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Evaluation of Occupational Safety Risk Factors in Building Construction Projects

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Abstract

The inability of construction operatives' to recognize and respond to hazards in rapidly changing and unpredictable environments hath led to the occurrence of high injury rates on construction site. The aim of the study is to evaluate the risk level of safety risk factors in building construction activities. Purposive sampling technique was used to distribute the questionnaire to construction professionals in Abuja. Risk prioritization number was used to analyse the risk level of hazard in building work items, result revealed that installation of electrical work, roof work, and installation of lift had the highest risk level with average risk scores of 11.48, 11.01, and 10.74 respectively. Evaluation of safety risk factors was conducted for the top three riskiest work items, result revealed that fall from high level, electrocution /contact with electricity and collapse of building structure were the most common accident type with average risk score of 11.23, 10.23and 8.46 respectively. It was concluded that different work operations have different magnitude of hazards and the levels of risk associated with them. It was recommended that different approaches should be applied in controlling health and safety risks across building work items and accident prevention measure should be provided for worker in order to control the tolerable risk on site. The study will serve as a guide for experts who want to carry out risk assessment on their site and will help construction practitioners in identifying the hazards in a specific construction work item on site.

Introduction

The construction industry is acknowledged as having inherent risks with high levels of change and uncertainty due to the increasing complexity of construction projects. The peculiarity of construction products have resulted to many hazardous sources

on the construction site. Improper handling of these hazardous sources will cause property losses or endanger the life and safety of the construction employees (Liang *et al*, 2021). Incidents or accidents that occurred at construction sites have caused numerous deficiencies in project performance, such as increase in project cost, delay in completion of project, and reduce productivity and creating negative impressions about the business (Nour & Abo, 2021). Construction industry has always been plagued with accident for a long time and is known as the most hazardous industry. According to an evaluation conducted by the International Labour Organization, up to 60, 000 fatal injuries on workplaces occur annually on the construction sites globally. This means that in every 10 minutes one fatal work injury occurs in this sector, and approximately 17% of fatal injuries at workplace resulting to one out of six accidents happens on the construction sites (Timofeeva *et al.* 2017). An effective safety management is essential in the construction industry in order to prevent work-related accidents (Alizadehsalehi, 2018).

Accurate safety evaluation and effective risk early warning on construction units must be carry out on the construction site, in order to reduce the harm caused by construction safety accidents (Liang *et al*., 2021). The inability of construction operatives' to recognize and respond to hazards in rapidly changing and unpredictable environments hath led to the occurrence of high injury rates on construction site (Goh and Chua, 2009). This was proven by the model designed by Albert *et al*. 2014 which indicated that there is a possibility of injury when a hazardous situation exists and workers are exposed to the hazard in the absence of adequate safety controls. They further explained that, when hazards are not properly recognized and communicated, however, the devised safety management programme may not be effective.

Although studies on safety has concentrated heavily on construction risk assessment as well as the selection of appropriate safety programme elements, the fundamental requirement to improving safety which is hazard identification, recognition and knowledge has received limited attention. Consequently, it is of utmost significance that operational hazard recognition and communication methods be established that overcome the inherent limitations connected with current methods. This is the gap this study intend to achieve, by determining the riskiest work items and to evaluate the risk level of safety risk factors in building construction projects.

Safety Risk Factors in Construction

Mihic (2020) described hazards as some degree of events which have the potential outcomes, which may cause ill effects to the safety and wellbeing of construction workers. According to Kale and Baraban (2020) risk is normally defined as the combination of two components: the probability or frequency of a defined hazard occurrence and the severity or consequences of the hazard occurrence. Probability is defined as the likelihood or rate of occurrence of an accident or hazards in a specific period of time (Hallowell *et al*., 2017). While Severity is defined as the magnitude of the outcome of an accident or hazards. Severity may be described in terms of numerically in terms of money impact to the organisation or firm or in terms of degree of injury such as medical case, lost work-time, fatality (Hallowell *et al*., 2017). Researchers have constantly calculated safety risk using equation (1), which express the quantity of risk as the product of probability and severity (Baradan & Usmen, 2006; Hallowell & Gambatese, 2009; Hallowell *et al*., 2017).

