Vol. 02, No. 4 (2020) 379-388, doi: 10.24874/PES02.04.005

Proceedings on Engineering Sciences

www.pesjournal.net

HAZARDS IDENTIFICATION & RISKS ASSESSMENT FOR HIGH-RISE BUILDING CONSTRUCTION BY FAILURE MODE AND EFFECTS ANALYSIS [FMEA] & PREVENTED BY OH&S MANAGEMENT SYSTEM

Thu Ya Mon[1]

Keywords:

Hazard; Risk; Risk assessment; FMEA method; High rise construction site; OH&S management system.

A B S T R A C T

Hazard is a potential source to cause the hostile consequences to physical or mental condition of a person in the workplace. Risk means the effect of uncertainty which may be either positive or negative. Risks assessment is the identification of risk sources, analyzing and evaluating them to understand the degree of safe and healthy work environment. Failure mode and effects analysis (FMEA) is the process of revising the practices as possible to identify potential failure modes in each activity, their root causes and effects on them. The purpose of this research is to analyze hazards and potential risks of work safety commonly occurred in high rise construction sites in Myanmar. Questionaries' are used for categorical data of hazards and potential risks to differentiate between real time and necessary control levels for work safety and introduce the applicable ways to be prevented. The research findings indicate the techniques to control and eliminate the hazards and potential risks through FMEA method and OH&S management system by identifying the critical work situations, the gaps between the control levels, understanding cross functional working relationship, standardizing safety norms and practices, reducing costs and increasing customers' satisfaction.

1. INTRODUCTION

In 2018, in the United States of private construction industry, the statistical data showed that 1008 out of 4,779 or 21.1% worker mortalities broke out due to work related accidents. This means that one in five workers deaths occurred in construction sites. The majority causes of private sector worker deaths (excluding highway accidents) in the construction industry were falls, struck by object, electrocution, and caught-in/between. Eliminating the Fatal Four hazards would save 591 workers' lives in America every year (OSHA, 2017). In Australia, preliminary worker death in construction sites before 07 April 2020 is 12, which is increased by 6 in that of 2019 (Safe Work Australia, 2020). In Myanmar, construction is one of the major driven industries of country economy (CSO: Ministry of Planning and Finance, 2018). Rapid development of construction projects throughout the country during a decade has led the rate of accidents and mortalities in work places. Less awareness on safety precautions during construction work has the impacts on construction cost and project schedule (Mon, 2020). The research data for this assessment have been collected from three high-rise construction sites in Yangon, Myanmar. Hazards in each activity are identified based on the nature and risks

Corresponding author: Thu Ya Mon
Email: iqcmyanmar@gmail.com, thu@lincoln.edu.my

ranking number (RRN) calculated by means of FMEA analysis. Preventive measure, moreover, to eliminate such kinds of risks is introduced with OH&S management system (ISO 45001:2018) standard.

2. LITERATURES REVIEW

"Failure modes" means the ways, or modes, in which something might fail. Failures are any errors or defects, especially ones that affect the customer, and can be potential or actual. "Effects analysis" refers to studying the consequences of those failures (Tague, N. R, 2005). A quantitative methodology that supports designers to evaluate the safety-related performance of residential construction designs by means of a risk analysis–based approach was introduced and with which construction companies can improve their onsite safety performance (Gangolells et al., 2010). Risks assessment for occupational health & safety on workplace and major sites is the essential analysis to accomplish satisfactory safety levels, especially to support decision-making for safety programs (Pinto et al, 2011). Liu and Tsai introduced a combined fuzzy-based risk assessment approach to manage occupational risks and hazards in construction workplaces. This methodology comprises the combination of Quality Function Deployment (QFD), Analytical Network Process (ANP), and Failure Mode and Effects Analysis (FMEA) methods to determine the relationships between construction items, types of risks and their causes, which leads to assess each risk value (Liu, H.T. and Tsai, Y.L, 2012).

The application of FMEA analysis is to prioritize the failure modes of the product, process or system in order to assign the inadequate resources to the most serious risk items (Liu et al., 2013). Although FMEA is widely applied as the risks assessment tool for construction projects, it has not been intended for this purpose. Unlike the manufacturing industry, where several approaches to modify FMEA method in order to tackle the predictable effects of uncertainty has been amended, the majority of the construction experts used the conventional method without any modification (Ahmed, 2014). An approach to safety cost estimation for the initial stages of construction bidding phase was designed by using risk assessment models and project scheduling was prepared by focusing on construction activities (Gurcanli et al., 2015). Five sets of safety risk drivers that can influence either the probability or the consequences of an accident were provided, which helps detecting more than 40% of potential fatalities in construction projects (Malekitabar et al., 2016). Productivity and safety simultaneously on construction projects were investigated by conducting a survey (Choudhry, 2017). In the analysis of occupational hazards and risks in construction sites, FMEA method presents the potential of integration and proposed a model to adapt the parameters as an attempt to reduce subjectivity (Cavaignac & Uchoa, 2018). Leave one clear line before and after a main or secondary heading and after each paragraph.

