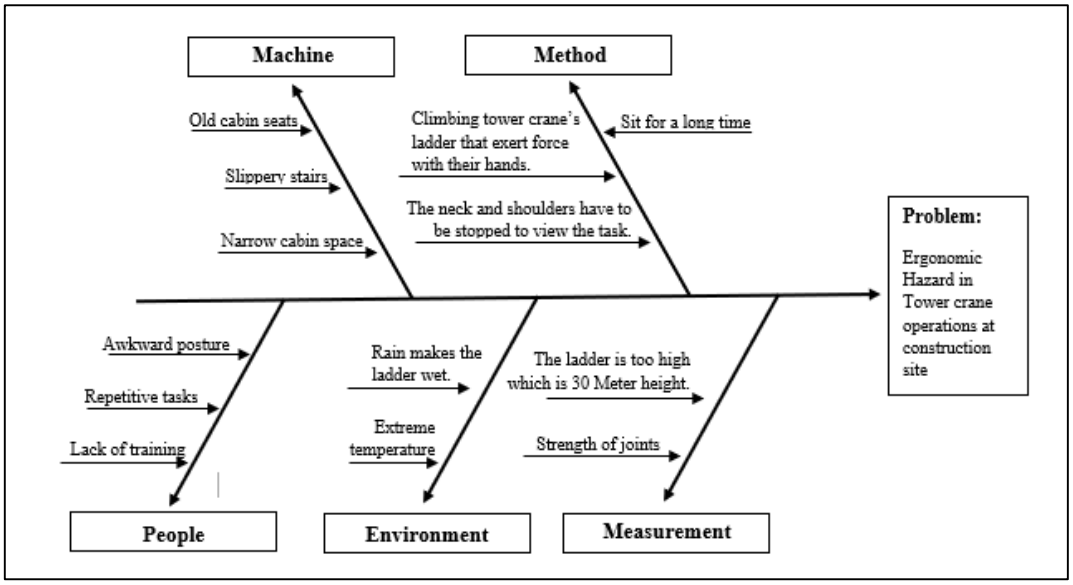

Figure 4: Cause-and-effect analysis of Ergonomic Hazard

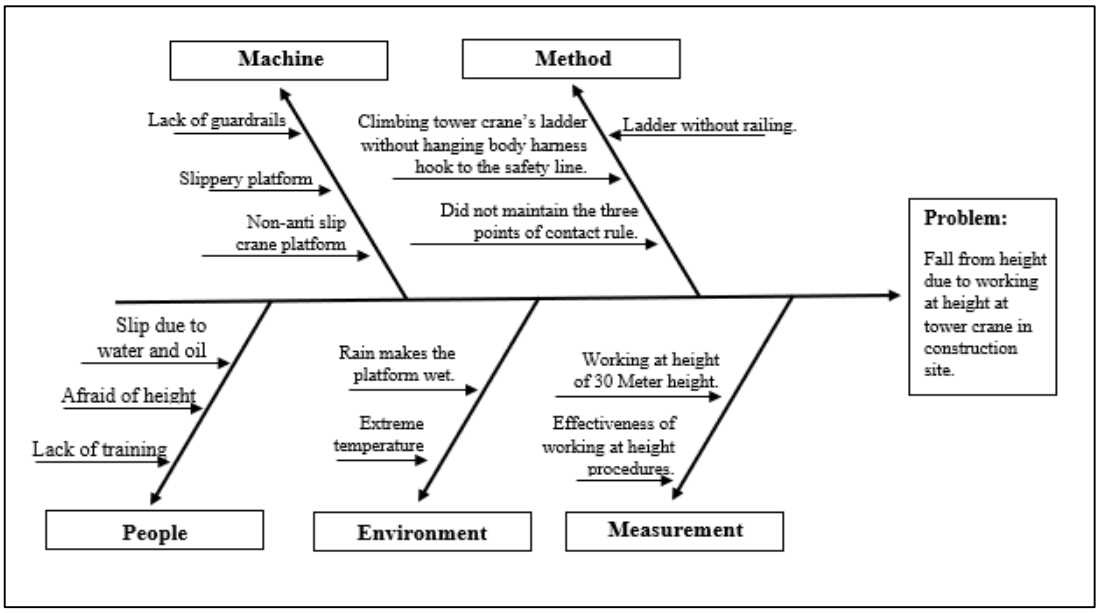

Figure 5: Cause-and-effect analysis of Fall from height (Safety Hazard)

