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Hazard Analysis in Building Construction Projects

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Abstract

The activities of construction workers results to accident happening more frequently at construction sites since building construction activities and trades are embodiments of health and safety risks and hazards. The aim of the study is to analyse the risk level of work items in building construction projects. Purposive sampling technique was adopted for data collection. The mean score method was used to analyse the most risky work items in building construction projects, result revealed that lift installation, electrical work, roof work, and steel structure, with mean scores of 4.03, 4.00, 3.95, and 3.80, respectively were the riskiest work items. The risk prioritization number were used to analyse safety risk assessment, result revealed that roof work, steel installation, reinforced concrete and cladding had similar top three critical hazards, fall from high level, struck by falling object and building structure collapse. It was concluded that work-related risk are strongly associated with construction trades, implying that construction safety risk management requires multiple management approaches. It was recommended that different approaches should be applied in the management of construction safety risks across building trades. The study will improve construction safety professionals' knowledge and awareness on safety risks and will enhance quality and reliability of risk assessment.

Keywords: *Construction, Hazard analysis, Project, Risk Assessment, Work item.*

Introduction

The construction industry poses a higher risk for accident when compared with other industries, due to the variety and complexity of skills required for the

diversity of work in the industry (Topal and Atasoylu, 2022). The activities of construction workers results to accident happening more frequently at construction sites since building construction activities and trades are embodiments of health and safety risks and hazards Okoye (2018). The construction industry has reliably accounted for a disproportionate injury rate universally (International Labour Organization, 2013). Such a high number of accidents and fatalities is not just a problem of undeveloped countries (Mihic, 2020). The United States has had 971 fatal accidents in 2017 which makes for 20.7% percent of all fatalities (U.S. Bureau of Labour Statistics, 2018), while in the EU, the construction industry participates with 21% of the fatal accidents (Eurostat, 2015). Nonfatal injuries are also much more common for workers in the construction sector than the average across all industries, even when compared to other production industries, taking the third place in the EU (Eurostat, 2015).

In other to provide a safe and healthy work environment occupational risk assessment is key (Topal & Atasoylu, 2022). Risk assessment therefore enables the identification of risk factors, their assessment and prioritisation (Conte, *et al*., 2011). The extent of damage occurring to the worker based on risk exposure is also revealed, and from which mechanisms to control risks are established (Pinos, *et al*., 2017). Gadd *et al*. (2004) clearly contended that the purpose of risk assessment is to determine if the levels of risk from work activities are acceptable or otherwise, and that measures must be taken to control and reduce the risk. It is understandable that the most effective way for improving safety performance is to prevent accidents before they occur. Thus, safety risk analysis is a necessary foundation upon which safety management can be built and risk assessment becomes a critical task, which forms an integral part of safety management systems. However, safety risk in construction cannot be effectively managed without first identifying the risk factors associated with different trades in construction.

LITERATURE REVIEW

Baradan and Usmen (2006) defined hazard in the context of occupational safety and health, as the potential for an activity or condition to produce harmful effects such as illness, injury, or fatality. On the other hand, safety risk is considered to be the likelihood of an injury or illness of a given level of severity (Baradan & Usmen, 2006: Hughes & Ferret, 2016). Safety risk have consistently been calculated by a number of researchers using equation (1), which is expressed as the quantity of safety risk as the product of likelihood of injury and severity of incident (Jannadi & Almishari, 2003: Baradan & Usmen, 2006; Hughes & Ferret, 2016)

Safety Risk value is expressed as: $R = P \times S$ (1)

Where: P = Likelihood of occurrence
S = severity of harm

Probability deals with the likelihood that an event will occur or that a hazard will be present. Severity is the potential loss when an event occurs and the loss may be measured in human terms, such as loss of life or death, serious injury, illness, number of loss of equipment or property (Baradan & Usmen, 2006; Kale & Baradan, 2020). And in numerically terms of financial impact to the organisation (Hallowell *et al.*, (2017).

The risk matrix provides an in-depth classification for likelihood (categorization for frequency of harm where the probability is characterized as; almost, frequent, occasional, remote and rare), classification of severity (categorization for consequence of harm where the probability is characterized as; catastrophic, major, moderate, minor and negligible), and risk classification (category of risk as; high risk level ranges from 12 to 25, medium risk level ranges from 4 to <12 and low risk level ranges from 0 to <4). Those three categories are correlated and a risk matrix is constituted as a result. Risk classification can be on the basis of risk acceptance, tolerable or not acceptable.