2.1 Hazard

A hazard is a cause that can origin harm or damage to humans, property, or the environment. A hazard can cause physical injury to our workers at site and if it has catastrophic severe, death can be caused. Hazards can be physical, chemical, biological, psychosocial, mechanical, and electrical or depend on movement and energy. Some types of hazards, moreover, might take some period to suffer ill health and lead to be sickness or death after certain period of time. Hazard level is determined by the extent of impacts and consequences, which can be categorized five levels as Trivial with severity value < 03 to Unbearable with that > 20. Table 1 illustrates hazard indexes and management actions to be taken due to their impacts.

Table 1. Index and hazard management actions to be taken

Hazard Index	Sort of Hazard	Level of Actions
Until 03 Severity < 03	Trivial hazards	Do not require special actions, preventive or detective
04 to 06	Bearable hazards	Does not require immediate action. Could be implemented in due course, depending on the availability of manpower and financial resources
08 to 10	Moderate hazard	Requires prediction and definition of terms (short-term) and responsibility for the implementation of actions
12 to 20	Relevant hazards	Requires immediate implementation of actions (preventive and detection) and definition of responsibilities. The work may be released for the execution only with accompaniment and continuous monitoring. The work interruption may occur when the conditions presents any uncontrolled situation
> 20	Unbearable hazards	The work cannot be started and if ongoing, should be stopped immediately and can only be restarted after implementing containment actions

Source: Faria, M. T (2010).

2.2 Risk

Risk is defined as the probability that exposure to a hazard will lead to a negative consequence, or more simply, a hazard poses no risk if there is no exposure to that hazard. Risk depends on the occurrences of a risk source (hazard) of an activity or process to cause injury or harm. Risk level is determined based on the consequences of impacts and its possibility. Risks can be reduced and mitigated by practicing management

standards like Quality Management System (ISO 9001:2015), Occupational Health & Safety Management System (ISO 45001:2018) and Risks management System (ISO 31000:2018).

2.3 Risk assessment

Risk assessment is a model of risk management process, which is the combination of risk analysis and risk evaluation. Risks can be categorized by evaluating their ranking numbers; RRN that can be calculated by FTA (Fault Tree Analysis), HACCP (Hazard Analysis and Critical Control Points), HAZOP (Hazard Operability Analysis) and LPA (Loss Prevention Analysis) methods. Other methods, moreover, multi-criteria decision-making (MCDM), mathematical programming (MP), artificial intelligence (AI), hybrid approaches are also applicable for risk evaluation. In this paper, risks prioritization is done by means of Failure Mode and Effects Analysis (FMEA), which comprises four stages as Hazards Identification, Defining Risk Determinants, Risk Evaluation and Risk Prioritization. Hazards identification means finding out risk sources that might cause risks and affect injury, harm or danger in construction sites. Defining risk determinants is establishing three risks attributes of Occurrence, Severity and Detection with their respective values. Risk evaluation is the calculating of risk ranking number, RRN, which is applicable to prioritize to be prevented or mitigated.

2.4 Failure Mode and Effects Analysis (FMEA)

FMEA can be applied as qualitative and quantitative method for failure analysis. An effective FMEA activity assists identification of potential failure modes and their effects based on experience with similar products, processes or system. It can be classified as three types; System FMEA, Design FMEA & Process FMEA due to the nature of analysis (Carlson, 2014). In construction sites, hazards and risks evaluation table can be done by following;

a) Create a major row for each component.
b) Identify failure modes and establish a sub-row for each mode.
c) Describe the effects on safety and system performance resulting from the failure. List the specific adverse outcomes.
d) Determine occurrence value if reliability data does not exist, estimate using qualitative ranks.
e) Determine severity value if experience data does not exist, estimate using qualitative ranks.
f) Determine causes of failure mode (if known): this includes environmental and/or operational stresses that increase the likelihood of the failure mode.
g) Determine methods of detecting failure mode (if known): although this entry does not prevent a failure from occurring, it is important to discover that a failure has occurred. This column is used to present signs and symptoms that a component has failed.
h) Suggest interventions: hardware modifications and/or compensatory actions to minimize effects.