As showed in figure 3.2, 3.3, and 3.4. there are 5 fives elements used which are, machine, method, people, environment and measurement. For ergonomic hazards cause and effect analysis as shown in figure 3.2, there are 3 hazards under machine element, 3 hazards under method element, 3 hazards under people element, 2 hazards under environment element and 2 hazards under measurements element. In addition, for cause-and-effect analysis for Fall from height (Safety Hazard) as shown in figure 3.3, there are 3 hazards under machine element, 3 hazards under method element, 3 hazards under people element, 2 hazards under environment and 2 hazards under measurement element.

Meanwhile, figure 3.4 shows the cause-and-effect analysis for Falling object (Safety Hazard). There are 3 hazards identified under machine element, 3 hazards under method element, 3 hazards under people element, 2 hazards under environment element and 2 hazards under measurement element.

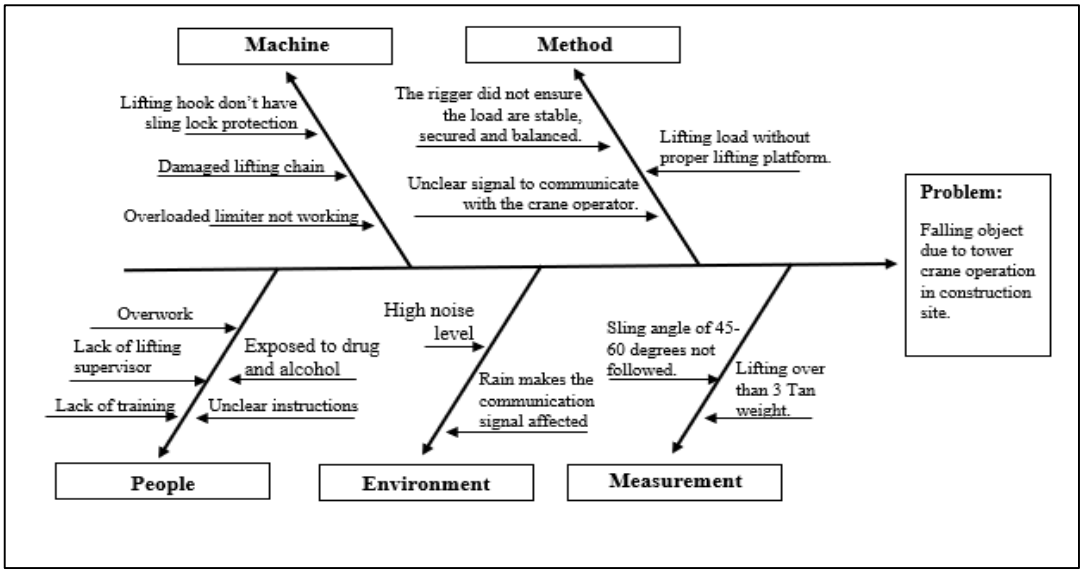

Figure 6: Cause-and-effect analysis of Falling object (Safety Hazard)

3.4 Risk Control

The most effective risk control is by eliminating the hazard. Next it is followed by substitution. If the hazard cannot be eliminated and substituted, then other solutions are controlled by engineering and administrative controls. Finally, the weakest risk control is use of PPE. Based on the hazard identification and risk assessment, there were some suggestions proposed as risk control was highly recommended to ensure the risk can be manage and control.

Table 5: Risk Control of each activity/hazard.

Item	Work Activity	Hazard	Risk Control 1) Elimination [E] 2) Substitution [S] 3) Engineering control [EC] 4) Administrative Control [AC] 5) Personal Protective Equipment [P]
1	Climbing a ladder with 30 Meter height to reach to the tower crane operation cabin.	a) Trips and falls due to lack of body harness. b) Exert force with their hands while climbing tower crane ladder.	a) [S] – Substitute ladder with passenger hoist [EC] – Build ladder guardrail [AC] – Establish training on three points contact rule. [P] – Wear body harness b) [EC] – Build ladder rest platform [AC] – Conduct training on stretching the muscle.

