Modelling the Cost of Health and Safety for Building Construction Projects

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ABSTRACT

The health and safety (H&S) statistics of the construction industry in terms of accident and injuries has remained high for many years. This is as a result of most construction firms lacking information on the costs of accident prevention measures due to inadequacy of available data and the absence of a model specifically developed for H&S. This study aims at modelling the cost of H&S in building construction projects. The quantitative approach used 40 Bills of Quantities (BOQ) for the collection of data on building construction projects from quantity surveying firms through purposive sampling. Data were analysed using simple percentile and regression analysis. Result on the estimation of the cost of H&S in construction projects revealed that, for projects costing between N0.15 billion and N2.88 billion the percentage of safety cost to the total construction cost of the projects is 5.67% and approximately ₦21, 271.98/m^2 as H&S cost per unit area. It was concluded that before execution of projects the cost of safety is predictable by engaging the information from the BOQ and by using project duration. It was recommended that a distinct section should be assigned for H&S in the BOQ for safety cost components such as PPE, CPM and ST for adequate estimating of safety cost items. This model would provide a reference for construction practitioners and professionals in estimating in details, the cost for H&S at early stage of project construction.

Keywords: Duration, Gross floor area, Logarithmic Regression, Project, Safety Cost,

INTRODUCTION

The construction sector not only contributes to the socio-economic advancement of nations, but it also plays a significant role in the global economy, generating employment for millions of people worldwide [1]. Despite its socio-economic importance, the construction industry is considered as one of the most hazardous industries, with very high rate of accidents and ill-health problems to workers, organisations, society and countries [2] [3]. With the advancing technologies and industrialization, poor workplace conditions are now a threat to Occupational Health and Safety (OHS) and thus to public health [4]. The International Labour Organization [5] estimates that over 6000 people die from work-related illnesses or accidents every single day, amounting to around 2.3 million men and women worldwide per year. In addition, the cost of poor work-related health and safety practices calculated by ILO cost the economy 3.94% of GDP annually [5]. It costs 3447.68 billion US dollars annually [6]. For this reason, it is essential to consider that workplace health and safety are vital factors that affect both individuals and society as a whole, rather of only being tied to costs.

The health and safety statistics of the construction industry in terms of accident and injuries has remained high for many years. One of the factors impacting negatively on the health and safety performance of the construction industry is the competitive nature of contracts award by client, which is based on price. As a result of this practice, contractors are compelled to lower their tender amount resulting to health and safety being marginalised [7][8][9]. [7] generalised that there are no detailed items included for health and safety in the contract documents such as bill of quantities. This is because the allocation of safety budget in terms of

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prevention of accidents is still not optimal in the construction industry resulting in rise in construction related accidents [3][10][11]. This is why [12] reiterated that in the construction industry, the procedure on how to calculate the cost of incorporating safety is not stringently regulated in the laws and regulations of countries. As such most construction firms' lacks information on the costs of accident prevention measures due to inadequacy of data and the absence of a model specifically developed for health and safety [11]. This research, therefore, set out to model the costs of health and safety using the gross floor area and project duration of building construction projects in Abuja, Nigeria.

LITERATURE

Safety cost is the expenses incurred to prevent or mitigate accidents, injuries, and illnesses on a construction site. Safety costs include the costs of implementing safety and health measures, such as personal protective equipment, engineering controls and training [13]. Safety costs in construction was categorised into two direct safety costs and indirect safety costs by [13]. Direct safety costs are expenses directly related to safety measures, such as: Personal Protective Equipment (PPE), safety training and safety equipment. Indirect safety costs are expenses related to safety measures, such as: administrative costs associated with safety management, costs of safety inspections and audits and costs safety-related record-keeping and reporting. A number of scholars have reviewed the cost associated with health and safety to construction projects. [14] determined the perceptions and practices related to financial provision for health and safety in South Africa, study's result revealed that H&S cost was 3.8% to the tender sum while cost of safety to total cost of construction was 2.4%. [16] developed a method for estimating OHS costs in Spain and revealed 1.54% -5% of the budgeted cost of the project. [7] examined the optimal percentage of monetary provision for H&S in South Africa, result revealed that the cost for health and safety was 2.5% of the tender sum [18] developed a cost model for safety for residential building, result revealed that the share of safety cost to cost of total construction was 1.92% and approximately 5.68 USD/ m^2 was the cost of OHS per unit area. [8] identified cost drivers for pricing health and safety on construction projects in South Africa and revealed the cost for health and safety to be approximately 2.39% - 4.90% of total cost of building project cost.

[21] developed a tool for valuing the cost of OHS for small and medium scale residential projects and findings revealed that OHS cost to total cost of construction was 5.15% and 8.47 USD/ m^2 per unit area. [22] determined effect of the costs of safety on safety risk on a commercial building. Result revealed that investment of 1.5% of construction budget on safety programme will decrease 75% of safety risks. [23] assessed the impacts of costs of H&S in Nigeria. Findings from the study revealed that the cost for health and safety ranged from 3-5% of the total construction cost.

[24] developed an estimating model in Turkey and result showed, the ratio of actual costs as well as estimated costs of OHS to be approximately 3.98% and 3.58% correspondingly. [25] assessed the impact of H&S prevention costs on the cost of construction, findings revealed that H&S cost ranged from 1.0% to 10.0% of the total construction cost. [10] investigated the cost of construction safety in Indonesia and revealed that the cost for H&S ranged from 0.72% to 1.06% of the total construction cost. [27] estimated the costs of health and safety in Nigeria and revealed that health and safety cost (HSC) to the total project costs was approximately 3.19% and health and safety cost per unit area was approximately N13,777.56/m^2. [28] determined the cost of health and safety for building projects and revealed that on the average 1.02% of total project cost would be required for providing workplace safety CPM and approximately ₦27,155.20 on CPM/ M^2 of construction area. Empirical studies as summarised in Table 1 revealed that the cost of implementing health and safety for construction projects ranges from 0.12% to 10% of the total cost of projects.

