DEVELOPMENT OF COST MODELS FOR PREDICTING HEALTH AND SAFETY COSTS OF BUILDING CONSTRUCTION PROJECTS

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A THESIS SUBMITTED TO THE POSTGRADUATE SCHOOL, FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA, NIGERIA IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF THE DEGREE OF DOCTOR OF PHILOSOPHY IN QUANTITY SURVEYING

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ABSTRACT

Most construction firms lack information on the costs of risk-prevention measures due to the inadequacy of available data and the absence of a model specifically developed for health and safety (H&S). The allocation of safety budget in terms of prevention of accidents is still not optimal in the construction industry resulting in the rise in construction related accidents. This study aims at developing cost models for predicting health and safety costs in building construction projects with a view to reducing accident rate and cost on construction sites. The quantitative approach used well-structured questionnaire and document analysis inform of Bill of Quantities (BOQ) for the collection of data on 40 building construction projects from quantity surveying firms in Abuja through purposive sampling. Data collected were analysed using both descriptive and inferential statistics (mean score item, Pearson correlation and linear regression). Result revealed that out of the eighteen potential hazards identified, Falls from height', 'building structure collapse' and workers being 'struck by falling objects', were ranked as the most critical safety hazards on building sites with a mean score of 4.46, 4.39 and 4.25 respectively. Levels of risk in seven work elements of buildings projects were determined using the Fine-Kinney approach. The method classified reinforced concrete work as a 'high' risk activity with an average risk score of 260.75; roof work was classified as 'medium' risk work, with an average risk score of 156.30, while excavation was classified as 'low' risk, with an average risk score of 46.86. An activity-based costing technique was used to estimate the cost of safety in construction projects. It was 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 an average of 4.38% of the total project cost needs to be spent in procuring Personal Protective Equipment (PPE) for projects. The study developed and validated a model for predicting the safety cost of projects using project duration as predictor in a logarithmic regression that had an R^2 value of 0.436 and Mean Standard Error (MSE) of 0.82. It was concluded that the cost of safety is predictable before execution of projects by employing the use of the BOQ. It was therefore recommended that construction site managers should focus on the critical hazards identified and different approaches should be employed in the management of safety risks in construction across building work activities. A separate section should be apportioned for H&S in the BOQ to aid the detailed estimation of the cost of H&S items.

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ABBREVIATIONS

ABC	Activity Based Costing
ABCM	Activity Based Cost Management
ABM	Activity Based Management
BSI	Basic Safety Investments
BESMM	Building and Engineering Standard Method of Measurement
BLS	Bureau of Labour Statistics
BOQ	Bill of Quantities
CEI	Contractor Efficiency Index
CFOI	Census of Fatal Occupational Injuries
CDM	Construction Design and Management
COS	Cost of Safety
COQ	Cost of Quality
CPE	Collective protective equipment
CPM	Collective Protective Measures
ETA	Event Tree Analysis
FTA	Fault Tree Analysis
FCT	Federal Capital Tertiary
FPCs	Fixed Prevention Costs
GAAP	Generally Accepted Accounting Principles
GDP	Gross Domestic Product
GFA	Gross Floor Area
HND	Higher National Diploma
H&S	Health and Safety
HSE	Health and Safety Executive
HSWA	Health and Safety Work Act
HRIRC	Human Rights Impact Resource Center
ILO	International Labour Organisation
ISPON	Institute of Safety Professionals of Nigeria

MAE	Mean Absolute Error
MAPD	Mean Absolute Percentage Deviation
MIS	Mean Item Score
MSc	Master of Science
MTech	Master of Technology
MSE	Mean Squared Error
NBS	National Bureau of Statistics
ND	National Diploma
NIA	Nigeria Institute of Architects
NIOB	Nigeria Institute of Building
NIQS	Nigerian Institute of Quantity Surveyors
OHS	Occupational Health and Safety
OHSM	Occupational Health and Safety Management
OHSMSs	Occupational Health and Safety Management Systems
OSHA	Occupational Safety and Health Administration
OSHMSs	Occupational Safety and Health Management Systems
PhD	Doctor of Philosophy
PMI	Project Management Institute
PPE	Personal Protective Equipment
PRM	Project Relationship Management
PRO	Probability of Occurrence
QSRBN	Quantity Surveyors Registration Board of Nigeria
RBM	Risk Breakdown Matrix
RMSE	Root Mean Squared Error
ROM	Rough Order of Magnitude
SEB	Standard error of B
SRA	Simple Regression Analysis
SRI	Severity Risk Impact

ST	Safety Training
TC	Traditional Costing
TSIR	Total Safety Investments Ratio
UPCs	Unexpected Prevention Costs
USA	United States of America
UK	United Kingdom
VPCs	Variable Prevention Costs
VSI	Voluntary Safety Investments
WBS	Work Breakdown Structure
WHO	World Health Organisation

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background to the Study

The construction industry has a significant impact on both the economy as well as the social policies in many developing countries (Bilir and Gurcanli, 2018). In terms of Gross Domestic Product (GDP), the construction industry in Nigeria accounts for a sizeable share of the country's economy (Ejiofor *et al.*, 2018). The contribution of the construction industry to GDP has risen over time, from 3% in 2012 to 3.46% in 2014 and 4.12% in 2021 (National Bureau of Statistics (NBS, 2012; NBS, 2014; NBS, 2021). Despite its contribution to the economy, construction remains one of the most dangerous sectors, with a very high rate of accidents and health issues for workers, organisations, society, and nations (Udo *et al.*, 2016; Adebiyi *et al.*, 2020; Yilmaz *et al.*, 2020; Yang *et al.*, 2021).

According to the World Health Organisation (WHO) and the International Labour Organisation (ILO) (WHO/ILO, 2021), work related diseases and injuries were responsible for 1.88 million deaths in 2016 worldwide. Report from the Census of Fatal Occupational Injuries (CFOI, 2019) revealed that the rate of fatal work injury in the United States (US) was 3.5 fatalities per 100,000 full-time equivalent workforces and 1061 construction workers died on the job. The Bureau of Labour Statistics data revealed that one worker died on the jobsite every 99 minutes in the United States in 2019 (BLS, 2020). The Health and Safety Executive (HSE, 2021) in the United Kingdom (UK) reported the rate of fatality in the construction as 1.91 fatalities and 39 fatal injuries per 100,000 workers, which is the highest compared to other industries such as agriculture (34); manufacturing (20); transportation (10). A study conducted by Hamalainen *et al*., (2009) in Nigeria, and places occupational fatality yearly rate at 24 deaths per 100,000 employees. According to Abubakar (2015) occupational fatalities are said to be on the rise in Nigeria.

When cost estimation is carried out with the minimal information available at the early stages of construction projects, owners and planners are able to curtail wastes in cost and time of both design and construction work (Yilmaz and Kanit, 2018). Costs of potential accidents are routinely built into the projected construction costs of projects because stakeholders in the construction industry have for too long viewed accidents as an inevitable part of the cost of doing business. The estimation of accident prevention costs presents several challenges to the contractors, which includes the complexity of allocating cost and the scarcity of available data for the management of safety costs (Lopez-Alonso *et al*., 2016). Furthermore, it is difficult to justify if the amount of money spent on the prevention of accident is economically justified unless such costs of prevention are known before the commencement of the project (Yilmaz and Kanit, 2018).

Occupational Health and Safety (OHS) has gained prominence through the criteria for assessing performance in form of quality, productivity, customers' satisfaction and sustainability, which are employed in strategic management (Yilmaz and Kanit, 2018). However, it is impossible to collect data for OHS estimation with the traditional costing (TC) systems employed to evaluate these criteria in the construction industry. To this end, Cooper and Kaplan (1992) have long suggested that an Activity-Based Costing (ABC) approach which allows cost information to be obtained which are ignored by the

TC system. Ayachit *et al*. (2014) and Kale *et al*. (2018) described ABC as a method of computing the cost of individual activities and assigning these costs to cost objects like product, task or services based on the activities performed for the cost objects. The cost of individual activities in the construction industry, might be represented by the activity costs such as excavation, filling, masonry and so on. The cost object of interest to this study is safety cost in building construction projects. In the ABC method the cost of each activity is assigned to the cost objects in proportion to the actual consumption of the activities (Kim, 2017; Tran and Tran, 2022). By utilizing the ABC method, comparison could be made by firms in terms of productivity, cost control and profitability (Rios-Manriquez *et al*., 2014). It has been observed that computing and preparing a financial plan for the prevention of accident at the commencement of project construction helps to provide a better estimate for the cost of safety (Yilmaz and Kanit, 2018).

1.2 Statement of the Research Problem

The high rate of injuries on construction sites is recognised to have significant financial effects on the construction sector as a whole (Okoye, 2018). According to ILO (2018), poor occupational and health practices cost the economy 3.94% of global GDP annually, which translates to 3,447.68 billion US$ in monetary terms (Stasista, 2018). According to Yoon *et al*. (2013), a survey on the costs of work-related accident by Health and Safety Executive in 1989 revealed that corporate losses from occupational accidents stood between 5–10% of the profits across all industries, and 8.5% of the tender price in the construction industry in the UK. Smallwood (2011); Gurcanli *et al*. (2015); Latib *et al*. (2016); Otaru *et al*. (2018); Yilmaz and Ugur (2019); Adekunle *et al*. (2020) and Fitriani *et al*. (2022), revealed that the cost of implementing an H&S

management system within a construction projects ranges between 0.21% to 10% of the contract sum.

Lopez-Alonso *et al*. (2016) noted that the costs of OHS are not recorded individually in the accounting system of construction firms; as a result the items that constitute these expenditures are not identifiable. This situation arises because most firms lack information on the costs of measures for preventing accident. Contractors are thus, unaware of how much would be adequate for OHS provision. This is why Fitriani and Latief (2019) reiterated that there are currently no structured guidelines for preparing safety cost for projects in the Indonesia construction industry. 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 (Fitriani and Latief, 2019).

Yang *et al.* (2021) affirmed that expenditures on safety are not spent based on the risk of accidents. Ahn *et al*. (2021) revealed that the estimating method for OHS management cost does not reflect the features of projects as can be observed on construction sites. There still exists sub-optimal allocation of safety budgets for construction projects, as evinced from the high accident rate in the industry (Yang *et al*., 2021 and Fitriani *et al*., 2022). This is attributable to the dominance of the TC method which has failed to provide accurate costs of safety, because the technique employs one-stage costing, where resources are directly assigned to the cost objects utilising volume-based allocation as a cost driver (Kim, 2017)

Although studies have revealed that ABC system allocates indirect costs better than the TC system (Nassar *et al.*, 2013; Charaf and Bescos, 2013; Mushonga, 2015), limited number of firms have keyed into the application of ABC in estimating safety cost in the construction sector (Hallowell, 2008; Hallowell and Gambatese, 2009; Yilmaz and Kanit 2018; Yilmaz and Ugur, 2019). The adoption of ABC in estimating safety cost in Nigeria is not helped by the fact that conventional regulations enshrined in the 4th edition (Revised) of the Building and Engineering Standard Method of Measurement (BESMM4) do not specify standard units or quantities for the derivation of health and safety cost in construction. This is unlike what obtains with other types of construction cost such as excavation or concrete work, which are measured in detail (NIQS, 2015). This research, therefore, set out to model the costs of safety using activity-based costing methodology for assessing the safety risks in work items of building projects in Abuja, Nigeria.

1.3 Research Questions

In view of the identified problem, answers to the following questions has been provided by this study:

i. What potential hazards exist in the construction of building projects?

ii. How can the level of risk for work items in building construction be assessed in terms of likelihood, frequency and severity?

iii. What is the cost of safety required for controlling accidents in building construction projects?

iv. How can an activity-based model for predicting the cost of health and safety for building construction project be developed?

v. How can the validity of the ABC model for health and safety for building construction project be established?

1.4 Aim of the Study

The aim of the research is to develop cost models for predicting health and safety costs in building construction projects with a view to reducing accident rate and cost on construction sites.

1.5 Objectives of the Study

The specific objectives of the study are to:

i. Examine the potential hazards in building construction projects.
ii. Assess the level of risks for work items in building construction projects in terms of likelihood, frequency and severity.
iii. Determine the cost of safety required for controlling accidents in building construction projects.
iv. Develop an activity-based model for predicting the cost of health and safety for building construction projects.
v. Test the validity of ABC model for health and safety for building construction projects.

1.6 Scope of the Study

The study covered cost data in respect of H&S cost for building projects in Federal Capital Tertiary (FCT) Abuja. The choice of Abuja for this study is because it is the nation’s capital, there are numerous infrastructural developmental projects in progress. In addition, the majority of the construction projects have been medium-rise buildings and are for residential, commercial, and institutional building developments. Another reason is that 25.7% of the active registered quantity surveying firms in Nigeria are located in Abuja (Quantity Surveyors Registration Board of Nigeria (QSRBN, 2021), which are the major source of information for this study. Nonetheless, the firms sampled had a mix of professionals such as Architects, Civil Engineers, Builders, Health and Safety Managers, Project Managers and Quantity Surveyors working with them. Such professionals in charge of projects adjudged suitable for the study were requested to participate in the study.

Relevant data on the safety cost aspects of building projects were extracted from the preliminary section of Bills of Quantities (BOQ) and Programme of works of selected construction projects located in Abuja (it was found that not all projects had detailed programmes of work). Projects completed within the three years preceding this study (2016 – 2019) were employed for the study; a timeframe of three years was chosen in order to ensure that relevant project information and empirical data were retrieved from respondents without undue stress (Windapo, 2013). Ongoing or completed building project were assessed for the study, this is due to the fact that construction stage of project execution has the highest occurrence of risk (Goh and Abdul-Raham, 2013).

1.7 Justification for the study

The importance of managing construction risks is to achieve the project objectives in terms of cost, time, quality, safety and environmental sustainability (Zou *et al*., 2017). The poor record of H&S in construction sector suggests that the industry is far from being sustainable (Chigara and Smallwood, 2019). The review of literature has showed that several authors have either researched on risk assessment or accident prevention cost in construction projects (Ikpe, 2009; Hallowell, 2011; Pellicer *et al*., 2014; Gurcanli *et al*., 2015; Otaru *et al*., 2018: Ghousi *et al*., 2018; Yilmaz and Ugur, 2019; Adekunle *et al*., 2020; Ahn *et al*., 2021). Study on OHS cost as part of construction projects cost are not common as well as the application of ABC in estimating the cost of safety and health in construction (Hallowell, 2008; Hallowell and Gambatese, 2009; Gurcanli *et al*., 2015; Bilir and Gurcanli, 2016; Yilmaz and Kanit 2018; Yilmaz and Ugur, 2019).

Empirical studies in various countries have demonstrated methods and techniques employed in assessing safety risk and efforts made in developing models for estimating the cost of safety in the construction industry (Aminbakhsh *et al*., 2013; Gurcanli *et al*., 2015; Ghousi *et al*., 2018). Safety risk assessment level for construction work activities was evaluated by authors such as Jannadi and Almishari (2003); Odeyinka *et al*. (2004); Baradan and Usmen (2006); Hallowell (2008); Hallowell and Gambatese (2009); Aminbakhsh *et al*. (2013); Memarian and Mitropoulos (2013); Gurcanli *et al*. (2015); Okoye (2018); Liang *et al*. (2021) and concluded that the degree of incidence and the extent of impact of different hazard varied across the various construction activities. None of the studies mentioned in this paragraph provided for appropriate countermeasures that will aid in the reduction of accidents on work sites.

Health and safety cost items had been identified and studied by Smallwood and Emuze (2014); Smallwood (2011); Misnan *et al*. (2012); Giessa *et al*. (2017); Akawi (2017); Malan and Smallwood (2018) and concluded that the cost of H&S should be priced in a special section of the BOQ and set out in detail in the contract documents. The items identified were more of project specific and location based. Furthermore, provision was not made for risk-prevention measures or the selection of safety programmes for a particular project.

The impact of OHS cost on total construction cost was assessed by Tang *et al*. (2004); Smallwood (2004); Lopez-Alonso *et al*. (2013); Gurcanli *et al*. (2015); Latib *et al*. (2016); Yilmaz and Kanit (2018); Ghousi *et al*. (2018); Otaru *et al*. (2018); Yilmaz and Ugur (2019); Marleno *et al.,* (2019); Adekunle *et al*. (2020); and Fitriani *et al*. (2022). It was revealed that the cost of implementing H&S within construction projects ranges from 0.21% to 10 % of the total construction costs. It was concluded that the costs of preventing accident increases the project costs significantly, however to attain a safer work environment more should be spent on the prevention of accident by contractors. The estimating method for OHS cost management does not reflect the features of projects as well as non-apportioning of OHS costs to any particular work item. In addition there was no standardised tool employed for implementing the cost of H&S for construction in the literature reviewed.

Several models have been developed by various researchers such as Pellicer *et al.* (2014); Gurcanli *et al.* (2015); Giessa *et al.* (2017); Yilmaz and Kanit (2018); Yilmaz and Kanit (2018); Ghousi *et al*. (2018); Yilmaz and Ugur (2019); Ahn *et al.* (2021) for estimating the cost of OHS for construction projects. The model 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. Although, Gurcanli *et al*. (2015) assessed the level of risk and simple logarithmic regression was used to develop and validate an activity-based cost model for safety, the study was still limited because the ABC model developed was limited to only reinforced concrete work. This is the gap in knowledge addressed by this research, by modelling the costs of safety using an activity-based costing methodology for the assessment of safety risks distribution across the work activities /items 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 Nigeria.

This model would provide a reference for construction practitioners, contractors, safety experts, project planners, project managers and academia in estimating in details, the cost for OHS at early stage of project construction in Nigeria. In addition, contractors can prepare safety plans and allocate the required budget for safety measures not only for cost control or project management, but also in order to protect human life and to ensure the safety of workers on site. This research work will aid construction professional to objectively evaluate the safety impact of alternative means and methods of construction and would allow safety to be considered along with traditional project metrics such as schedule, budget and quality at all stages of construction.

1.8 Limitations of the Study

There was a lack of uniformity in the format of BOQs that would have been eliminated if a general Standard Method of Measurement (SMM) had been utilized; this feature limited the number of BOQs that were found suitable for use in the study. A further limitation was that construction work programmes were not available for all of the 40 projects, necessitating the manual derivation of work programmes for those projects that lacked them. The work items employed in this study were those for which man-hour data (labour work output) was found in literature and were published in NIQS databank. In addition only work items that were generally available across the entire sample of 40 projects were used. Due to variations in size, complexity and type of project, it was impossible to develop statistical models for Collective Protective Measures (CPM) and Safety Training costs, statistical model was developed for safety cost and PPE only. Finally, it is essential to indicate that this study is based on projected cost of construction, which;

i. Can change overtime if conditions change.

ii. Can change where re-use of PPE and CPM is practiced, as this will lower the costs of safety.

iii. Can change since the price of PPE materials may vary over the time period within which projects were surveyed; in this study a constant price was employed.

iv. Although inflation can cause change in construction cost in an economy within a short period of time, its impact on the safety cost evaluated by this study was not examined.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Characteristics of the Construction Industry

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 (Umar, 2019). Overall, the world's workforce is employed by the construction industry, which accounts for 7% of worldwide employment and 13% of global GDP (Deloitte, 2017). The industry that is in charge of erecting or putting together structures or infrastructure on a specific site is known as construction. With the claim that all construction projects contain high risk, the construction sector has been labelled as complicated and dynamic (Asworth and Perera, 2015).

Due to a number of factors that do not exist in other industries, the construction industry has a high accident rate (Pinos *et al.,* 2017). The construction sector differs from other sectors including manufacturing, services, and agriculture due to a variety of distinctive characteristics. According to Abudayyeh *et al*. (2006), several of the fundamental qualities of the construction industry, such as dynamic work conditions, fragmentation of the industry, multiplicity of operations, close proximity of various crews, and industrial culture, contribute to the high rate of accidents in the sector. Many of these traits influences unanticipated and unfamiliar dangers or workers' risky behaviour.

The construction work environment is unique, transient and dynamic (Tam *et al*., 2004). Hallowell (2008) and Cingilloglu (2012) noted that building sites are dynamic workplaces that are subject to a variety of unforeseen factors (such as weather, soil, and traffic accidents) and may differ drastically from earlier projects. The rate of accident is higher in the construction industry than other sectors because it is a labour-intensive sector with many tasks being performed simultaneously (Jeong and Jeong, 2022). Additionally, proximity of multiple crews due to diverse task teams working in the same sections of the building sites. Also, the project's work teams constantly change over time, and their personnel likewise does (Cingilloglu, 2012). Even though the activities are basic and familiar to the workers, all of these factors raise the risk of accidents and divert them from executing them properly (Hinze and Wilson, 2000; Carter and Smith, 2006).

The fragmentation of the parties engaged throughout the numerous stages in the construction of the projects is one of the exceptional features of the construction sector. In a standard design-bid-build contract, the design phase is completed by architects, engineers, and other specialists. Next, proposals are requested, and the selected contractors execute the project (Sousa *et al*., 2014). Contingent types of contracting, such as the challenge of coordinating numerous interdependent contractors, sub-contractors and trade-contractors resulting to multiplicity of operations on a single site that otherwise may lead to an increased injury risk on projects activities (Pinos *et al*., 2017; Bilir and Gurcanli, 2018).

Lack of effective communication and the cultural differences of construction workers make it difficult to prevent accidents, which may be a factor in the high incidence rate in the sector (Cingilloglu, 2012; Sousa *et al*., 2014). Communication difficulties arise from a number of factors, including machismo, substance addiction, language problems, a lack of education, and the coexistence of workers from many ethnicities (Hallowell, 2008; Sousa *et al.*, 2014). The attitude of workers in the construction industry increases their risk tolerance, which in turn increases the frequency and seriousness of accidents (Hinze, 1997).

2.1.1 Safety and health practices in the construction industry

In the construction sector workers are more likely to die on the job or suffer an injury than those in other sectors due to the industry's reputation as a dangerous and high-risk workplace (Cingilloglu, 2012 and Umar, 2019). With the advancing technologies and industrialization, poor workplace conditions are now a threat to OHS and thus to public health (Yilmaz *et al.*, 2020). The International Labour Organization (ILO, 2018) 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. Notwithstanding the fact that human life is inestimably valuable and cannot be measured in monetary terms, the ILO calculates that poor work-related health and safety practises cost the economy 3.94% of GDP annually (ILO, 2018). It costs 3447.68 billion US dollars annually (Stasista, 2018). 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.

2.1.2 Causes of construction accidents on sites

Accidents in the construction industry does not only comprise of direct physical harm to people or property but can also result in situations that have short- or long-term impacts on workers H&S (Umar, 2019). Unsafe activities and condition was identified by Abdelhamid and Everret (2000); HSE (2004); Ikpe (2009) and Hughes and Ferret

(2016) as the major cause of accident in building projects. The management related factors, risky acts, and unsafe conditions are displayed in Table 2.1.

Table 2.1 Causes of construction accidents on sites

Unsafe acts	Unsafe condition	Management related causes
Wrong usage of equipment	Insufficient or missing guard	Inadequacy in planning
Failure in warning others of danger	Absence of platform guardrails	Design inadequacy
Unsafe keeping of equipment in a dangerous condition	Faulty tools and equipment	Deficiency in training and awareness
Failure of using or wearing PPE	Acts of noise and violence	Inadequacy in supervision
Use of deflective equipment	Insufficient fire warning system	Management ineffective policy
Vehicular contact	Electricity contact	Failure in complying with the operating instruction
Struck by falling/moving/flying object	Atmospheric conditions that is hazardous	
Handling manually	Hazards due to fire	
Struck against something stationary or fixed	Exposure to explosion	
Failure in correctly lifting up loads	Inadequate lighting on work site	
Consumption of drugs or alcohol on site	Exposure to excessive noise	
Fall on same level or slip trip	Exposure to dust	
Working unauthorized	Exposure to harmful substances	
Fall from high level		

Source: Abdelhamid and Everret 2000; HSE, 2004; Ikpe, 2009; Hughes and Ferret, 2016

2.2 Types of Safety Hazards in Construction

Construction involves a lot of hazard sources that are unpredictable, which complicates the site circumstances. These risk categories could lead to safety risk incidents and significant financial losses if they are not recognised and controlled during the execution of a building project (Liang *et al*., 2021). The categorization of prevalent hazards in construction is a crucial stage in other to quantify safety risk. Many incidents can be attributable to negligence of some kind and may entail dangerous working condition, improper usage of tools as well as equipment and inadequate precautions for safety. Main hazards or accident type in building construction utilized for the study are explained in the following subsection.

2.2.1 Fall from high level

Construction workers frequently have to operate at great heights while using scaffold and ladders on roofs and in windows. The Bureau of Labour Statistics (BLS 2016) reports that these mishaps are to accounts for 34% of all construction workers' fatal workplace accidents. Plans for construction safety must include precautions to save employees from falling from precarious heights. Stairwells without guardrails are another location where falls are frequently risky. Since these falls frequently involve great elevations, the outcomes for those who suffer major injuries can be catastrophic. Construction sites with insufficient or non-existent fall protection are the primary cause of deaths on site.

2.2.1.1 *Ladder*

Ladder accident is one of the main reasons for damage and permanent impairment. The majority of ladder incidents, including falls, are caused by workers using the incorrect sort of ladder for the task at hand or poorly erecting the ladder, maybe on a slick or unstable surface, which causes the ladder to shift or slip unexpectedly (Kibe, 2016). Additionally, employees could trip over a foot, lose their balance, or overreach. Ladders could also be defective or incorrectly maintained.

2.2.1.2 *Scaffold mishap*

Despite stringent controls, accidents on scaffolding still happen. According to BLS (2016) survey, 72% of workers hurt on scaffolds blamed the mishap on the planking or support collapsing, slip by employee, being struck by falling object. In general, poor design or careless upkeep are at blame for the majority of scaffolding mishaps.

2.2.2 Slip, trip and fall

Slip and falls are among the most frequent incidents on sites resulting to over a third of all serious injuries on construction site (Hughes and Ferret, 2016). Unsafe conditions, such as exposed pegs and holes or trenches, could be to blame for these mishaps. On a construction site, there are several hazards that could cause a person to slip, trip, or fall, from loose equipment and materials to irregular ground or holes.

2.2.3 Electrocutions

An individual, tool, or piece of equipment can be electrocuted if they come into touch with power lines or other exposed electrical sources. According to Hughes and Ferrett (2016), electric shocks account for 2% of all workplace fatalities. These accidents can occasionally happen because workers are simply not aware of all electrified power sources, including broken receptacles and connectors as well as overhead and subsurface power lines.