A review of literature on safety risk was conducted to throw more light on the study. Barandan and Usmen (2006) based their study on the definition of risk as the product of probability (frequency) and severity, they explained that simultaneous consideration of the severity and frequency displays a broader result than analysing risk based on severity or on frequency only and revealed that ironworkers and roofers were the riskiest building trades.. Gurcanli *et al.* (2015) determined activity-based risk assessment and safety cost estimation for residential building construction projects and revealed that fall from height, manual handling hazards, struck by fling/falling objects, were the most critical hazards and the most dangerous work activities were reinforced concrete work, excavation, and electrical work. Lee and Lim (2017) developed a risk assessment model to analyse the degree of risk of accident during construction and established that risk assessment identifies potential risk factors that occur in the course of work and establishes countermeasures in order to abate the possibility of an accident while on the workplace. Okoye (2018) evaluated the occupational health and safety risk level of building construction trades, by determining the average the risk level of some selected trades and acknowledged that roof, masonry, iron bending, steel fixing, tiling work and painting are high risks and fall from height, manual handling activities and climbing step and walking platforms were the most impactful health and safety risk factors in building trades.

Ghousi *et al.* (2018) designed a flexible method of building construction safety risk assessment and discovered that structural steel, excavation, roof work and building facade are the most risky building trades in construction projects. While struck by

falling objects and fall to lower level were the critical hazard in building construction projects

Kale and Baradan (2020) identified the factors contributing to severity of construction injuries using logistic regression model, it was observed that work experience, accident type, unsafe condition and unsafe act have significant influence injury severity on workplace. A risk assessment model for small-scale construction work was developed by Topal and Atasoylu (2022), result revealed that fall at height, contact with electricity, struck by moving objects, traffic accident and contact with machine are the most common accident type in North Cyprus.

Literature on safety risk concentrated mainly on risk quantification of occupational injury and illness. Literature have revealed that the fundamental prerequisite for improving health and safety which is risk assessment has received little consideration, limited studies have quantified the safety risk level of each work activities. This is the aim of this study, to analyse the risk level of work items in building construction projects.

The most acknowledged health and safety hazards on building construction sites identified by various studies include: fall from height, struck by fling/falling objects, building structure collapse, caving in, exposure to electricity, manual handling hazards, overexertion, lifting (overstrain), contact with objects, slips and trips, caught in between object, struck against an object, equipment injury, handling materials/objects, electrocution, stepping on sharp object, drowning, climbing step and walking platforms, vehicle/equipment, contact with working tools and fall to lower level (Baradan & Usmen, 2006; Gurcanli & Mungen, 2013; Choi, 2015; Gurcanli *et al.*, 2015; Hughes & Ferret, 2016; Bilir & Gurcanli, 2016; Williams *et al.*, 2017; Okoye, 2018; Ghousi *et al.*, 2018; Kale and Baradan, 2020; Liang *et al.*, 2021; Topal & Atasoylu, 2022).

Materials and Method

Questionnaire survey was used for the study. A well-structured questionnaire was designed to determine the most risky work items and to determine the risk level of potential hazard for the six (6) most risky work items in building construction projects. The questionnaire was divided into two. Part A comprises the background and general information of the respondent, and Part B determined the risk level, which focused on the eighteen health and safety hazard on construction sites that were identified from literature reviewed (Gurcanli & Mungen, 2013; Memarian & Mitropoulos, 2013; Gurcanli *et al.*, 2015; Choi, 2015; Orji *et al.*, 2016; Udo *et al.*, 2016; Bilir & Gurcanli, 2016; Williams *et al.*, 2017; Okoye, 2018; Ghousi *et al.*, 2018; Liang *et al.*, 2021). Purposive sampling technique was used for data collection. The study's population consist of Health and safety managers, Project Managers, Site Engineer, Quantity

surveyors Architects, and safety officers in Abuja. Respondents were asked to rank the severity and probability of safety hazards across building construction sites Respondents were asked to rank the severity and probability of work items in order to assess the risk level of safety hazards in building construction projects. A Likert scale of 1 to 5 was deployed, where: 1- Very Low risk, 2-Low risk, 3- moderate risk, 4-High Risk, 5-Very High risk, for the most risky work item in building construction projects. Table 1 presents the ranking for the severity of risk and the probability of risk occurrence (PRO) in projects.