Table 1: Summary of Health and Safety Costs to Construction Projects

S/N	Author	Aim	% of OHS Cost to project sum	OHS Cost /construction unit area	Location
1	[14]	Assess the optimum percentage financial provision for H&S	1-2.4%		South Africa

2	[15]	Identify safety cost in construction	2%		Malaysia
3	[16]	Develop a method to assess OHS cost in construction project.	5%		Spain
4	[17]	Investigate cost of compliance with HSM among contractors	0.41%		Malaysia
5	[7]	Financial provision for construction H&S	2.5%		South Africa
6	[18]	An approach to estimating OHS cost construction	1.92%	5.68	Turkey
7	[19]	Determined contract documents on OHS requirements	0.2- 1.99%		Malaysia
8	[20]	Costing H&S in the Egyptian building projects	1.22%		Egypt
9	[21]	Estimating compulsory OHS costs for residential building construction projects	5.15	8.47	Turkey
10	[22]	Effect of safety costs on safety risks.	1.13- 1.5%	6.20	Turkey
11	[23]	Assessment of the Cost Impacts of H&S practices on projects.	3-5%		Nigeria
12	[24]	To estimate the OHS costs to the actual cost of maintenance	3.58%		Turkey
13	[25]	Assessed the impact of H&S prevention cost on construction projects	1.0% to 10.0%		Nigeria
14	[26]	Model for sustainable H&S for high-rise buildings.	PPE 9.8%, and CPM 49.5%		Korea
15	[27]	Estimated the costs of health and safety	3.19%		Nigeria
16	[10]	Investigate the factors that affects safety cost	0.72%- 1.06%		Indonesi a
17	[28]	Determined health and safety cost for building projects	1.02% CPM		Nigeria

Most of the models developed focused on estimating the percentage of safety costs to the total construction cost of the project and percentage of safety costs to construction area. However, estimating the cost of OHS requires more feature than the aforementioned, this is the point at which the contributions of other authors are limited. It was proposed that different project characteristics such as project duration, total number of workers should be considered, more work items/activities be sampled and estimated, the sample size should be increased and multiple regression method should be applied in modelling the variables selected for the study. This is the gap in knowledge addressed by this study, by modelling the costs of safety using gross floor area and the duration of building projects as well as considering the costs of safety as part of project cost in order to provide a clear methodology to be applied in accurately predicting the cost of safety in construction projects. This will be achieved with the following objectives: To estimate the cost components of health and safety for building projects, and to develop a model for estimating the cost of health and safety for building projects.

RESEARCH METHOD

The study's population comprises of building construction projects managed by quantity surveying firms registered in Abuja by the Quantity Surveyors Registration Board of Nigeria (QSRBN) as at July 2021 [29]. Purposive sampling, which is a non-probability sampling technique, was adopted for the selection of the study's participants. A lack of information on the actual number of projects that met the study's criteria informed the decision to adopt a purposive sampling approach. These criteria were four, outlined as follows: (i) building projects that were either ongoing or had been completed within the last three years, (ii) building projects that are having a health and safety officer attached to the project, (iii) building projects that had their BOQs' preliminary section broken-down cost wise, as well as (iv) the possession of detailed knowledge about health and safety cost components by the construction professional in charge of the project site. This last criterion, according to [30] is a key factor in the choice of the purposive sampling technique.

The quantitative data employed by this study was the health and safety cost components for building projects in Abuja. The information was generated for project safety cost under the following categories: costs of Personal Protective Equipment (PPE), costs of Collective Protective Measures (CPM) and the costs of Safety Training (ST). [22] Identified these cost items as the three essential parts of safety programmes for a successful building project. These costs when summed up gave safety cost for the projects concerned. The cost of safety was expressed mathematically by [18] as presented in equation 1-3.

Safety cost = PPE cost + CPM cost + ST cost…………………………………..1

PPE cost = $\sum_{i-1}^{n}(PPEi\ x\ N)$……………………………………………………..2

CPM cost = $\sum_{i-1}^{n} Ci$……………………………………………………………...3

ST cost = was determined by the sample project site safety budget

Where PPE cost represents the cost of personal protective equipment, CPM cost represents the cost of collective protective measures and ST cost represents the cost of safety training.

Personal Protective Equipment (PPE) are equipment clothing, and devices worn by individual workers to shield them from hazards and risks to their health or safety on a construction site. The derivation of PPE cost includes calculating the number of skilled and unskilled workers required for each activity of work. PPE items required by individual worker under the different building construction work items were determined from literature on construction safety as presented in Table 2. From the information presented it was observed that helmet, protective clothing, protective boot and gloves where needed for each of the building construction trades that were studied [18] and [22]. The study was limited to five work items which have been identified in literature by [19] [31] to have accounted for 70.8% of share of accident both fatal and non- fatal. The work items employed include excavation, reinforced concrete, masonry, roof and finishing.

Table 2: PPE Items Identified for Different Building Trades from Literature

PPE Items	Excavation	Masonry work	Concrete work	Roof work	Finishing
Dust Mask	√			√	√
Face Shield		√	√		

Gloves	√	√	√	√	√
Goggle					√
Helmet	√	√	√	√	√
Protective Boot	√	√	√	√	√
Protective Clothing	√	√	√	√	√
Reflective Vest	√				
Safety Harness/ Belt		√	√	√	

The PPE items engaged in this study include: helmet, protective clothing, reflective vest, protective boot, gloves, safety, goggle, face shield, dust mask and harness/belt). Subsequently, a market survey was conducted to obtain the cost of each PPE item, this aided in the determination of the cost for the PPE package for each work item. The overall PPE cost for the project was obtained by simply summing up the PPE costs of the different work activities.

Collective Protective Measures (CPM) are the safety measures implemented to protect multiple workers from hazards and risk on a construction site. The information employed in the derivation of CPM costs was extracted from two main sources: (i) Literature reviewed such as [15][18][9][21][24]. and (ii) the preliminary section of the bill of quantities of the projects sampled. The number of items considered as CPM varied from project to project; however a maximum of six items were included, as presented in Table 3.