2.5 Occupational Health & Safety Management System (OH&SMS) - ISO 45001:2018

ISO 45001 is published in March 2018 as an ISO standard for management systems of occupational health and safety (OH&S). The objective of ISO 45001 is to reduce occupational injuries and diseases as well as protect physical and mental health in the work environment. It is based on OHSAS 18001, established guidelines of the International Labour Organization. It is intended to provide a framework for managing OH&S risks and opportunities by effective preventive and proactive measures to eliminate hazards and minimize risks. OH&S policy is a set of principles by which top management can support the organizational goal and continual improvement of its performance with their high commitment. Different methods to assess OH&S risks can be applied to address different hazards or work activities. The method and complexity of OH&S risks assessment does not depend on the size of organizations but on the hazards related work activities.

3. OBJECTIVES

The objectives of this paper are

- To investigate hazards and potential risks commonly occurred in high-rise construction sites.
- To analyse the real time and necessary control levels for potential risks by means of Failure Mode and Effects Analysis (FMEA).
- To recommend implementation of ISO 45001:2018 in construction projects as the preventive action to eliminate risks for continual improvement.

4. RESEARCH METHODOLOGY

To collect categorical data for qualitative survey, three local construction companies that were performing three different building types: residential, commercial and multiple purposes, of high-rise building construction in Yangon. By questioning three representatives (Project Engineers, Safety Managers & Supervisors) from each site of these companies, data were collected. Based on the collected data, hazards are identified and listed. Risk analysis by FMEA is done through the procedures in Figure 1.

Based on the survey questions and on site situations, risks sources, hazards, causes and effects are listed as in Table 2. To determine risk level and RRN, the values of three risk determinants factors are represented with their degree of extent as in Table 3, 4 and 5.

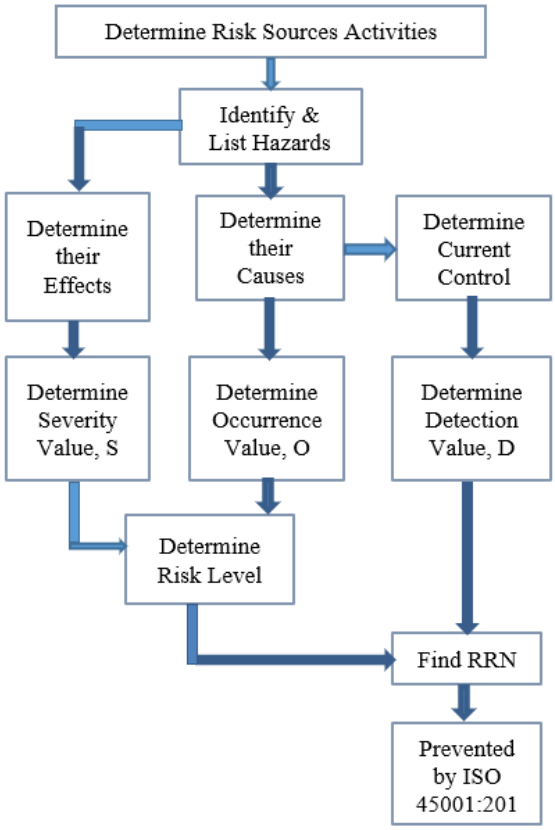

Figure 1. Risk Assessment Model by FMEA

Table 2. List of Work Activity, Hazard, Cause & Effect

No.	Work Activity	Hazard	Cause	Effect
1	Subsoil Structure (Demolition/Excavation/ Foundation)	Noise	Equipment & Environment	Temporary Headache or Deafness
		Vibration	Piling machines Crackers	Stress, Pain in Back & Limb
		Landslide	Soil excavation	Burial Tilting Adjacent Buildings
		Falling Objects	Change of height	Fracture, Injury
2	Concreting Work (Manual)	Cement Powder Dust	Diffusion in air while putting inside concrete mixer	Choking Respiratory Organs Damage to Eyes & Skin
3	Concreting Work (Ready Mixed)	Noise & Vibration	Use of station pumps	Stress Temporary Headache or Deafness
4	Working at Height & Scaffold	Falling People	Less fitness of Scaffolds Less awareness at height	Injury & Death
		Falling Objects	Careless manner at height	Damages to objects Harmful to workers by Injury & Death
5	Loading, Unloading by Manpower	Struck by Moving or Falling Objects	Careless or Lack of Awareness for Safety Precautions	Pain in Back, Limb, Injury & Death
6	Lifting Operation by Machines	Dropping Loads during Lifting	Use of Unskilled Operators Lack of Regular Machine Calibration	Damages to objects Harmful to workers by Injury & Death
7	Working with Electrical Equipment	Electrocution	Lack Awareness for Handling Equipment Wrong Connections	Incident, Injury & Death
8	Carpentry Formwork Fitting	Unfit or Weak Formwork	Lesser Competency of Workmanship Lack of Supervision during & after work	Disclose or Collapse of Formwork those wastes and damages materials Injury or Death
9	Welding for Structural or M&E Work	Eye Contact with Radiation	Lack of Goggles for Eyes Protection	Conjunctivitis
		Breathe in Welding Fume	Lack of Respiratory Cover (Mask)	Choking Respiratory Functions