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

Where P = Likelihood of occurrence.
S = Potential severity of harm.
In this study the two independent components of risk (probability and severity) will be compared, quantified, analysed and ranked.

Literature Review on Safety Risk Factors on Construction Sites

This section investigated several studies on the various hazard types that causes occupational accident in building construction projects. Baradan and Usmen (2006) conducted a study on occupational injury and fatality on building trades and identified Ironworkers, roofers, electricians and masons as the most dangerous building trades. Hallowell and Gambatese (2009) quantified construction safety and health risks and findings revealed that fall to lower level, toxic exposure, struck by object, caught in and transportation were the top safety risk. The causes of occupational accident was analysed by Gurcanli & Mungen (2013) and findings revealed that the major causes of accident in construction projects were fall, struck by thrown/ falling objects, building structure collapse and exposure to electricity. Gurcanli *et al.* (2015) Studied an activity-based risk assessment 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.

The effect of lack of adequate attention to safety measures on construction sites was studied by Udo *et al*. (2016) and discovered that injury while handling materials/objects, injury while lifting materials/objects, slips and trip on objects and caving in of excavation were the most common accidents type that occurs on sites. Bilir and Gurcanli (2016) determined activity-based accident frequencies in building construction projects, findings revealed that roof, reinforced concrete and excavation, were the most hazardous activities and fall from height, struck by falling object, building structure collapse and contact with electricity were the frequent causes of accident in construction activities. Accidents in building construction sites was examined by Orji *et al*. (2016) and acknowledged that equipment injury, stepping on sharp object and falls from height were the most frequent accidents encountered on construction sites. Timofeeva *et al.* (2017) assessed the professional risk in construction, findings revealed that electric and gas welders, bricklayers, concrete workers, carpenter are constructional occupations with greatest occupational risks. Occupational health and safety risk level of building construction trades was assessed by Okoye (2018), and acknowledged that masonry, roofing and iron bending are trades with high risks and fall from height and manual handling activities were the most impactful safety risk factors in building trades. A flexible method of building construction safety risk assessment was designed by Ghousi *et al.* (2018), findings showed Struck by falling objects and fall to lower level were the critical hazard in building construction projects in addition the most dangerous building trades were structural steel, excavation and building facade. Liang *et al.* (2021) evaluated safety risk of construction in China and findings revealed that fall from high place, pit collapse, object striking accident, electric shock and fire were the most common accident types. From the literature reviewed it can be observed that researcher have identified several hazards that exist on construction site

and suggested measures to minimise accidents, but there is no specific study that evaluated the risk level of safety risk factors in building construction projects in Abuja, by performing an activity risk assessment for each work items.

Materials and Method

A well-structured questionnaire was designed to determine the riskiest work items and to evaluate the risk level of safety risk factors for the most risky work items in building construction projects. The questionnaire was split into two divisions. Section A covered the background and general information concerning the respondent, and section B asked the respondents to rank the severity and probability of safety risk factors across building construction sites. Purposive sampling technique was used to distribute the questionnaire. The sample population consisted of Project Managers, Health and safety managers, Site Engineer, Architects, Quantity surveyors and safety officers in Abuja. Respondent opinion was requested based on their knowledge and experience on the severity and probability of the riskiest work items and the risk level of safety hazards of the most risky work items in building construction projects. A Likert scale of 1 to 5 was deployed, as presented in table 1. A total of 40 questionnaires were retrieved representing a response rate of 41.67% out of 96 questionnaires that were distributed to respondents.

Table 1 Likert scale used to determine the level of Probability and Severity

Probability (Likelihood)	Description	Scale	Severity (Consequence)
Never	First aid injuries only and/or minimal impact	1	Insignificant
Unlikely	Minor injuries and/or short-term impact	2	Minor
Possible	Serious injuries and/or significant impact	3	Moderate
Likely	Fatalities and/or major short-term impact	4	Major
Always	Large number of fatalities and/or major long-term impact	5	Catastrophic

Source: researcher's field work 2021

Data Analysis

The data for the study was analysed using risk prioritization number (RPN). Risk prioritization number is used to compute the degree of risk score which determines the level of risk which are obtained by multiplying the probability and severity columns (Workplace Safety and Health Council 2011). A further classification of the risk is carried out using the risk matrix. The risk matrix shows the numeric rating which is used to compare the RPN to attain the level of risk for a particular work item as shown in Table 2.