Table 3: Collective Protective Measures identified from the Project BOQ

S/N	**Collective Protective Measures in BOQ**
1	First aid
2	Scaffolding, plant and equipment
3	Temporary fencing
4	Hoardings and barriers
5	Other safety measures (Access for workmen)
6	Protection against damage

Safety training (ST) refers to the process of educating workers on the hazards and risks associated with construction work and providing them with the knowledge, skills, and attitudes necessary to perform their jobs safely. The components of ST needed on building construction projects were determined from literature on construction safety. Thereafter a market survey was carried out to obtain the ST cost of each item. Information obtained from the market survey, enabled the cost of the ST package for each project to be determined. The number of items considered as ST and included in the pricing varies from project to project; however three items were discovered to be common to almost all projects that were surveyed as presented in Table 4. These three items were (i) safety training, (ii) safety promotion, and (iii) safety staff salary. The survey of the market prices of these three ST components (first on a monthly basis, which was then reduced to a daily basis) generated a range of costs, the average of which was then obtained and utilised for the study.

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Table 4: Safety Training Components

S/N	Safety Training Components
1	Safety Staff Salary
2	Safety Education and Training
3	Safety Promotion

A total of 76 BOQs were collected from the archival records of QS firms, but only 40 projects were found to meet the criteria for this study after thorough filtering for relevance and fitness for purpose. The 36 BOQs were discarded because the Standard Methods of Measurement used in the preparation of the BOQs were not in accordance with BESMM4; in addition the preliminaries sections of some of the BOQs were not broken down (did not provide details of items that had been included). A major challenge encountered in this study was the lack of uniformity in the format of BOQs; this would not have been the case if a standard format of reporting H&S cost items had been available and adopted. This feature limited the number of BOQs that were found suitable for use in the study. Descriptive statistics and inferential statistics were used in analysing the data. Descriptive statistics inform of simple percentile with the aid of Microsoft Excel spreadsheets. Inferential statistics was regression analysis which was analysed using Statistical Package for the Social Sciences (SPSS) 20 version.

RESULT AND DISCUSSION

Health and safety Cost Estimation for Building Construction Projects

This section reports the aggregation of the safety costs items that directly constitutes the safety costs for the 40 building projects surveyed in the study. The safety costs components include: costs of Personal Protective Equipment (PPE), costs of Collective Protective Measures (CPM) and costs of Safety Training (ST). The values of the main safety costs components are presented in Table 5. The result is arrived at by aggregating the costs of PPE, costs of CPM and ST as revealed in equation 1. Project 11 had the highest cost of (₦89,372,918.65) and Project 4 had the lowest cost of (₦6,920,596.32).

Table 5: Summation of Safety Cost Components (₦) of 40 projects

Project	Total Project Cost	GFA	PPE Cost	CPM Cost	ST Cost	Safety Cost of Project
1	179,168,916.18	333	30,432,000.00	3,000,000.00	297,402.00	33,729,402.00
2	115,425,377.94	440	6,063,000.00	462,418.32	395,178.00	6,920,596.32
3	153,390,480.00	553	11,579,000.00	15,016,825.85	497,028.00	27,092,853.85
4	269,092,892.75	593	19,430,000.00	700,000.00	529,620.00	20,659,620.00
5	269,092,892.75	593	14,175,000.00	404,646.75	549,990.00	15,129,636.75
6	263,619,794.82	673	26,038,000.00	945,000.00	602,952.00	27,585,952.00
7	647,361,909.45	678	35,687,000.00	1,319,000.00	607,026.00	37,613,026.00
8	186,704,270.84	700	8,381,000.00	4,400,000.00	627,396.00	13,408,396.00
9	261,065,710.75	884	17,957,000.00	1,850,000.00	790,356.00	20,597,356.00

10	122,232,133.81	980	6,126,000.00	378,105.60	879,984.00	7,384,089.60
11	2,625,326,180.02	990	62,773,000.00	25,711,786.65	888,132.00	89,372,918.65
12	195,950,245.40	1020	10,018,000.00	896,000.00	912,576.00	11,826,576.00
13	666,623,420.10	1030	27,683,000.00	6,527,248.45	924,798.00	35,135,046.45
14	125,734,353.21	1033	6,040,000.00	388,939.20	924,798.00	7,353,737.20
15	688,126,228.94	1187	11,293,000.00	14,487,000.00	1,063,314.00	26,843,314.00
16	128,804,911.11	1253	8,067,000.00	398,438.40	761,838.00	9,227,276.40
17	228,305,474.78	1287	15,113,000.00	952,000.00	782,208.00	16,847,208.00
18	823,679,438.38	1293	28,700,000.00	8,065,083.05	786,282.00	37,551,365.05
19	506,056,330.96	1293	22,441,000.00	2,038,545.00	786,282.00	25,265,827.00
20	243,283,404.79	1400	14,038,000.00	6,750,000.00	851,466.00	21,639,466.00
21	142,043,382.73	1413	9,005,000.00	459,062.40	859,614.00	10,323,676.40
22	181,880,725.74	1607	10,180,000.00	789,666.40	977,760.00	11,947,426.40
23	982,856,744.36	1640	22,872,000.00	9,623,646.40	998,130.00	33,493,776.40
24	165,821,449.11	1720	7,892,000.00	512,942.40	1,047,018.00	9,451,960.40
25	697,688,335.24	1860	23,712,000.00	9,250,000.00	1,132,572.00	34,094,572.00
26	255,002,560.40	1973	17,029,000.00	3,400,000.00	1,197,756.00	21,626,756.00
27	1,253,308,886.37	2027	22,912,000.00	15,896,698.18	1,230,348.00	40,039,046.18
28	741,404,557.05	2047	14,941,000.00	6,705,040.14	1,242,570.00	22,888,610.14
29	767,011,860.89	2047	14,941,000.00	6,975,097.20	1,242,570.00	23,158,667.20
30	631,980,919.67	2047	14,941,000.00	6,397,157.90	1,242,570.00	22,580,727.90
31	804,083,695.02	2047	14,941,000.00	6,128,136.04	1,242,570.00	22,311,706.04
32	630,898,120.05	2047	14,941,000.00	6,386,197.38	1,242,570.00	22,569,767.38
33	805,005,376.95	2047	14,941,000.00	6,135,160.42	1,242,570.00	22,318,730.42
34	759,955,377.51	2453	10,810,000.00	5,894,821.67	1,491,084.00	18,195,905.67
35	1,158,850,565.88	2593	28,431,000.00	5,456,915.00	1,576,638.00	35,464,553.00
36	969,766,039.70	2627	24,246,000.00	3,105,000.00	1,597,008.00	28,948,008.00
37	1,115,910,245.02	3300	16,819,000.00	5,262,267.44	2,004,408.00	24,085,675.44