Table 3. Level of Severity Value Based on Work Absence

Grading	Effect	Description	Absence
01	Slight	Accidents without injury	No absence
02	Moderate	Accidents with non-disabling injuries	01 to 30 days absence
03	Substantial	Accidents with disabling injuries without loss of substance or members	31 to 60 days absence
04	Severe	Accidents with disabling injuries, with losses of substance or members	61 to 90 days absence
05	Catastrophic	Death or permanent disability	No returning to work activity

Source: Faria, M. T (2010).

Table 4. Level of Occurrence Value Based on Frequency

Grading	Effect	Description	Absence
01	Unlikely	Very low possibility for damage to occur	Once every 2 years
02	Possible	Low probability for damage to occur	Once a year
03	Occasional	Moderate probability for damage to occur	Once a semester
04	Steady	High probability for damage to occur	Once every 3 months
05	Certain	Very high probability for damage to occur	Once a month

Source: Faria, M. T (2010)

Table 5. Level of Detection Value

Grading	Effect	Description
01	Certain	Control will almost certainly detect a potential cause/mechanism and subsequent failure mode
02	High	High chance the control will detect a potential cause/mechanism and subsequent failure mode
03	Moderate	Moderate chance the control will detect a potential cause/mechanism and subsequent failure mode
04	Low	Low chance the control will detect a potential cause/mechanism and subsequent failure mode
05	Uncertain	Control will not and/or cannot detect a potential cause/mechanism and subsequent failure mode; or there is no design control

5. FINDINGS AND DISCUSSION

5.1 Findings by risk evaluation model

Based on the qualitative survey at the selected construction sites, 14 types of risks might be observed due to different types of hazards in various construction activities. Risk value (RV) is calculated by multiplication of severity and occurrence depending on situations. Figure 2 displays comparison among RV in each construction sites. RV by some hazards, Noise, have the same value, 5, in each site while that by some, landslide, have different values 15, 20 and 25.

Impacts of hazards by means of landslide during excavation and dropping loads by lifting machine have catastrophic severity level. If these cannot be controlled in advance, the consequences can lead disadvantages not only to occupational safety but also socio-economic of the construction companies and so its severity value represents the highest, 5, in all construction sites. Such risks, in contrary, certain control actions are done to be prevented and so represent lowest detection value, 1. Risks by hazards, however, as noise and vibration during excavation and concreting work have slightly or moderate impacts, uncertain control level has been observed in each site and so represent the highest detection value, 5.

Risk ranking number, RRN, can be calculated by multiplication of detection value and mean risk value. Depending on the survey results of actual work situations, the priority numbers of some risks with low mean risk values; Noise & Vibration in excavation, occur high ranking number for being uncertain control to detect the potential causes during construction process. This shows that preventive actions for these risks are poorly practiced and even safety precautions for such risks are not established in all sites. Although mean risk value of land slide during excavation is the maximum, its ranking number is not the highest for practicing certain control procedures and precautions to avoid suck kind of risk. In this survey, variety standards and norms for work safety during construction are observed in each site.

Figure 3 demonstrates the mean risk values (Real Time Control Level- RTCL) and risk ranking number (Necessary Control Level- NCL) for different forms of hazards. Risks by noise & vibration during ready mixed concreting work has the highest ranking number, 50, whilst that for dropping loads due to lifting machine has the lowest, 7. The graph displays that safety precautions and practices for only two potential risks, landslide and dropping loads by lifting machine, are sufficient whereas the remaining risks require the strong policy, regulations and practices for risks elimination. Risks by noise and vibration have the greatest gap between RTCL and NCL. The gap between the two control lines indicates the extent of preventive actions to be implemented. The greater the gap, the higher the degree of actions to be eliminated the potential risks.