2.2.4 Caught between objects or materials

Accidents classified as caught in-between occur when a worker's body part is pinned, squeezed, squashed, or crushed between two or more items (Kibe, 2016). Examples of such hazard include rollovers of equipment, getting trapped between fixed things, such a wall, and large pieces of heavy equipment, cave-ins or falling materials, body parts getting stuck in the moving sections of an unsecured piece of machinery, and more. Construction workplaces are cluttered with bulky equipment, supplies, and tools. Workers frequently become trapped between heavy equipment, falling debris, or other immovable items.

2.2.5 Struck or hit by an object

The aforementioned category describes potentially harmful interactions between people and large machinery. In the vast majority of incidents trucks and cranes are the primary causes of accidents and fatalities. Caution must be taken around shaky walls and falling debris in addition to heavy automobiles. In 2012, 78 construction workers lost their lives after being struck by an object. If the workers had received the appropriate training and had used the tools and machines in the right ways, several of these fatalities would have been avoided (HSE, 2014). It is common for falling tools, construction supplies, or beams to harm workers below on multi-level projects.

2.2.6 Machinery and equipment accidents

Heavy equipment is frequently used by construction workers. A mistake or mishap with these items, such as cranes, bulldozers, jackhammers, and nail guns, can be extremely hazardous. Power tool and machinery injuries can happen for a variety of reasons, such as mechanical flaws, electrical malfunctions, inadequate training, failure, or a lack of adequate safety equipment (HSE, 2014). The usage of heavy machinery and power tools results in a considerable number of injuries.

2.2.7 Getting hit by a vehicle

Forklifts, graders, backhoes, and dump trucks are among the risky equipment used on construction sites. Forklift accidents frequently happen when the truck is rotated or manipulated while the load is raised. Huge vehicles frequently back up and strike pedestrians. Falling from a car is another danger on construction sites. There are frequently roads or highways next to or nearby construction sites. A worker might be struck by a passing car or truck because drivers are occasionally preoccupied with their work; if they are not paying attention or it is night time, they risk being hit (HSE, 2014).

2.2.8 Trench collapse/ cave-ins

On construction sites, a need for trenches is frequently present. If a worker is within a trench and it collapses, a worker could be buried in the surrounding dirt or struck by anything such as tools, machinery, or materials. Contrary to popular assumption, cave-ins are not the main reason for trenching accidents and fatalities. Other dangers to be on the lookout for include the following: lacking sufficient oxygen in a small area, causing asphyxiation drowning and unforeseen contact with subsurface pipelines and lines are both caused by toxic gases (HSE, 2014).

2.2.9 Fires and explosions

Hughes and Ferrett (2016) observed that fires and explosions frequently occur on building sites as a result of unfinished pipe, leaking gas lines, and inadequate electrical systems. On-site fires are caused by various activities for example: plumbers performing braising work, subterranean work are carried out on gas lines, electricity cables, high-voltage lines, mechanical equipment that uses diesel as well as gasoline, and harmful chemicals (Kibe, 2016).

2.2.10 Manual handling of materials and tools

Hughes and Ferret (2016) described manual handling as the transporting or movement of a load solely through human effort. Any action requiring a person to apply force in order to lift, push, pull, carry, move, or constrain a moving or immobile object is included (HSE, 2014). Sprains and strains of the muscles are a common reason for accidents, disability claims, and medical expenses in the construction industry. The accidents often occur as a result of physical demands placed on workers' bodies by their jobs.

2.2.11 Collapse of building structure

Accidents wherein buildings or structures collapse while being built or after being put into operation, causing damage to property and casualties. Buildings that are inclined to collapse, cracks in the walls and columns, the collapse of cantilever plates on the roof, uneven settlement of the foundation, landslides brought on by changes in the geological structure, balconies, cornices, and other floors are examples of the collapse accidents (Liang *et al*., 2021).

2.2.12 Related works on safety risk hazards in construction of projects

Several authors had researched on the various safety hazards that causes occupational accident in building construction projects Table 2.2 presents a summary of the most occurring accident types on construction projects. Hallowell and Gambatese (2009) studied the risk mitigation of construction safety and activity-based quantification of total risk for formwork in concrete was proposed. They also assessed the relative effectiveness of safety programme elements. Findings revealed that fall to lower level, toxic exposure, struck by object, caught in and transportation were the top safety risk.

Okeola (2009) assessed OHS in the construction projects, findings revealed that step on sharp object, fall on to same level and tool injury were the most frequent occurring hazards on construction site. Gurcanli and Mungen (2013) analysed the causes of occupational accident and the distribution of fatalities, findings revealed that trades with high risk were roof work, painting and plastering, formwork, excavation and masonry work. While the major causes of accident in construction projects were fall, being struck by thrown or objects falling, collapse of building structure and electrical exposure.

Table 2.2 Summary of most critical safety risk hazards in the construction of projects

S/N	Hazards in Construction sites	Gurcanli and Mungen (2013)	Memarian and Mitropoulos (2013)	Pellier *et al.* (2014)	Gurcanli *et al.* (2015)	Choi (2015)	Orji *et al.* (2016)	Udo *et al.* (2016)	Bilir and Gurcanli (2016)	Yilmaz and Basaga (2018)	Okoye (2018)	Yao *et al.* (2018)	Ghousi *et al.* (2018)	Williams *et al.* (2019)	Liang *et al.* (2021)
1	Struck by falling objects	*	*	*	*	*	*	*	*	*			*	*	*
2	Fall from height	*	*	*	*	*	*	*	*	*	*	*		*	*
3	Cave –ins / Trench collapses														*
4	Fall to lower level												*		
5	Slips/ trips and fall the same level		*	*		*	*	*			*			*	
6	Building/structure collapse	*							*			*			
7	Equipment/ vehicle accidents				*		*	*		*	*		*		*
8	Struck by moving vehicles								*				*	*	
9	Manual handling of material/Machine/tool and usage hazards				*			*			*		*		
10	Contact with electricity	*	*	*	*		*		*			*	*	*	*
11	Contact with underground lines														
12	Collapse of underground cavities / pits														
13	Traffic /transportation accident													*	
14	Noise exposure														
15	Fire exposure									*					
16	Caught in-between Objects or Materials			*		*				*					
17	Exposure to harmful substance														
18	Overexertion		*	*		*					*				

Source: Author's summary (2022)

Memarian and Mitropoulos (2013) researched on accidents in construction as they pertained to masonry work, the most common incident occurrences were overexertion, being struck by an object, coming into touch with an object, slipping or falling, as well as falling from elevation.

Pellicer *et al*. (2014) designed a method for estimating the costs of OHS at the design stage of project construction and investigated the key cause of accident on site in Spain findings showed that; getting hit by or colliding with an object, overstrain (lifting), slips / trips and fall from heights were the prominent accident type on construction site. Gurcanli *et al*. (2015) assessed the risk in residential buildings and estimated the safety cost using an activity-based technique. Results showed that reinforced concrete work, excavation and electrical work were the most dangerous job activities in building projects, whereas falls from great heights, manual handling risk and collisions with flying or falling objects were the most common accident types in construction projects. In the US construction industry, according to a study by Choi (2015), labourers, carpentry, ironworkers and operators are the construction trade with the highest rates of injury. While the main accident types in the execution of projects were being struck by material or an object, getting caught between two objects, and falling from a higher level.

Orji *et al*. (2016) examined accidents in building construction sites and acknowledged that equipment injury, stepping on sharp object and falls from height were the most frequent accidents types on construction project sites. Udo *et al.* (2016) studied the consequences of inadequate safety measures on construction sites and discovered that injuries sustained while handling materials or objects, injuries sustained while lifting materials or objects, slips and trips on objects, and caving in of excavation were the most frequent accident types that occur on sites. Bilir and Gurcanli (2016) determined accident frequencies on building projects using an activity-based approach. Findings revealed that roof work, reinforced concrete work and excavation were identified as the most hazardous work activities and fall from high level, being struck by flying or falling objects and collapse of building structure were the frequent type of accident in construction projects

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. The causes of fatal accidents on construction sites was analysed by Williams *et al*. (2017) and established that fall from high level, being struck by an object, being electrocuted, drowning, and accidents involving vehicles or equipment were the most common types of accidents on sites. Okoye (2018) assessed OHS risk factors in building trades were falling from height, activities involving manual handling and step climbing as well as walking on platforms. In addition the trade with high risk in the construction of building were masonry, roofing and bending of iron. Ghousi *et al*. (2018) investigated the monetary aspects of safety programmes, while developing a flexible technique for assessing building construction safety risk. Results showed that the most risky building trades were steel structure construction, excavation, and building facade, and that the most significant hazards in building construction projects were being struck by falling debris and objects and falling to a lower level.

Yao *et al*. (2018) studied the management of risk in civil projects at the construction stage which was based on the risk matrix method. Findings showed that the major hazard factors include collapse, fall and electrocution in China. Bilir and Gurcanli

(2018) studied method to determined accident probability in construction industry, finding revealed that excavation work, reinforced concrete work, masonry work, plastering and painting and construction of roof were the most risky activities. While the most frequent accident types in construction projects were falling from height, being stroked by falling or falling objects, struck by moving vehicle were the most frequent accident types in construction projects. Yilmaz and Basaga (2018) assessed construction work-related accident in Turkey. They discovered, fall, hand-tapping with a hand tool, injury with a sharp tip tool, material bouncing and fire or explosion were the top occupational accident by accident type.

A study on the cause of accident on building sites of South-Western states in Nigeria by Williams *et al.* (2019), the most frequent occurring accident type were; contact with tools when working, accidents related to vehicle, slip/trip and accident related to fall. Mon (2020) assessed risk in high-rise buildings and identified hazard using failure mode to analyse the effects. It was discovered that landslide, fall from height, struck by, exposure to harmful substance, noise and vibration and electrocution were the major accident type on construction sites in Myanmar. Liang *et al*. (2021) evaluated the level of safety risk on project site in China using analytical hierarchy procedure centred on unascertained measures and findings revealed that fall from high place, pit collapse, object striking accident, electric shock and fire were the most common accident types. Abas and Blismas (2021) identified hazard risk in construction process for selected approaches in Malaysia, result revealed that working at height, struck by, exposure to chemical hazard, electric shock and vehicular/equipment accident are the hazard prone to accident in Malaysia.

2.3 Risk in the Construction Industry

2.3.1 Definition of risk

The term "risk" has many different definitions and can be used to describe a variety of things, including the likelihood of accidents or fatalities, the sample size of a population, probability and dependability, or the potential impacts on a project (Dario, 2017). Risk can be distinguished from uncertainty by being defined as the situation in which it is possible to anticipate the result of an occurrence using statistical probability (Dario, 2017). Iqbal (2015) defined risk as exposure to loss or gain, or the possibility of an occurrence of loss or gain multiplied by its corresponding extent. According to the Project Management Institute, risks in the construction industry are typically viewed as occurrences that have an impact on the main project objective of time, cost, and quality (PMI, 2013).

The likelihood, severity, and exposure of any activities' potential risks are all measured as risk (Jannadi and Almishari, 2003). Construction risk is characterized by Odeyinka *et al*. (2004), as a construction process variable that, if it occurs, creates uncertainty regarding the project's ultimate cost, time, and quality. The impact of risk on various objectives is frequently discussed in terms of probability and consequences, as noted by Dario (2017). A potential occurrence must have a probability of between 0 and 1, which indicates a spectrum in which the event is either impossible or unavoidable, for it to be deemed a risk (Loosemore *et al*., 2006). As a result, risk exists when a decision is expressed in terms of a range of potential outcomes and when known probabilities can be associated with predetermined outcomes (Smith *et al*., 2006). Lee (2019) described risk as the frequency of the accident and the intensity of the accident. Risk in construction projects is defined by Liang *et al*. (2021) as the likelihood of causing fatalities, accidents, dangers, and losses of property. There are many types of risk that can arise in the construction of building projects which includes contractual, economic, financial, technical, political, environmental, and health and safety risks (Edwards and Bowen, 1998; Zou *et al*., 2017). The focus of this research is on H&S risk more attention to reviewing H&S risk would be given in this study.

2.3.2 Health and safety risk

Several definitions of risk have been employed in relation to H&S. Some of these definitions include: the potential severity of harm or illness that may result from an event or exposure(s) that are hazardous; and the combination of the likelihood that the event or exposure(s) will occur (British Standard Institute, 2008). The possibility of a given substance, activity, or a process to cause harm (Hughes and Ferrett, 2016). Risk is the likelihood that harm will occur, according to HSE (2001; 2006). Since the HSE is the recognised authority on H&S issues, this definition of risk is adopted in the research. It has been observed that risk and the word "hazard," despite the fact that they are distinct, are frequently used interchangeably (HSE, 2001). Hazard is defined as the inherent potential for harm to be caused (HSE, 2001) and is related to risk in the following way: risk is the likelihood that someone or anything of value will be negatively affected by a hazard in a specific way. Concentrating on the H&S of persons, the likelihood that a person or persons would be hurt is risk (that is negatively affected) by a danger (that is the possibility of something to cause harm).

H&S risk in construction needs to be effectively managed, and with the advent of rules like the CDM Regulations, there has been a significant focus on controlling H&S risk from the very beginning of the project. The need to manage H&S risk is mandated by the Management of Health and Safety at Work Regulations 1999 (HSE, 2006). The method of managing H&S risk is similar to the generic risk management framework (identification of risk, analysis/evaluation of risk, risk response, and the monitoring of risk), though this process is referred to as risk assessment in some literature (HSE, 2006). HSE (2006) recommends steps for managing H&S risk, which are titled "Five steps to risk assessment". These steps are categorised hierarchically.

2.3.2.1 *Identification of hazard*

Hazard identification is the first step, and it entails thoroughly identifying hazards in the workplace. The HSE suggests performing a tour of the workplace to find objects that could reasonably be anticipated to cause harm, asking workers or their representatives for their input, consulting HSE and trade association guidance on the occurrence of hazards, consulting manufacturers' instructions, and consulting accident and ill-health archives (HSE, 2006).

2.3.2.2 *Identification of people at risk*

The task in this step is finding the groups of persons that might be harmed by the impact of the hazard. Consideration must be given to the employees who are having special requirements (people who are disabled), guests, and members of the public who may not be present at the work site all the time (HSE, 2006).

2.3.2.3 *Evaluating health and safety risk*

Evaluating the risk level which in other word is regarded as risk assessment (Jannadi and Almishari, 2003) involves analysing the degree of risk. Determining the risk control measures to be put in place comes after assessing the amount of risk. Risk evaluation techniques for health and safety have mostly been divided into qualitative and quantitative categories (British Standard Institute, 2008; Pinto *et al*., 2011).

2.4 Risk Assessment

Risk assessment is defined as a process used to determine the priorities and establish objectives for removing hazards as well as reducing risks (Hughes and Ferret, 2016). A key step in lowering hazards and injuries on site is by assessing the safety risk (Kozlovska and Strukova, 2012). Risk assessment aimed at predicting exactly when, where, and how the harm to health may occur before anyone is injured or sick, if possible, and to take precautions from the very start (Gul *et al.*, 2022). Aminbaksh *et al*. (2013); Ak (2020) and Suti *et al.* (2021) identified risk assessment stage as a key stage in OHS because it enables identification of hazard, their assessment and prioritisation as well as the establishment of risk control mechanisms. The purpose of risk assessment is to determine if the level of hazard in work activities is considered acceptable or otherwise (Suti *et al.,* 2021). The most significant issues in risk assessment approaches is the knowledge of calculating or assessing the parameters of accident likelihood or probability (Bilir and Gurcanli, 2018). Hughes and Ferret (2016) classified risk assessment into qualitative and quantitative risk assessment.

2.4.1 Qualitative risk assessment

A qualitative risk assessment uses descriptive scale (words) to describe the magnitude of potential severity and the likelihood of the impact of occurrence (Purohit *et al*., 2018). The qualitative risk assessment is subject to expert knowledge and experience, intuition and judgement to determine the likelihood and severity of classification (Bahamid and Doh 2017 and Purohit *et al*., 2018). Qualitative risk assessment includes valuing the probability as well as the impact of the numerous risks and to improve project performance by identifying risks with high priority. The evaluation of the priority of risks identified is prepared on the bases of probability or likelihood of risks occurrence, the corresponding impact of the risks if it occurs as well as the urgency of risk response (Nadaf *et al*., 2018). According to Hughes and Ferret (2016) the level of risk in qualitative risk assessment is either low, medium or high risk. The main qualitative analytical techniques are: brainstorming, checklists, expert judgement, Event Tree Analysis (ETA), Delphi, cause and effect diagram, Risk Breakdown Matrix (RBM) and risk data quality assessment (Bahamid and Doh 2017).

2.4.2 Quantitative risk assessment

A quantitative risk assessment assesses the amount of risk by comparing the possibility of risk occurring to the likely severity of the result and assigning the risk a numerical value (Dario, 2017). It is based primarily on the probabilistic dispersion of risks. Nonetheless, if enough data are provided, it can deliver impartial results (Bahamid and Doh, 2017). Quantitative analysis combines data from a range of sources, such as past accident experience and scholarly study, to determine numerical values for both severity and likelihood rather than the descriptive scales used in qualitative and semi-quantitative analysis (Purohit *et al*., 2018). While decision tree analysis, expected monetary value, Fault Tree Analysis (FTA), Fine-Kinney, fuzzy logic, probability distributions, sensitivity analysis, and tornado diagram are among the fundamental quantitative tools (PMI, 2013). Additionally, computer-based simulation tools like Monte Carlo simulations and system dynamics applications for Project Relationship Management (PRM) are used in risk analysis methodologies (Choudhry *et al*., 2014). This research will employ the Fine-Kinney method, which will be further described.

2.4.2.1 *Fine-Kinney risk assessment method*

The Fine-Kinney method of risk assessment is a mathematical evaluation tool for controlling hazards in which a framework to estimate risks is proposed. This method was originally published in literature in 1976 as a quantitative risk assessment technique (Kinney and Wiruth, 1976). The risk value in this method is calculated by multiplying three parameters: the severity of the consequences for a worker in the event of dangers and hazards (C), the exposure frequency of dangers and hazards occurring (E), and the likelihood or probability of an accident (P) (Fine, 1971). When analysing risk in the Fine-Kinney method, probability, frequency, and severity parameters, as well as scale tables for each parameters are all included. Reference points are established when developing these scale tables, and other scores are established based on experience using the reference points as a guide. Tables 2.3 to 2.5 contain recommended scales for the probability, frequency, and severity parameters for use with the Fine-Kinney approach.

2.4.2.2 *Fine-Kinney probability or likelihood scale*

The chance that an accident or hazard will occur within a given time frame is defined by likelihood or probability. An incident rate, such as the number of worker-hours per incident, is a way of expressing risk likelihood or the probability of an event in terms of safety (Hallowell, 2011). The Risk Assessment Team must take into account any pre-existing medical conditions of the affected individuals that could have an impact on the likely rating when determining likelihood. On a scale of one to ten, the probability scale values indicated that the incident "Might Well be Expected" and indicated that it has happened before, may happen again, and will happen in the future (kinney and Wiruth, 1976). Based on experience, the intermediate values are chosen as presented in Table 2.3.

Table 2.3 Fine-Kinney scale of Likelihood or Probability

Likelihood or probability	**Value**
*Might well be expected	10
Quite possible	6
Unusual but possible	3
*Only remotely possible	1
Conceivable but very unlikely	0.5
Practically impossible	0.2
*Virtually impossible	0.1

Source: Kinney and Wiruth (1976); Oturakci and Kokangul (2015)

2.4.2.3 *Fine-Kinney frequency of exposure scale*

The time spent engaging in an activity is referred to as exposure (Hallowell, 2008). Also refer to as the average event rate per unit of time (Hallowell, 2011). There are two reference points established for the exposure frequency scale values. As with the probability scale, the frequency table's reference values range from 1 to 10. Based on the frequency of incidence by hour, day, and year, risks are categorised in the frequency table (kinney and Wiruth, 1976). As shown in Table 2.4, if an incident occurs on an hourly basis, it is considered as "continuous," and the frequency value used to calculate risk is set at "10," with the lowest value being "1" and the highest value being "3."

Table 2.4 Fine-Kinney scale of Frequency of Exposure

Frequency	**Value**
Continuous	10
Frequent (daily)	6
Occasional (weekly)	3
Unusual (monthly)	2
Rare (a few years per year)	1
Very rare (yearly)	0.5

Source: Kinney and Wiruth (1976); Oturakci and Kokangul (2015)

2.4.2.4 *Fine-Kinney severity scale*

The magnitude of the result is determined by severity. The degree of the harm (such as a mortality, lost productivity, or medical case) or the financial impact on the organisation are two ways to define severity (Hallowell *et al*., 2017). If a risk is anticipated to result in financial loss to occupational health and safety, a different severity score is determined. Values between 1 and 100 are utilised on the risk scale since the risk's intensity has a greater impact on the overall risk score (kinney and Wiruth, 1976). The reference point of 1 to 100 would be accepted, and intermediate values are computed using the formula: Severity Value = $(loss/100)^{0.4}$.

Table 2.5 Fine-Kinney scale of Severity

Severity	**Value**
*Catastrophe (many fatalities, or >$107 damage)	100
Disaster (few fatalities, or >$106 damage)	40
Very serious (fatality, or >$10 5 damage	15
Serious (serious injury, or >$10 4 damage)	7
Important (disability, or >$10 3 damage)	3
*Noticeable (minor first aid accident, or >$ 100 damage)	1

Source: Kinney and Wiruth (1976); Oturakci and Kokangul (2015)

2.4.2.5 *Risk score scale of Fine-Kinney*

The risk score of Fine-Kinney is computed numerically as the product of three parameters; likelihood, exposure and severity (possible consequence) values obtained from the table and multiplied. The risk score value would be categorised in accordance with Table 2.6, and risk prevention operations would be organised in accordance with each hazard's risk priority order. Risk score expressed in eq. (2.1) according to Kokangul *et al.* (2017).

$$\text{Risk score} = P \times E \times C \qquad (2.1)$$

Where P= Probability or likelihood of hazardous event

E= exposure frequency

C= severity of possible consequence

Table 2.6 Fine-Kinney Risk Score Scale

Risk score	Risk situation	**Action**
R<20	Risk	Perhaps acceptable
20<R<70	Possible risk	Attention indicated
70<R<200	Substantial risk	Correction needed
200<R<400	High risk	Immediate correction required
R>400	Very high risk	Consider discontinuing operation

Source: Kinney and Wiruth (1976); Oturakci and Kokangul (2015)

An acceptable risk score is one with a risk score value of less than 20, which reflects little risk. The requirement for correction arises when a situation's risk score value is between 70 and 200. An environment with a risk score between 200 and 400 is considered to be high risk and suggests that immediate correction is required. A risk score value greater than 400 indicates a very high risk, indicating a risky situation that necessitates stopping the operation pending at least a temporary measure implemented to correct the deficiency or otherwise a perpetual stoppage turn out to be essential if the process cannot be made harmless.

2.5 Cost Estimation in Construction

The estimated cost of a building project is the sum needed to complete the construction work. Oyedele (2015) defined construction cost estimate as the probable sum that is computed to finish a building activity. Cost estimate is defined by Gurcanli *et al*. (2015) as the initial budget of various stages of the project. Cost estimate is also referred to as a forecast made by an estimator or a cost engineer at a specific phrase of a project's execution using the data that is currently available. As more data is gathered, the estimates become more accurate (Oyedele, 2015 and Gurcanli *et al*., 2015). A cost estimate enables owners and planners to assess a project's viability and successfully manage expenses during the intricate project design phase (Gurcanli *et al.*, 2015).

According to Kim *et al.* (2004) if cost estimating models can estimate construction costs early on in a project with little project data, they can be helpful in the basic design stage. These cost-estimating techniques include the unit method, superficial method, approximate quantities method, artificial neural networks, fuzzy logic, genetic algorithms, and regression analysis, to name a few. Many cost estimation models that use parametric techniques have been created since project success depends critically on the accuracy of construction cost estimates as well as contingency for contractors. The 1970s saw the development of cost estimation, which now encompasses linear regression analysis and statistical techniques (Kouskoulas and Koehn, 1974; Singh, 1990; Wilson, 2005). A new method of cost estimating was launched in the late 1980s based on user experience and greater investigation into the capabilities of artificial intelligence, such as expert systems (Kim *et al.*, 2004). In the late 1980s, ABC was seen as the contemporary alternative for absorption estimation that would enable managers to better grasp the net profitability of their products and clients (Kim *et al*., 2004).

2.5.1 Background of activity-based costing

2.5.1.1 *Traditional costing system*

Bvumbi (2017) and Kim (2017) acknowledged the Traditional Costing (TC) method as the widely utilised estimating approach but lacked the capacity to precisely calculate the actual production and services costs, resulting in cost distortion. The TC technique employs one-stage costing, where resources are directly assigned to cost objects utilising volume-based allocation as a cost driver (Kim, 2017). TC approach operates under the presumption that resources are immediately used by goods or services. Due to the categorization of resources as opposed to activities or products, it was unable to provide adequate process visibility on cost (Johnson and Kaplan, 1987; Cooper and Kaplan, 1992; Kim, 2017). Traditional costing techniques have a propensity to inflate product costs and result in subpar strategic decision-making, according to Johnson and Kaplan (1987) and Johnson (1991).

According to Lind (2001), the main drawbacks of the conventional costing system can be summed up as follows:

i. Costs of products are often cross-subsidized;
ii. Capital expenses associated with technology are handled as period costs;
iii. Processes rather than specific groupings of products are costed;
iv. Various products are challenging to effectively account for because volume-based accounting is used.

The above highlights the challenges faced by organisations employing the traditional costing approach, due to the lack of clarity and traceability of cost information's, which prevents it from being linked to any particular activity (Lind, 2001). The issue with traditional costing systems is that a lot of indirect costs are still allocated using allocation variables that have nothing to do with what led to the costs being incurred (Krishnan, 2006). Organisations that are successful tend to be those that can reduce costs while increasing quality and efficiency of operations and eliminating goods and services that result in losses (Drury, 2011). For the purpose of assisting them in making decisions, managers require a cost management system that is timely and provides high-quality data. In order to accomplish this, a lot of organisations have switched to ABC, a more widely used cost methodology approach, from conventional or traditional costing systems (Drury, 2011). Understanding how ABC differs from the conventional costing system is crucial, for this reason.

2.5.1.2 *Development of ABC from the shortcomings of the traditional costing*

ABC was created as an alternative to existing costing systems, which were widely utilised but lacked the accuracy to calculate actual production and service costs or give usable data for decision-making (Bvumbi, 2017). Managers were exposed to making decisions based on erroneous data since they were using the information supplied by the conventional costing method to inform their decisions (Cardos and Pete, 2011).