Table 2 Risk Matrix for Likelihood and Severity showing numeric rating

Likelihood Severity	Rare (1)	Remote (2)	Occasional (3)	Frequent (4)	Almost certain (5)
Catastrophic (5)	5	10	15	20	25
Major (4)	4	8	12	16	20
Moderate (3)	3	6	9	12	16
Minor (2)	2	4	6	8	10
Negligence (1)	1	2	3	4	5

Source: Workplace safety and health 2012

The total risk level of construction activity is the summation of construction hazards related to each activity (Zolfagharian *et al*., 2014). Total risk level was classified into three categories when using the risk matrix as; high (which ranges from 12 - 25), medium (which ranges from 4 - <12) or low (which ranges from 0 - <4) in accordance to the (Workplace Safety and Health Council, 2011).

Results and Discussions

Analysis of Respondents' Profile

This section discloses the respondents' profile by exploring their gender, educational qualification and working experience. Table 3 presents the data collated in respect of this.

Table 3 revealed that 22.5% of the population sampled were female, while the 77.5% of the respondents were male. 95% of the respondents had educational qualification of HND/B.SC/B.TECH and above, signifying that the respondents are competent to provide relevant data for the study. Only 12.5% of the respondents had less than 5years working experience, while about 55% had over 10 years' experience, it can be acknowledged that the respondents could be considered well qualified for the study.

Table 3 Respondent's Gender, Education Qualification and Work Experience

Parameter	Frequency	Percent (%)
Gender		
Female	9	22.5
Male	31	77.5
Total	40	100
Qualification		
ND	2	5.0
HND/BSC/BTECH	25	62.5
MSC/MTECH	8	20.0
PhD	2	5.0
Others	3	7.5
Total	40	100.0
Working Experience		
<5 years	5	12.5
5-9 years	13	32.5
10-14 years	11	27.5

15-19 years	5	12.5
20 years and above	6	15.0
Total	40	100.0

Source: Researcher's fieldwork 2021

Determination of Riskiest Work Items in Building Construction Projects

This section determined the riskiest work items in building construction projects, as presented in table 4.

Table 4 summaries the safety risk assessment of the common work activities for building construction projects. Result revealed that installation of electrical work had the highest medium risk level with an average risk score of 11.48. Roof work was second with an average risk score of 11.01. Installation of lift was third in position with an average risk score of 10.74. Landscaping had the least with an average risk score of 2.80. The result shows that 16 out of the 17 making 94.12% of the work items in building construction projects are medium risk with a tolerable acceptable level risk.

Table 4 Risk Assessment of work items in building construction projects

SN	Work Items in Building Construction.	Severity	Likelihood	Risk Score	Risk Level	Rank
1	Installation of electrical works	3.79	3.03	11.48	Medium	1
2	Roof Construction	3.41	3.23	11.01	Medium	2
3	Installation of lift	3.78	2.84	10.74	Medium	3
4	Structural steel work	3.63	2.95	10.71	Medium	4
5	Concrete work	2.89	2.79	8.06	Medium	5
6	Cladding work	2.95	2.54	7.49	Medium	6
7	Mechanical works	3.05	2.4	7.32	Medium	7
8	Excavation work	2.88	2.53	7.29	Medium	8
9	Masonry work	2.76	2.64	7.29	Medium	9
10	Finishing work	2.56	2.5	6.40	Medium	10

Source: Researcher's fieldwork 2021

Evaluation of Safety Risk Factors in Building Construction Projects

This section presents the evaluation of eighteen safety risk factors identified in literature, for the top three most risky work items (installation of electrical works, roof work and installation of lift) in building construction projects using the 5x5 Risk Matrix approach as shown in Table 5 and 6.

Table 5 presents the evaluation of safety risk factors of the top three risky work items sampled. In the installation of electrical works: were contact with electricity; Contact with underground lines; Manual handling of machine/tool hazards were the potential hazards with risk score of 14.64, 8.77 and 8.69 respectively. Traffic / transportation accident was the least with risk score of 3.00. In roof works: fall from height; Building/structure collapse; fall to lower level were the potential hazards with risk score of 13.47, 12.06 and 10.20 respectively. Contact with underground lines was the least with risk score of 2.39. In lift installation: fall from height; contact with electricity and equipment accidents were the potential hazards with risk score of 12.9, 10.10 and 9.40 respectively. Contact with underground lines was the least with risk score of 2.41.