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38	1,179,859,664.31	3827	19,633,000.00	5,313,917.46	2,326,254.00	27,273,171.46
39	2,883,968,720.00	4900	31,355,000.00	16,267,541.31	2,978,094.00	50,600,635.31
40	896,130,605.85	2000	23,387,000.00	5,251,203.37	1,214,052.00	29,852,255.37

Proportion Analysis of Safety Cost of 40 projects

This section presents the analysis of safety cost using some fiscal features of the surveyed projects such as: total project cost and Gross Floor Area (GFA) as presented in Table 6. Result from the analysis shows that the average value of safety cost as a percentage to total project cost was 5.67%. The findings of safety cost per square meter of GFA revealed that the average value of safety cost per square meter of GFA was ₦ 21,271.98. From related literature, previous researchers such as Gurcanli *et al*., 2015) had established $5.68, as the cost of Safety Cost/M^2; at an exchange rate of N400 to $1, this gives a comparable value of ₦2,272. It must be noted however that only concrete work was studied, and the study area was in Turkey. The three projects that had the highest safety cost per square metre of gross floor area all had gross floor areas that were less than 1000 M^2 (these were Project Nos 1, 11 and 7, which have been highlighted in Table 6, in bold face type). As noted earlier, this observation might suggest that the relationship between safety cost and gross floor area might not be strictly linear.

Table 6: Cost Summary Information (₦) of 40 projects

Project	Total Project Cost	GFA	Safety Cost of Project	Safety Cost per M^2	Safety Cost (% of TPC)
1	179,168,916.18	333	33,729,402.00	**101,289.50**	18.83
2	115,425,377.94	440	6,920,596.32	15,728.63	6.00
3	153,390,480.00	553	27,092,853.85	48,992.50	17.66
4	269,092,892.75	593	20,659,620.00	34,839.16	7.68
5	269,092,892.75	593	15,129,636.75	25,513.72	5.62
6	263,619,794.82	673	27,585,952.00	40,989.53	10.46
7	647,361,909.45	678	37,613,026.00	**55,476.44**	5.81
8	186,704,270.84	700	13,408,396.00	19,154.85	7.18
9	261,065,710.75	884	20,597,356.00	23,300.18	7.89
10	122,232,133.81	980	7,384,089.60	7,534.79	6.04
11	2,625,326,180.02	990	89,372,918.65	**90,275.68**	3.40
12	195,950,245.40	1020	11,826,576.00	11,594.68	6.04
13	666,623,420.10	1030	35,135,046.45	34,111.70	5.27
14	125,734,353.21	1033	7,353,737.20	7,118.82	5.85
15	688,126,228.94	1187	26,843,314.00	22,614.42	3.90
16	128,804,911.11	1253	9,227,276.40	7,364.15	7.16
17	228,305,474.78	1287	16,847,208.00	13,090.29	7.38

18	823,679,438.38	1293	37,551,365.05	29,042.05	4.56
19	506,056,330.96	1293	25,265,827.00	19,540.47	4.99
20	243,283,404.79	1400	21,639,466.00	15,456.76	8.89
21	142,043,382.73	1413	10,323,676.40	7,306.21	7.27
22	181,880,725.74	1607	11,947,426.40	7,434.62	6.57
23	982,856,744.36	1640	33,493,776.40	20,423.03	3.41
24	165,821,449.11	1720	9,451,960.40	5,495.33	5.70
25	697,688,335.24	1860	34,094,572.00	18,330.42	4.89
26	255,002,560.40	1973	21,626,756.00	10,961.36	8.48
27	1,253,308,886.37	2027	40,039,046.18	19,752.86	3.19
28	741,404,557.05	2047	22,888,610.14	11,181.54	3.09
29	767,011,860.89	2047	23,158,667.20	11,313.47	3.02
30	631,980,919.67	2047	22,580,727.90	11,031.13	3.57
31	804,083,695.02	2047	22,311,706.04	10,899.71	2.77
32	630,898,120.05	2047	22,569,767.38	11,025.78	3.58
33	805,005,376.95	2047	22,318,730.42	10,903.14	2.77
34	759,955,377.51	2453	18,195,905.67	7,417.82	2.39
35	1,158,850,565.88	2593	35,464,553.00	13,677.04	3.06
36	969,766,039.70	2627	28,948,008.00	11,019.42	2.99
37	1,115,910,245.02	3300	24,085,675.44	7,298.69	2.16
38	1,179,859,664.31	3827	27,273,171.46	7,126.51	2.31
39	2,883,968,720.00	4900	50,600,635.31	10,326.66	1.75
40	896,130,605.85	2000	29,852,255.37	14,926.13	3.33
Average				**21,271.98**	**5.67**

Modelling the Costs of Health and Safety for Building Projects

This section employed the data generated on the cost of safety for building projects in the development of a Simple Regression Analysis (SRA) model. The best predictors of the value of the dependent variable are estimated by linear regression, which uses one or more independent variables. There are four fundamental conditions that must be satisfied in order for the findings of a linear regression to be reliable. The following are the assumptions:

i. The distribution of the dependent variable for each value of the independent variable must be normal; (The error term should have a normal distribution with a mean of 0.).