Table 6. Description of Risk Analysis

No.	Work Activity	Hazard	Site-A			Site-B			Site-C			Mean Value
			S	O	Risk Value	S	O	Risk Value	S	O	Risk Value	
1	Subsoil Structure (Demolition/Excavation/ Foundation)	Noise	1	5	5	1	5	5	1	5	5	5
		Vibration	2	4	8	1	5	5	2	5	10	8
		Landslide	5	4	20	5	3	15	5	5	25	20
		Falling Objects	3	1	3	2	1	2	3	2	6	4
2	Concreting Work (Manual)	Cement Powder Dust	2	5	10	1	5	5	1	5	5	7
3	Concreting Work (Ready Mixed)	Noise & Vibration	2	5	10	2	5	10	2	5	10	10
4	Working at Height & Scaffold	Falling People	2	3	6	3	4	12	5	2	10	9
		Falling Objects	3	3	9	1	4	4	5	3	15	9
5	Loading, Unloading by Manpower	Struck by Moving or Falling Objects	3	1	3	3	1	3	3	2	6	4
6	Lifting Operation by Machines	Dropping Loads during Lifting	5	1	5	5	1	5	5	2	10	7
7	Working with Electrical Equipment	Electrocution	3	1	3	5	1	5	5	2	10	6
8	Carpentry Formwork Fitting	Unfit or Weak Formwork	3	1	3	4	1	4	4	2	8	5
9	Welding for Structural or M&E Work	Eye Contact with Radiation	2	4	8	2	3	6	2	4	8	7
		Breathe in Welding Fume	2	4	8	2	3	6	2	4	8	7

Table 7. Description of Risk Evaluation Model

A	B	C	D	E	F	G	H
1	Subsoil Structure (Demolition/Excavation/ Foundation)	Noise	5	Uncertain	5	25	High
		Vibration	8	Uncertain	5	40	High
		Landslide	20	Certain	1	20	High
		Falling Objects	4	Low	4	16	Median
2	Concreting Work (Manual)	Cement Powder Dust	7	Uncertain	5	35	High
3	Concreting Work (Ready Mixed)	Noise & Vibration	10	Uncertain	5	50	High
4	Working at Height & Scaffold	Falling People	9	High	2	18	Median
		Falling Objects	9	Moderate	3	27	High
5	Loading, Unloading by Manpower	Struck by Moving or Falling Objects	4	Moderate	3	12	Median
6	Lifting Operation by Machines	Dropping Loads during Lifting	7	Certain	1	7	Low
7	Working with Electrical Equipment	Electrocution	6	Moderate	3	18	Median
8	Carpentry Formwork Fitting	Unfit or Weak Formwork	5	High	2	10	Median
9	Welding for Structural or M&E Work	Eye Contact with Radiation	7	Moderate	3	21	High
		Breathe in Welding Fume	7	Low	4	28	High

A= No., B= Work Activity, C= Hazard, D= Mean Value, E= Control level, F= Detection value, G= RRN Value, H= Action Taken Priority Level