Table 5 Risk levels of Safety Risk Factors of Riskiest Work Items in Building Construction Projects

Safety Risk Factors	Electrical			Roof Work			Lift		
	SRI	PRO	RS	SRI	PRO	RS	SRI	PRO	RS
Struck or hit by falling objects	2.38	2.14	5.09	3.45	2.79	9.61	3.50	2.52	8.80
Fall from high level	2.84	2.60	7.36	4.00	3.37	13.47	4.33	2.97	12.86
Cave –ins	1.88	1.67	3.13	2.08	1.77	3.67	2.83	1.89	5.35
Fall to lower level	2.26	2.44	5.52	3.55	2.87	10.20	3.17	2.60	8.23
Fall to the same level	2.16	2.29	4.94	2.90	2.11	6.10	1.67	2.13	3.55
Collapse of building structure	2.92	2.31	6.73	4.45	2.71	12.06	2.83	2.32	6.58
Equipment / vehicle accidents	2.68	2.60	6.94	3.03	2.30	6.95	3.67	2.56	9.40
Struck/hit by moving vehicles	2.25	1.88	4.23	2.24	1.55	3.45	2.00	1.68	3.35
Manual handling of material / Machine/tool & usage hazards	3.00	2.90	8.69	2.95	2.89	8.52	3.33	2.36	7.88
Electrocution/ Contact with electricity	3.90	3.76	14.64	2.76	2.17	5.98	4.17	2.42	10.08
Contact with lines underground	3.45	2.54	8.77	1.70	1.41	2.39	1.50	1.61	2.41
Underground cavities/pits collapse	1.94	1.70	3.29	2.20	1.44	3.16	2.83	1.72	4.88
Traffic accidents/ Transportation	1.81	1.66	3.00	1.70	1.56	2.65	1.67	1.90	3.17
Exposure to Noise	2.43	2.34	5.69	2.39	2.42	5.77	1.83	2.52	4.61
Exposure to Fire	3.03	2.71	8.19	2.13	2.03	4.32	3.00	2.20	6.60
Caught in between objects/material	2.57	2.64	6.80	2.77	1.87	5.17	3.17	2.33	7.39
Exposure to harmful substance	2.33	2.36	5.52	2.08	1.83	3.82	3.25	2.08	6.77
Overexertion/ strain	2.64	2.60	6.85	2.46	2.50	6.14	2.25	2.90	6.53

Source: Author's fieldwork (2021)

Notes: RS; Risk Score; RL= Risk Level; R=Rank; L=Low; M= Medium; H= High

A further investigation was carried out to determine the average risk level of the safety risk factors for the most risky work items as shown in Table 6, result revealed that fall from high level was ranked first with risk score of 11.23. Electrocution/ Contact with electricity was ranked second with risk score of 10.23. Collapse of building structure was ranked third with risk score of 8.46, while manual handling of material / Machine/tool & usage hazards and fall to lower level are ranked 4th and 5th with risk score of 8.36 and 7.99 respectively.

Table 6 Average Risk Level of Safety Risk Factors for Top Three Most Risky Work Items

Safety Risk Factors /Work Items	Electrical	Roof	Lift	Average	Risk Level	Rank
Fall from high level	7.36	13.47	12.86	11.23	M	1
Electrocution/ Contact with electricity	14.64	5.98	10.08	10.23	M	2

Collapse of building structure	6.73	12.06	6.58	8.46	M	3
Manual handling of material / Machine/tool & usage hazards	8.69	8.52	7.88	8.36	M	4
Fall to lower level	5.52	10.20	8.23	7.99	M	5
Struck or hit by falling objects	5.09	9.61	8.80	7.83	M	6
Equipment / vehicle accidents	6.94	6.95	9.40	7.77	M	7
Overexertion/ strain	6.85	6.14	6.53	6.51	M	8
Caught in between objects/material	6.80	5.17	7.39	6.45	M	9
Exposure to Fire	8.19	4.32	6.60	6.37	M	10
Exposure to chemical /harmful substance	5.52	3.82	6.77	5.37	M	11
Exposure to Noise	5.69	5.77	4.61	5.36	M	12
Fall to the same level	4.94	6.10	3.55	4.86	M	13
Contact with lines underground	8.77	2.39	2.41	4.52	M	14
Cave –ins	3.13	3.67	5.35	4.05	M	15
Underground cavities / pits Collapse	3.29	3.16	4.88	3.78	L	16
Struck or hit by moving vehicles	4.23	3.45	3.35	3.68	L	17
Transportation /Traffic accident	3.00	2.65	3.17	2.94	L	18