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ii. For all possible independent variable values, the variance of the distribution of the dependent variable should remain constant; (The variance of the error term ought to be homoscedastic, meaning it is constant across cases and unaffected by the variables in the model.).

iii. The dependent variable and each independent variable should be related to one another linearly, and each observation should be independent.

iv. All observations should be independent.

In order to confirm if these assumptions have been satisfied or violated, several kinds of graphical plots can help in the validation of the assumptions of normality, linearity, and equality of variances. The study data should be plotted in order to choose which model to employ. A simple linear regression model should be utilised if it appears that the research variables are linearly connected. An attempt to alter the data in order to use curve estimation could be done when the variables are not linearly connected [32].

Using the help of scatter plots, the study investigated the linearity assumption regarding the relationship between the variables. The plots for safety cost are presented in Fig. 1 and Fig. 2; they showed that the data was mostly clustered within the lower left quadrant; only very few data points fell outside of this quadrant. All of the points were positive. There were two data points that appeared to be outliers; these had very high safety costs coupled with small gross floor areas. The general appearance of the plots appeared to support a linear relation between the variables, albeit of a negative nature, implying that as one variable increases, the other variable would reduce.

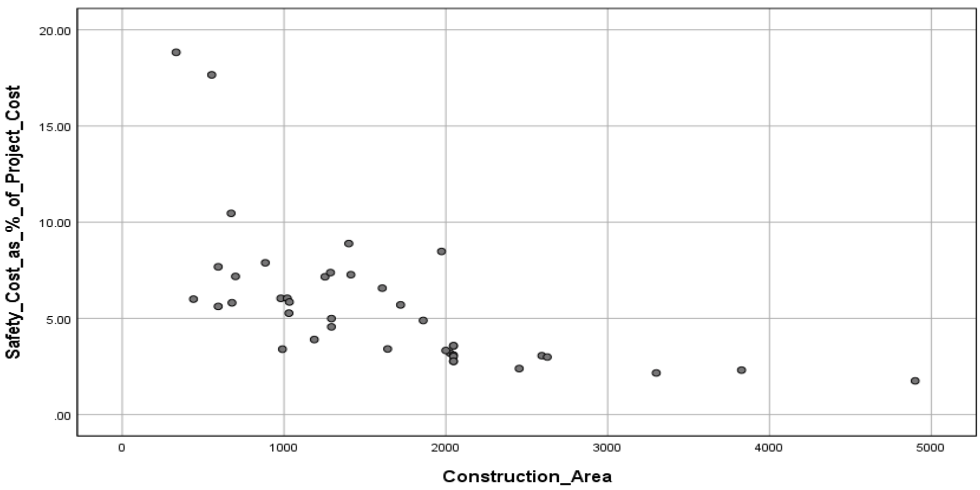

Figure 1: Scatter plot of Safety Cost and Gross Floor Area

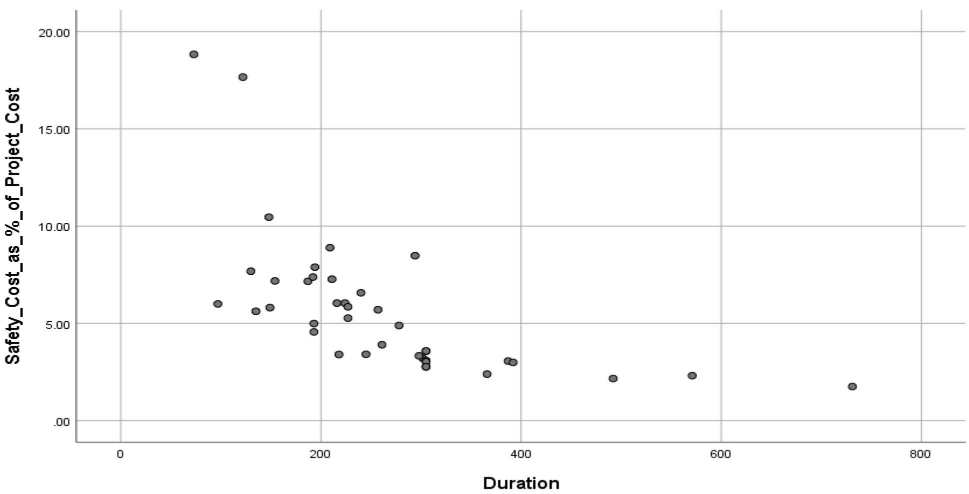

Figure 2: Scatter plot of Safety Cost and Project Duration

Prediction of safety cost using gross floor area

This section provides information on safety cost model development employing logarithmic regressions. Model was developed with the following information provided; the independent variables were gross floor area, and Project duration, constant (a) unstandardized regression coefficient (B) standardised regression coefficient (β), standard error of B (SEB), coefficient of correlation (r), coefficient of determination (r^2) and probability value (P) as presented in Table 7 and 8 and figure 3 and 4.

The result of the first phase of model development, where safety cost was modelled using gross floor area is provided in this section as presented in Table 7. Result on gross floor area gave an R^2 value of 0.391. The inference is that only 39% of the change in safety cost is accounted for by the gross floor area of projects. The coefficients of the regression model which were obtained from statistical output revealed that the regression coefficients (B) were negative values; this was an indication of negative linearity. This meant that larger gross floor areas would be associated with smaller safety costs, and vice versa. The values of the F statistic was larger than the critical value of $F_{0.05}$. In addition, the probability values (P) was much smaller than 0.05. These meant that in the model gross floor area was significantly but weakly related to safety cost.

Table 7: Logarithmic Regression model results for Safety Cost and Construction Area

Variable	**Logarithmic Regression model**		
	B	***β***	SEB
Constant	32.3		4.767
GFA	-3.712	-.547	
R	.547		
R^2	.391		
ΔF	11.074		
P	.003		

This position was supported by the visual representation of the trend of the relation between safety cost and gross floor area of buildings, as displayed in Figure 3. The log curve shows that as the GFA gets larger, safety costs tends to decrease.