Table 1 Likert scale used for determining the level of Probability and Severity

Severity	*Description*	*Level*	*Probability*	*Description*
Catastrophic	Fatality, fatal diseases or multiple major injuries	5	Almost	Certain continual or repeating experience.
Major	Serious injuries or life-threatening occupational disease	4	Frequent	Common occurrence.
Moderate	Injury requiring medical treatment or ill-health leading to disability	3	Occasional	Possible or known to occur.
Minor	Injury or ill-health requiring first-aid only	2	Remote	Not likely to occur under normal circumstances.
Negligible	Not likely to cause injury or ill-health	1	Rare	Not expected to occur but still possible.

Source: Workplace Safety and Health Council 2012.

Data Analysis

The data for the study was analysed using descriptive statistics which consist of mean score and risk prioritization number (RPN). The response items were ranked using the mean score (MS) according to the central tendency of responses, as presented in equation (2)

$$MS = \frac{1n_1+2n_2+3n_3+4n_4+5n_5}{n_1+n_2+n_3+n_4+n_5} \quad (2)$$

The degree of risk score was computed using the risk prioritization number to determine the level of risk which are obtained by multiplying the probability and severity columns as expressed in equation (3):

$$R = \frac{\sum PRO}{N} \times \frac{\sum SRI}{N} \quad (3)$$

Where PRO = Probability of occurrence, SR = Severity of risk impact and N= Number of items.

The scoring of risk will require rating the risk as high (which ranges from 12 - 25), medium (which ranges from 4 - <12) or low (which ranges from 0 - <4) depending on the likelihood of an activity to cause harm and how serious the harm might be (Workplace Safety and Health Council 2011).

RESULTS AND DISCUSSION

Questionnaire Response's Rate

96 questionnaires were distributed and 40 were returned making a response rate of 41.67%.

Respondent's Profile

This section discloses the respondents' profile by exploring their workforce, educational qualification and working experience. Table 2 presents the data collated in respect of this.

Table 2 revealed that result of the number of staff in the respondent's organisations. 40.0% of the respondent's worked in a small sized construction firms, 45.0% of the respondent's worked in a medium sized construction firms, 15.0% of the respondent's worked in a large sized construction firms. It is anticipated that the level of safety adherence will be higher being that about 60% of the respondents worked in both medium and large sized construction firms when compared with the small sized ones owing largely to the fact that they will have more resources to be deployed in ensuring that safety issues are taking very seriously. The educational qualifications of the respondents as shown in Table 2 shows that 5% had National Diploma (ND) and Doctorate degree (PhD), 62.5% had Higher National Diploma/ Bachelor of Science/Bachelor of Technology 20.0% had Master of Science/Master of Technology (MSc/M Tech) while the remaining 7.5% of the respondents had other qualification not listed. This is an indication that the respondents are competent and well experienced to provide reliable information for the study. On the work experience of respondents, the highest score of respondents were those that had worked for 5-9years

representing 13(32.5%) next were 10-14years representing 11(27.5%) of the sampled population. Third were 20years and above representing 6(15%), the least in the chart were 15-19 and less than 5years representing 5(12.5%). With the outcome of the result it would be concluded that the respondents could be considered well-informed.

Table 2 Respondent's Workforce, Education Qualification and Work Experience

Parameter	*Frequency*	*Percent (%)*
Total number of Workers		
1-49	16	40.00
50-249	18	45.00
250 and above	6	15.00
Total	40	100
Education Qualification of respondent		
ND	2	5.00
HND/BSC/BTECH	25	62.50
MSC/MTECH	8	20.0
PhD	2	5.00
Others	3	7.50
Total	40	100.0
Work Experience of respondent		
0-4	5	12.50
5-9	13	32.50
10-14	11	27.50
15-19	5	12.50
20 years and above	6	15.00
Total	40	100.0

Determination of Most Risky Work Items in Building Construction Projects

In this section the most risky work items was determined as presented in table 3.