DISCUSSION OF FINDINGS

Result revealed that out of the ten common work items, findings from risk assessment revealed that the work item with the greatest medium risk level is installation of electrical works with medium risk score of 11.48, This outcome agrees with the findings Baradan and Usmen (2006); Timofeeva *et al.* (2017) and Ghousi *et al.* (2018) who identified electrical work as high-risk trade in construction. Roof construction work was identified second, with medium risk score of 11.01. This is in agreement with Baradan and Usmen (2006) and Okoye (2018) who identified roof work as a trade with susceptible frequent risk occurrence in construction. Installation of lift was the third most hazardous work item in building construction projects with risk score of 10.74. This is in line with Ghousi *et al.* (2018) who acknowledged lift installation as a work activity that presents approximately 10- 22% of the total risk in a project. Result on evaluation of safety risk factors for the most risky work items, result revealed that fall from high level was ranked first with risk score of 11.23. This is in agreement with Gurcanli and Mungen (2013); Gurcanli *et al*. (2015); Udo *et al*. (2016); Bilir and Gurcanli (2016); Orji *et al*. (2016); Okoye (2018) and Liang *et al*. (2021) who identified fall from height as one of the major causes of death on construction sites. Electrocution/Contact with electricity was ranked second with mean score of 10.23. This is in line with Orji *et al*. (2016)

and Liang *et al*. (2021) who identified electrocution as a high risk hazard in work site. Building structure collapse was ranked third with risk score of 8.46. This is in line with Gurcanli and Mungen (2013) and Bilir and Gurcanli (2016) who affirmed that building structure collapse is one of the main causes of construction accident. Hazards due to manual handling of machine & tool usage was ranked fourth with risk score of 8.36. This outcome agrees with the findings of Udo *et al*. (2016) and Okoye (2018) who established that one of the impactful hazard in building trades was manual handling activities. Fifth in position was fall to lower level with an average risk score of 7.99. This outcome is in line with the findings of Hallowell (2009) and Ghousi *et al*. (2018).

Conclusion and Recommendation

An evaluation of safety risk factors of building construction projects was carried out to determine the most critical safety risk factors in work items. The study determined the riskiest work item in building construction projects. Findings revealed that the work items with high risk are, lift installation Electrical works and roof work. An evaluation of safety risk factors was conducted to examine the safety risk level of hazards for the top three risky work items. Result revealed that fall from high level, electrocution/contact with electricity, building structure collapse were of high risk. While contact with lines underground, hazards due to manual handling of machine & tool usage, fall to lower level and equipment accident were safety risk factors with medium risk.

A further assessment was conducted to ascertain the average risk level of safety risk factors of the most risky work items, result revealed that fall from high level, electrocution/Contact with electricity, Building structure collapse, Hazards due to manual handling of machine & tool usage and fall to lower level were of medium risk.

It was therefore concluded that different work item are accompanied with diverse hazards indicating that depending on the nature and type of activities involved in any work item, the approach of operations have different magnitude of hazards and the levels of risk associated with them varies. It was also observed that experts will experience more of medium level risk safety risk factors in the study area which are tagged tolerable risk. It was therefore recommended that different approaches should be applied in controlling health and safety risks across building work items. Adequate provision should be made on site for arresting fall during project execution being it was the most prominent safety risk factors identified. In addition collective and individual accident prevention measure should be provided for worker in order to control the tolerable risk on site. The knowledge acquired from the study will serve as a guide for experts who want to carry out risk assessment on their site and will help construction practitioners or safety professionals in identifying the safety risk factors in a specific construction work item on site. Besides, the study will help them to plan the best methods for eliminating or controlling those safety risk factors.

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