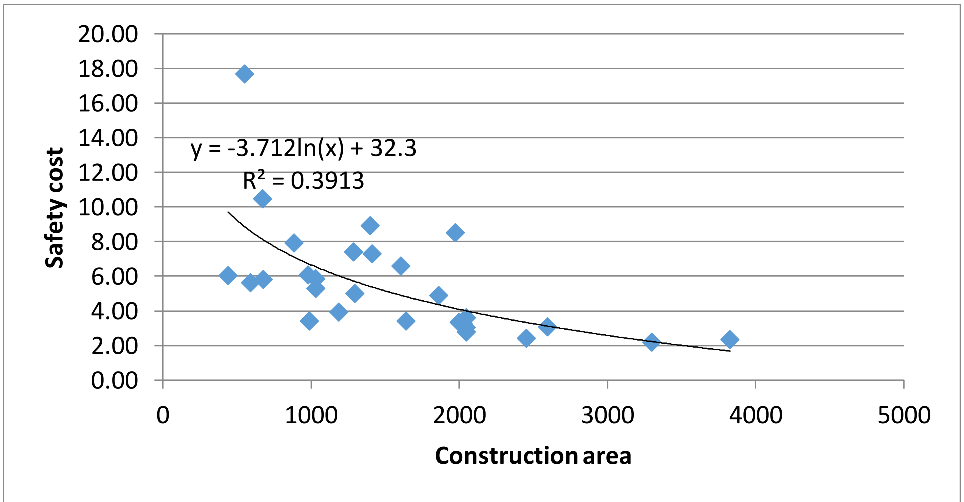

Figure 3: Logarithmic Regression model results for Safety Cost and Construction Area

Prediction of safety cost using duration of projects

The result of the modelling of safety cost using project duration is reported in this section. Result in Table 8 using project duration gave an R^2 value of 0.436 for the logarithmic model. The inference is that only 44% of the change in safety cost is accounted for by the projects duration. The regression model coefficients show that the regression coefficients (B) was a negative values; this was an indication of negative linearity. This meant that longer project durations would be associated with smaller safety costs, and vice versa. The value of the F statistic was larger than the critical value of $F_{0.05}$. In addition, the probability value (P) was much smaller than 0.05. The inference was that the duration of projects was significantly but weakly related to safety cost.

Table 8: Logarithmic Regression model results for Safety Cost and Duration

Variable	**Logarithmic Regression model**		
	B	***β***	SEB
Constant	35.01		.841
Duration	-5.399	-.614	.841
R	.601		
R^2	.436		
ΔF	15.772		
P	.001		

The result presented in Table 8, was supported by the visual representation of the trend showing the relation between the cost of safety and projects duration, as displayed. Figure 4 shows that longer project durations would be associated with smaller safety costs.

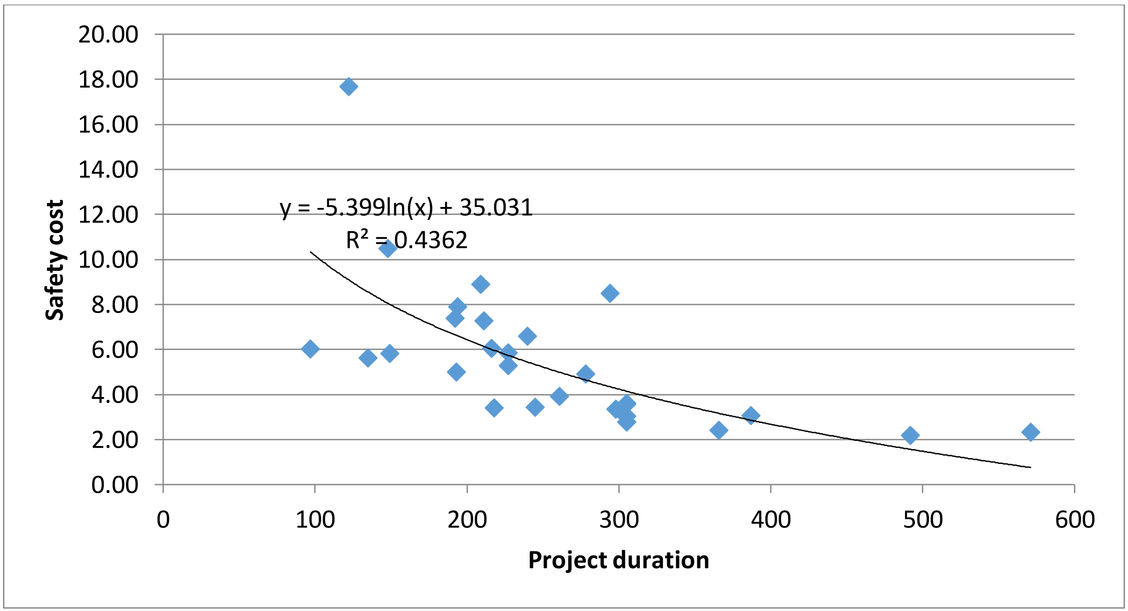

Figure 4: Logarithmic Regression model results for Safety Cost and Duration

Validation of Safety Cost model

The report of the validation of the regression model which was developed for safety cost is provided in this section. Two independent variables were employed as predictors of the safety cost of projects; these were gross floor area and project duration. Each of these predictors were employed using logarithmic regression model, as presented in Table 9 and 10 and figure 3 and 4. A choice was made between the two predictors as to which performed best, in Table 11. Using the MSE as a measure of model performance.

Validation of regression models for safety cost and Gross Floor Area

The report of the validation of the logarithmic regression model which was developed for safety cost using gross floor area as predictor was provided in this section. Table 9 revealed that the highest MSE values of 1.09 belonging to the middle range of GFA (0 – 2700M^2), while the lowest MSE value of 0.53 belonged to the smallest range of GFA (the 0 – 1100M^2). The decision on which model performed best was made using the (the 0 – 4900M^2 range), which was the largest range with MSE value of 0.99, containing all of the 40 projects that were surveyed in the study.