Table 3 demonstrations the result of the top five most risky work items in building construction project, Lift installation with mean score of 4.03 was ranked first. This is in agreement with Ghousi *et al.* (2018) who identified installation of lift as a work item that presents approximate 10- 22% of project total risk. Electrical works with mean score of 4.00 was ranked second. This is in line with Baraban and Usmen (2006); Gurcanli *et al.* (2015) who attested that electrical works is one of the high-risk trades in building construction projects. Roof work with mean score of 3.95 was ranked third, this is in line with Baraban and Usmen (2006); Choi (2015); Okoye (2018) who acknowledged roof work as a trade with frequent risk occurrence in construction. Steel structure with mean score of 3.80 was ranked fourth. This is in agreement with Ghousi

et al. (2018) and Okoye (2018) who identified Steel structure as one of the most dangerous trade in building construction projects. Reinforced concrete work and Cladding works were ranked fifth with mean score of 3.33 as the riskiest work activity in building construction project. The result is in agreement with Bilir and Gurcanli (2018) who identified reinforced Concrete work as a risky work item. This outcome is in line with the findings of Ghousi *et al.* (2018) who identified building façade as a hazardous trade.

Table 3 Top Ten Riskiest Work Items of Building Construction Projects

S/N	*Work Item in Building Construction Projects*	*Mean Score*	*Rank*
1	Installation of Lift	4.03	1
2	Installation of electrical works	4.00	2
3	Roof construction	3.95	3
4	Steel structure	3.80	4
5	Concrete work	3.33	5
6	Cladding work	3.33	6

Risk Level of Work Items in Building Construction Projects

This section presents the risk level of the eighteen hazard identified in literature, of the top five most risky work items (lift installation, electrical works, roof work, Steel structure, reinforced concrete work and cladding work) in building construction projects. The level of risk was determined by multiplying the severity and probability of safety hazard using the Risk Matrix method. Table 4-10 captured the result of the top five hazard for each work item was as shown.

Table 4 demonstration result of Potential hazard in lift installation work was determined, result revealed that fall from high level was the most common accident type with high risk score of 12.90. Electrocution /contact with electricity is second in number with medium risk score of 10.10. Apart from this, equipment accidents have a considerable rate with medium risk score of 9.40. Traffic / transportation accident was the least accident types of all with low risk score of 3.00. Result of the findings was similar to that of Williams *et al.* 2017 Ghousi *et al.* (2018) and Liang *et al.* (2021) who established that fall from height, electrocution, vehicle/equipment related accident were the most fatal accidents type on construction sites.

Table 4 Determination of Risk Level in Lift Installation Work

Hazard in lift installation Work	*Severity*	*Likelihood*	*Risk Score*	*Risk Level*	*Rank*
Fall from height	4.33	2.97	12.90	High	1
Contact with electricity	4.17	2.42	10.10	Medium	2
Equipment accidents	3.67	2.56	9.40	Medium	3

Struck by falling objects	3.50	2.52	8.80	Medium	4
Fall to lower level	3.17	2.60	8.23	Medium	5

Table 5 demonstration result of Potential hazard in the installation of electrical work was determined, result revealed electroçution /contact with electricity was the most common accident type with high risk score of 14.64. Contact with underground lines is second in number with medium risk score of 8.77. Apart from this, Hazards due to manual handling of machine & tool usage have a considerable rate with medium risk score of 8.69. The result agrees with the position of Gurcanli *et al.* (2015) who acknowledged that electrocution /contact with electricity and hazards due to manual handling of machine & tool usage were the most common accident type in electrical works.

Table 5 Determination of Risk Level in Electrical work

Hazard in Electrical Work	*Severity*	*Likelihood*	*Risk Score*	*Risk Level*	*Rank*
Contact with electricity	3.90	3.76	14.64	High	1
Contact with underground lines	3.45	2.54	8.77	Medium	2
Manual handling of machine/tool hazards	3.00	2.90	8.69	Medium	3
Fire	3.03	2.71	8.19	Medium	4
Fall from height	2.84	2.60	7.36	Medium	5

Table 6 shows the determination of potential hazard in roof work, result revealed that fall from high level was the most common accident type with high risk score of 13.47. Building structure collapse is second in number with high risk score of 12.06. Fall to lower level had a considerable rate with medium risk score of 10.20. This outcome is in line with the findings of Gurcanli and Mungen (2013) who identified fall from height and building structure collapse as the leading causes of death in roof work.