2	Crane operator conduct daily internal and external inspection of tower crane.	a) Fall from height. b) Dealing with tiring works tasks such as daily inspection of tower crane.	a) [EC] – Ensure all edges are install with guardrail [AC] – Establish safe work practice. [P] – Wear body harness b) [AC] – Provide simple checklist form to the crane operator
3	Tower crane operator identify material to be lifted / hoisted.	a) Dangerous machine b) Flying object c) Narrow cabin space d) Sit for too long	a) [S] – Substitute old parts [AC] – Establish safe work practice b) [S] – Substitute old communication devices with high quality performance. [AC] – Establish safe work practices [AC] – Install adequate signage [AC] – Establish training to workers [AC] – Prohibit workers to working if exposed to drug and alcohol. c) [E] – Eliminate all unnecessary material or parts inside the cabin. [S] – Substitute cabin with cabin with larger space. d) [S] – Substitute old chairs [EC] – Provide adjustable and flexible chairs to the crane operators. [AC] – Establish rest time to stretching the muscle
4	Rigger / General workers to attached the load hook to the material to be lifted.	a) Exposed to sharp object b) Pinch point c) Unproper sling angle	a) [AC] – Conduct toolbox briefing. [AC] – Establish safe work practices. [P] – Wear safety gloves b) [AC] – Conduct awareness training [AC] – Conduct safe operating procedure

			[P] – Wear safety gloves c) [AC] – Establish workers training. [AC] – Prohibit non-competence person to work
5	Hoisting material to designated loading platform / area.	a) Falling object due to unproper sling angle and hook sling lock. b) Blind spot and miscommunication c) Insecure rigging d) Unstable load e) Old loading platform	a) [EC] – Construct multi-loading platform. [AC] – Provide adequate signage. [AC] – Hire a signal man (competence person) [AC] – Hire a rigger with better experience. b) [S] – Substitute old sling [AC] – Conduct regularly tower crane internal and external inspection. c) [AC] – Provide adequate signage. [AC] – Provide a high-quality walkie-talkie to communicate [AC] – Prohibit unfit workers to working. [AC] – Conduct toolbox briefing d) [AC] – Conduct training to workers e) [AC] – Conduct training to workers.
6	Lowering hoisted material to designated platform / area.	a) Blind spot and miscommunication b) Falling object due to defective sling. c) Insecure rigging	a) [AC] – Provide adequate signage. [AC] – Use walkie-talkie to communicate b) [AC] – Provide adequate signage. [AC] – Hire a signal man (competence person) c) [AC] – Conduct training to workers
7	Rigger / General worker to remove the load hook to the lifted material.	a) Pinch point b) Exposed to sharp object c) Falling / flying object.	a) [AC] – Establish safe operating procedure [P] – wear appropriate personal protection b) [AC] – Provide training to workers

		[P] – Wear appropriate personal protection [P] – Provide First-Aid kit c) [AC] – Provide adequate safety signage.

4. Conclusion

As conclusion, the aim of this study was to conduct hazard identification, risk assessment and risk control (HIRARC) for lifting operation at condominium construction in Sabah. Thus, in order to achieve the aims, there were three objectives was constructed. Workplace inspection was implemented by using Hazard identification checklist during the inspection. Based on the inspection, the work activities were identified, and hazard were also being identified. In addition, conducting risk assessment on the hazard identified using risk matrix. It was found that there were four hazards involving four activities categorized under high level of risk. Hence, by using Hierarchy of Control on the hazards identified. The risk control proposed were presented to the safety team for further improvement. Therefore, it is recommended that further studies will be focus on association of multiple methods towards improving the safety and health at the work place and at the same time can reduce accidents and injuries among the workers such as Standard Operating Procedure (SOP), Emergency Response Plan (ERP) and Safety Policy [20].

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