2.5.2 An overview of ABC development

Robin Cooper and Robert Kaplan initially introduced ABC at the end of the 1980s (Yousif and Yousif, 2011). This concept was based on the idea that since every company’s activity supports production and provision of goods and services, it makes sense to treat them all as product costs. Furthermore, because almost all manufacturing facilities and corporate support expenditures are splittable, they can be linked to specific goods. Yousif and Yousif (2011) went on to note that the reasoning behind ABC is found in creating products that are produced as a result of activities. Actions frequently call for the provision of resources, which results in expenses. Companies will be helped by ABC to trace each product's cost if they are able to define their operations. According to Kim (2017), ABC is a system that will accurately and economically track the consumption of an organization's resource costs (such as salaries and supplies) to products, as well as the various channels and customer groups that demand different levels of workload from the company.

2.5.2.1 *Concept of ABC*

A variety of words are used to describe ABC in the various research, including method (Garrison *et al.*, 2011), methodology (Narong, 2009) and accounting technique (Pandey, 2012), a system (Bvumbi, 2017). Resources, activities, and cost targets are shown in Figure 2.1 along with how they relate to one another in the ABC process.

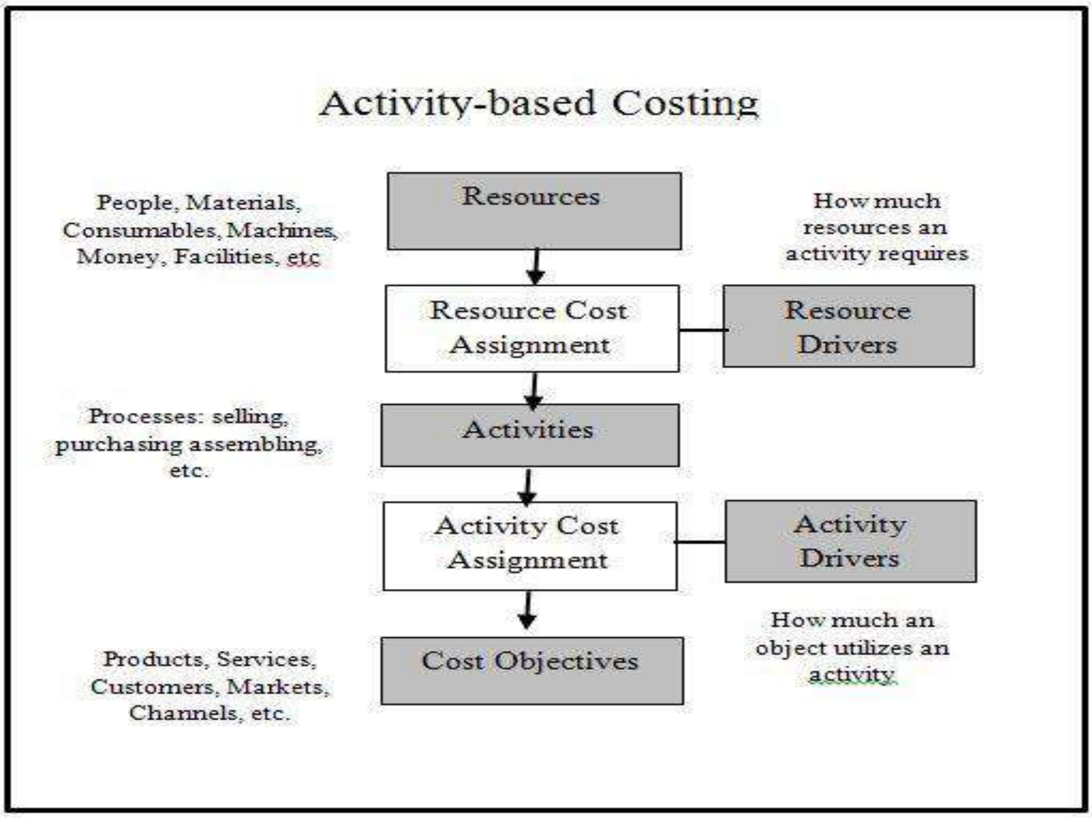

Figure 2.1 ABC Process
Source: Bvumbi (2017)

The ABC process introduced in the diagram starts with resources, which stand for the necessary personnel, supplies, and equipment needed. The next step in the flow is the resource cost assignment, which shows the cost drivers for resources and helps determine how much of each resource is required for each activity. The following are the defined activities, which indicate the course of action that an organisation will embarked on, such as buying, selling, and assembling. The activity drivers, which govern how much an item uses an activity, will then be represented by an activity cost assignment for each activity. The end product, such as services, clients, and markets, is represented by the cost objectives. Garrison *et al*. (2011) described ABC as a system that provides cost information to managers to aid in decision-making that may have an impact on both fixed and variable costs.

Narong (2009) defined ABC as a system that generates a bill of activities that includes the price of each distinct good and service. As an activity is at the core of ABC, organisations should identify their activities in detail in order to cut costs and boost revenues. ABC offers a chance to spot needless and ineffective tasks. Organizations who do this are able to identify where their money is going and may then decide whether to lower expenditures or cut them altogether in order to increase profit (Bvumbi, 2017). ABC is a technique created to protect against potentially catastrophic financial issues that might develop when an organization's accounting expenses differ significantly from its actual costs, according to (Pandey, 2012). To help management with decision-making, organisations need a costing system that can assess the performance and cost of activities (Pandey, 2012). Production expenses can be reduced to a marginal level when management is able to specify the activities needed for the products.

According to Pandey (2012), ABC is a framework that identifies cost goals or activity centres inside an organisation. Pandey (2012) described how ABC gathers expenses into working activity cost objectives when employing individual cost drivers and links them to products or services depending on the types of transactions or events occurring. For each process, the organisation must recognise the cost drivers for each cost activity, identify the cost of activities, and compute the cost per driver (Chea, 2011). By counting the drivers, costs are calculated. The primary concern while establishing an ABC system will be to identify and account for the cost drivers (Chea, 2011). As a result, ABC assists organisations in identifying activities and calculating cost drivers to meet each aim. Due to its capacity to do so, ABC has demonstrated its popularity in the industrial setting since its beginnings (Pandey, 2012). The ABC approach has successfully kept operational costs at a minimal level while yet being able to provide better customer service in the manufacturing industry (Pandey, 2012).

ABC is said to be useful in assisting performance management and the balanced scorecard when used in conjunction with other frameworks. A substantial beneficial association between ABC and performance management exists when ABC is utilised in conjunction with the balanced scorecard, according to a 2007 study by Elmezughi on Australian enterprises. Cost reduction has a favourable effect on financial performance, as discovered by Maiga and Jacobs in 2007. This demonstrates that applying ABC in an organisation actually enhances its performance as a whole. ABC is thought to provide data that is more accurate than that provided by other costing systems (Bvumbi, 2017).

2.5.2.2 *Purpose of ABC*

Activities-based costing serves two purposes, according to Priya and Divya (2016). The main purpose is the avoidance of distortion of cost. The lumping of all indirect costs into a single cost pool by the TC method results to distortion of cost. This pool is divided up according to a resource that is common to all of the company's products, usually direct labour. ABC prevents cost distortion, by implementing multiple cost pools (activities) and cost drivers (Priya and Divya, 2016). Another goal of the ABC approach is the reduction of waste or removal of non-value activities, by giving a process picture. With numerous cost pools (activities) and cost drivers, this goal can be accomplished through activity analysis.

2.5.2.3 *Stages of ABC system*

In ABC costing, various activities take place. According to Priya and Divya (2016), the crucial ABC stages are as follows:

i. Identify the various activities carried out by the organisation.

ii. Relate the operating expenses to the activities.

iii. Subsequently, support activities are dispersed among the primary activities.

iv. Determine the cost drivers for the activity.

v. Calculate the amount of cost drivers used by each product, or the activity cost drivers rate.

2.5.2.4 *Classification of activities*

According to Priya and Divya (2016), activities in activity-based costing are identified and categorised into various production process segments. Preferably, the various levels at which activities are conducted are used to group the activities. Activities are broadly categorised into the following categories (Priya and Divya, 2016):

i. **Activities at unit-level:** Activities at the unit level are those that are carried out each time a single product or when a unit is produced. These tasks are routine in nature. Direct labour hours, machine hours, power hours, are a few examples of the activities utilised each time to produce a single item. Activities involving direct materials and direct labour are likewise at the unit level, even though they have no overhead expenses (Priya and Divya, 2016). The cost of unit level activities varies according to the quantity produced.

ii. **Activities at batch level:** Activities at the batch level are those that are carried out each time a batch of goods or a collection of similar goods is produced (Priya and Divya, 2016). Each unit in a given batch is identical in both nature and size. Depending on how many batches are calculated, the cost of batch level operations varies. Activities at the batch level that are related to batches include machine setups, inspections, production scheduling, and material handling.

iii. **Activities at product level:** These tasks are completed in order to support the creation of each unique type of product. A few examples of tasks performed at the product level include equipment maintenance, engineering fees, testing procedures, managing bills of materials (Priya and Divya, 2016).

iv. **Activities at facility level:** These tasks are required to maintain a factory's standard manufacturing process. It is quite challenging to connect these activities to activities particular to a given product because they are shared by many different products (Priya and Divya, 2016). Many examples of tasks that take place at the facility level are factory management, maintenance, security, and plant depreciation.

2.5.2.5 *Cost driver of ABC*

Any factor that causes a change in the consumption of an activity by other goods, suppliers, or customers might be referred to as an activity cost driver (Cokins, 1996). A factor that exhibits a linear relationship with an activity cost is, in essence, referred to as an activity cost driver. Moreover, a factor whose volume rises as an activity cost does is known as a cost driver. The cost driver is the core of ABC. In ABC, a base for allocating costs to activities is referred to as a cost driver. ABC uses several cost drivers to allocate activity costs to goods or services, which is a key difference between it and traditional cost system. Information on the cost drivers is the output of an activity-based costing. An understanding of the causal link between an activity and its cost driver will allow management to concentrate on improvement efforts on the areas that will yield the best outcomes. Cost drivers for an activity can shift because causal relationships might alter depending on the circumstance. To ensure that the proper cost drivers are being employed, a review and an update on activity data is a necessity.

2.5.2.6 *Benefits of applying ABC in the private and public sectors*

According to Rundora *et al.* (2013), employing and implementing ABC has the following benefits:

i. Offers more precise product line costing, especially when manufacturing a diverse product line with significant non-volume related overheads;

ii. Is adaptable enough to analyse costs for cost objectives other than products, such as processes, areas of managerial responsibility, and customers;

iii. Assists in identifying and understanding cost behaviour, potentially improving cost estimation. ABC offers plant managers a better organised method to assess the costs related to particular operations needed to support a product;

iv. It allows for more precise measurements of product and customer profitability and more informed strategic choices on price, product lines, and market segments;

v. It offers more precise measures of activity-driving expenses, assisting managers in making better decisions on product design, customer service, and value-enhanced projects that will boost the profits produced by the organisation;

vi. It provides the data to pinpoint areas that require process improvement, which can also be accomplished by applying Activity Based Management (ABM) concepts;

vii. Improved product costs result in more accurate job cost estimates for pricing, budgeting, and planning;

viii. It offers greater data to pinpoint the price of underutilised capacity and keeps separate accounting for this expense.

2.5.2.7 ***Application of ABC in construction***

According to the literature, there has not been much progress made in using ABC in the construction industry. Fayek (2000 studied activity-based data acquisition along with job costing modelling, and proposed linking the two system. A schedule activity was considered as an ABC activity. The study described activity-based costing as the method of assigning a price to each job and schedule activity, and concluded that ABC is not equal to assigning costs to schedule activities in construction projects. Kim and Ballard (2001) investigated the relationship between activity-based costing and lean construction, and revealed that by adopting ABC system in lean, projects cost control can be incorporated into such projects. An activity-based safety risk was quantified by Hallowell and Gambatese (2009) on concrete formwork construction at the activity level in the United States, it was discovered that there are 13 major tasks involved in building concrete formwork; form oil application, lifting and lowering of parts of formwork, offloading of materials from crane posing the greatest risks.

Ayachit *et al.* (2014) studied Activity-Based Costing (ABC) in construction projects and proposed a theoretical model for its efficient application to obtain the best possible duration and cost. An activity-based costing grant chart was used by Ayachit *et al.* (2014) instead of the critical path method, which is typically used to determine how long a project will take. The outcomes of the study established that implementing ABC can still be used to improve the process of construction.

Gurcanli *et al*. (2015) develop a safety cost model by fusing an activity-based risk assessment with an activity-based cost analysis to provide a method for calculating the safety cost for the initial phases of building project. A cost analysis was performed on 25 concrete residential building. Activity-based costing for construction companies was studied by Kim (2017), and outlined that ABC should be used in various construction industry settings and a roadmap for its implementation. The benefits for operational manager and the management of overhead costs in a construction organisation was highlighted, as well as its logical underpinnings and ease of use. Kale *et al*. (2018) studied ABC in Indian construction projects and evaluated the effective management of activities to attain the optimal duration for the construction of repeated kind of housing projects construction by applying appropriate resource to the construction activities. Bilir and Gurcanli (2016) determined activity-based accident frequencies in building construction projects. . The most frequent accident categories and the activities in which these accidents occur were identified. Among these activities the most dangerous activities were determined using, expert witness reports of 13 years long. The results of this analysis were combined with the Social Security Institution construction industry accident statistics and accident rates based on the activity and accident type were obtained

Tran and Tran (2022) examined a number of different factors when applying the ABC approach in companies in a transitional nation. The methodology employed by the study was quantitative and a model was developed using logit regression. 71 Vietnamese enterprises with public listings were sampled in the study's model testing. According to the research, decision by firms in the implementation of ABC is highly influenced by the cost apportioned to indirect cost, competitor’s pressure on prices as well as quality and diversification of product.

2.6 Costs of Health and Safety in Construction Projects

The costs connected to construction H&S costs on site includes: price for materials, supplies as well as labour used to enhance working conditions and lower the accident rate as well as the costs associated with the incidents and accidents themselves (Lopez-Alonso *et al.*, 2016).

2.6.1 Factors affecting construction health and safety cost

According to Lopez-Alonso *et al.* (2013) the costs associated with H&S for construction firms, are the consumption worth of productive factors, goods, and services used in implementing company actions to enhance working conditions and lower accident rates on construction sites, as well as the negative value derived from the occurrence of incidents as well as accidents. A number of authors have identified several project characteristic that affects the management of the cost of safety on construction sites to include: size of project, duration of project, size of contractor, type of project and project complexity (Feng, 2011). Lopez-Alonso *et al.* (2013) identified the factors impacting on safety cost include, operating budget for the contract, H&S budget, kind of labour contract, the project's state of completion, penalties and the project award discount. Pellicer *et al.* (2014) identified relevant factors influencing safety management in construction site to be the projects budget, the schedule of the work this include the number of workforces and exposure time and prevention costs. Gurcanli *et al.* (2015) acknowledged the factors associated with safety cost to include contract requirements, project scope, total employment, man-hour values, duration of project, number of workers and prevention cost. Fitriani and Latief (2019) established that a number of variables, including location, height of building, Work Breakdown Structure (WBS), work procedures, risks, systems of control, programmes, general and specialised safety expenses, affect COS in construction projects.

2.6.2 Classification of H&S costs in projects

Lopez-Alonso *et al*. (2013) and Lopez-Alonso *et al*. (2016) grouped the cost related to workplace H&S into three categories as presented.

2.6.2.1 *Costs of safety*

The costs incurred by a company to uphold health and safety regulations which include the cost of the resources required to carry out the necessary preventive measures, either under legal obligation or voluntarily (Lopez-Alonso *et al*., 2016). Within the category of safety expenditures costs for prevention are different from those for evaluating and monitoring.

i. Costs of prevention

These are expenses incurred in order to take steps to prevent the occurrence of accidents during work construction, to adhere to legislative obligations with regard to accident prevention, as well as to enhance H&S conditions throughout the entirety of the project execution.

ii. Costs for evaluating and monitoring

They are a result of the company's efforts for proper testing and upkeep of the health and safety measures implemented with regard to every aspect of the work in question, with the intention of lowering or minimising the risk of accident or occupational sickness.

2.6.2.2 *Non safety cost*

These result from a lack of attention to workplace health and safety. This includes the expenses a business must pay after accidents as well as potential fines for violating safety rules. A workplace accident is any unplanned, unanticipated event that harms or injures a person while they are at work (Asanka and Ranasinghe, 2015). Intangible costs and tangible costs were used by Lopez-Alonso *et al*. (2016) to categorise non-safety costs.

i. Accident related to tangible costs

When an accident occurs at work, there are costs involved which are valued or computed using conventional accounting techniques, these reflects the tangible costs of accidents. Subsequently, these costs consist of those incurred due to an accident or incident in the firm and those related to noncompliance with legal safety standards.

ii. Accident related to intangible costs

Intangible costs of accidents are those costs that cannot be measured economically as well lacked performance index in measuring their influence in an organisation. Examples are damaged corporate reputation, low employee confidence, work related issues and loss of share in the market.

2.6.2.3 *Other extra-ordinary costs*

Any losses brought on by occurrences that are either completely unavoidable, such as natural disasters, and cannot be stopped by the technological or human resources that construction projects have at their disposal. This cost category encompasses all expenditures that fall outside the purview and control of management and are, therefore, categorised as uncontrollable costs that cannot be incorporated into a structured model created to control expenditures related to workplace safety.

2.6.3 Investment in safety

Investments in safety are expenses incurred to protect people's lives, health, and quality of life (Hinze, 2000). According to Tang *et al*. (1997) the goal is to safeguard the workers' physical and mental well-being as well as contractor's material assets. Hinze (2000) revealed that safety investment is also referred to as safety costs, these are expenses incurred due to placing priority on safety, whether it be through safety staffing, testing for drugs, PPE, training, initiatives for safety or incentives for safety. Expenditures in safety should not be seen as only an operational expense but rather as a way to increase revenue and, therefore, to lower the rate of injuries (Hinze, 2000). The terms "safety investments," "cost of OHS", "investments in workplace safety," "investments in safety control activities," and "accident prevention costs" are interchangeable (Feng, 2011; Yilmaz and Kanit, 2018).

2.6.3.1 Aspects of safety investments

The tangible safety investment refers to the dollar or funds allocated to accident prevention efforts. Intangible safety investments are time spent on accident prevention efforts, such as: the amount of time spent on safety meetings, inspections, emergency response drills, safety training, orientation (Teo and Feng, 2011). It is an aspect frequently overlooked by practitioners, because it is not observable (Teo and Feng, 2011).

2.6.3.2 Classification of safety investments

Investments in safety were divided into three categories by Brody *et al.* (1990): fixed costs of prevention, variable costs of prevention and unexpected cost of prevention.

i) Fixed costs of prevention

They are incurred prior to the start of production and are present irrespective of the rate of accident, instance include individuals who are dedicated to safety are an example of FPCs.

ii) Variable costs of prevention

Variable costs of prevention are costs inversely correlated to severity and frequency of accident. Example includes period spent by specialist in the analysis of accident in order to identify the causes as well as recommend remedial measures.

iii) Unexpected cost of prevention

Unexpected costs of prevention are metrics that are initially unanticipated when a technique in production is considered initially or procuring or fabrication of machinery.

2.6.4 Types of safety investments

Safety investments can be divided into two categories: basic safety investments and voluntary safety investments as depicted in figure 2.2 by Feng (2011).

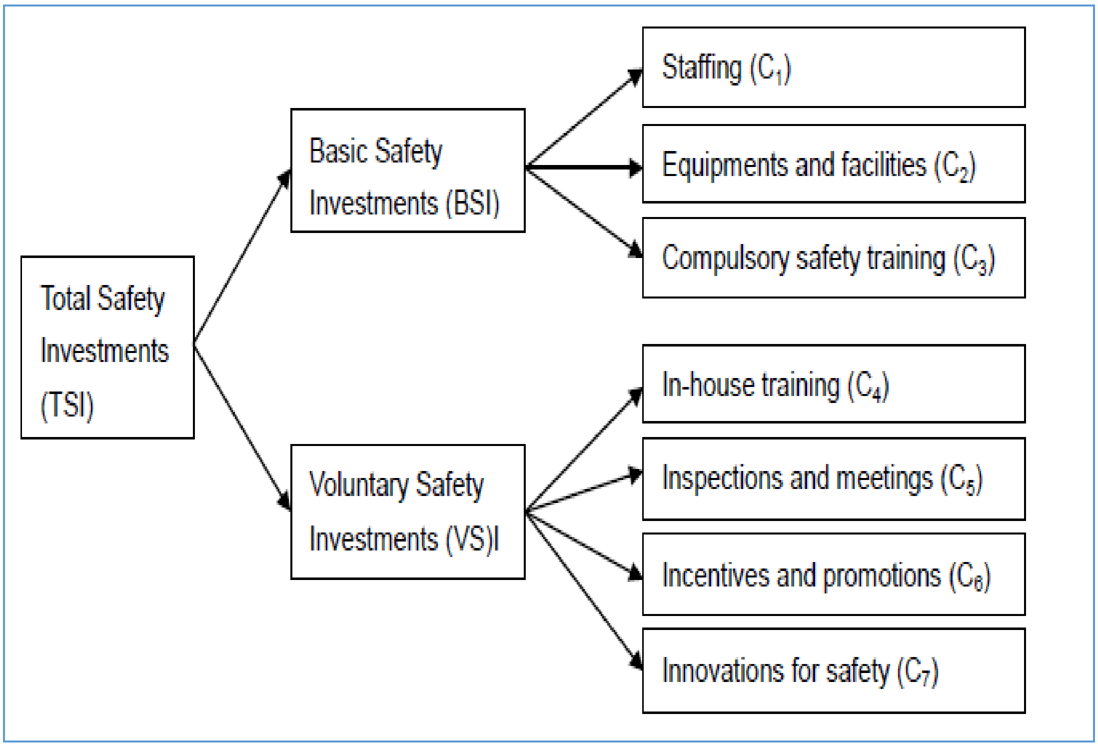

Figure 2.2 Types of safety investments
Source: Feng (2011)

2.6.4.1 *Basic safety investments*

These are the minimal safety protection measures required by industry or government legally in order to prevent accidents occurrence during project construction (Yilmaz and Kanit, 2018 and Yilmaz *et al*., 2020). These costs include: safety personnel cost, compulsory cost for training and safety equipment costs as well as facilities.

2.6.4.2 *Voluntary safety investments*

This type of safety investments are decided by specific firms on projects basis (Yilmaz and Kanit, 2018; and Yilmaz *et al*., 2020). These kinds of safety investments are made by voluntarily taking part in safety preventive activities such as orientation and internal training on safety, inspections on safety and meetings, incentives on safety and promotion, innovative on the development of safety technology, procedures as well as instruments.

2.6.4.3 *Total safety investment ratio*

A dimensionless number that makes it possible to compare the amount of investments in safety made in projects of various sizes is called Total Safety Investments Ratio (TSIR).

Thus, the following is the definition of TSIR:

$$TSIR = \frac{Total\ Safety\ Investments}{Contract\ Sum} \times 100\% \qquad 2.1$$

Where Total Safety Investments = $\sum_{i-1}^{7} Ci$, where C_i is the i[th] component of safety investment Similar to this, two dimensionless numbers, the Basic Safety Investments Ratio (BSIR) and Voluntary Safety Investments Ratio (VSIR), are used to compare the level of Basic Safety Investment (BSI) and Voluntary Safety Investment (VSI) among projects of various sizes correspondingly. Hence, the following is the definition of BSIR and VSIR:

$$BSIR = \frac{Basic\ Safety\ Investments}{Contract\ Sum} \times 100\% \qquad 2.2$$

$$VSIR = \frac{Voluntary\ Safety\ Investments}{Contract\ Sum} \times 100\% \qquad 2.3$$

Where Basic Safety Investments = $\sum_{i-1}^{3} C_i$

Where C_i is the i^{th} safety investment component.

And Voluntary Safety Investments = $\sum_{i-4}^{7} C_i$

Where C_i is the i^{th} safety investment component

2.6.5 Safety programme

A safety programme was referred to as a fundamental and essential basic programme for building projects construction (Ghousi *et al*., 2018). A good safety programme must include Personal Protective Equipment (PPE), safety measures or Collective Protective Measures (CPM), and safety training, according to Ghousi *et al*. (2018). Investing in safety can lower project operation accident costs (Hallowell, 2009). The costs of safety are influenced by the kind of safety programme that the project authorities' selects. It is important to define a necessary and pertinent safety programme before investing in safety cost.

2.6.5.1 *Personal protective equipment (PPE)*

Personal protective equipment is any tool intended to be used by a worker while they are at work to shield them from dangers to their health or safety. Some examples are safety helmets, gloves, eye protection, high-visibility clothes, safety footwear, and safety harnesses (Strank, 1986). One could argue that the cost of accident prevention and accident prevention on construction sites is most significantly impacted by the provision of PPE (Ikpe *et al*., 2011). Hence, having enough of these tools available can help prevent accidents on building sites.

i. Safety helmet

Safety helmet is the equipment of safety that guards the head. The helmet shield the wearer from sharp items, glasses, and things falling from great heights. Workers at the building site must use safety helmets while performing their tasks. To protect both the workers' and the site's safety, the employer (contractor) is required to provide safety helmets to all participants (Misnan *et al.,* 2012).

ii. Safety boot

Safety boots are used to prevent foot injury from unintentional contact with sharp items and to ease moving around construction sites, (Misnan *et al*., 2012).

iii. Safety gloves

Safety gloves are utilised to protect hands from threats such as abrasion, piercing by sharp objects, extreme cold or heat, chemicals, and fire. The common materials used to produce safety gloves are animal skin, butyl rubber, viton rubber, polyethylene, aramids, cotton, chain link, stainless steel cord (wrapped in synthetic fibre), and other materials. (Misnan *et al*., 202).

iv. Eye protective equipment

According to Misnan *et al*. (2012), eye protective equipment are made up of two types: safety goggles and face shields. Protection equipment is used to shield the eyes and face from work-related smears, flying debris, chemicals that could irritate the eyes, and laser or high-intensity light exposure.

v. Safety belt

When working on platforms or in high places, workers are required to wear safety belts and life belts (lifelines) to prevent falls (Misnan *et al*., 2012).The safety belt equipment includes a number of different components, including an anchorage strap, body harness, lanyard, connectoe, rope grab, and others.

Personal safety measures only protect the user and rely on PPE (Personal Protective Equipment). The majority of personal safety measures are active, which means that the user must utilise them in order for them to be successful. An example of this would be linking PPE to a fall prevention system.