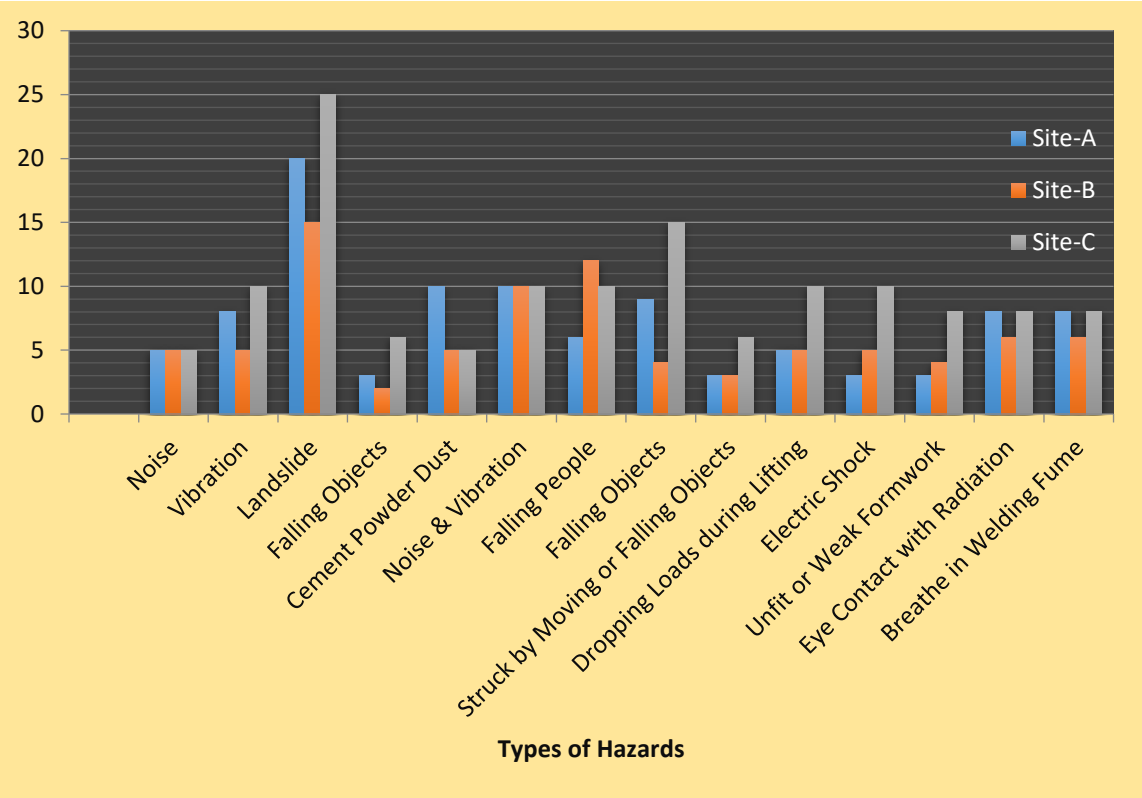

Figure 2. Comparison of Risk Value by Selected Construction Site

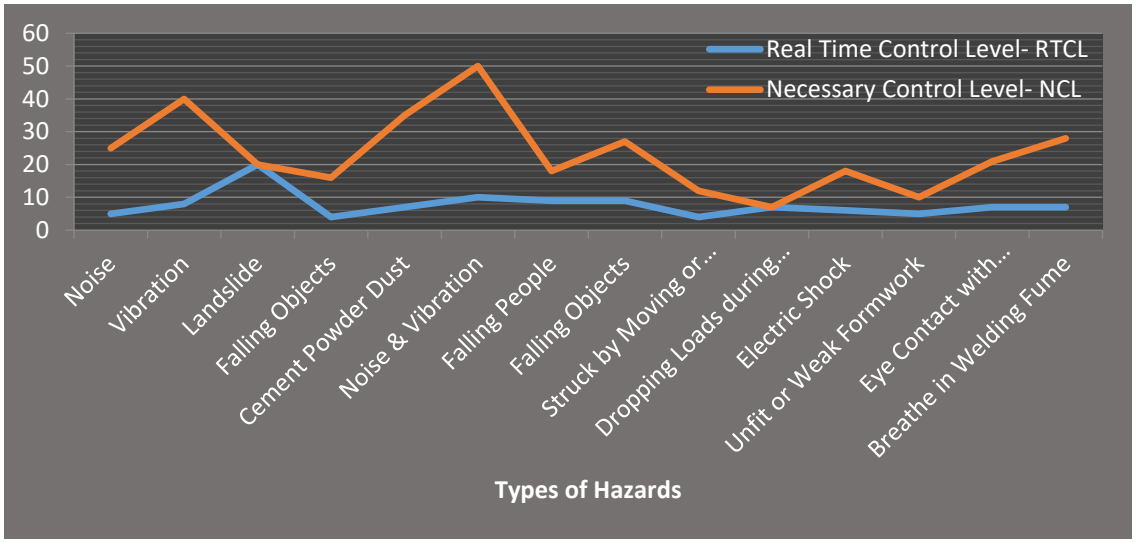

Figure 3. Real Time vs. Necessary Control Levels

5.2 Implementation of ISO 45001-2018 clauses as preventive actions for hazards and risks elimination

Risks can be controlled to some extent by preventive actions instead of mitigation plan. Risk mitigation, moreover, causes unacceptable consequences to the organizations. The results of risks assessment model can be overcome by planning the consideration the relationships and interactions between the activities and requirements for the management system as a whole. The continuing proactive hazards identification initiates at the conceptual design stage of any construction projects. The actions planned should be accomplished through OH&S management System and integrated other established and applicable standards, regulatory and statutory requirements for design, quality, environment, human resources, financial and business development. Table 8 describes the preventive actions and related clauses to eliminate hazards and risks by FMEA analysis.