Table 6 Determination of Risk Level in Roof Work

Hazard in roof work	*Severity*	*Likelihood*	*Risk score*	*Risk level*	*Rank*
Fall from high level	4.00	3.37	13.47	High	1
Building/structure collapse	4.45	2.71	12.06	High	2
Fall to lower level	3.55	2.87	10.20	Medium	3
Struck by falling objects	3.45	2.79	9.61	Medium	4
Manual handling of machine/tool hazards	2.95	2.89	8.52	Medium	5

Table 7 demonstrates the result of Potential hazard in the steel construction was determined, result revealed Building structure collapse was the most common accident type with medium risk score of 11.26. Fall from high level was second in number with medium risk score of 11.25. Apart from this, Struck by falling objects had a considerable rate with medium risk score of 11.19. This outcome is in line with the findings of Ghousi *et al.* (2018) who identified fall from height, struck by falling objects, manual handling of machine/tool hazards and construction equipment accidents where the most critical hazards in steel work.

Table 7 Determination of Risk Level in Steel Construction Work

Hazard in Steel construction Work	*Severity*	*Likelihood*	*Risk score*	*Risk level*	*Rank*
Building/structure collapse	3.79	2.97	11.26	Medium	1
Fall from high level	3.83	2.94	11.25	Medium	2
Struck by falling objects	3.77	2.97	11.19	Medium	3
Manual handling of machine/tool hazards	3.17	2.89	9.15	Medium	4
Equipment accidents	3.55	2.46	8.70	Medium	5

Table 8 demonstrates result of Potential hazard in Reinforced Concrete work was determined, result revealed Building structure collapse was the most common accident type with medium risk score of 11.56. Fall from high level was second in number with medium risk score of 9.45. Apart from this, Struck by falling objects had a considerable rate with medium risk score of 9.12. The result of the finding is similar with Bilir and Gurcanli (2018) who identified fall from height, Struck by falling objects and Building structure collapse as the top accident type in reinforced Concrete work.

Table 8 Determination of Risk Level in Reinforced Concrete Work

Hazard in Reinforced Concrete	*Severity*	*Likelihood*	*Risk score*	*Risk level*	*Rank*
Building/structure collapse	3.92	2.95	11.56	Medium	1
Fall from height	3.30	2.87	9.45	Medium	2
Struck by falling objects	3.32	2.74	9.12	Medium	3
Overexertion	3.10	2.70	8.37	Medium	4
Equipment accidents	2.95	2.50	7.37	Medium	5

Table 9 demonstrates the result of Potential hazard in the cladding work was determined, result revealed fall from high level was the most common accident type with medium risk score of 11.32. Struck by falling objects was second in number with

medium risk score of 8.74. Apart from this, Building structure collapse had a considerable rate with medium risk score of 8.09. This outcome is in line with the findings of Ghousi *et al.* (2018) who identified fall from height, struck by falling objects and hazards due to tool usage as the most critical hazards in building façade.

Table 9 Determination of Risk Level in Cladding Work

Hazard in cladding Work	*Severity*	*Likelihood*	*Risk score*	*Risk level*	*Rank*
Fall from height	3.56	3.18	11.32	Medium	1
Struck by falling objects	3.35	2.61	8.74	Medium	2
Building/structure collapse	3.28	2.47	8.09	Medium	3
Fall to lower level	2.91	2.74	7.98	Medium	4
Manual handling of machine/tool hazards	2.57	2.44	6.27	Medium	5

Conclusion and Recommendation

The study determined the safety risk level of six (6) building construction trades. The result of the study has confirmed that the inherent risks in building construction trades are many and varies from trade to trade in addition the level of risk associated with each trade differs. However result have shown that electrical work, roof work and lift installation are building trades associated with high risk hazards and when such hazards occur it has high impact on the workers. On the other hand most hazard in the study are of medium risk, signifying that workers are still exposed to accident and injury that could be tolerable on sites. It was observed that roof work, steel installation, reinforced concrete and cladding had similar top three critical hazards, but it was noticed that the rate of occurrence and the magnitude of impact of safety risk differ across the trades. Indicating that some risk factors have more impact on some trade than others. This specifies that the magnitude of risks in building operations depends on the nature, types of activities and the mode of operations involved in any trade.

It was concluded that work-related risk are strongly associated with construction trades, implying that construction safety risk management is multidimensional, in other word requires multiple management approaches. It was recommended that different approaches should be applied in the management of construction safety risks across building trades. It was further suggested that caution should be taken when carrying out activities on the high risk trades and measures should be taken to control and reduce the risks to an acceptable level. The study will improve construction safety professionals' knowledge and awareness on safety risks and will enhance quality and reliability of risk assessment, which will aid in understanding the hazard associated with each work item. Further study should be carried on the strategies mitigating the risks associated with building construction trades.

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