2.6.5.2 *Safety measures or collective protective equipment (CPE)*

Collective protective equipment (CPE) is a term used to describe facilities and methods used to avoid or reduce accidents during different phases of construction (Okeola, 2009). First aid, protective gear, safety signals, monitoring, and enforcement are particularly important to occupational health and safety (OHS) of employees. Collective measures is meet to protect many people at a time, which are self-contained and effective without user involvement.

i. First aid kit

First-aid kits are resources for handling urgent situations when there are small mishaps on the job place (Misnan *et al*., 2012). First aid kits come in a variety of sizes. To ensure that the tool can accommodate all injured workers in the event of an accident, the number of workers present on the workplace must be accounted for by the contractor. To prevent any waste, contractors should make sure that the safety committee includes individuals who are knowledgeable on how to use the supplies and medications in first aid kits (Misnan *et al*., 2012).

ii. Guardrail systems

Workers are protected by safety measures such as guardrails, barriers, or other types of special protection when operations are at a higher height (Misnan *et al*., 2012).

iii. Safety signage

Temporary signage is an instrument used when working on a construction site to warn the public of the dangers and risks they may encounter on a particular site. The main factors in determining how much such signage may costs are design, choice, position, distance, maintenance, inspection, removal, and transfer.

iv. Scaffolding

A temporary arrangement employed during the phases of construction and utilised as a detour to travel to other location (Misnan *et al*., 2012). Moreover, a scaffold can use it as a field support. At construction sites, there are two different kinds of scaffolding: Put in log scaffolding and Independent scaffolding.

v. Ladder

Work in high places requires the use of a ladder, which also makes moving from one floor to another one easier (Misnan *et al*., 2012). In order to prevent something undesired like a broken or collapsed ladder, the ladder must be maintained in good condition.

vi. Safety net

During construction, safety nets are erected all around the building. Strong and difficult to disintegrate mesh nets are required. It must be of the type and have the approval of an expert of the British Standard 3913. There are two different varieties of what is frequently used, namely sizes of 100mm and 12-19mm. The 100mm mesh is used to stop humans from falling to the ground, whilst the 12-19mm mesh is used to hold equipment or objects in place and prevent them from falling out. Every week, the nets used should be inspected to make sure they are in good shape and have not been torn or have any loose net bonding (Misnan *et al.*, 2012).

vii. Accessibility and fencing

Well-constructed fences and accessibility should be adequately provided. To avoid outside incursion, the entire building site must be walled. By doing this, situations like public and kid intruders will be avoided. An effective fence can protect tools and commodities at a building site from theft.

2.6.5.3 *Safety training*

According to Hughes and Ferret (2016) Training Regulation 28 under Health and Safety Work Act (HSWA) of 1974 mandates a significantly wider range of training for anyone engaged in construction activity. To ensure a decrease in the danger of others being injured, all staff must possess the necessary training, expertise or experience (HSE, 2003). Training gives more specific instructions on how a task should be carried out, (Haslam *et al.*, 2005). Thus, it is proposed that training will enable them to identify, analyse, and create accident prevention and control procedures. To prevent accidents on construction sites, training is therefore essential (Ikpe, 2009).

2.6.6 Components of safety cost

Misnan *et al.* (2012) opined that contractors must set up an effective safety management system based on the Occupational Safety and Health Act of 1994 so as to avert mishaps at location where construction is been carried out. One such measure is to provide a safety policy outlining the company's policy, organisation as well as arrangement on site for the safety measures. Misnan *et al.* (2012) classified the cost of safety items into five components shown in Table 2.7

Table 2.7 Components of Safety costs

Cost of Safety Management	
1	Health and safety officer
2	Safety Supervisor/promoter
3	Trainer
4	AGT (Authorised Gas Tester)
5	Traffic Management Officer (TMO)
6	Inspector
7	Scaffolding
Cost of safety procedures	
1	Greencard
2	Levi CIDB
3	Courses and seminars
4	Worker's training
5	Bond Insurance
6	Workers' Compensation Fund
7	Cover All Risk Insurance (CAR)
8	Qualifications examination
9	Accident Insurance
10	Detention Fund
Cost of Safety in Building	
1	Safety promotion
2	Safety signage
3	Lighting
4	Waste (unscheduled /schedule)
Cost of site Safety	
1	Shoring
2	Safety net
3	Fire fighting
4	Confine Space
5	Scaffolding
6	Fencing or hoarding
Cost of Worker's safety	
1	Safety helmet
2	Safety boot
3	Safety belt
4	Safety gloves
5	First aid kits
6	Ear plug
7	Dust mask
8	Goggles (eye protection devices)

Sources: Misnan *et al.* (2012)

Some of the safety cost components explained by Feng (2009) are stated below:

2.6.6.1 *Costs of staffing*

The salaries paid to safety professionals, including managers, officers, coordinators, lifting supervisors, and others, are included in the expenditures associated with staffing the safety department (Feng, 2009). Costs associated with hiring safety personnel at the project and corporate levels were gathered. For the expenses incurred by the corporate office for safety personnel (such as safety director, safety coordinator, administrative support to safety personnel).

2.6.6.2 *Costs of equipment and facilities for safety*

The equipment along with facilities for safety consist of PPEs, safety fencing, safety barricades, and any additional facilities that have to do with providing safety on construction sites (Feng, 2009). The cost of installing and maintaining safety facilities and equipment includes the cost of purchasing the necessary tools, materials, machineries, and equipment as well as the cost of labour.

2.6.6.3 *Compulsory safety training costs*

The cost associated with training on safety include those associated with internal safety training courses and orientation programmes (Feng, 2009). Project managers, foremen, supervisors, labourers, and operators/signalmen are among the groups of people who must complete mandatory safety training programmes.

2.6.6.4 *In-house safety training costs*

The activities that make up internal safety training include orientation on safety each day before the start of work, response on emergency and training for a variety of potential situations, briefing on facilities for first aid, first aiders and procedure for first aid, job site briefings on the main risks, workshops on safety for supervisors and above, exhibitions and seminars on safety, demonstrations of practises that are safe for work and drills on first aid as well as other internal training activities (Feng, 2009).

2.6.6.5 *Costs of safety inspections and safety meetings*

Ordinarily, safety meetings and inspections often do not involve money directly, but they do take up participants' productive time and sometimes results to stoppage of construction work that is ongoing (Feng, 2009).

2.6.6.6 *Costs of safety promotions and incentives*

Costs associated with safety incentives and promotions include expenses incurred for printing flyers along with posters, production of banners for safety and publicising boards for safety, planning campaigns for safety, providing support financially for committees activities on safety, reward of employees monetarily, personnel from management, or subcontractors financially for achieving a high level of safety, among other things (Feng, 2009).

2.6.7 Health and safety items in building and engineering standard method of measurement (BESMM)

2.6.7.1 *The building and engineering standard method of measurement (BESMM 4R)*

Nigeria presently measures construction works using the Building and Engineering Standard Method of Measurement (BESMM 4R) (Abdullahi *et al*., 2020). The BESMM 4R is a formal document that outlines the norms for describing the nature of construction works and outlining how the work is measured, taken-off, and quantified (Abdullahi *et al*. 2020). The BESMM 4R offers uniform measuring basic for building, civil as well as industrial engineering through Bills of Quantities (BOQ) production.

The BESMM regulations cover every facet of BOQ production, including outlining the data that must come from the employer and other construction consultants in order for a bill of quantities to be generated as well as handling the computation of work items that are non-measurable and their risks. Likewise guidance is provided on the content, arrangement, and presentation of the format of BOQ in addition the benefits and applications of BOQ.

Four (4) versions of the SMM known as the BESMM have been successfully published by the Nigerian Institute of Quantity Surveyors (NIQS). The BESMM 4R, which is Nigeria's most recent standard for measuring construction works was published in 2015 by the Nigerian Institute of Quantity Surveyors. The Industrial Standard Method of Measurement (ISMM), the Civil Engineering Standard Method of Measurement (CESMM 4), and the RICS New Rules of Measurement 2 (NRM 2) served as the foundation for the development of the BESMM4, with a few minor adjustments made to suit the primary contracting culture in the Nigerian construction industry (NIQS, 2015).

2.6.7.2 *Bill of quantities (BOQ)*

The BESMM 4R defined the bill of quantities as a list of items with specific identifying explanation and firm amounts that make up the sections of a building, engineering facility, or industrial facility that are included in the scope of work covered by a contract (NIQS, 2015). The primary function of the BOQ is to provide a harmonised list of items, along with the identifying descriptions of quantities, which includes the works to assist contractors to prepare tenders effectively and precisely as soon as a contract has been awarded. In addition, the BOQ provides a basis for the evaluation of work executed for the purpose of making interim payments to the contractor and to provide a base for the evaluation of variation in work.

The following are often included in the sections of a typical bill of quantities: the tender form, summary, preliminaries, measured work, risk, provisional sum, day works, and annexes. Focus will be on the preliminary section.

2.6.7.3 *Preliminaries section*

The preliminaries section addresses and communicates items not immediately related to any component, element, or work division to the contractor (NIQS, 2015). The information provided in the preliminaries will facilitate the contractor to calculate the price for managing the construction project, the preparation of the site, security, safety, protection of the environment, commonly used mechanical equipment, and employer completion as well as post-completion requirements. The preliminaries section comprises of two separate divisions: a. information and requirements section and b. the pricing schedule section.

a. Information and requirements

Information and requirements is the descriptive section of the preliminaries of the main contract which sets out the particulars of the project, the drawings on which the BOQ was based is identified, shows the site's boundary, and provides details about any existing buildings and mains services on the site or next to the site, and information about any existing records that could alert the main contractor to any known or potential risks that should be taken into consideration (NIQS, 2015).

b. Pricing schedule

The pricing schedule is a list of cost centres included in the bill of quantities where charges for preliminary expenses related to the employer's needs and all cost items of the contractor will be inserted by the main contractor (NIQS, 2015). Employer requirements and main contractor cost items are the two main cost centres that make up the pricing schedule for the main contractor's preliminary work. Part B of the BESMM 4R contains a list and definition of the components that make up the cost centres.

Table 2.8 Health and Safety items in the BESMM4 R

Code	Items of health and safety	Unit
1.21	Management And Staff	
1.2.1.1	Project specific	
1.2.1.1.4	Health & Safety manager/officer	Nr
1.2.1.2	Visiting management	
1.2.1.2.4	Health & Safety manager	Nr
1.2.2	Site Establishment	
1.2.2.1	Site Accommodation	
1.2.2.1.5	Temporary accommodation: Temporary shed for workers, lab, workshop, secure store, material storage	Item
1.2.2.1	Sanitary accommodation (Toilet and washroom)	Item
1.2.2.1	First aid room	Item
1.2.3	Furniture and Equipment	
1.2.3.6	Canteen equipment, including purchase/rental, maintenance and other running costs.	Item
1.2.2.5	Consumables and Services	
1.2.2.5.6	First aid consumables	Week
1.2.2.7	Sundries	
1.2.2.7.2	Safety and information board	Item
1.2.2.7.3	Fire point	Item
1.2.2.7.6	Crane signage	Item
1.2.3	Temporary Services	
1.2.3.1.3	Temporary water	Item
1.2.3.2.4	Temporary electricity supply	Item
1.2.4	Security	
1.2.4.1	Security staff	
1.2.4.1.2	Security staff (watchmen day and night)	Nr
1.2.4.3	Hoardings, Fences and Gates	
1.2.4.3.1	Perimeter hoardings & fencing and the like to site boundaries and to form site compounds.	M
1.2.5	Safety and Environmental Protection:	
1.2.5.1	Safety Programme	
1.2.5.1.1	Health & Safety manager/officer	Nr
1.2.5.1.2	Safety audit, including safety audits carried out by external consultant	Nr
1.2.5.1.3	Staff Safety training	Item
1.2.5.1.4	Site Safety incentive scheme	Item
1.2.5.1.5	Notices and information to neighbours	Item
1.2.5.1.6	Personal Protective Equipment (PPE) including for employer and consultants.	Nr
1.2.5.1.7	PPE for multi-service gangs.	Nr
1.2.5.1.8	Fire points	Nr
1.2.5.1.9	Temporary fire alarm	Nr
1.2.5.1.10	Fire extinguishers	Nr
1.2.5.1.11	Statutory Safety signage	Item

Code	Items of health and safety	Unit
1.2.5.1.12	Nurse	Nr
1.2.5.1.13	Traffic marshals	Nr
1.2.5.2	Barriers and safety scaffolding	
1.2.5.2.1	Guard rails and edge protection (to edges of suspended slabs and roofs).	Item
1.2.5.2.2	Temporary staircase balustrades (to new staircases during construction).	Item
1.2.5.2.3	Lift shaft protection.	Item
1.2.5.2.4	Protection to holes and openings in ground floor slabs, suspended slabs and the like.	Item
1.2.5.2.5	Debris netting/plastic sheeting	Item
1.2.5.2.6	Fan protection	Item
1.2.5.2.7	Scaffold inspections	Nr
1.2.5.2.8	Hoist run-offs	Item
1.2.5.2.9	Protective walkways	Item
1.2.5.2.10	Other safety measures	Item
1.2.5.3	Environmental Protection Measures:	
1.2.5.3.3	Environmental monitoring.	Item
1.2.5.3.4	Environmental manager/ consultant	Nr
1.2.5.3.5	Environmental audit, including safety audits carried out by external consultant	Nr
1.2.6	Control And Protection	
1.2.6.1	Survey, Inspection and Monitoring	
1.2.6.1.5	Environmental survey	Item
1.2.6.1.6	Movement monitoring	Item
1.2.6.1.7	Maintenance and Inspection costs.	Item
1.2.7	Mechanical Plant	
1.2.7.2	Tower Crane:	
1.2.7.2.9	Periodic safety checks/inspections	Week
1.2.7.2	Hoists	
1.2.7.2.8	Periodic safety checks/inspections	Month
1.2.8	Temporary Work	
1.2.8.1	Access Scaffolding:	
1.2.8.1.1	Bring to site, erection & initial safety checks	Nr
1.2.8.2	Temporary Works	
1.2.8.2.1	Bring to site, erection & initial safety checks.	Nr
1.2.9	Site Records	
1.2.9.1.2	Operation and maintenance manuals	Item
1.2.9.1.2	Compilation of health and safety file	Item
1.2.11	Cleaning	
1.2.11.1	Site Tidy	
1.2.11.1.3	Waste management, including rubbish disposal (compactor visits; skips and waste bins; roll-off, roll-on waste bins) and disposal.	Week
1.2.11.3	Building clean	
1.2.11.3.1	Final builder’s clean	Item
1.2.14	Insurance Bonds, Warrantee & Guaranties	
1.2.14.1	Work Insurance	
1.2.14.1.1	Contractor’s ‘all-risks’ (CAR)	Item
1.2.14.1.5	Other insurance in connection with the works.	Item
1.2.14.3	Employer’s (main contractor’s) liability insurance	
1.2.14.3.2	Work operatives	Item

Source: NIQS (2015)

2.6.7.4 *Past works of authors on H&S cost items in building construction*

In the USA construction sector the cost of accidents and injuries was examined by Everett and Frank (1996) and they established that safety staff salaries, medicals for personnel, tools and equipment inspection, safety orientation session, inspections of site, PPE and health and safety programs were the major H&S cost items. The economic and social costs of accidents in construction was investigated by (Tang *et al*., 2004). Safety investment consist of three components which are personnel involved in the administration of safety, head office and site staff, salaries for safety staff. First-aid facilities, safety fences, safety boots, safety goggles, and helmets are examples of safety equipment. Tang *et al*. (2004) identified health and safety items to include safety training and promotion. The optimal safety investment for a construction project was approximately 0.8% of the total contract cost.

Idoro (2008) examined the extent of H&S performance-related to management activities made by contractors. The provision of PPE, adherence to laws on H&S, providing facilities for H&S, office structure for H&S management on site, head office structure for H&S management and providing incentives for H&S are the health and safety cost components that have been identified. A study by Wells and Hawkins (2009) on the promotion of construction H&S through procurement for developing countries and identified H&S plan preparation and updating; providing temporary works like hoarding and scaffolding; H&S training; H&S committee meetings and attendance; providing for welfare facilities; provision of PPE; in addition medical check-ups were identified as the H&S cost items. For small projects and major projects, the cost for health and safety was estimated to be 2% and 1%, respectively, of the anticipated contract value.

In UK, Ikpe (2009) investigated the costs and benefits of the prevention of accident and developed a model for the prevention of accident on construction projects using cost benefit analysis. First-aid facilities, PPE, H&S promotion, training on H&S personnel, firm budget on expenditure for H&S measures, and additional measure to reduce accidents as health and safety items. With a ratio of about 3:1, the benefits of preventing accident outweighs the expenditures by a wide margin. A cost model for safety was developed by Gurcanli *et al*. (2015) by combining an activity-based approach to evaluate the risk as well as to estimate safety cost for residential buildings. Result revealed that safety training, first aid tools, PPE, guardrails, ladder, fences, safety strips, safety net, standard caution signs and safety tapes, abutment, radio and fire protect tools are health and safety cost items.

Latib *et al.* (2016) investigated the implementation of OHS in project construction, by qualitatively analysing seven contract documents to identify the extent of OHS requirements and budgeting. Their findings showed that H&S cost items includes OHS forums or meetings for OHS, training and induction for OHS, medical facilities and services, safety tools and equipment, incentives and rewards schemes for OHS, PPE, emergency response for resources, signage for safety and posters and personnel for OHS.

Yilmaz and Kanit (2018) developed a tool for estimating OHS costs that are compulsory for small and medium scale building projects, findings revealed that the costs for safety staff, costs for safety education and training, costs of PPE, costs of CPM, laboratory examinations fee are the H&S cost items.

Table 2.9 Identification of H&S Cost Items from Literature

Author/ health and safety items	Everett and Frank (1996)	Tang *et al.* 2004	Idoro (2008)	Ikne (2009)	Misnan 2012	Pellicer *et al* (2014	Hamid *et al.* (2014)	Gurcanli *et al.* (2015)	Malan and Smallwood (2015)	Latib *et al.* (2016)	Giessa *et al.* (2017)	Ghousi *et al* 2018)	Marleno *et al.* (2019)	Yilmaz and Ugur (2019	Malan and Smallwood ((2018)	Ahn *et al.* 2021	Fitriani *et al.* 2022
Staff for site and head office		*	*		*										*	*	*
Safety staff salaries	*	*			*		*			*			*	*	*	*	*
Medical for personnel	*					*				*	*			*	*	*	*
Safety site meetings	*						*		*	*					*		
Personal protective equipment	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Tools and equipment inspection	*				*	*	*								*	*	
Safety training		*		*	*		*	*		*		*		*	*	*	*
Safety promotion/ Health programs	*	*		*	*					*			*				*
Incentive & rewards schemes			*							*							
Provision of H&S facilities			*	*				*	*	*			*	*	*	*	*
First aid facilities				*		*		*	*	*		*			*		*
Insurance					*	*				*			*				
Safety signage					*					*		*	*		*		*
Lighting					*					*	*				*		
Ventilation					*												
Waste					*												
Scaffolding					*			*	*	*	*	*			*		
Temporary hoarding									*	*		*			*		
Fence					*			*				*				*	*
Shoring (Topang)					*										*		
Safety Net					*			*				*				*	*
Fire Protection Equipment								*		*	*	*			*		*
Guardrails								*				*					*
Safety tapes								*				*					
Access/Existing roads and traffic safety										*					*		
Accident Reporting Procedure																	
H&S Policy/Plan									*						*		
Drinking Water																	
Cloak & Toilet Service									*		*				*		
Mess room /Canteen									*						*		
Risk assessment															*		
House keeping															*		
Storage									*						*		
Accommodation									*						*		
Environmental measurement									*						*		

Source: Researcher’s summary (2022)

Malan and Smallwood (2018) assessed contractors along with quantity surveyors perspectives on the provision of H&S finance in construction projects, They identified the H&S cost items as follow; first aid, H&S plan, PPE, individual equipment for arresting fall, and special equipment for respiration, hoarding and walkways for the public, guarding as well as barricade storage for flammable goods, risk assessment temporary electrical installations, special scaffold, design for engineering or certification, suspended scaffold, temporary works design, design for permanent structures, H&S Audits, H&S Representatives, welfare facility, H&S file, method statements, Access and catch platforms, Signage, education and training, meetings, inspections, Medicals H&S Officer and transport of workers. They came to the conclusion that the BOQ should have a section for H&S preliminaries and the 39 H&S items viewed as important be included in the section.

The effect of the costs of safety on safety risk in commercial building was determined by Ghousi *et al*. (2018) by designing a method which is flexible for assessing safety risk and examining the financial aspects of programmes for safety in building construction. Result revealed that safety training, PPE, side guards, fences, safety net, caution signs and safety tapes, abutment, radio, safety switch are health and safety cost items. Yilmaz and Ugur (2019) conducted a comparison of estimating costs of OHS with the real expenses in repair and maintenance of public building projects in Turkey and developed a calculation model using computer software. Health and safety cost factors were identified as safety cost for staff on site, safety education and training costs, PPE costs, costs of CPM, laboratory examinations fee.

Ahn *et al*. (2021) developed a health and safety cost model in order to sustainably manage residential high-rise building in Korea. H&S cost identified to be; cost of labour and several payments for salary of H&S managers, the cost of facilities for safety, cost of PPE purchase along with equipment for safety on sites, worker training events cost, the cost of worker health care, and the fee for technical advice for head office overhead. Fitriani *et al*. (2022) investigated the cost of construction safety and considered the costs of security as part of safety cost in the construction of flats in Indonesia, using Monte Carlo analysis to demonstrate how variables like location of construction as well as height of building affects the costs of safety in flats construction. The following items were identified as the safety costs items in construction project: staff training on safety and induction, safety facilities, H&S managers' salary PPE and, workers' health care safety meeting, safety net, guardrail.

2.6.8 Cost of construction project

Project costs consist of costs of labour and materials, service and consulting fees for mechanical, electrical, and architectural and structural systems, fees for supervision, and lastly general expenses for construction site amenities (Gurcanli *et al*., 2015). The entire cost of construction comprises material and labour expenses, project service expenses (architectural, electrical and mechanical design), expenses on inspection service on building, overhead expenses on site, expenses on OHS (Gurcanli *et al*., 2015). A bid estimate for the contractor is provided to the client or owner for negotiation or competitive bidding and includes direct expenses on construction, comprising supervision, general operating cost and profit. To compute the direct construction costs for bid estimates, a combination of subcontractor quotes, quantity take off, and necessary construction technology/procedures is typically used; however, safety costs are frequently neglected.

This study utilised selected work items which have been identified in literature to have accounted for 70.8% of share of accident both fatal and non- fatal were employed. These work activities include excavation, reinforced concrete, masonry, roof and finishing (floor, plastering and painting) (Gurcanli *et al*., 2015; Okoye, 2018; Bilir & Gurcanli, 2018). The level of hazards associated with seven work items (which can also interchangeably be referred to as work elements) was determined in the study.

Table 2.10 presents the summary of authors on health and safety costs to construction projects. In the South Africa construction industry Smallwood (2011) determined the perceptions and practices related to financial provision for health and safety by general contractor utilizing provisional sum and preliminaries items**.** Study's result revealed, H&S cost was 3.8% to the tender sum while cost of safety to total cost of construction was 2.4%. Misnan *et al.* (2012) determined the safety cost for construction project in Malaysia and five types of safety costs components were identified. Findings revealed the cost for health and safety to be approximately 2% of total cost of building project cost.

Pellicer *et al*. (2014) developed a method for estimating OHS costs at the design stage of project construction in Spain. An application of the method on a case study revealed, that the mean value for risk prevention cost of the projects sampled was 1.54%-5% of the budgeted cost of the project. The optimal percentage of monetary provision for H&S by general contractor was examined by Smallwood and Emuze (2014) in South Africa, construction industry, result revealed that the cost for health and safety was 2.5% of the tender sum. Hamid *et al.* (2014) investigated the cost benefits of safety and health management compliance amongst contractors by identifying different approaches taken to implement health and safety in their organization. Result of the investigation revealed that compliance cost ranges from 0.15% to 1.08% is of an average of 0.41% from the project cost.

Table 2.10 Summary of Health and Safety Costs to Construction Projects

S/N	Author/ year	Aim	% of OHS Cost to project sum	OHS Cost /construction unit area	Location
1	Smallwood (2011)	Assess the optimum percentage financial provision for H&S	1-2.4%		South Africa
2	Misnan *et al.* (2012)	Identify safety cost in construction	2%		Malaysia
3	Pellicer *et al.* (2014)	Develop a method to assess OHS cost in construction project.	5%		Spain
4	Hamid *et al.* (2014)	Investigate cost of compliance with HSM among contractors	0.41%		Malaysia
5	Emuze and Smallwood (2014)	Financial provision for construction H&S	2.5%		South Africa
6	Gurcanli *et al.* (2015)	An approach to estimating OHS cost construction	1.92%	5.68	Turkey
7	Latib *et al.* (2016)	Determined contract documents on OHS requirements	0.2- 1.99%		Malaysia
8	Giessa *et al.* (2017)	Costing H&S in the Egyptian building projects	1.22%		Egypt
9	Yilmaz and Kanit (2018)	Estimating compulsory OHS costs for residential building construction projects	5.15	8.47	Turkey
10	Ghousi *et al.* (2018)	Effect of safety costs on safety risks.	1.13- 1.5%	6.20	Turkey
11	Otaru *et al.* (2018)	Assessment of the Cost Impacts of H&S practices on projects.	3-5%		Nigeria
12	Yilmaz and Ugur (2019)	To estimate the OHS costs to the actual cost of maintenance	3.58%		Turkey
13	Adekunle *et al.*, (2020)	Assessed the impact of H&S prevention cost on construction projects	1.0% to 10.0%		Nigeria
14	Ahn *et al.* 2021	Model for sustainable H&S for high-rise buildings.	PPE 9.8%, and CPM 49.5%		Korea
15	Fitriani *et al.* (2022)	Investigate the factors that affects safety cost	0.72%-1.06%		Indonesia

Source: Researchers summary (2022)

Gurcanli *et al.* (2015) developed a cost model for safety in order to offer a method for estimating the safety cost for the initial phases of the building phase. A cost analysis was performed on 25 concrete residential building, result from the study revealed that the percentage 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. The implementation of OSH requirements in construction project was investigated by Latib *et al.* (2016) by qualitatively analysing seven contract documents to identify the extent of OSH requirements and budgeting. Their finding shows that the visible allocated budget for OSH requirements ranges from 0.21% to 1.99% of the contract value.

Giessa *et al.* (2017) designed a cost model for H&S in the Egyptian building projects, three case studies were used. Their discovery disclosed that the cost for health and safety was approximately 1.22% total cost of the budget. Yilmaz and Kanit, (2018) developed a tool for valuing the cost of OHS for small and medium scale residential projects was. The findings revealed that OHS cost percentage to total cost of construction was 5.15% and 8.47 USD/ m^2 was the OHS cost per unit area. Ghousi *et al.* (2018) determined effect of the costs of safety on safety risk on a commercial building by designing a flexible technique to assess risk in building projects and investigated the monetary impacts of safety programmes. Result revealed that investment of 1.5% of construction budget on safety programme will decrease 75% of safety risks.