Table 8. Preventive Actions by ISO 45001:2018

RRN Value	Hazard	Preventive Actions	ISO 45001:2018 Clauses No:	Description
50	Noise & Vibration	-Putting on ear protector such as ear plug or ear muff. -Replacing equipment with quieter one. -Maintenance of the machinery or tools.	6.2.1/c/1 7.3/a 8.1.2/a	-The OH&S objectives shall take into account the applicable requirements. -Workers shall be made aware of the OH&S policy and OH&S objectives. -The organization shall eliminate the hazards.
40	Vibration	-Use ear plugs and ear muffs -Establish as the requirements in the work instruction -Train to practice due to work instruction	8.1.2/e 6.2.1/d 6.2.1/e 7.4.2	-Use adequate PPE -OH&S objectives shall be monitored -OH&S objectives shall be communicated -Internal Communication
35	Cement Powder Dust	-Use facial masks during concrete mixing work -Establish as the requirements in the work instruction -Train to practice due to work instruction	8.1.2/e 6.2.1/d 6.2.1/e	-Use adequate PPE -OH&S objectives shall be monitored -OH&S objectives shall be communicated
28	Breathe in Welding Fume	-Use facial masks during welding work -Establish as the requirements in the work instruction -Train to practice due to work instruction -Use the competent welders for the related work	8.1.2/e 6.2.1/d 6.2.1/e 7.2/a	-Use adequate PPE -OH&S objectives shall be monitored -OH&S objectives shall be communicated -Determine the necessary competence of workers that affects or can affect OH&S performance
27	Falling Objects	-Make sure people in work area wearing helmets & safety shoes. -Use of safety signage at the working area. -Use checklists before working at height	8.1.2/e 6.2.1/d 6.2.1/e 7.3/f	-Use adequate PPE -OH&S objectives shall be monitored -OH&S objectives shall be communicated -Workers shall be aware of the ability to remove themselves from danger
25	Noise	-Use ear plugs and ear muffs -Establish as the requirements in the work instruction -Train to practice due to work instruction	8.1.2/e 6.2.1/d 6.2.1/e	-Use adequate PPE -OH&S objectives shall be monitored -OH&S objectives shall be communicated
21	Eye Contact with Radiation	-Use the competent welders for the related work -Use of goggles to protect eyes from welding light -Establish as the requirements in the work instruction -Train to practice due to work instruction	8.1.2/e 6.2.1/d 6.2.1/e 7.2/a	-Use adequate PPE -OH&S objectives shall be monitored -OH&S objectives shall be communicated -Determine the necessary competence of workers that affects or can affect OH&S performance
20	Landslide	-Area isolation - Studying the movement of the equipment and the soil resistance -Use of sheet piles or temporary false work in advance -Decide the required resources, established as the preliminary requirements and implement	7.1 7.2/a 7.3/e 7.4.2 8.1.1/b 8.1.2/c	-Determine and provide resources needed. -Determine the necessary competence of workers that affects or can affect OH&S performance -Workers shall be aware of hazards, OH&S risks and actions determined that are relevant to them. -Internal communication -Implementing control of the processes in accordance with the criteria -Eliminate hazards & risks by using engineering control and reorganization of work

18	Electrocution	-Wear protective gloves during handling electrical equipment. -Remove defective plug, socket, & wires. -Check wrong connection and poor contact. -Establish as the requirements in the work instruction -Train to practice due to work instruction	8.1.2/e 6.2.1/d 6.2.1/e	-Use adequate PPE -OH&S objectives shall be monitored -OH&S objectives shall be communicated
18	Falling People	-Make sure people in work area wearing helmets & safety shoes. -Use of safety signage at the working area. -Use checklists before working at height	8.1.2/e 6.2.1/d 6.2.1/e 7.3/f	-Use adequate PPE -OH&S objectives shall be monitored -OH&S objectives shall be communicated -Workers shall be aware of the ability to remove themselves from danger
16	Falling Objects	-Make sure people in work area wearing helmets & safety shoes. -Use of safety signage at the working area.	8.1.2/e 6.2.1/d 6.2.1/e 7.3/f	-Use adequate PPE -OH&S objectives shall be monitored -OH&S objectives shall be communicated -Workers shall be aware of the ability to remove themselves from danger
12	Struck by Moving or Falling Objects	-Make sure people in work area wearing helmets & safety shoes. -Use of safety signage at the working area.	8.1.2/e 6.2.1/d 6.2.1/e 7.3/f	-Use adequate PPE -OH&S objectives shall be monitored -OH&S objectives shall be communicated -Workers shall be aware of the ability to remove themselves from danger
10	Unfit or Weak Formwork	-Use competent and skillful workers -Establish close supervision pre, during and post formwork installation -Keep the records as checklists for related work -Keep the competency of workmanship as the documented information	7.2/a 5.3 7.2/d 8.1.1/c	-Determine the necessary competence of workers that affects or can affect OH&S performance -Organizational roles, responsibilities and authorities -Retain appropriate documented information as evidence of competence -Maintain and retain documented information to the extent necessary to have confidence that the processes have been carried out as planned
7	Dropping Loads during Lifting	-Make regular calibration for related machines -Keep as the records of calibration and maintenance as the documented information -Use checklists before operating machines -Establish communication as the vital requirements in the work instructions	9.1.1 7.3/f 5.4 7.4.2	-Monitoring and measuring equipment is calibrated or verified as applicable and retained as documented information as evidence -Workers shall be aware of the ability to remove themselves from danger -Consultation and participation of workers -Internal communication

5.2 Limitations for FMEA method

Failure Mode and Effects Analysis (FMEA) has been criticized comprehensively for some limitations though it is one of the most applicable traditional risk assessment tools for preventive actions. In analysing the risk assessment, risks ranking number RRN considers only three risk determinants although the relative importance among these factors is not taken into consideration which leads to low reliability on this method especially in the complex systems (Liu et al., 2013). Denoting the values for these factors, additionally, has been prepared based on the qualitative data through experience, which might have some variances among the researchers.