Table 9: Validation of Safety Cost and Gross Floor Area model

Type of regression model	GFA range (M^2)	MSE	MAPD	MAE
Logarithmic	0 – 1100 (593-1020)	0.53	9.84	0.70
	0 – 2700 (593-2626)	1.09	1.97	0.40
	0 – 4900 (593-4900)	0.99	-1.10	0.31

Notes: (Values in parenthesis are the minimum values and the maximum values for holdout projects within the GFA range concerned)

Figure 3 was a line graph depiction of the MSE values in Table 9. The displayed results in the chart showed clearly that for the largest range (0 – 4900M^2), the logarithmic model had the MSE value of 0.99. The decision on which model performed best was made using the (the 0 – 4900M^2 range), which was the largest range, containing all of the 40 projects that were surveyed in the study.

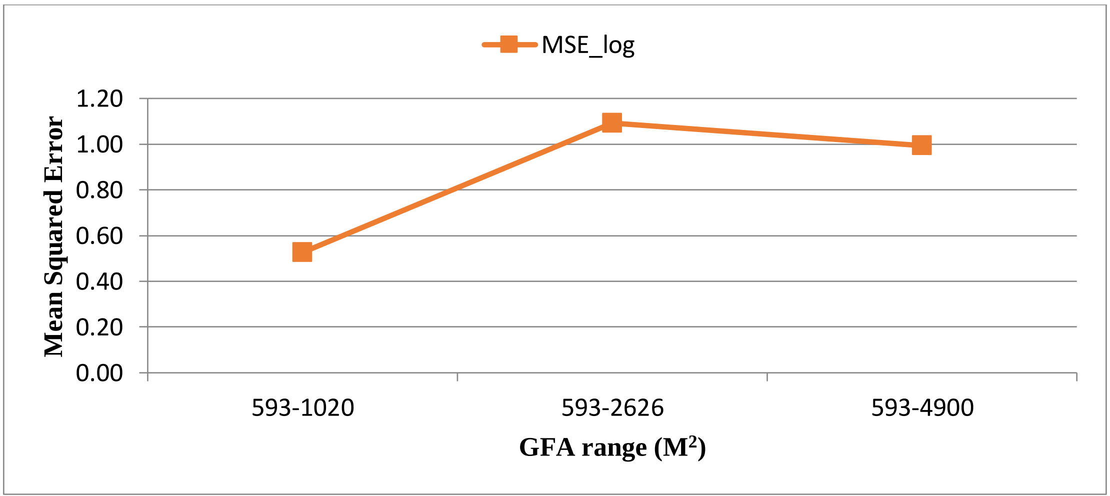

Figure 3: Comparison of MSE for Safety cost & GFA

Validation of Safety Cost and Duration model

The report of the validation of the logarithmic regression model which were developed for safety cost using project duration as predictor was provided in Table 10. Based on only the MSE as a measure of model performance, and focusing on only the largest duration range (0 – 800 days), it was observed that projects with the smallest project durations (the 0 – 200 days range) appeared to be associated with the highest levels of error, with MSE value of 1.05. The lowest observed MSE value 0.82 belonged to the largest duration range (0 – 800 days).

Table 10: Validation of Safety Cost and Duration model

Type of regression model	Duration range (Days)	MSE	MAPD	MAE
Logarithmic	0 - 200 (130-193)	1.05	3.58	0.43
	0 - 400 (130-392)	0.89	0.09	0.27
	0 - 800 (130-731)	0.82	3.42	0.30

Notes: (Values in parenthesis are the minimum values and the maximum values for holdout projects within the Duration range concerned)

Figure 4 presents a line graph depiction of the MSE values of the logarithmic regression model in Table 10. The results in the chart showed that the highest MSE values belonged to the smallest range of project duration (0 – 200 days), while the lowest MSE belonged to the largest project duration range (0 – 800 days).

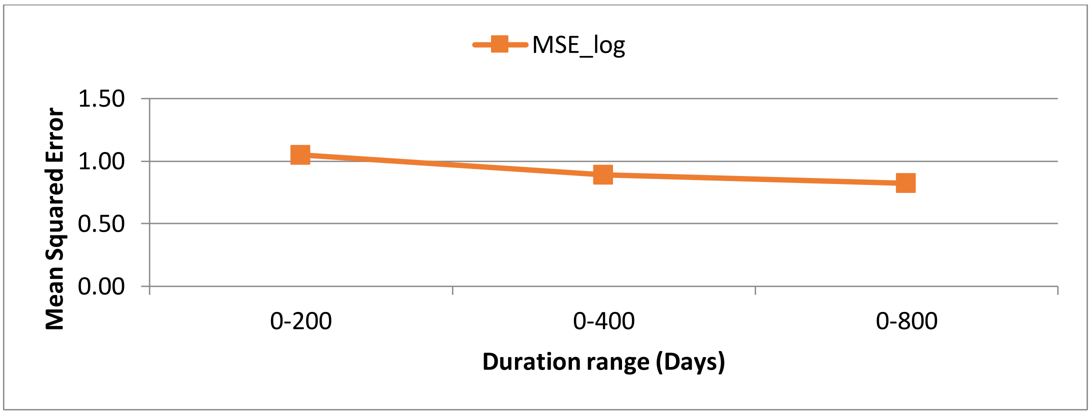

Figure 4: Comparison of MSE for Safety cost & Duration

Regression model adjudged most effective for predicting safety cost

The choice of the predictor which performed best, in terms of being a statistically significant regression model and having the lowest MSE as provided in Table 11. The choice of most effective predictor was a straightforward one from the results shown in Table 11. The second predictor, Project Duration, had an MSE of 0.82, compared to that of the first predictor, gross floor area, which was 0.99. Based on this, project duration was adjudged the most effective predictor. Table 11 provides the formula for the logarithmic regression model, alongside with the model's coefficient of determinant (R^2) of 0.436. The validated model employed projects duration to predict the safety cost of projects, by using this formula:

Safety cost = 23.24 + (-3.338 * ln(Duration)), with an R^2 value of 43.6% and MSE of 0.82. Although the R^2 value is quite low, this logarithmic regression model that has been developed in this study represents a scientific way through which the safety cost of construction projects can be determined (as a percentage of the proportion of the total project contract sum) even before work has commenced on the project site.