Otaru *et al.* (2018) assessed the impacts of costs of H&S practices on construction projects in Nigeria. Findings from the study revealed that the cost for health and safety ranged from 3-5% of the total construction cost. The authors concluded that the costs of H&S practices and programmes are important in increasing the costs of projects. Marleno *et al.* (2019) investigated OSH costs in project construction in Indonesia by comparing the costs of implementing construction project activities such as roads, bridges, drainage and buildings and revealed that the cost for health and safety ranged from 0.8% to 1.7% of the total project value.

Yilmaz and Ugur (2019) compared the estimated cost for OHS with the real expenses repair and maintenance of public building projects and developed an estimating model in Turkey. Their result showed, the ratio of actual costs as well as estimated costs of OHS to be approximately 3.98% and 3.58% correspondingly. Adekunle *et al*. (2020) 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. Ahn *et al*. (2021) developed a cost assessment model in order to sustainably manage the H&S of high-rise building projects in Korea. The percentage value of PPE to be 9.8%, and CPM 49.5% to project cost was established. Fitriani *et al*. (2022) investigated the cost of construction safety and considered the costs of security as part of safety cost in the construction of flats in Indonesia. Findings revealed that the cost for H&S ranged from 0.72% to 1.06% of the total construction cost.

2.7 Theoretical and Conceptual Framework

2.7.1 Theoretical model

A theory is a collection of connected ideas (concepts), definitions, and assertions that provide a systematic view of phenomena by defining relationships between variables in order to explain and predict the events (Kerlinger and Lee, 2000). In three different methods, Kivunja (2018) explains theory: (1) A theory is a set of propositions made up of defined and interrelated constructs. (2) A theory lays out the interrelationships among a set of variables (constructs) and (3) A theory explains phenomena by describing which variables are related to which variables and how they are related, allowing the researcher to predict from one set of variables to another set of variables.

The theoretical framework allows the researcher to define the study philosophically, methodologically, and analytically; it guides researchers in positioning and contextualising formal theories into their studies; it directs the researcher's decision regarding the research design and data analysis strategy; and it also directs the kind of data to be gathered for a particular study (Grant and Osanloo, 2014; Ravitch and Carl, 2016). Thus, the theoretical framework helps the researcher to choose the most appropriate research approach, analytical tools, and methods for the research inquiry. It strengthens the significance and generalizability of the study findings (Akintoye, 2015). This study intends to develop a conceptual framework for health and safety costs as such the following underlying theories were considered.

2.7.1.1 *Heinrich's domino theory*

One of the straightforward models for sequential linear accidents is the Heinrich's Domino Theory. It is founded on the series of circumstances that result in an incident. In the chain of accident events sometimes referred to as dominos, Heinrich (1931) recognised the following axioms: Potential injuries only arise from the "Final Domino" harm; accidents only come from human or mechanical dangers; human faults are inherited, born into, bred into, and schooled; risks only arise from human flaws. According to the idea, the effect of the flow of events will not result in an accident if any of the occurrences that are likely to create an accident are removed (an optical domino cause). The eradication is accomplished through educating the workforce about the risks that exist in the workplace (Heinrich, 1931). Most notably, Heinrich (1931) invented the "safety pyramid" and the "five domino model" of accident causation. The latter is a sequential accident model that has influenced the way people think about workplace safety.

According to the "domino theory," a series of accidents can be attributed to a causal chain of occasions that are symbolised by falling dominoes. The first domino to fall causes the second to follow, then the third, and so forth until the entire row has fallen. Heinrich asserted that if even one of the many factors that make up an "injury" is eliminated before it occurs when its occurrence is determined to be the result of a series of events, the injury will not occur. Heinrich's model identified the following five factors: domino

Domino 1: A worker's ancestry and social environment have an impact on their abilities, convictions, and "traits of character";

Domino 2: The employee's negligence or flaws that prevent him from giving the assignment enough attention;

Domino 3: a dangerous action or a mechanical or physical hazard, as a worker error;

Domino 4: the accident;

Domino 5: Damage or loss as a result of the accident.

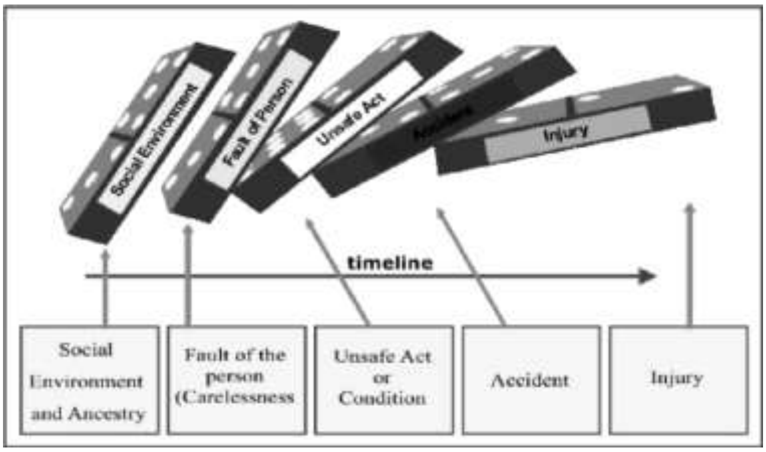

Figure 2.3: Domino theory of accident causation

Source: Heinrich (1931)

Heinrich (1931) asserted that the employer has the primary duty for preventing accidents. And emphasised that a manager who genuinely cares about safety and who represents the employer would make sure that employees follows instructions. The managers will always exert their authority, secure conformity, carry out their plan, and see that the dangerous conditions are corrected. As a solution for non-compliance, Heinrich advised stringent oversight, remedial training, and discipline. Identifying the causes of accidents and dangers, as well as taking preventative action, involves 10 phases based on the concepts of Heinrich's Domino Theory.

The Domino theory holds that

i. A person's wrongdoing, mistakes, or carelessness may have contributed to the accident's background causes.
ii. The worker must be strategically trained, informed, and successfully supervised by the supervisor in order to stop any unsafe behaviour.
iii. It also calls for management commitment to fostering an atmosphere in which there is no accumulation of unsafe act-related energy.

iv. Assuring the availability of policies for the highest levels of quality control and productivity.
v. In order to avoid risky acts from posing risks and accidents,
vi. Corrective actions and
vii. Preventive activities must be used to stop risky acts from posing risks and creating accidents.
viii. Accidents and hazards frequently have unintended consequences, and
ix. Indirect costs that eventually result in injury and
x. Its related direct costs.

According to Cleverland State University (CSU), any safety initiatives that take into account the 10 axioms will have an impact on accident prevention (CSU, 2017). In other words, the causes listed above cause injuries, and by eliminating the risky behaviour or situation, the impact of the factors can be mitigated and accidents/injuries can be avoided (Burnham, 2008). Heinrich's views were criticised for focusing too much on the immediate causes of accidents and ignoring management practise, which is a crucial component of accident causation and prevention (Hosseinian and Torghabeh, 2012); despite this, Heinrich's research and work served as the basis for many other researchers.

2.7.1.2 *Epidemiology of accident theory*

Epidemiological accident models have their roots in the investigation of disease epidemics and the quest for the causes of their spread. Gordon introduced the Epidemiology of Accidents Theory in 1949. Gordon proposed that specific epidemiologic occurrences, such as seasonal change, demographics, and an individual's predisposition, were the root cause of injuries (Hulme and Finch, 2015). According to Gordon (1949), accidents are caused by a combination of forces from at least three sources, including the host, the agent, and the environment. Because injuries and diseases are equally susceptible to this approach, it is important to understand that this approach can help us better understand accidents. Man, who has a primary interest, is referred to as the host in the accident's cause. Any tool the host or man uses to alter the environment could be the agent. This could be a different person, piece of machinery, device, or any substance or chemical the host uses. The host and agent are situated within a system or environment, respectively. An accident could happen in an unsupportive setting.

The theory holds that both accident conditions and accident effects are influenced by two components, namely predisposition qualities and situational characteristics (Hulme and Finch, 2015). Injury and property loss suffered by individuals are considered accident impacts. These outcomes serve as the quantifiable indicators of the accident. Accidents occur as a result of unanticipated, unavoidable, and unintentional activities brought on by situational factors and predispositions (Gordon, 1949). According to Bonilla-Escobar and Gutiérrez (2014), some predisposition features include the susceptibility of the individuals (host), a dangerous environment, and an agent that causes harm. The hypothesis holds that every person has a special propensity for harm based on their own inherent risk factors, and additional external risk variables operating "from outside" make the person vulnerable to injury. Risk assessment by the individual, the supervisor's priorities, and the dominant mentality are situational features (Hulme and Finch, 2015). According to this idea, accidents are caused by predisposition and environmental factors. This means that certain people are more prone to sustain specific accidents while carrying out their activities due to their propensity and situational features, necessitating the need for occupational health safety (Hulme and Finch, 2015). This hypothesis served as the foundation for the connection between workplace health and safety.

2.7.1.3 *System model of construction accident causation*

An accident causation system model was designed by Mitropoulos *et al*. (2005). It posited that dangerous conditions are produced when the construction activity and the context characteristics interact. At the same time, production demands prompt productive work habits. Workers are exposed to risks, when efficient work practises and dangerous circumstances coincide. According to Mitropoulos *et al*. (2005), workers' efforts to regulate conditions and/or an inclination for competent action can help reduce hazard exposures. The possibility of an accident risk exists when human mistake and/or altered conditions coincide with hazard exposure. Understanding construction accidents requires the inclusion of context and activity characteristics, such as task unpredictability, as they reflect the dynamic nature of building sites.

The model outlines the variables that determine the chance of accidents occurring during a construction activity. As opposed to event-based models, which emphasise the incident level, it concentrates on the activity level. With the help of this model, it is hoped to find out what causes and mechanisms affect how many accidents occur throughout a building project. It adopts a systems approach to accidents, using causal modelling to look at the production as a system made up of interdependent variables rather than just individual isolated events (Sterman, 2000). As a result, accidents are seen as by-products of the production system, and research on them focuses on how these characteristics create dangerous situations, influence how people behave at work, and examine the circumstances under which hazards are released. The model is based more on descriptive than on prescriptive models of work behaviours. By contrast to the normative behaviours and practises that employees "should" adhere to, it considers the actual production behaviours.

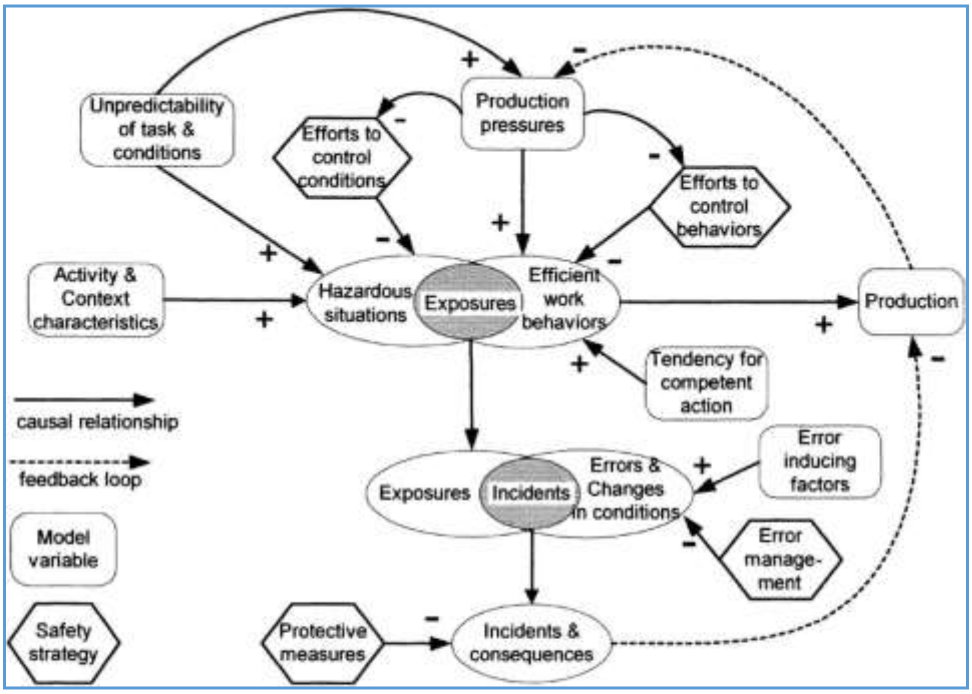

Figure 2.4 Systems Model of Construction Accident Causation

Source: Mitropoulos *et al*. (2005)

The accident causation model, shown in Figure 2.4, expands on the Rasmussen model and other models of accident causation in the building industry. According to Mitropoulos *et al*., (2005) the major elements and mechanisms that cause accidents are shown in the causation model in Figure 2.4. This theoretical framework examines the factors that affect the probability of accidents occurring during a building operation. Cause-and-effect connections are shown by the arrows. The signs show the direction of the link between the variables; a positive sign denotes that when the causal component X changes, the effect Y also changes, either in the direction of X increasing or X decreasing (Mitropoulos *et al*., 2005). If there is a negative sign, the effect is changing in the opposite direction (X increases, Y decreases, or X increases, Y decreases).

Work behaviours that put employees in danger are indicated by the shaded area where "hazardous work conditions" and "work behaviours" overlap. Hazard exposures are decreased by safety initiatives to manage employee behaviour. Hazard exposures can, but do not always, result in occurrences. The hazard has to be released for an occurrence to happen. A "mismatch" between actions and circumstances is produced by human error and environmental changes, which leads to the release of dangers. Mitropoulos *et al*. (2005) posited that not all errors result in the release of hazards; many faults are trivial, while others are "trapped," allowing control to be regained before the danger is released. The errors under conditions of exposure that release hazards and produce incidents are indicated in the shaded portion where "Exposures" and "Errors and Changes in Conditions" overlap. The task, the surroundings, and the workers' capacity variables all affect how likely errors are to occur. An incident could result in a "near miss," an injury accident, or a fatality, depending on the outcomes.

The model recognises the inevitable occurrence of exposures and errors and the crucial role that task unpredictability plays in creating unanticipated hazardous circumstances. The model highlights the necessity for two accident prevention techniques: error management to improve staff members' capacity to avoid, catch, and ameliorate errors, and dependable production planning to lessen task unpredictability (Mitropoulos *et al*., 2005). The weakness of the model is that it does not operationalize or quantify the variable because it is a conceptual model.

2.7.1.4 *Theory on the cost of safety*

The Cost of Safety (COS) model is the most popular cost model developed to conceptually express the cost-benefit of accident prevention (Chalos, 1992). The COS model's central tenet is that as money is spent on injury prevention, injury rates decreases and the overall cost of injuries reduces (Hallowell, 2011). This model is exemplified in figure 2.5

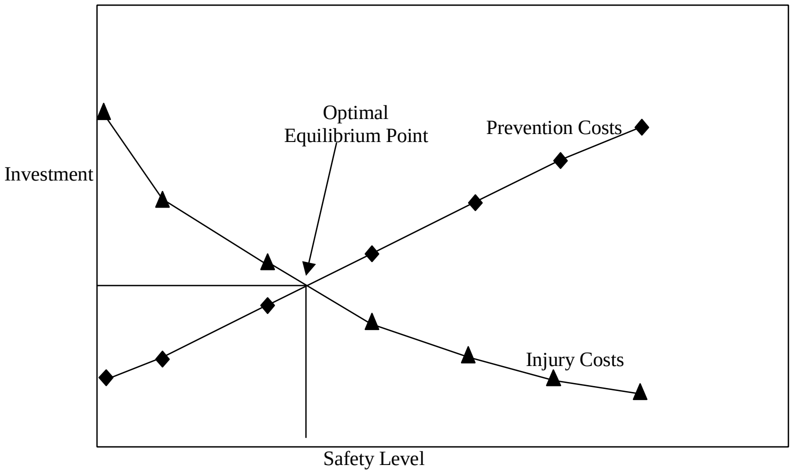

Figure 2.5 Cost of safety model

Source: Chalos (1992)

The figure demonstrates how high accident costs will result if the costs of prevention and detection are low. The costs of accidents should fall as prevention and detection costs increases, since more money is being spent to reduce the impact of risk. The COS model suggests that there exists a theoretical equilibrium point where the overall costs of prevention are equal to the total costs of accidents (injuries), and this point represents the optimum investment (Chalos, 1992). This point is found through linear regression and it is dynamic. The theoretical ideal equilibrium point offers a discretionary budgeted amount for preventive and detection costs that will nevertheless result in failures at a level such that the sum of all Safety, Health, and Environment (SH&E) costs is optimal or minimised. The model illustrates that in order for the SH&E profession to attain zero accidents or near to zero accidents, preventative and detection costs must be considerably increased (Behm *et al*., 2004). The COS model should not be confused with the concept that an organisation should strive for zero accidents goal. Beyond a certain point of extremely high safety, achieving and maintaining the aim of zero accidents (defects) becomes exceedingly expensive.

In order to sustain an organization's financial stability, some level of risk must be deemed acceptable. This is another premise of the COS model (Behm *et al*., 2004). The expenses of managing such risk can be overwhelming, according to Manuele and Main (2002), who also asserted that some inherent risk level are entailed in any work processes. Each organisation must decide what amount of risk is acceptable, what risk-reduction measures are performed, and how much funding will be allocated for these measures (Behm *et al.*, 2004). While certain risks can be avoided or almost eliminated with minimal effort and expense, others cannot be done so without exorbitant costs.

In the course of applying the model Son *et al.* (2000) and Behm *et a*l. (2004) stated that the best financial strategy for injury prevention is to develop a programme that results in the lowest possible costs of safety. The total of the money spent on injury prevention and the direct costs and indirect costs of injuries is used to calculate the minimal costs of safety. Son *et al*. (2000) advanced the COS model by providing a formal technique of computing cost data.

And proposed the theory of safety control costs, which states that the higher the design, implementation and construction safety level to be achieved, the lower will be the overall predictable costs, due to the smaller likelihood of accidents. However, in order to reach these greater levels of safety, additional expenses will be needed, which are typically the contractor's responsibility (Son *et al.*, 2000). Hence, determining the minimal overall predicted total costs benefits the contractor (Stranks, 1986). In order to use this method the total amount of money expended on the prevention of injury annually must be calculated, as well as the direct and indirect costs of injuries. According to Son *et al*. (2000) the procedure comprises yearly incremental assessments that simply map the rate of investment against the cost of savings. The shape of the analysis as presented in figure 2.6, confirms the original cost model.

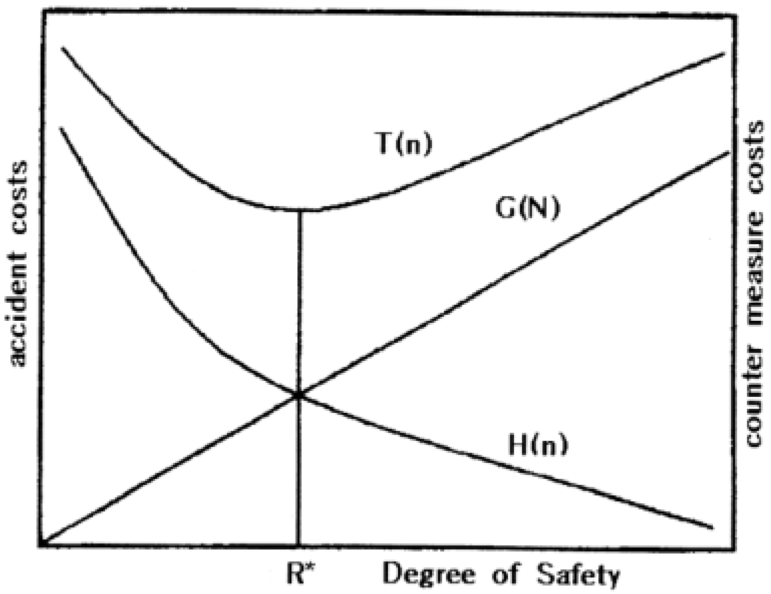

Figure 2.6 Total expected cost curve

Source: Son *et al*. (2000)

Where T(n) = Annual total expected cost, H(n)= Annual cost of accident, G(n)= Annual countermeasure or control cost and R*= Minimum cost point.

Behm *et al.* (2004) engaged the Cost of Quality (CoQ) classification to categories the cost of safety into four groups including prevention and inspection expenses as well as internal and external failure costs. The COS model was examined in a number of case studies, and the findings indicated that the accident prevention approach offers an optimum safety cost plan. The cost of safety, as depicted in Figure 2.7, equals the overall cost of inspection and prevention, as well as the direct and indirect costs of damage. The optimal point occurred at the intersection of two charts, though the exact location of this point varies depending on the project.

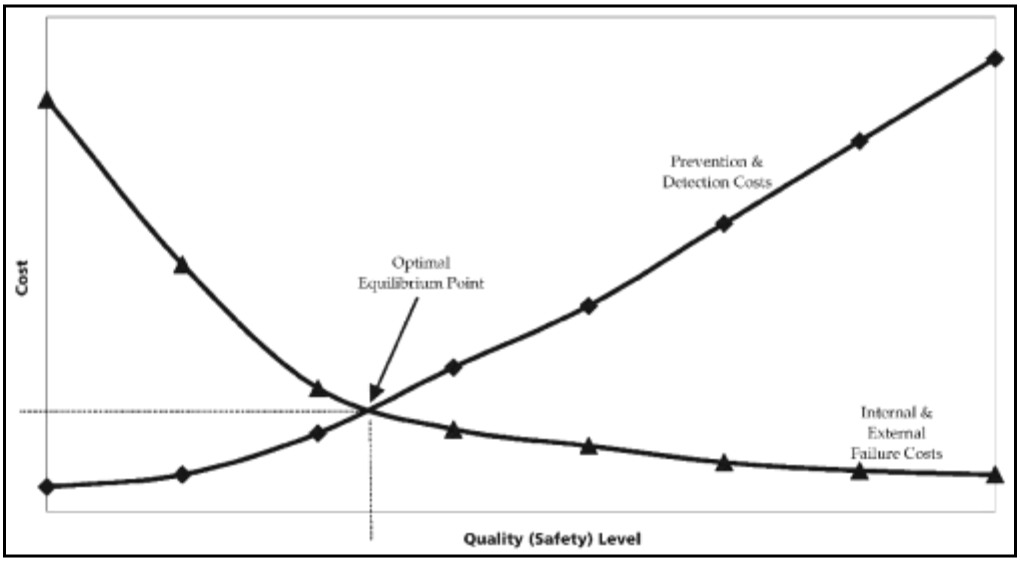

Figure 2.7 Cost of quality (safety)

Source: Behm *et al*. (2004)

However, the conceptual model also demonstrates that any further efforts in injury prevention, while altruistic, are inefficient from a financial perspective after the optimal investment point because they provide declining returns. The optimal-cost strategy reduces accidents to the point where an organisation spends only what is necessary to minimize safety-related expenses to a minimum. This concept could be diametrically opposed to the accepted viewpoint in the SH&E profession, from a financial perspective, the COS model gives the manager a framework for cost analysis, budget creation, and setting attainable targets (Behm *et al*., 2004). Since this is a short-term model, it needs to be checked yearly to avoid experiencing a diminishing rate of return. The model makes sense from a risk management perspective.

The main goal of any cost analysis operation is to recognise the low-hanging fruit, in other word target or goals which are easily achievable and which do not require a lot of effort. As with most financial instruments, the business must interpret the data in accordance with corporate standards and management philosophy in order to make appropriate financial decisions (Behm *et al*., 2004). The COS model simply present's financial data that can be utilised to guide operational action and decision-making and does not mandate these actions. The linkages between safety cost categories provides a useful tool for cost analysis, cost tracking, and budgeting future SH&E activities.

The COS model is limited in that there is no integration or consideration of the relative cost or effectiveness of any particular techniques thus reducing its application practically. In addition it is dependent of extrapolation of comparatively small quantity of data and the models relationship are not based on any risk based principle or monetary standard to structure a reliable and an efficient financial models.

2.7.1.5 ***Highlights from the review of safety models***

This section provided the highlights from each of the safety models reviewed. From the first model, Heinrich Domino accident model: focuses on two central points, the action of the preceding factors are the cause of injuries. The elimination of the central factor such as unsafe conduct or hazardous condition neutralizes the effects of the supporting variables, thereby preventing accidents and injuries. This model neglected the prevention and management aspect of accident. The Epidemiological of accident model: The model focused on identifying the causes of accident and injuries which are seasonal change, demographic characteristics and individuals' susceptibility and revealed the causes of accident are from a combination of force from at least three major sources, which include host, agent and environment. The model gave us cue on the responsible factors for accidents occurrence, although the accident type that can occur on site was not identified neither did, they make provision for accidents prevention.

The system model of construction accident causation focused on incorporating activity in construction and context characteristics, which takes into account task unpredictability which combine to create hazardous conditions. The concept of the framework is to identify the variables that effects the likelihood of accident in a construction activity. The need for two tactics to prevent accident was identified by the model which are: reliable construction arrangement to lower job unpredictability and management of error to improve employees' capacity to evade trap and errors mitigation. The model weakness is that it requires the use of system dynamics and does not operationalize or quantify the variable because it is a conceptual model.

The cost of safety model: focused on the cost as well as benefit of preventing accident by concentrating on the optimum investment point. COS model recognizes that for an organisations financial stability, some risk must be well thought-out acceptable and what level of risk would be acceptable must be determined by the organisation. The model provides a financial instrument that an organisation can use to pilot decision making and operational action within the safety functions. Although not founded in any principle based on risk, nonetheless provision is made for an organisation to determine the risk level that is acceptable, which would allow a monetary standard that will structure a reliable and an efficient financial model.

Among the models presented, the epidemiology of accident and safety cost model provided guidance for the implementation and selection of safety cost components on an activity-based level for the management and reduction of construction safety risk incident. The study proposes a new model that merges the two selected theories to develop an optimal activity-based health and safety risks cost for estimating the safety cost for work activities in building construction projects.

2.7.2 Conceptual framework

The conceptual framework explains the connections between a study's main ideas from a statistical perspective. It is organised logically to help create a picture or visual representation of how concepts in a subject relate to one another (Grant and Osanloo, 2014). According to Akintoye (2015), conceptual frameworks are typically adopted by researchers when pre-existing theories are either inapplicable or insufficient to establish a solid foundation for the study. According to Ravich and Carl (2016) a conceptual framework is a reproductive outlines that captures the thought involved throughout the whole process of the research. The variables and constructs are clearly defined through the use of diagrams and arrows which shows relationships between constructs. It helps researcher in recognising and creating their worldview on the phenomenon to be studied (Grant and Osanloo, 2014). A researcher builds a model on their own so as to clarify the relationship among key variable of the study (Adom *et al*., 2018).