6. CONCLUSIONS

According to the research, the results indicate the gap between real time control level RTCL and necessary control level NCL that describes the degree of preventive actions to be taken although there might be some boundaries. The results, moreover, enhance the types of hazards and potential risks in construction projects to be alert. Preventive action is more effective rather than mitigation plan to eliminate hazards and risks. Using the

preventive measures make the projects reduce unnecessary cost and construction period. OH&S management system (ISO 45001:2018) is designed as proactive plan, implementation and monitoring guidelines for safety risk management model. Being high level structure (HLS), it can be integrated with other management standards as quality, environment and risk management system. By implementation this framework, hazards and risks can be eradicated as well as strengthen organizational practices for continual improvement.

7. RECOMMENDATIONS

For identifying and evaluating potential construction failures, it is recommended to apply service specific failure mode and effects analysis (SSFMEA) and Grey relational analysis. It is more detail analysing of three risk dimensions; Severity, Occurrence, Detection, by identifying 19 service specific elements under each category. This method provides the all-inclusive view of the construction processes and appropriate decision criteria for evaluating failure modes. Evaluating RRN for each failure mode by Grey relational analysis categorized by multiple criteria decision making in a complex interconnected situation.

References:

Ahmed, A. M. M. M. (2014). Composite FMEA for Risk Assessment in the Construction Projects Based on the Integration of the Conventional FMEA with the Method of Pairwise Comparison and Markov Chain. School of Industrial and Information Engineering, Politecnico Di Milano, pp.56.

Carlson, C. S. (2014). Understanding and Applying the Fundamentals of FMEAs. *Reliability and Maintainability Symposium*, IEEE.

Cavaignac, A., & Uchoa, J. (2018). Obtaining FMEA's indices for occupational safety in civil construction: a theoretical contribution. *Brazilian Journal of Operations & Production Management*, *15*(4), 558-565.

Choudhry, R. M. (2017). Achieving Safety and Productivity in Construction Projects. *Journal of Civil Engineering and Management*, *23*(2), 311-318. http://dx.doi.org/10.3846/13923730.2015.1068842

CSO: Ministry of Planning and Finance (2018). *Myanmar Statistical Yearbook: Nay Pyi Taw*, pp. 257.

Faria,M. T. (2010). *Risk Management Tools*. Handout prepared for the engineering course of work safety. UTFPR, Curitiba, PR.

Gangolells, M., Casals, M., Forcada, N., Roca, X., & Fuertes, A. (2010). Mitigating Construction Safety Risks Using Prevention through Design. *Journal of Safety Research*, *41*, 107-122.

Gurcanli, G. E., Bilir, S., & Sevim, M. (2015). Activity based risk assessment and safety cost estimation for residential building construction projects. *Safety Science*, *80*(7), 1-12. http://dx.doi.org/10.1016/j.ssci.2015.07.002

ISO / FDIS 45001:2018(E) *Occupational Health and Safety Management Systems- Terms and definitions*, pp. 3.

Liu, H. T., & Tsai, Y. L. (2012). A fuzzy risk assessment approach for occupational hazards in the construction industry. *Saf. Sci*, *50*, 1067-1078.

Liu, H.C., Liu, L., & Liu, N. (2013). Risk evaluation approaches in failure mode and effects analysis: A literature review. *Expert Systems with Applications*, *40*(2), 828-838. Retrieved from http://www.sciencedirect.com/science/article/pii/S0957417412009712

Mon, T. Y. (2020). Study of Risks Assessment for Implementation of QMS in Myanmar Construction Industry. *Proceedings on Engineering Sciences*, *02*(1), 2020, 73-80. doi:10.24874/PES02.01.008

OSHA, OSHA Data & Statistics / Commonly Used Statistics. Osha.gov. Retrieved 21 February 2017.

Pinto, A., Nuns, I. L., & Ribera, R. A. (2011). Occupational Risk Assessment in Construction Industry – Overview and Reflection. *Safety Science, 49*, 616-624.

Safe Work Australia (2020). *Fatality Statistics*. https://www.safeworkaustralia.gov.au/statistics

Tague, N. R. (2005). *The Quality Toolbox*, 2nd Edition. American Society for Quality.

Thu Ya Mon
Faculty of Engineering,
Research Fellow in Engineering,
Centre of Postgraduate Studies,
Lincoln University College,
Malaysia
iqcmyanmar@gmail.com,
thu@lincoln.edu.my