Table 11: Most effective predictor of Safety Cost

Measure / Model	MSE of Predictors		Model structure	R^2 (%)	Remark
	x1 (GFA)	x2 (Duration)			
MSE / Logarithmic	0.99	0.82	Safety cost = 23.24 + (-3.338 * ln(Duration))	43.6%	Using **Project Duration as predictor** returned the lowest error in prediction of Safety cost.

Notes: x1=first predictor; x2=second predictor; GFA=Gross floor area; MSE=Mean squared error; ln=natural log

Discussion of Results

Analysis from the estimation of health and safety cost components for building projects. The findings of the analysis revealed that the average value cost of safety as a proportion of total project cost was 5.67%. This percentage value is lower than what is in previous research conducted in Nigeria by [25] who established 1-10% for construction work. Result of safety cost per square metre of gross floor area revealed that the average safety cost per square metre of gross floor area was ₦21,271.98. Previous researchers such as [18] [21][28]had established 5.68 USD, 8.47 USD, and ₦27,155.20 as the cost of Safety Cost/M^2 in Turkey and Nigeria respectively.

The results from the modelling of safety cost, the predictive strength of the two independent variables employed (the Gross Floor Area and project duration) was low, since they accounted for only 39% to 44% of the changes in safety cost. It was found that an inverse proportional association existed between the dependent and independent variables. However, the independent variable had a significant but weak relationship with the cost of safety. In terms of the quality of the models, based only on the r^2 values, [18] and [33] work is the closest study with which comparison can be made. The study of [18] modelled cost of safety for reinforced concrete construction, an r^2 value of 67% was obtained from a logarithmic regression. [33] revealed that Heinrich's safety cost model, Simond's safety cost model and Bird-Fine's model had an R-squared value of 0.32,0.37 and 0.39 respectively. This is comparable to the 39% to 44% r^2 value that was obtained in this study; which indicates that the model explains about 39% to 44% of the variation in cost of safety. This study has thus confirmed the position of influence occupied by construction area and duration with regards to safety cost. [34] posited that the cost of safety in the construction of projects is influenced by several factors; they identified five such factors. These are project scope, project duration, number of accidents at work, components of safety and costs of an accident if it occurs. This study has worked on the project scope and duration. The focus of most studies in the general area of safety cost has been the determination of direct costs as well as indirect costs of accidents. The study successfully validated the model using logarithmic regression model that was developed by the study. This study has developed a mathematical model for predicting the cost of safety using project duration applicable to projects costing between ₦0. 15b to ₦2.88b), by using the following formula: Safety Cost = 23.24 + (-3.338 * ln (Duration)), with R^2 value of 43.6% and MSE of 0.82. However, the explanatory power of the models are limited, suggesting that other factors may be contributing to the cost of safety. This study has several limitations, first, the sample size is relatively small, which limits the generalisation of the results. Secondly, the model only includes a limited number of predictors, which may not capture all of the factors that contribute to the cost of safety.

CONCLUSION AND RECOMMENDATION

The study presents an approach for contractors to estimate the cost of safety for building projects and apportioning the cost of safety throughout the project. The cost of safety of construction projects was synthesized using the gross floor area of building projects, result revealed that main contractors will need to spend approximately twenty one thousand naira/m^2 as OHS cost per unit area and approximately 6% on the percentage of safety cost to total project cost. The inference drawn from these results was that utilization of the approximately 6% of total project cost will ensure that construction workplaces are safe through CPM, PPE and ST. The performance of the independent variables using gross floor area and project duration was determined and was observed to have a statistically significance weak relationship with total safety cost of building projects. It is was assert that both variables cannot satisfactorily predict the changes in safety cost in building projects. It was concluded that there are other variables that are contributing to the variation in the cost of safety, outside gross floor area and project duration. This study provides evidence that Gross Floor Area and project duration are significant predictors of the cost of safety. However, the explanatory power is limited, suggesting that other factors may be contributing to the cost of safety.

In the validation of logarithmic model using gross floor area and project duration, the duration of project was chosen as the best performing model for predicting the cost of safety of building projects. It was thus concluded that before execution of projects by stakeholders the cost of safety is predictable by engaging the information from the BOQ and by using project duration in order to reduce the rate of accident on sites. The study has recommended that a distinct section should be assigned for health and safety in the BOQ in order to ensure the detailed estimation of health and safety cost items for projects. In addition a special subheadings should be included in the preliminaries section that will be assigned to the safety cost components such as PPE, CPM and ST for adequate estimating of this cost items.

Practically, this study has provided a procedure by which the bill of quantities can be used as the main source of data for the synthesis of safety cost for construction projects. This model would provide a reference for construction practitioners and professionals in estimating in details, the cost for OHS at the early stage of project construction. The logarithmic regression formula provides a practical way to estimate the safety costs of building projects as a percentage of the proportion of the total project costs. Additionally, safety plans and budget required for safety measures can be organised by contractor even before work commences, as such will help during the bidding process since they are knowledgeable on the cost of providing safety on project site.

It was suggested that more performance measurements metrics such as MAPE and MAE could be considered in validating future versions of the study. This study has developed a mathematical model for predicting the cost of safety using project duration, applicable to projects costing less than three billion naira. The authors suggest that, in future study sample size should be increased, stratified sampling technique and multiple regression method should be applied in predicting the relationship between percentage of safety expenditure to project duration and gross floor area. In addition other project characteristics which could be limiting the explanatory power of the model such as types of projects, height of building projects and number of workers could be used to model the cost of safety.

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