The conceptual model for the study was broken down into sub sections and covered the major objectives of the study which includes hazard identification of work activities, safety risk assessment, cost of safety and model for safety cost. The conceptual framework in figure 2.8 demonstrates the relationship of the various variables. Gross floor area and the duration of a project determines the nature and types of hazards encountered on a project. Hazard identification aids in examining the different types of hazards which are peculiar to each work activity resulting to the assessment of the level of risk which will assist in the determination of safety cost components that will be expended in the project. The interaction of the variables results in an optimal activity-based health and safety risks cost which will reduce accidents to the minimum on construction site.

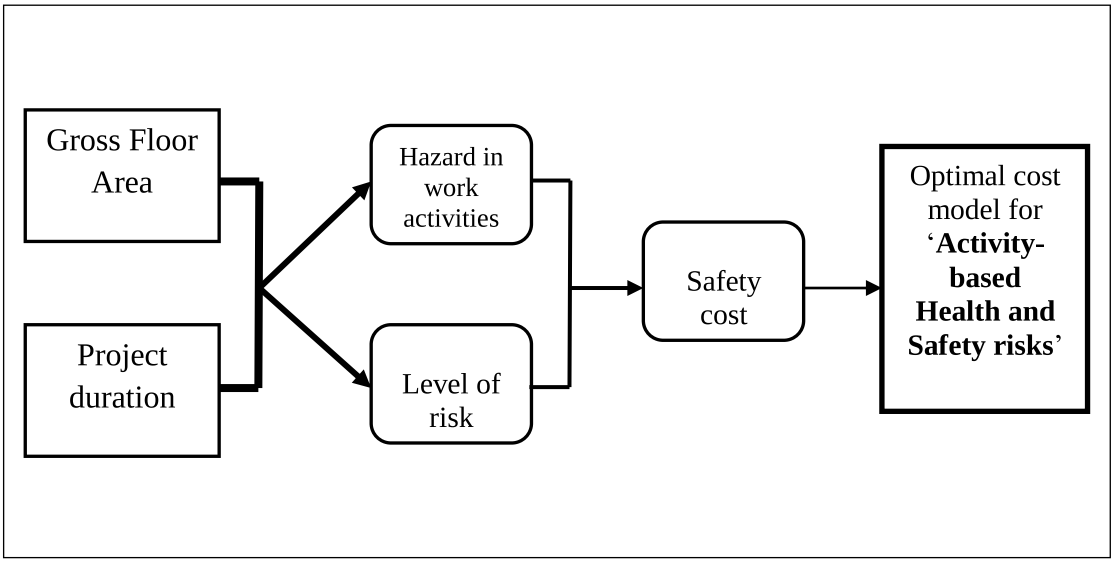

Figure 2.8: Conceptual framework of the study

Source: Author (2022)

Yang *et al.* (2021) argued that to effectively prevent accidents at construction sites, safety cost planning should consider the risk of ongoing construction activities. Park and Kim (2013) explain that in an efficiently accomplished project, activity-based risk identification is a crucial aspect in the management of safety plan on site. Section 2.2 presented the potential hazards that were peculiar to building construction activities. The epidemiology theory revealed that project characteristic such as construction area and project duration has a relationship to potential hazard on projects site. This in other words results in the assessment of the risk level of the occupational hazards. Manuele and Main (2002), asserted that some inherent risk level are entailed in most work procedures. Gurcanli *et al* (2015) emphasised that the major goal of performing hazard analysis is to determine the safety expenses required in the prevention of accidents by carrying out a risk assessment and lessening risk scores to an acceptable level by utilizing PPE, CPM as well as other techniques or equipment and programmes in training. The level of risks for each work activities were assessed using the Fine-Kinney technique as presented in section 2.4.2. And the procedure employed was detailed in section 3.8. One of the premise of the COS model is for each organisation to decide what amount of risk is acceptable, what risk-reduction measures are performed, and how much funding will be allocated for these measures (Behm *et al*., 2004).

Suggestions from Son *et al*. (2000) and Behm *et al*. (2004) on the best monetary strategy for the prevention of injury is developing a programme which will result in the lowest possible safety costs. The safety programme and the cost components in section 2.6.5 and 2.6.6 was determined by summing up the cost items in order to attain an optimal activity-based health and safety risks cost which will help in reducing accident rate to the minimum on site. A mathematical equation for managing H&S cost is presented in section 2.7.2.1.

2.7.2.1 ***Mathematical equation for modelling safety costs for building project***

Based on the issues originating from the conceptual framework of health and safety costs, the steps for developing a mathematical equation for managing the cost of safety in construction are presented as expressed by Gurcanli *et al*. (2015), which is the summation of the cost for PPE, CPM and Safety training as expressed in equation 2.4 - 2.6.

Safety cost = PPE cost + CPM cost +ST cost 2.4

PPE cost = $\sum_{i-1}^{n}(PPEi\ x\ N)$ 2.5

CPM cost = $\sum_{i-1}^{n} Ci$ 2.6

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.

2.7.2.2 ***Model for health and safety costs for building project***

An optimal activity-based health and safety risks cost model was developed using the following data: gross floor area which is also regarded as the construction area or scope and project duration which is also regarded as the completion time. Three types of regressions were employed in modelling safety cost and PPE cost these includes: linear, logarithmic and quadratic regressions.

2.7.2.3 ***Development of hypotheses***

The regression modelling exercise was carried out in phases. In the first phase, safety cost was modelled using first, Gross Floor Area (GFA) and Project duration. And the following hypotheses were proposed:

There is a relationship between gross floor area and the cost of safety.

There is a relationship between project duration and the cost of safety

The second phase comprised the modelling of PPE cost using gross floor area and project duration. And the following hypotheses were proposed:

There is a relationship between gross floor area and the cost of PPE.

There is a relationship between project duration and the cost of PPE

In the third and final phase, the PPE costs for seven different work elements were modelled using gross floor area.

There is a relationship between gross floor area and the cost of PPE for excavation work

There is a relationship between gross floor area and the cost of PPE for masonry work

There is a relationship between gross floor area and the cost of PPE for concrete work

There is a relationship between gross floor area and the cost of PPE for roof work

There is a relationship between gross floor area and the cost of PPE for floor finishing

There is a relationship between gross floor area and the cost of PPE for plastering/rendering work

There is a relationship between gross floor area and the cost of PPE for painting work

CHAPTER THREE

3.0 RESEARCH METHODOLOGY

3.1 Research Philosophy

Research philosophies are sets of assumptions and beliefs about how knowledge is developed (Saunder *et al*. 2019). This implies that research philosophy comprises significant assumptions about how a researcher perceives the world. All facets of the research initiatives are influenced by these presumptions. The nature of any research problem will dictate the methodological framework and techniques that will be used to solve it. This would create way for determining the best philosophical stance for the investigation. Research philosophy is the basis of knowledge development (Kagioglou *et al.*, 2000). At least three main categories of assumptions are made by all research philosophies, these are ontological, epistemological and axiological assumptions. Different philosophies can be distinguished by researchers by the differences and resemblance in their ontological epistemological and axiological assumptions (Saunders *et al*., 2019)

3.1.1 Ontological assumption

This relates to the beliefs held by researchers regarding the nature of reality and the world. The topic of a researcher's work, as well as how they see and approach it, are determined by the ontological assumptions that underpin it. Ontology raises problems about the beliefs scholars have about how the world works and the adherence to particular viewpoints to a larger extent than epistemological considerations (Saunders *et al*., 2019). Two primary assumptions of the ontology are objectivism and subjectivism (Blaike, 2007; Saunders *et al*., 2009). Subjectivism is based on the idea that social phenomena are produced by the perceptions, ideas, and subsequent actions of the social actors concerned with their existence, whereas objectivism is based on the idea that social entities' existence is in fact independent of the social actors concerned with it. In line with the ontological stance, this study tends towards objectivism point of view. The idea that social entities' existence is actually independent of the social players who are concerned with it is the foundation of an ontological objective view (Creswell, 2009; Saunders *et al*., 2009). As a result, knowledge exists independently of any one person and the researcher. The data that can help clarify the financial facets of building safety is mostly objective and quantitative.

3.1.2 Epistemological assumption

This relates to presumptions about knowledge, including how people know what they claim to know, what qualifies as genuine information, acceptable knowledge, and how knowledge can be shared with others. What kind of knowledge can be added as a consequence of study depends on the epistemological assumptions that are made (Saunders *et al*., 2019). Epistemology is also concerned with providing rationales from a philosophical standpoint for deciding what types of knowledge are knowable and how to assess whether information already obtained is both sufficient and legitimate (Crotty, 2003). Similar to this, Vogt *et al.* (2012) asserted that the study of the development and justification of knowledge and its assertions constitutes epistemology. The perception of the researcher on knowledge development is determined by epistemology. Positivist and interpretivist epistemological stances are the two basic stances that researchers might adopt. Positivism is predicated on the notion that only observable phenomena can result in valid data, with the latter being gathered based on hypotheses drawn from pre-existing theory. The positivist researcher is focused on the facts and believes that research should be conducted in an environment free from bias so that neither the research topic nor the researcher may influence one another. According to interpretivism, it's important for researchers to comprehend how people behave differently in their positions as social actors. The interpretivist researcher actively participates in the topic under investigation because they hold the subjective and socially created worldview (Saunders *et al*., 2019). This study adopts a positivist epistemological perspective. The positivist's epistemological philosophy aspires to objectivity, measurability, controllability, predictability, patterning the construction of laws and rules of behaviour, and acknowledging outcome. The research aim to determine the cost of health and safety for building projects, by calculating the safety cost as a proportion of the project's overall construction costs, which is in line with the positivist viewpoint.

3.1.3 Axiology assumption

This branch of philosophy is concerned with the role that ethics and morals play in the research procedure. However, Saunders *et al*., (2019) emphasised that the values of the participants in the research and one selves should be well treated. According to positivists, the research process has no intrinsic value because the researchers are not a part of the subject matter being studied. Axiology displays a perspective on the significance of values in the methods and data collection employed in research. It may cover aesthetical and ethical values (Collis & Hussey, 2003; Mertens, 2007; Collins *et al*., 2007; Saunders *et al.,* 2009). However the primary focus of axiology as a field of philosophy is the process of social inquiry connected with the part the researcher(s)' values play throughout the study process (Saunders *et al*., 2019). It talks about potential moral conundrums that could come up during the investigation (Collins *et al*., 2007).

These values play a crucial role in determining what is accepted as reality and the interpretations that follow (Collis & Hussey, 2003). In line with the axiological point of view, the study tends towards objective (value free). The axiological philosophical view of the positivists which believe that they are not part of what they are researching. The relationship between activity-based risk assessments techniques are assumed to exist and be independent of the researcher which is aligned to objective view (value-free).

3.1.4 Philosophical stance of this study

The type of paradigm that must be used is influenced by the research phenomenon being considered and the primary research questions (Remenyi *et al*., 1998). The epistemological position of this study is positivism while ontological position of this study is objectivism, research paradigm tended towards positivism. An objectivism approach allows the use of quantitative data from many external viewpoints selected to best enable participants in the research to respond to the research question (Creswell, 2009; Saunders *et al*., 2019).

It is clear from the research questions provided in Chapter one that they are reliant on measurement; as a result, it is natural to accept positivism as an overarching world view for the phenomenon being examined in order to get objective measurements. Quantitative data required was obtained through questionnaire survey and archival data for building projects. The cost estimating model in this study is expected to offer a practical solution to be implemented in practice that is the view of the positivist paradigm.

3.2 Research Paradigm

Research paradigms give an understanding of the methodological direction to position the research to accomplish the study's objectives (Creswell, 2009). A comparisons of the five research paradigms mostly used in management research is presented in Table 3.1 showing their ontological, epistemological, axiological stances and data collection techniques most commonly used. Positivism paradigm is explained since it is considered most suitable for this study due to its ability to the use of quantitative data.

Positivism is an epistemological perspective that supports using the techniques from the natural sciences to explore social reality and other subjects. This involves working with observable social reality and the result may be generalities that resemble laws like those found in the physical and natural sciences (Saunders *et al*., 2019). Positivism is also said to incorporate the following tenets: only phenomena, and knowledge that has been verified by the senses, may be properly justified as knowledge (the phenomenalism principle); the purpose of theory is to develop testable hypotheses that will enable for evaluation of how well laws are explained (the deductivism principle); knowledge is attained by assembling evidences that offers the bases for laws (principle of inductivism); science must (and can be presumable as possible) be piloted in a value free manner (objectivism principle) (Creswell, 2014; Saunders *et al*., 2019). The research paradigm of this study tended towards positivism.

Table 3.1: Comparison of research philosophies in business and management research

Ontology: the nature of reality or being of the researcher's view)	Epistemology: (what constitutes the researcher's acceptable knowledge)	Axiology: (the role of values to the researcher)	Typical methods
Positivism			
Real, external, Independent one true reality (universalism) Granular (things) ordered	Scientific method Observable and measurable Facts law-like generalisations Numbers causal explanation and prediction as contribution	Value-free research Researcher is detached, neutral and independent of what is researched Researcher maintains objectives stance	Typically deductive, highly structured, large samples, measurement, typically quantitative methods of analysis, but a range of data can be analysed
Critical realism			
Stratified/layered (the empirical, the actual and the real) External, independent Intransient Objective structures Causal mechanisms	Epistemological relativism knowledge historically situated and transient Facts are social constructions Historical causal explanation as contribution	Value-laden research Researcher acknowledges bias by world views, cultural experience and upbringing Researcher tries to minimise bias and errors Researcher is as objective as possible	Retroductive, in-depth historically situated analysis of pre-existing structures and emerging agency Range of methods and data types to fit subject matter
Interpretivism			
Complex, rich Socially constructed through culture and language Multiple meanings, interpretations, realities Flux of processes, experiences, practices	Theories and concepts too simplistic Focus on narratives, stories, perceptions and interpretations New understandings and worldviews as contribution	Value-bound research Researchers are part of what is researched, subjective Researcher interpretations key to contribution Researcher reflexive	Typically, inductive. Small samples, in-depth investigations, qualitative methods of analysis, but a range of data can be interpreted
Postmodernism			
Nominal complex, rich Socially constructed through power relations some meanings, interpretations, realities are dominated and silenced by others Flux of processes, experience, practices.	What counts as 'truth' and 'knowledge' is decided by dominant ideologies Focus on absences, silences and oppressed/repressed meanings, interpretations and voices Exposure of power relations and challenge of dominant views as contribution	Value – constituted research Researcher and research embedded in power relations Some researcher narratives are repressed and silenced at the expense of others Researcher radically reflexive	Typically, deconstructive – reading texts and realities against themselves In-depth investigations of anomalies, silences and absences Range of data types, typically, qualitative methods of analysis
Pragmatism			
External, Multifaceted, rich, reality is the real-world consequences of thoughts Flux of procedures, experiences and practices	Practical meaning of knowledge in specific contexts 'True' theories and knowledge is those that enable successful action Focus on problems, practices and relevance problem solving and informed future practice as contribution	The research is driven by value Research initiated and sustained by researcher's doubts and beliefs Researcher's Reflexive	Following research problem and research question Range of methods: mixed, multiple, qualitative, quantitative, action research Emphasis on practical solutions and outcomes

Source: Saunders *et al*. (2019).

3.3 Research Method

The methodologies and guiding concepts used in doing research are known as research methods, and the discipline or body of knowledge that employs these approaches is known as research methodology (Kinash, 2008). Research methodologies come in three different types: quantitative, qualitative, and mixed-method approaches, which blends quantitative and qualitative methods to study a phenomenon (Creswell and Creswell, 2018).

3.3.1 Qualitative research

Qualitative research is an approach for investigating and comprehending the meaning that individuals or groups assign to a social or human situation (Fellows and Liu, 2008). The research process includes developing questions and techniques, data collection that typically takes place in the participant's environment, inductive data analysis that builds from specifics to broad themes, and the researcher's evaluation of the significance of the findings (Creswell and Creswell, 2018). Data are often acquired in participant settings. The final report's structure is adaptable. Those that engage in this type of research advocate an approach to research that values an inductive approach, an emphasis on personal significance, and the significance of accurately describing the complexity of a situation. The qualitative technique analyses language, discusses topics involving people, objects and circumstances, and concentrates on naturally occurring, typical events in their natural surroundings (Farrell, 2011). According to Amaratunga *et al.* (2002) the four main limitations that the technique must overcome are; the volume of data, the complexity of the analyses, the specifics of the categorization records, and the flexibility and speed of the analyses.

3.3.2 Quantitative research

Quantitative techniques follow the "scientific method," wherein a preliminary examination of theory and literature results in specific goals and objectives as well as propositions and hypotheses that will be put to the test (Fellows and Liu, 2008). Quantitative methodology aim to collect factual data, investigate relationships between facts, and assess how such facts and relationships align with theories and the results of any previous research that has been conducted (Fellows and Liu, 2008). The quantitative research method entails examining the quantities or amounts of one or more relevant variables. Using the standard physical measures of the world, such as rulers and thermometers, a quantitative researcher measures the variables in some numerical form (Leedy and Ormrod, 2014). The four levels of measurement that are available are nominal, ordinal, interval, and ratio. However, the most fundamental level is nominal measurement, in which things, events, and people are classified according to common traits (Blaikie, 2010).

3.3.3 Mixed research

The mixed method, also known as multi-methodology, is a research methodology whereby a researcher collates and analyse data, combines the discoveries, and draws inferences using both qualitative and quantitative approaches in a particular study (Cresswell, 2009). For a better understanding of the research challenges, it combines the advantages of the two methodologies. As a result, where necessary, researchers should be aware of the possibilities of combining qualitative and quantitative methodologies to answer their research problems (Creswell, 2009).

3.4 Research Strategy

The formulation of the research strategy is the challenging process that comes after the task of determining the research problem. Kothari (2004) defined research strategy as the prearrangement of conditions for the collection of data and analysis in such a way that attempts to provide reliance to the goal of the research with economy in method. In actuality, research design serves as the conceptual framework for research and serves as the blue print for the collection of data, measurement and analysis. Choosing a research strategy that is appropriate for the study comes after adopting a research philosophy (Saunders *et al*., 2009).

Inductive approach of research intends to develop a worldwide generalisation that can be utilised as a pattern of clarifications by first gathering data to produce generalisations that are then used as patterns to explain more observations. While deductive approach to research, on the other hand, tries to test existing theories, to eliminate incorrect ones, and to support the survivor by discovering a regularity to be explained, building a theory, or deducing hypotheses that are then tested by comparing them with empirical facts (Blaikie, 2007). In other words, the deductive approach is focused on testing theory and is mostly based on the gathering of quantitative data, whereas the inductive approach aims to develop theory and is primarily based on the collection of qualitative data. Also, the inductive strategy takes a long time to collect data and analyse it since concepts arise gradually, however, the deductive approach does it in a shorter amount of time if proper care is taken to set up the study properly before beginning (Saunders *et al*., 2009).

Deductive approach (quantitative research approach) was the research design chosen for this study. It involved the testing of pre-existing hypotheses and the development of the conceptual framework for the investigation. Quantitative data were collected and relationships were established between the study's variables, which includes establishing a relationship between ABC estimating and activity-based risk assessment for H&S in building projects. As such it sought to explain how safety costs compare to overall construction costs in a project, safety cost per unit area and identification of high-risk activities that occur during residential building construction.

The researcher has a choice between six mixed research approaches to accomplish the objectives of this study. These include sequential mixed method, concurrent mixed method, ethnography, case study, survey, grounded theory, and grounded theory with grounded practise (Saunders *et al*., 2009 and Creswell, 2009). When considering the choice of a research strategy, the researcher should be guided by the aim and the research questions, the depth of current knowledge on the subject matter, the researcher's time constraints, and availability of resources and philosophical position of the researcher. The adoption of these techniques is not mutually exclusive, and for one research project, a suitable combination of two or more strategies may be employed (Creswell, 2009). This study tended towards a quantitative research approach. The survey and archival research were adopted in this study, because it allowed the researcher to collect and collate a substantial amount of quantitative data within a limited resource and time framework while still ensuring the data were reliable (Saunders *et al*., 2019).

3.4.1 Survey research

The "who," "what," "where," "how much," and "how many" research questions are typically addressed using the survey strategy, which is typically connected with the deductive approach to research (Saunders *et al*., 2009). Survey research analyses a sample of the population to describe the opinions, trends, or attitudes of the population statistically or numerically. A survey strategies enables the very efficient economical way of collecting of data from a representative sample of respondents (Fellows & Liu, 2003). A closed ended questionnaire was used for this research. It can be used to recommend potential relationships between different variables as well as producing models of these correlations (Saunders *et al*., 2009). The level of risk for each work item in building construction activities and the cost of safety measure required for controlling each construction activity in building projects was determined.

3.4.2 Archival research

Research issues that are focused on the past as well as changes over time are addressed using an archival research strategy. In order to answer research questions that may be exploratory, descriptive, or explanatory in character, archival research strategy primarily uses administrative records and documents as sources of data (Saunders *et al*., 2009). The archival data for this study includes: bills of quantities (BOQ) and program of work. Table 3.2 present the summary of the research strategy adopted for this research.

Table 3.2 Summary of Research Strategy

Objective	Data type	Sampling Method	Method Of Data Collection	Method Of Data Analysis
1. To examine the potential hazards in building projects	Quantitative (Primary data)	Purposive sampling (Non-probability sampling)	Literature review. Close ended Questionnaires administered to the selected contractors	Mean index score
2. To assess the level of risk for each work item in building construction projects in terms of likelihood, severity & frequency.	Quantitative (Primary and secondary data)	Purposive sampling (Non-probability sampling)	Literature review. Close ended Questionnaires and Bills of quantities.	Mean index score and Risk score of Fine-Kinney
3. To determine the cost of safety required for controlling accident in construction activities in building construction projects	Quantitative (Primary and secondary data)	Non-Probability sampling (purposive)	Literature review Close ended Questionnaires and archival data (Bills of quantities. Market survey	Activity-Based Costing and percentile
4. To develop an activity-based model for estimating the cost of safety for a building construction project	Quantitative (secondary data)	Non-Probability sampling (purposive	Data obtained and analysis extracts from Objective 2-3	Simple Linear Regression Analysis
5. To test the validity of the ABC model for health and safety for building construction project.	Quantitative (secondary data)	Non-Probability sampling (purposive	Data obtained and analysis extracts from Objective 4	Logarithmic Regression Analysis

Sources: Researcher Fieldwork (2022)

3.5 Study Population

Population refers to the targeted group identified by the study's objective (Morenikeji, 2006). The study population is a full set of elements (objects or people), according to the sample criteria established by the researcher, who shares some distinctive and common characteristics (Cassim, 2014). Building projects in Abuja are the study's analytical unit. Building projects managed by the 56 active quantity surveying firms registered in Abuja by the Quantity Surveyor Registration Board of Nigeria (QSRBN) as at July 2021 made up the study's population (QSRBN, 2021). The actual number of the projects that meets the study’s criteria was unknown; this informed the decision to adopt a purposive sampling approach, in order to reach as many projects that are suitable for analysis as possible.

3.6 Sampling Frame and Sample Size

Morenikeji (2006) described sampling frame as a list that contains information about the study's population and allows samples to be drawn. A sample is a smaller portion of a population that is picked for observation and investigation (Naoum, 2007). A sample size is the number of individual included in a research study to represent a population. The ongoing and completed building projects in Abuja, managed by active quantity surveying firms constitutes the sampling frame for this study. A total of 76 BOQ were collected from the archival records of the selected QS firms. The BOQ that met the criteria were considered.

i. Each bill must have their preliminary section broken-down cost wise (in order for the project to serve as a source of data for this study).

ii. The contract sum must be above N100, 000000.00. (It was believed that projects with large contract sum were more likely to include items of H&S in the BOQ).

iii. It must be projects executed within the last 3years (in line with the scope of the study).

However, only 40 projects were found to meet the criteria for this study after thorough filtering for relevance and fitness purpose. A detailed breakdown of the 76 projects collected from the firms is found in Appendix B of the study.

3.7 Sampling Technique

A sampling technique is a method of choosing components from a population (Kothari, 2004). According to Saunders *et al*. (2009) there are two major types of sampling techniques the probability sampling technique and the non-probability technique. In probability sampling, the components of the population have some well-known chance or likelihood of being chosen as subjects. While in non-probability sampling, parts of the population have no known chance of being chosen as sample subjects, elements of the population. Purposive sampling which is a non-probability sampling was adopted for the selection of the study's participants. The decision to adopt a purposive sampling approach was informed because the actual number of the projects that meets the study's criteria was unknown. In order to reach as many projects that are suitable for analysis as possible. The decision of purposive sampling was also buttressed by the need for the projects to meet the criteria outlined in section 3.6.

Purposive sampling is used to pick instances for a study depending on the researcher's assessment of the appropriate examples, such as choosing a variety of case types for in-depth analysis (Blaikie, 2010). The ability to provide a representative sample of the sampled elements based on certain specified criteria (such as building projects ongoing and completed within three years, having BOQs and programme of work), and the possession of detailed knowledge required by the study, were key factors in the choice of the purposive sampling technique (Patton, 2001). As the name implies, purposive sampling assures that the researcher selects individuals or other units for a specific goal, as noted by Leedy and Ormrod (2014). Particular goal was based on provision of BOQs and programme of work for the study being they were confidential documents in any given contract.

3.8 Data Sources and Collection Instruments

This study utilised both secondary data and primary data sources.

3.8.1 Secondary data

The secondary data for this study was cost data in respect of building projects in Abuja, which was obtained from BOQs and schedule/programmes of work. The BOQs were used as a source for information about the tasks involved in creating the sampled building projects based on the ABC approach used in this study. The quantitative size of these activities, as well as their duration, were obtained from the archival records. The availability of this information enabled the computation of the safety cost for specific group of activities in the BOQ. Seventy-six (76) bills of quantities for building construction projects were obtained, which after thorough filtering of the data 40 BOQs were used for the final analysis. The 36 BOQs discarded was because the standard of measurement used in the bill preparation was not in accordance with BESMM and the preliminaries section of some of the bill were not broken down.

3.8.2 Primary data

The primary data for the study was collected using questionnaire. A well-designed questionnaire on the topic of health and safety risk in Nigerian construction projects was self-administered to respondents who managed and supervised ongoing projects in the sampled active Quantity Surveying firms. These were based on a survey of the established literature and a study to find out what actually occurs in practice.

The distribution of the questionnaire was according to the number of projects obtained from the Quantity Surveying firms; respondents were those who participated in the execution of the projects obtained. A total of 76 questionnaires were obtained, but only 40 of the questionnaires were usable making (52.63%), this was due to the fact that most of the questionnaires were not filled properly. The typical response rate for postal questionnaire surveys, according to Ankrah (2009), was between 20% and 30%. Kheni (2008); Ankrah (2009) and Ikpe (2009) had response rates of 32.42%, 15.42%, and 15.8%, respectively. Also, in Agumba and Haupt (2014) the response rate was 15.72, were questionnaire was administered by mail and self-administered. The rate of response in this study is adequate, judging by the statistics of acceptable return rates in literature.

3.8.3 Data collection procedure

The Fine-Kinney technique for assessing the level of risk uses three metrics – these are the likelihood (probability), frequency (exposure) and severity (consequence) of the hazard under consideration. Questionnaire was utilised in obtaining the severity and likelihood of accident occurrence by using a Likert scale of 1 to 5. The likelihood or probability of occurrence ranged from 1 – rare risk, 2 – remote risk, 3 – occasional risk, 4- frequent risk and 5 – almost certain risk. The severity of risk impact include: 1- noticeable, 2- important, 3-serious, 4- very serious and 5- disaster.

The frequency (also called 'exposure') of hazards, were generated in a completely different manner. Since by definition frequency refers to the length of time in which workers are exposed to a particular hazard, data on frequency of hazards had to be obtained from the construction work programmes of the various projects that were sampled in this study. An intermediate challenge arose from the discovery that construction work programmes were not available for all 40 projects. Figure 3.1 detailed the approach adopted to overcome this temporary obstacle.

The frequency ('exposure') of hazards was generated using the methodology described in Figure 3.1, which was based on a practical approach to research. The adoption of this approach was necessitated by the realization that construction work programmes were not available for all of the 40 projects that were employed in this study. Yet it was imperative that data on frequency of hazards had to be obtained from the construction work programmes of projects; this was the approach used by researchers who had investigated the cost of safety in building construction projects such as (Jannadi and Almishari, 2003; Hallowell and Gambatese, 2009; Gurcanli *et al*., 2015; Ghousi *et al*., 2018). In point of fact, Gurcanli *et al*. (2015), working on modelling safety cost for reinforced concrete work in Turkey, had to employ the use of a construction management software (Primavera) in order to develop construction work programmes for projects employed in that study before extracting the durations for all work items involved in reinforced concrete work.

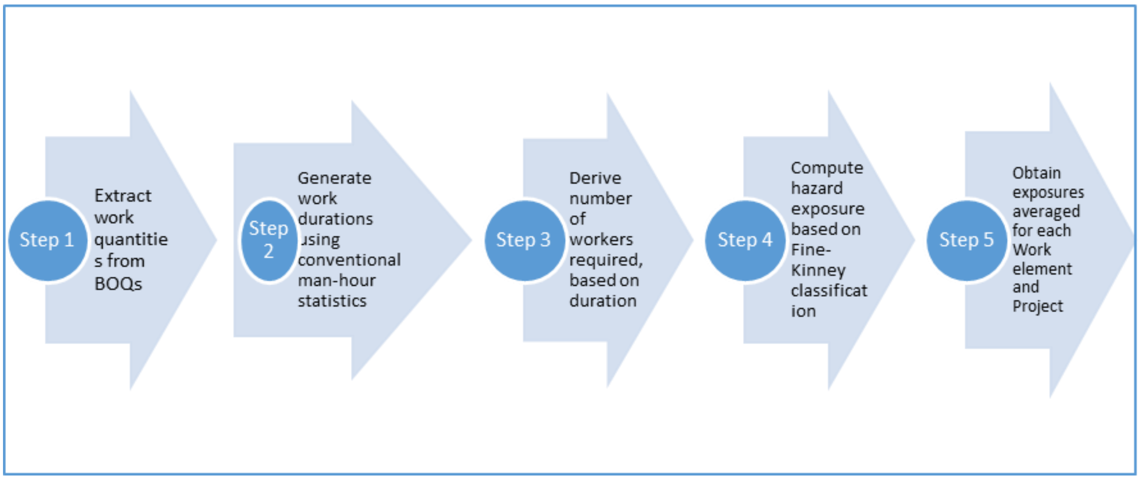

Figure 3.1: Method of computing workers' exposure to safety risk hazards

A detailed explanation of the different steps involved in the derivation of frequency of hazards under the Fine-Kinney technique, as described in Figure 3.1, is presented in the subsequent paragraphs of this section, in tandem with the data presented in Table 4.8a, 4.8b and 4.8c; Table 4.24a and 4.11b; Table 4.12a and 4.12b. The starting point of all of these activities was the perusal of the bills of quantities for all of the 40 projects employed in the study. This also underscored why it was absolutely necessary to have the project bills of quantities provided for the purposes of this study by the survey respondents.

3.8.3.1 *Extract work quantities from bills of quantities (BOQs)*

In this preliminary step, the quantities of work supplied in the BOQ were extracted and employed to generate a spreadsheet in Microsoft Excel. Work items were identified according to the Work Breakdown Structure (WBS) adopted by the BESMM 4R of the Nigerian Institute of Quantity Surveyors (NIQS, 2015). For example, works in foundations were broadly grouped under Substructure, with 'Excavation and Filling' being a subsection of Substructure, and Trench excavation, Laterite filling and Hard-core filling all being examples of entries under the WBS Subsection. The results are presented in Table 4.8a, 4.8b and 4.8c.

A final point that needs to be made here has to do with the particular work items selected for inclusion in the study. Although it would have been desirable for this study to cover all of the work items in the WBS of a typical building project, which would include elements such as doors and windows, electrical services, mechanical equipment and fittings, the practical realities dictated otherwise. This was because not all of the 40 projects employed in this study had the same arrangement of works in their BOQs. In fact, some work items did not exist in some projects at all; an example was Lift installation. The decision thus had to be made to use only work items that were more generally available across the entire sample of 40 projects; this was why the data extraction focussed on substructure, superstructure (frames), walls (masonry), roof, finishing and painting. Subsequent fine-tuning of these work sections resulted in the adoption of only five sections – excavation, reinforced concrete work, masonry, roof work, and finishing.

3.8.3.2 *Generate work durations using conventional man-hour statistics*

Work output statistics, more conventionally known as 'output constants' were rigorously sourced from practicing construction professionals, most especially Quantity Surveyors. Sources such as Nigerian Institute of Quantity Surveyors (NIQS) databank and construction price book publications (Consol's Nigeria Building price book (Consol Associate, 2019) were also consulted as presented in Appendix C. The result of this search was presented in Table 4.9.

The quantities of work presented in Table 4.8a, 4.8b and 4.8c were then divided by the values in the sixth column of Table 4.9. The resulting quotient represented the period of time in days that it would take a single worker to complete the quantity of work presented in Table 4.8a, 4.8b and 4.8c. This quotient, for all of the different work activities/items, was provided in Table 4.10a and 4.10b.

3.8.3.3 *Derivation of the number of workers required based on project duration*

The derivation of the number of workers required some specialist knowledge of construction project management. For this reason it was carried out in consultation with some of the respondents who were available and the output of the results from NIQS databank and Consol's Nigeria Building price book (Consol Associate, 2019) was utilized, which provided the estimated output and number of worker required for a day's job. Given a rough idea of how fast work can be done on site, within the constraints of the available resources in terms of finance, plant, labour and supervision, experienced construction project managers can estimate how many days should be allocated to a particular activity.

The derivation of the number of workers exposed to hazards during building work activities was carried out as presented in Figure 3.1 of Section 3.8.3, with specific reference to Step 3. After consultation with some of the project managers for the projects surveyed in this study, certain numbers of days were allocated to specific work activities as presented in Table 4.25a and 4.25b. The number of workers required to carry out the works were computed using the following formulae.

i) Time required to complete work activity using only one worker (worker-days):

$$Number\ of\ worker-days = (Quantity\ of\ work \times Manhour)/8hr \quad 3.1$$

Where *Quantity of work* was provided in Table 4.8a, 4.8b and 4.8c; *Manhour* was provided in Table 4.9; *8hrs* is the standard working period in a day.

ii) Number of workers required to complete work activity during time period allocated in Program of Works:

Number of workers = Number of worker-days/Time allocated for work activity

3.2

Where *Number of worker-days* is obtained from Equation 3.1, and *Time allocated for work activity* was provided in Table 4.10a and 4.10b.

The resulting quotient of the arithmetical operation in Equation 3.2, the number of workers that are required to complete the work, was presented in Table 4.11a and 4.11b.

Determining how many workers are needed simply becomes a matter of dividing the number of days that it would take a single worker to complete a quantity of work by the number of days the expert construction project manager has allocated to the particular activity. The resulting quotient of such an arithmetical operation is the required number of workers that are expected to complete the task at the pace specified in the eighth column of Table 4.9. This quotient, the number of workers that are expected to finish the task was not required for the determination of the exposure level under the Fine-Kinney approach, it was however employed in the determination of the cost of PPE.

3.8.3.4 *Computation of hazard exposure based on Fine-Kinney classification*

Hazard exposure was computed in three steps. First, the duration of each work activity was calculated as a percentage proportion of the total duration for each element. Secondly, the resulting % value was compared with the frequency scale developed from the work of (Kinney and Wiruth, 1976; Jannadi and Almishari, 2003; Oturakci and Kokangul, 2015; Gurcanli *et al*., 2015; Kokangul *et al*., 2017; Dogan *et al*., 2022) the scale developed in this study for ranking work activity durations as a percentage proportion of the total elemental duration is presented in Table 4.11.

Thirdly, a new table was generated that had the work activity duration replaced with the Fine-Kinney frequency (exposure) value that corresponded to the % value of the work activity duration. This was labelled as Table 4.12a and 4.12b.

3.8.3.5 *Obtain exposures averaged for each work element and project*

The last step involved in the computation of exposure of workers to hazards under the Fine-Kinney technique had to do with obtaining the average Fine-Kinney frequency (exposure) value for each work element. This was the value that would be taken as the frequency of hazards during the execution of works under that element. The resulting values are presented in Tables 4.13c and 4.13d, and were from now on employed in the determination of the level of risk in work items and projects under the Fine-Kinney approach.

The assessment of risk for the different work items was conducted, in other to ascertain the action to be taken on a particular work activity. To ascertain the level of risk, the total of the risk score is computed by apportioning arithmetical values to each of the three parameters, to reflect the weight of the hazards. Risk score is the product of three parameters as expressed in equation (3.3) (Kinney and Wiruth, 1976, Yilmaz and Ozcan, 2019).

$$Risk\ score(R) = Probability(P) \times Severity\ (S) \times Frequency(F) \qquad 3.3$$

Computation of the risk score was done by determining the arithmetical values associated to the hazards from the tables and multiplying the values. The risk level generated from the three metrics is described in five ways –very low, low, medium, high and very high. The risk scale of the Fine-Kinney runs from 1 to 400; a risk score of less than 20 indicates ‘risk’ (acceptable). Risk scores greater than 20 but less than 70 denote ‘possible risk’ (attention indicated). While risk scores greater than 70 but less than 200 denote ‘substantial risk’ (correction needed). Risk scores greater than 200 but less than 400 denote ‘high risk’ (immediate correction required), while values of risk greater than 400 are an indication of ‘very high risk’ (considering discontinuing task). The risk score values presented in Table 2.6 was employed in determining the level of risk for each activity.

3.8.4 Procedure for determining the cost of safety in construction projects

This section reported the procedure for obtaining the costs components that are directly concerned with the safety of building construction projects that was computed for the study. Activity-based costing was used to generate information for projects safety costs under the following categories: costs of PPE, costs of CPM and safety training costs. These costs when aggregated gave the costs of safety for the projects concerned.

3.8.4.1 *Computation of personal protective equipment (PPE) costs*

The procedure for the derivation of the cost of PPE involved computing the number of workers (skilled and unskilled) that was required for each work activity (and thus, by extension, the number of workers that would be exposed to hazards during building work activities as presented in section 3.8.4). PPE items required by individual worker under the different building construction work items were determined from literature on construction safety (for instance Gurcanli *et al*., 2015 and Ghousi *et al*., 2018). PPE items comprises of helmet, protective clothing, reflective vest, protective boot, gloves, safety, goggle, face shield, dust mask and harness/belt). Afterward a market survey was carried out 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. The cost of PPE arrived at depended on the number of workers (skilled and unskilled) required for the job, which was determined from the period of time allotted for the completion of the works.

3.8.4.2 *Computation of collective protective measures (CPM) costs*

The costs of CPM were derived for projects that were surveyed in this study. Collective Protective Measures (CPM) is the type of protection that is not tied to persons or particular work activities. The information employed in the derivation of CPM costs was extracted from two main sources: (i) the preliminaries section of project BOQs, and (ii) (literature reviewed such as Smallwood (2011); Gurcanli *et al*., (2015); Malan and Smallwood (2015); Yilmaz and Kanit (2018); Yilmaz and Ugur (2019). Section H of the research questionnaire as filled in by the respondents. The number of items considered as CPM varied from project to project; however a maximum of six items were included, these six items were (i) first aid, (ii) temporary fencing, (iii) scaffolding, plant and equipment, (iv) hoarding and barriers, (v) protection against damage and (vi) other safety measures (such as 'access for workmen').

3.8.4.3 *Computation of safety training (ST) costs*

Apart from providing workforce protection (through PPE) and workplace protection (through CPM), there is also the need for training of the workforce on how to be safety conscious and develop a pro-safety mind-set. This is usually accomplished on building construction projects through Safety Training (ST). How the costs of ST were derived for projects was also revealed in this study.

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 information employed in the derivation of ST costs was extracted from two main sources: (i) Section H of the research questionnaire as filled in by the respondents, and (ii) the market survey mentioned earlier.

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. These three items were (i) safety education and 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. Safety staff salary refers mainly to a Safety Officer, who is employed to oversee and coordinate safety activities for the project. Depending on the level of qualification and experience, safety staff salaries vary widely. Safety education and training is usually carried out by a Specialist Safety Consultant; from interaction with the project managers who formed part of the respondents to this study, such training should ideally be carried out for selected staff at least twice a month. Different groups of project staff are usually trained during each session. There are no standard fees for such training; an Institute of Safety Professionals of Nigeria (ISPON) is only now coming into being across Nigeria. Safety promotion has to do with visual signs and warnings placed at prominent locations throughout the project site. By multiplying the figures for daily cost of ST components by the duration (in days) of each of the projects that were employed for this study, the cost of ST components per project was arrived at.

3.9 Method of Data Analysis

Using the proper techniques for data analysis is one of the crucial aspects in attaining the research aim. The proper choice in data analysis aids in the accurate communication of research findings and results in the drawing of reliable and appropriate conclusions (Ankrah, 2009 and Awodele, 2012). Both descriptive and inferential statistical methods were used to analyse quantitative data. The descriptive statistics used were percentiles and mean scores while the inferential statistics used were correlation and Simple Regression Analysis (SRA). Using the logarithmic regression method, the conceptual model from Chapter 3 was validated.

3.9.1 Descriptive statistics

Data was presented using tables and bar charts, in order to meet the study's first and second objectives. The potential hazards on building construction project sites where examined and the risk level for work items in building construction activities in terms of likelihood, frequency and severity where determined using Mean Item Score (MIS). The MIS is calculated by averaging the responses provided by respondents to a series of inquiries that are scale-linked. In order to analyse the respondents' background profiles and the organization's occupational health and safety practises, the MIS technique was employed. MIS have been used in earlier studies such as (Smallwood, 2011; Smallwood and Emuze, 2014 and Jimoh *et al*., 2017). Based on a Likert scale of 5-point, the MIS and standard deviation were used to order the potential hazards in building construction projects in order of their risk; 1-Very Low Risk, 2- Low Risk, 3-Moderate Risk, 4- High Risk, and 5-Very High Risk (see Appendix A). MIS was used to rank each task in building construction projects according to its level of risk on a Likert scale: of 5-point. For severity: 1 - noticeable, 2 - important, 3 - serious, 4- very serious, and 5 - disaster. And for likelihood; 1- rare, 2- remote, 3- occasional, 4-frequent and 5- almost. The following formula was used to calculate the MIS for each of the variables in the research instrument:

$$\frac{5n^5+4n^4+3n^3+2n^2+1n^1}{n^5+n^4+n^3+n^2+n^1} \qquad 3.4$$

Where: n^1= the number of survey participants that selected Very Low risk or Noticeable or Conceivable.

n^2= the number of survey participants that selected Low risk or Important or Remote.

n^3= the number of survey participants that selected Moderate risk or Serious or Unusual but possible

n^4= the number of survey participants that selected High risk or Very serious or Quite possible

n^5= the number of survey participants that selected Very High risk or Disaster or Might well be expected

Table 3.3 gives description of the 5 point Likert scale and the related variables

Table 3.3 Description of 5 point Likert scale and related variables

Hazard	Severity	Likelihood	Exposure	Variable
Very Low risk	Noticeable	Conceivable	Rare	n1
Low risk	Important	Remote	Unusual	n2
Moderate risk	Serious	Unusual but possible	Occasional	n3
High risk	Very serious	Quite possible	Frequent	n4
Very High risk	Disaster	Might well be expected	Continuous	n5

Source: Researchers compilation (2022)

The decision rule used to assess the level of health and safety risk is presented in Table 3.4. Reference should be made to section 2.4.1.5, (risk score of Fine-Kinney method) and Table 2.6 (risk scale of Fine-Kinney method) for decision rule for Fine-Kinney technique.

Table 3.4 Decision rule and ranking of the level of safety risk

Scale	Cut-off point/ Mean score	Decision/Remark	Risk score Fine-Kinney	Decision/Remark
1	1.0-1.49	Very Low risk	R<20	Risk
2	1.50-2.49	Low risk	20<R<70	Possible risk
3	2.50- 3.49	Moderate risk	70<R<200	Substantial risk
4	3.50- 4.49	High risk	200<R<400	High risk
5	4.50-5.00	Very High risk	R>400	Very high risk

Source: Adapted and modified from Kinney and Wiruth (1976); Morenikeji (2006); Jimoh *et al*. (2017).

3.9.2 Inferential statistics

These are mathematical techniques that uses probability theory for determining (inferring) the characteristics of a population from the enquiry of those of a data sample taken from it. In this research, correlation and simple regression analysis were the types of inferential statistics used.

3.9.2.1 *Correlation analysis*

A statistical technique known as correlational analysis determines the types of relationships that exist between the research variables and assesses the strength as well as significance of the association between two variables. These relationships can be either positive or negative, or they can simply not exist (Hair *et al*., 2010). A correlation coefficient that runs from +1 to -1, where +1 denotes a perfect positive association, 0 denotes no relationship, and -1 denotes a perfect negative association, is used to quantify this relationship. According to Hair *et al*. (2010), correlational analysis is a useful confirmatory statistical approach that aids in the creation of a regression model. In this study, Pearson correlation analysis was used to determine the constructs' level of variability.

3.9.2.2 *Regression analysis*

Regression analysis is an improved form of correlational analysis, is a statistical method which assesses how an independent variable's actions affect a dependent variable's behaviour within a research construct. It is equally applicable to multiple independent and dependent variables. There are two types of regression analysis: multiple and linear. A relationship between two variables in which the actions of one variable affect the actions of the other is measured using linear regression.

Simple regression analysis was used in this research work to examine the research hypotheses, because it offers a certain amount of control in examining the predictive power of the model and its validation. The impact of independent variables on dependent variables was quantified by the R^2 coefficient of determination, which has a range of zero to +1. This was utilised to calculate the cost of safety in the building construction project for objectives 3 and 4. Two linear regression variables was employed in this study as expressed mathematically.

$$Y = \text{a} + \text{bX} \quad 3.5$$

Where: Y = dependent variable, a = intercept, X = independent variable, b = coefficient of x

The share of safety expenses in overall project cost Y for each project is called the residual which is the error in prediction and may be expressed as

$$Residual = Y - \bar{Y} \quad 3.6$$

In the equation above, the expression for a and b are as follows:

$$a = Y - b\bar{X} \quad 3.7$$

$$b = \frac{\sum(X-\bar{X})(Y-\bar{Y})}{\sum(X-\bar{X})^2} \quad 3.8$$

Where $\bar{X}$ and $\bar{Y}$ are the arithmetic means of the X and Y variables respectively

From the study, Y represents the percentage of safety expenses in overall project cost and X is the construction area or Gross Floor Area (GFA) as well as the project duration.

3.9.2.3 Preliminary tests of data suitability for linear regression modelling

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).
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 (International Business Machine (IBM, 2011).

a. Variables normality

Identifying the normality of a dataset can be done by first determining how skewed a distribution is. The asymmetry of a distribution is measured by skewness. The normal distribution has a skewness value of zero, which is symmetric about the mean. Skewness with a strong positive distribution shows a long tail right ward, while skewness with a strong negative distribution shows a long tail left ward. When a distribution's skewness value exceeds twice the skewness standard error, the distribution is normally accepted as asymmetrical.

Kurtosis is a measurement of how closely observations cluster around a central point and is used as a second measure of a distribution's shape. When a distribution has a normal shape, the kurtosis statistic has a value of 0.

The Shapiro-Wilk test of normality was used to conduct a further analysis of the variables' normality that were included in the modelling of safety cost. This test was preferred over the Kolmogorov-Smirnov test because of its specific applicability to small samples of less than 50.

b. Variables linearity

Using the help of scatter plots, the study investigated the linearity assumption regarding the relationship between the variables. The detection of outliers, unexpected findings, and significant cases can all be accomplished with the aid of scatter plots. A single point on a graph is noted for the respective observation from the sets of variable under investigation.

c. Variances equality

Box plots (also known as box and whisker plots) aids in summarizing the distribution of one or more numerical variables and assist researchers visualize distributions as well as dispersion by representing the changeability of the measure being revealed. The various parts of a box plot provide information on up to five statistical measures of both central tendency and dispersion.

d. Variables independence

Computing the correlation coefficient (r) between pairs of the variables in this study is a good starting point when determining whether or not they are independent of one another. Correlations quantify the relationship between different variables or rank orders. Before computing the correlation coefficient, it is wise to filter the data for outliers, which are numbers that are exceptionally large or tiny in comparison to the rest of the data. Outliers might lead to inaccurate conclusions. The Pearson's correlation coefficient is a measure of linear relationship that employs symmetric quantitative variables and can be used to demonstrate a linear relationship. However, there was a need to determine if one of the independent variables was a linear function of the other. Collinearity is the name given to this unwanted circumstance.

3.10 Pilot Study

It is a normal practice to experiment the instrument so as to evaluate its soundness and consistency and the accuracy of the information it gathers. The researcher's supervisory committee guided the researcher in refining the questions and ensured that the instrument was well tested. The pilot survey was conducted by distributing questionnaire to 30 professionals (Architect, Quantity Surveyor, Builder and Civil

Engineer) with ongoing or completed construction projects within the study area. All comments and suggestions from the pilot study were carefully evaluated before the construction of the final questionnaire for administration. The pilot study respondents equally participated in the main survey and also the results from the pilot study served as part of the final result from the main data obtained afterwards. A pilot study was conducted after confirming the full coverage of the research's objectives by the study's questions. This was to ensure that the questions in the questionnaire were clear, understandable as well as simple to complete

The project under research was in the same study region, and just two questions were modified as a result of the pilot survey, thus the combination of the replies from the survey were deemed appropriate. This suggests that the instrument used in both incidents was essentially the same. All of the surveys questionnaire were included in the analysis that was subsequently performed because they had all been sufficiently filled out. The safety risk hazard was defined for each work item and the appropriate PPE was identified for each work activity after the data from the pilot survey was analysed using basic percentile and mean scores. The result aided in the final preparation of the study questionnaire.

3.11 Validity of Variables

The extent to which a test can unswervingly measure anything is referred to as validity. Validity is necessary during all phases of the research, such as design, collection of data as well as analysis. Saunders *et al*. (2009); Creswell and Clark (2011); Vogt *et al*. (2012) classified validity test into four categories, as described in section 3.11.1 – 3.11.4.

3.11.1 External validity

External validity is interested with the drawing generalizable inferences out of observation of the research's discoveries, and the major criterion for selecting the population and samples for the study is the population's and samples' quality (Saunders *et al.*, 2009). The survey participants ensured that professionals in construction and Quantity surveyors who prepared bills of quantities for the QS firms in Abuja were chosen to provide the relevant information for the study.

3.11.2 Internal validity

Internal validity is the capacity of the data and study methods to successfully discourse the questions in the research. The internal validity is appropriate to both causal and explanatory research (Yin, 2003). With careful consideration of pertinent hypotheses and the creation of an appropriate study design, internal validity was ensured. In designing the research an appropriate methodology was adopted which achieved the specified objectives.

3.11.3 Validity of construct

Construct validity is involves the coding of data, which assesses how accurately and suitably the concepts operationalized in the instruments for the collection of data are answering the questions of the research (Saunders *et al.*, 2009). In the current study, pilot study of questionnaire and results validation from the sampled quantity surveying firms were the steps engaged in ensuring validity of the construct. The pilot study allowed for thorough assessment of the validity of the questions asked, and disclosed any ambiguity in the questions before distributing to more of the respondents.

3.11.4 Evidence inference validity

Validity of evidence-inference procedures depends on how well-suited the data analysis methods utilised in the study are and how much they contribute to trustworthy interpretations of the findings (Creswell and Clark, 2011). The data collection and analysis methodologies in the current study were chosen carefully in order to achieve evidence-inference validity, also known as reliability. Validation was also done using a logarithmic curve to validate the model for the study.

3.11.5 Validation tools used for the study

There are several statistical measures of the error level; of these, the three that were employed in the study include the Mean Absolute Percentage Deviation (MAPD), also known as the Mean Absolute Percent Error (MAPE), the Mean Squared Error (MSE), and the Mean Absolute Error (MAE).

3.11.5.1 *Mean absolute percentage deviation (MAPD)*

The Mean Absolute Percentage Deviation (MAPD) can be determined using the following formula:

$$MAPD = \sum ni = \{\frac{(Actual - Predicted)}{Actual} / n\} \times 100 \quad 3.9$$

Where "Actual" refers to the values of the actual data observed, and "Predicted" refers to the values of the predicted data, and "n" is the overall number of cases available for validation. MAPD is the indicator that is most suitable to quantify relative error when the data used to generate the model (pre-processed data and raw data) are not the same scales (Azadeh *et al*., 2011).

3.11.5.2 *Mean square error (MSE)*

The Mean Squared Error (MSE) was calculated with the following formulae:

$$MSE = \left(1/_{n}\right) \times \sum i\,(xi + yi)^2 \qquad 3.10$$

Where "n" is the total number of instances available for validation, "x" is the estimated value of the dependent variable and "y" is the value observed for the dependent variable.

By compelling the square of each difference, both positive and negative differences contributes equally to the final value, it is plausible to say that the model is more accurate if the MSE value is smaller.

3.11.5.3 *Mean absolute error (MAE)*

The Mean Absolute Error (MAE) measures the absolute differences between observed and predicted values rather than squaring them, is another method for evaluating the accuracy of a prediction:

$$MAE = \left(1/_{n}\right) \times \sum i\;(\mathrm{xi} - \mathrm{yi}) \qquad 3.11$$

Although there are several areas in which these measures may be compared, the most important is usually how affected an error measure is by outliers in the data. The MSE is sensitive to outliers, and tend to punish larger errors more than smaller errors; smaller values indicate better models. MAE treats larger and smaller errors equally, is not sensitive to outliers and a small value indicates a better model. The R^2 or R Squared (coefficient of determination) is not sensitive to outliers, and the nearer the value is to 1, the better the model.

This study adopted the MSE as the preferred measure of the error in the output of the developed regression models. The major purpose for this preference was the ease of application of the MSE; all the possible values of this error measure are usually positive. It is thus very easy to determine which model gives the smallest error. This removes the confusion that might at times be associated with determining which of several errors is the least, if such errors have different arithmetical signs.

3.12 Reliability

Reliability refers to how consistently a test can measure the subject matter under consideration or designed to assess. The most commonly used technique in evaluating internal consistency of an item sets, when a number of Likert scale is used in a survey where questionnaire is adopted is the Cronbach's alpha test. The following guideline was provided by George and Mallery (2003) in ranking the values: ">0.9 - Excellent, >0.8 - Good, >0.7 - Acceptable, >0.6 - Questionable, >0.5 - Bad, and 0.5 - Unacceptable.

It is suggested to eliminate one variable from the sample list of survey questions if the Cronbach Alpha value is lower than 0.7, then the significance or changes could be observed. For instance, it means that a variable should be dropped from the construct if the Cronbach Alpha value rose and above 0.7 following the deletion of one of the variables. This study conducted the Cronbach Alpha test to evaluate the precision of the quantitative data. The results of the test is presented in Table 3.5.

Table 3.5: Reliability Test for the measured variables

Measured Constructs	Cronbach's Alpha
Potential hazard in construction project	0.806
Risky work item in construction project	0.918
Severity of work item	0.958
Likelihood of work item	0.989

Source: Researcher’s Analysis (2022)

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Analysis of Respondents' Demographics

The basic information relating to the background of the respondents in terms of educational qualification, professional qualification, membership of professional institutions, working experience and size of workforce are presented in Table 4.1. From the information presented in Table 4.1 in terms of respondent's education qualification, result shows that 62.5% of the respondents which was more than half of the respondents possessed either HND (Higher National Diplomas) or B.Sc/B.Tech (Bachelor of Science/Bachelor of Technology) degrees in various construction disciplines. A further 8 respondents (20%) had obtained MSc/MTech (Master of Science/Master of Technology) degrees; 3 respondents (7.5%) qualifications was not specified in the questionnaire, and was categorised as others. Only 2 respondents (5% of the sample), held only ND (National Diploma) while a further 2 respondents had obtained PhD (Doctor of Philosophy) degrees. These results show that all of the respondents have undergone courses of instruction in various disciplines related to the construction industry. This increases the likelihood of obtaining data that will be appropriate for the study from these respondents.

In relation to the profession of the respondents the data analysed and presented in Table 4.1, showed that the study was skewed towards the Quantity Surveying profession. This was because 29 respondents (72.5% of the sample) were Quantity Surveyors, 5 respondents (12.5%) were Civil Engineers, and 3 respondents (7.5%) were Architects and Builder respectively. The large number of Quantity Surveyors was necessary, because the data was sourced from QS firms. However, it should be noted that among the professionals sampled, some are members of Institute of Safety Professionals of Nigeria (ISPON).

Table 4.1: Respondents' Demographics

Parameter	Frequency	Percent (%)
Academic Qualification		
ND	2	5.0
HND/BTech/BSC	25	62.5
MTech/MSc	8	20.0
PhD	2	5.0
Others	3	7.5
Total	40	100.0
Profession		
Quantity surveyor	29	72.5
Builder	3	7.5
Engineer	5	12.5
Architect	3	7.5
Total	40	100.0
Professional Membership		
MNIQS	24	60.0
FNIQS	5	12.5
MNIOB	3	7.5
MNSE	5	12.5
MNIA	3	7.5
Total	40	100.0
Experience of worker		
<5years	5	12.5
5-9 years	13	32.5
10-14 years	11	27.5
15-19 years	5	12.5
Above 20 years	6	15.0
Total	*40*	*100.0*
Size of workforce		
1- 49	28	70.0
50-249	*6*	*15.0*
250 and above	*6*	*15.0*
Total	*40*	*100.0*

Source: Author's fieldwork (2022)

Results relating to membership of professional associations revealed that of the 40 respondents in the total sample, 29 respondent (72.5%) were members registered with the Nigerian Institute of Quantity Surveyors (NIQS), while 5 respondent (12.5%) were registered members of Nigeria Society of Engineers (NSE). In addition, 3 respondent (7.5%) each was a registered member of the Nigeria Institute of Architects (NIA) and

Nigeria Institute of Building (NIOB) respectively. These results, which are presented in Table 4.1, provide an indication of the competence of the respondents for the study based on professional qualifications.

The final subsection of Table 4.1 contained results relating to the respondent’s work experience which signifies the familiarity and the proficiency developed in carrying out tasks in construction, including health and safety tasks. It was found that 13 respondents (32.5%) had worked for 5-9 years, while there were 11 respondents who had worked for 10-14 years (27.5%). 6 respondents (15%) had work experience of more than 20 years, while those with less than 5 years’ experience were 5 in number and made up 12.5% of the sample. This is an indication that the respondent responses could be considered experienced as they should have the necessary knowledge of health and safety. In terms of workforce, 28 respondents (70% of the sample) were from organisations that had between 1 and 49 employees, while 6 respondents (15%) worked with organizations that employed between 50 and 249; the balance of 6 respondents (15%) worked with organizations that employed more than 250 workers.

4.2 Analysis of Occupational Safety and Health Practices of Respondents

The basic information relating to the organizations health and safety practices that were surveyed is presented in this section, such as the type of costing system adopted for Occupational Safety and Health Management Systems **(**OSHMSs). All of the results relating to these organizational demographics are presented in Table 4.2.

In terms of costing system employed result revealed that the traditional and job costing systems were the most used types of costing for health and safety with 32.5% and 25% of the respondents respectively. Insurance and activity-based costing shared third position, being employed by 5 respondents each (12.5% each). This result revealed the low level of use of activity-based costing for construction projects.

Table 4.2: Costing System adopted by Respondents' Organisations

Type of costing system adopted for health and safety	Frequency	Percent (%)
Insurance	5	12.5
Traditional costing	13	32.5
Job costing	10	25.0
Activity-based costing	5	12.5
Others	7	17.5
Total	40	100

Source: Author's fieldwork (2022)

4.2.1 Items included in occupational health and safety management systems (OHSMSs)

The result in Table 4.3 represents the items included in OHSMSs of projects that respondents' had worked on. In summary, it was found that only 20 (50%) of respondents' projects had safety officers included in their OHSM system; 21 respondents (52.5% of the sample) worked with project that have a written Health and Safety Policy, while 13 (32.5%) respondents projects have an Accident Reporting System in their organisations.

In terms of Safety Audit, only 8 respondents (20.0%) reported their organisation as having a Safety Audit included in their OHSM system. Only 11 respondents (27.5% of the sample) worked with organizations that carry out Document Risk Assessment while Insurance cover for sites is provided in the OHSM system of 23 respondents' organisations (57.5%).

Table 4.3: Items included in OHSMSs in organisation

OHSMs items provided	Frequency	%
Safety Officer	20	50.0
Written Health & Safety Policy	21	52.5
Accident Reporting System	13	32.5
Safety Audit	8	20.0
Document Risk Assessment	11	27.5
Insurance cover for sites	23	57.5

Source: Author’s fieldwork (2022)

4.2.2 Contract documents where health and safety costs are assigned

Table 4.4 presents the result, on the identification of the section of contract documents where the costs of health and safety are assigned. Result revealed that almost all the H&S costs items are domiciled in the Preliminaries section of the BOQ. Specifically, Health and safety manager/officer costs are assigned to the preliminaries section of the bill of quantities by 33 out of 40 respondents; the same method of assignment is employed for ‘Safety Audit by External Consultant’ by 21 respondents; for ‘Staff Safety Training’ by 32 respondents; and for ‘Site Safety Incentive scheme’ by 26 respondents.

Furthermore, costs associated with ‘First Aid’ are assigned to the preliminaries section of the BOQ by 35 respondents; costs associated with ‘Personal Protective Equipment (PPE)’ are assigned to the preliminaries section of the BOQ by 34 respondents. While 24 respondents assign costs associated with ‘Fire points (temporary Alarm)’ to the preliminaries section of the BOQ. The pattern remained unchanged for Fire Extinguisher; Statutory Safety Signage/Promotion 28; Nurse 20; Traffic Marshals 25; Mobile Clinic 14; and Insurance of Workers 30. It can be deduced that adequate provision is made in the contract document for health and safety especially in the preliminary section of the BOQ.

Table 4.4: Section of contract documents where Health and Safety costs are assigned

Location of H&S cost in contract document	Preliminaries	Body of BOQ	Contingency	Total
Health &Safety manager/officer	33	4	0	37
Safety Audit by External Consultant	21	9	1	31
Staff Safety Training	32	4	1	37
Site Safety Incentive scheme	26	4	1	31
First Aid	35	3	2	40
Personal Protective Equipment (PPE)	34	3	2	39
Fire points (temporary Alarm)	24	7	2	33
Fire Extinguisher	28	7	2	37
Statutory Safety Signage/ Promotion	27	7	0	34
Nurse	20	10	2	32
Traffic Marshals	25	7	0	32
Mobile Clinic	14	12	1	27
Insurance of Workers	30	4	0	34

Source: Author's fieldwork (2022)

Notes: n = 40; some total values are less than 40 owing to non-response to this section of the research questionnaire by some respondents.

4.2.3 Type of pricing system used for costing health and safety programme

The type of pricing system used by respondents' organisation for costing health and safety programmes was determined. Table 4.5 shows the results which discloses that in almost all items of Health and Safety are priced using the 'lump sum' approach. Health and Safety Manager/officer' were priced using the 'lump sum' approach by 21 respondents; 12 respondents utilize the percentage method. With respect to 'Safety audit by external consultant', 13 respondents use lump sum approach; 9 respondents utilize the percentage method.

This pattern of pricing was maintained for the rest of the eleven (11) items of health and safety cost; in each case, lump sum pricing was preferred to percentage pricing or detailed calculation of the cost of individual activities. Thus the 'lump sum' approach was employed by 22 respondents for 'Staff Safety training'; 20 respondents for 'Site

Safety incentive scheme'; 24 respondents for 'First Aid', and 19 respondents for 'PPE'. In respect to other health and safety items, the 'lump sum' approach was employed by 18 respondents for 'Fire points (temporary Alarm)'; 23 respondents for 'Fire Extinguisher'; 19 respondents for 'Statutory Safety Signage/ Promotion'; 16 respondents for 'Nurse'; 13 respondents for Traffic Marshals; 15 respondents for Mobile Clinic; and 16 respondents for Insurance of Workers. It can be inferred that adequate provision for health and safety are made by respondents' organisations and the firms are suitable for this study.

Table 4.5: Type of Pricing System used for Costing Health and Safety Programme in the Contract Document

Type of pricing	Percentage method	Lump sum method	Total
Health &Safety manager/officer	12	21	33
Safety Audit by External Consultant	9	13	22
Training of safety staff	8	22	30
Incentive scheme for safety on site	8	20	28
First Aid	10	24	34
Personal Protective Equipment (PPE)	14	19	33
Fire points (temporary Alarm)	8	18	26
Fire Extinguisher	9	23	32
Statutory Safety Signage/ Promotion	11	19	30
Nurse	8	16	24
Traffic Marshals	10	13	23
Mobile Clinic	7	15	22
Insurance of Workers	12	16	28

Source: Author's fieldwork (2022)

Notes: n = 40; some total values are less than 40 owing to non-response to this section of the research questionnaire by some respondents.

4.3 Identification of Potential Hazards in Building Projects

In achieving objective one of the study, the mean score analysis was employed in the analysis of data, which generated a weighted ranking of the various hazards encountered in building construction projects.

4.3.1 Determination of potential hazards in building construction projects

Eighteen potential hazards were identified in the study from literature as shown in section 2.2.12. The result of the weighting of these potential hazards by the surveyed respondents were achieved by adopting a 5 point Likert scale questionnaire as presented in Table 4.6. The study found that 'falls from height' was ranked as the highest potential safety hazard with a mean score of 4.46, which could be interpreted as 'High risk'. This result is in agreement with Gurcanli and Mungen (2009); Gurcanli and Mungen (2013); Bilir and Gurcanli (2016); Williams *et al*. (2017); Okoye (2018); Yilmaz and Basaga (2018) Abas and Blismas (2021); Topal and Atasoylu (2022) who acknowledged that the main cause of death on sites was fall from high level. 'Building structure collapse' was ranked as the second highest potential safety hazard with a mean score of 4.39. This result agrees with the position of Gurcanli and Mungen (2013); Bilir and Gurcanli (2018); Yao *et al*. (2018); Liang *et al*. (2021) affirmed building structure collapse as a high risk hazard in construction. The third highest potential safety hazard was identified as workers being 'struck by falling objects', which had a mean score of 4.25. This is in consonance with the findings of Memarian and Mitropoulos (2013); Gurcanli *et al.* (2015); Choi (2015); Ghousi *et al*. (2018); Mon (2020); Topal and Atasoylu (2022) who confirmed that collapse of building structure is a major cause of accident on construction site.

The fourth highest potential safety hazard was identified as workers being electrocuted or having contact with electricity with a mean score of 4.15. The study's findings agrees with Williams *et al*. (2017); Yao *et al*. (2018); Topal and Atasoylu (2022) who affirmed that electrocution is a hazard with high risk on site. The lowest ranked potential hazards were 'fall to lower level' (mean score 3.19); 'noise' (mean score 2.97) and 'fall to the same level/slip trip' (mean score 2.82).

Table 4.6: Summary of potential hazards in building construction projects

S/N	Potential Hazard	Mean Score n=40	Standard Deviation	Rank	Interpretation
1	Fall from height	4.46	1.02	1	High risk
2	Building/structure collapse	4.39	1.17	2	High risk
3	Struck by falling objects	4.25	1.22	3	High risk
4	Contact with electricity	4.15	0.93	4	High risk
5	Equipment accidents	4.10	1.01	5	High risk
6	Exposure to harmful substance	4.05	0.88	6	High risk
7	Collapse of underground cavities /pits	3.83	1.17	7	High risk
8	Struck by moving vehicles	3.80	1.22	8	High risk
9	Contact with underground lines	3.77	1.13	9	High risk
10	Fire	3.70	1.20	10	High risk
11	Manual handling of machine/tool hazards	3.68	1.12	11	High risk
12	Cave –ins / Trench collapses	3.46	1.12	12	Moderate risk
13	Traffic accident	3.40	0.98	13	Moderate risk
14	Caught in between objects/mat	3.30	0.99	14	Moderate risk
15	Overexertion	3.21	1.04	15	Moderate risk
16	Fall to lower level	3.19	1.04	16	Moderate risk
17	Noise	2.97	1.14	17	Moderate risk
18	Fall to the same level/ Slip trip	2.82	0.88	18	Moderate risk

Source: Author's fieldwork (2022)

The main areas of difference centred on the ranking of critical hazards. While in this study the highest ranked hazard was 'falls from height', in earlier studies such as (Choi (2015); Ghousi *et al.* (2018), the highest ranked critical hazard on construction project sites was struck against an object which was ranked third in this study. Likewise, among the least potential hazard was fall to the same level or slip/trip this result was in contradiction with Memarian and Mitropoulos (2013); Pellicer *et al*. (2014); Udo *et al*. (2016) who ranked fall to the same level or slip/trip as one of the top high risk hazard on site. One reason why this difference in ranking of most critical hazard manifested might be that some of the studies concentrated on a single work item instead of combining all work items, Hallowell and Gambatese (2009); Gurcanli *et al.* (2015) concentrated on concrete work, Bilir and Gurcanli (2018) concentrated on excavation work. Such difference in ranking of most critical hazard would have serious implication for the design of accident mitigation strategies, since such mitigation measures must be crafted to fit each type of hazard that can lead to accidents.

4.4 Assessment of Risk Level for Work Items in Building Projects

The analysis of data concerned with achieving Objective two of this study is reported in this section. The mean score analysis was utilised in the analysis of the data, which generated a weighted ranking for severity, likelihood and frequency of various hazards encountered in construction projects. These weightings were then combined to obtain the level of potential risk present in each work item. The Fine-Kinney approach was employed in carrying out the risk assessment.

4.4.1 Determination of level of risk in work items using Fine-Kinney approach

The Fine-Kinney technique for assessing the level of risk uses three metrics – these are the likelihood (probability), frequency (exposure) and severity (consequence) of the hazard under consideration. Table 4.7 present the weighting factors employed for this study.

Table 4.7 Fine Kinney scale of likelihood, severity and exposure (frequency)

Likert scale	Likelihood	Value	Severity	Value	Frequency	Value
5	Might well be expected	10	Disaster	40	Continuous	10
4	Quite possible	6	Very serious	15	Frequent (daily)	6
3	Unusual but possible	3	Serious	7	Occasional (weekly)	3
2	Only remotely possible	1	Important	3	Unusual (monthly)	2
1	Conceivable but very unlikely	0.5	Noticeable	1	Rare (a few year per year)	1

Sources: Adapted and modified from Kinney and Wiruth (1976)

Data as presented in this section that has to do with the weightings of the likelihood or probability (Table 4.13a), severity (Table 4.13b) and frequency (also called 'exposure', in Table 4.13c and 4.13d), of the hazards indicated at the extreme left column on the tables. Drawing from respondents' knowledge, competence and experience of the respondents, the study was able to generate weightings of hazard likelihood and severity for the different work activities in building projects.

The frequency (also called 'exposure') of hazards, were generated in a completely different manner. Since by definition, frequency in the Fine-Kinney technique refers to the length of time period during which workers are exposed to a particular hazard, data on frequency of hazards had to be obtained from the construction work programmes of the various projects that were sampled in this study. An intermediate challenge arose from the discovery that construction work programmes were not available for all 40 projects. Section 4.4.1.1 detailed the result of the approach adopted to overcome this temporary obstacle.

4.4.1.1 *Result on the computation of level of exposure of workers to safety risk hazards under the Fine-Kinney approach*

The frequency ('exposure') of hazards was generated using the methodology described in Figure 3.1, which was based on a pragmatic approach to research. Result of the different steps involved in the derivation of frequency of hazards under the Fine-Kinney technique, as described in Figure 3.1, is provided in the following Table 4.8a, 4.8b and 4.8c; Table 4.24a and 4.11b; Table 4.12a and 4.12b.

Table 4.8a, 4.8b and 4.8c presents result on data extraction of work quantities from bills of quantities (BOQs). The Microsoft Excel spreadsheet contained 44 columns. The first three columns contained details of the WBS section, subsection and work items; the fourth column contained the units in which the work items were measured. The rest 40 columns contained the quantities of work that were extracted from BOQs; owing to the size of the spreadsheet however, the contents had to be displayed in three tables in order for it to fit into A4 size paper. These were the tables numbered as Table 4.8a, 4.8b and 4.8c.

A final point that needs to be made here has to do with the particular work items selected for inclusion in the spreadsheet. Although it would have been desirable for this study to cover all of the work items in the WBS of a typical building project the practical realities dictated otherwise. This was because not all of the 40 projects employed in this study had the same arrangement of works in their BOQs. The decision thus had to be made to use only work items that were more generally available across the entire sample of 40 projects; this was why the data extraction focussed on substructure, superstructure (frames), walls (masonry), roof, finishing and painting. Subsequent fine-tuning of these work sections resulted in the adoption of only five sections – excavation, reinforced concrete work, masonry, roof work, and finishing.

Table 4.8a: Work quantities extracted from BOQs of 40 projects used for analysis (Project Nos. 1 – 13)

WBS Section	WBS Sub-section	WBS Work Items	Unit	P.1	P.2	P.3	P.4	P.5	P.6	P.7	P.8	P.9	P.10	P.11	P.12	P.13
SUBSTRUCTURE	Excavation and Filling	Trench exc.		474	452	994	1160	601	3220	4531	1107	2496	971	4790	1326	15908
		Laterite filling		91	66	141	311	228	377	344	149	131	587	434	272	327
		Hardcore		46	132	471	104	117	100	588	149	91	242	217	907	627
SUPER STRUCTURE	Frames	Concrete work		230	11	56	115	154	171	425	90	224	10	1743	83	665
		Reinforcement		41280	2750	10913	28750	19940	40583	83200	12055	49432	2020	348000	12475	133000
		Formwork		1997	153	744	1813	1736	2264	4515	872	1456	182	17483	1024	7356
EXTERNAL & INTERNAL WALL (MASONRY)	Concrete work	Concrete work		25	5	13	48	22	67	45	13	36	12	72	17	9
		Reinforcement		3300	802	1675	7200	2430	4037	4300	1560	4306	1450	6840	2227	1350
		Formwork		467	42	172	545	298	598	555	246	421	158	626	224	114
	Blockwork	Blockwork		1969	584	1527	2675	2799	5086	5511	1323	4852	1724	11055	3020	1562
ROOF	Covering	Roof covering		498	394	739	965	621	1255	2682	692	839	919	1420	1272	1695
FINISHING	Floor	Screeding		1998		895		1084	2153	1406	1235	2416	1817	14329	1568	8221
		Tiling		1442	275	895	1490	915	2472	1548	342	2416	838	13034	1568	369
	Wall	Rendering		5099	1491	4405	5005	5567	9370	14373	2616	6648	3437	34457	6124	5603
		Tiling		1213	868	711	630	615	926	809	649	1121	480	4882	949	385
PAINTING DECORATION		Emulsion		2811	1491	2207	4358	4615	7267	11770	2017	9579	2158	21516	3293	5416

Source: Author's fieldwork (2022)

Notes: n (number of sampled projects) = 40; P.1, P.2, P.3….P.40 represent code numbers of the 40 projects that were sampled.

Table 4.8b: Work quantities extracted from BOQs of 40 projects used for analysis (Project Nos. 14 – 26)

WBS Section	WBS Sub-section	WBS Work Items	Unit	P.14	P.15	P.16	P.17	P.18	P.19	P.20	P.21	P.22	P.23	P.24	P.25	P.26
SUBSTRUCTURE	Excavation and Filling	Trench exc.		1057	2132	1170	2030	6616	3742	1640	1307	1402	2538	1293	2556	1886
		Laterite filling		614	318	753	286	387	876	745	846	449	492	1031	502	513
		Hardcore		279	624	313	953	194		196	353	1445	492	430	502	1711
SUPER STRUCTURE	Frames	Concrete work		12	172	13	140	477	209	72	14	24	641	13	544	173
		Reinforcement		2070	23974	2410	29940	95000	23992	17390	2590	5119	128000	1590	62000	30859
		Formwork		202	1905	222	1406	4555	1143	869	240	400	5367	221	5529	2401
EXTERNAL & INTERNAL WALL (MASONRY)	Concrete work	Concrete work		10	24	10	21	39	41	20	11	15	52	12	113	54
		Reinforcement		1240	2984	1170	2728	5850	5273	3030	1240	1871	7800	1490	11000	7015
		Formwork		134	283	126	278	501	574	284	88	191	568	160	1233	700
	Blockwork	Blockwork		1888	3633	1559	2725	5315	5441	2902	1395	1622	5615	1865	6326	5606
ROOF	Covering	Roof covering		1033	1410	957	1542	784	2680	1985	2113	2238	1739	1735	1816	2476
FINISHING	FLOOR	Screeding		1021	3213	885	2390	5346	2271	2399	1275	1620	7154	1355	5275	3642
		Tiling		922	3741	1339	2390	4512	1282	2523	1164	1620	6076	1228	5504	3642
	Wall	Rendering		3761	8812	2623	5358	21283	10027	5796	3809	4668	8068	4156	19078	12475
		Tiling		510	468	981	823	2076	1784	995	559	443	896	722	2357	1171
PAINTING& DECORATION		Emulsion		2443	8389	1615	2714	9661	8243	4588	2309	2892	5195	2289	17117	8357

Source: Author's fieldwork (2022)

Notes: n (number of sampled projects) = 40; P.1, P.2, P.3….P.40 represent code numbers of the 40 projects that were sampled.

Table 4.8c: Work quantities extracted from BOQs of 40 projects used for analysis (Project Nos. 27 – 40)

WBS Section	WBS Sub-section	WBS Work Items	Unit	P.27	P.28	P.29	P.30	P.31	P.32	P.33	P.34	P.35	P.36	P.37	P.38	P.39	P.40
SUBSTRUCTURE	Excavation and Filling	Trench exc.		3401	2340	2340	2340	2340	2340	2340	4401	18444	3269	5872	12598	18921	4515
		Laterite		1670	542	542	542	542	542	542	957	2,596	787	768	2083	4116	1300
		Hardcore		1758	271	271	271	271	271	271	957	3,388	787	3036	3472	4116	
SUPER STRUCTURE	Frames	Concrete		358	137	137	137	137	137	137	365	629	1048	514	419	1932	310
		Reinforcemen		94632	27072	27072	27072	27072	27072	27072	91000	134788	157200	110146	93649	483000	77000
		Formwork		4280	1996	1996	1996	1996	1996	1996	2818	6818	9944	7080	5006	12116	4184
EXTERNAL & INTERNAL WALL (MASONRY)	Concrete work	Concrete		46	44	44	44	44	44	44	26	69	137	62	72	304	76
		Reinforcemen		6606	5391	5391	5391	5391	5391	5391	10000	9473	17808	8312	9605	7600	12000
		Formwork		633	615	615	615	615	615	615	186	912	1496	812	934	4106	770
	Blockwork	Blockwork		7515	5846	5846	5846	5846	5846	5846	2850	9360	11393	8122	11816	26679	10277
ROOF	Covering	Roof		1884	2188	2188	2188	2188	2188	2188	1539	4102	2987	3908	4625	6616	2147
FINISHING	FLOOR	Screeding		4720	3552	3552	3552	3552	3552	3552	1725	6266	9870	6745	8706	14700	5235
		Tiling		4720	3929	3929	3929	3929	3929	3929	2591	6266	3384	6745	8706	15547	5738
	Wall	Rendering		14870	10425	10425	10425	10425	10425	10425	4216	20878	18967	13490	27871	58425	14905
		Tiling		4622	2522	2522	2522	2522	2522	2522	527	2468	1457	1,613	3154	4180	1682
PAINTING& DECORATION		Emulsion		9938	10215	10215	10215	10215	10215	10215	1996	11593	13991	9277	15340	3243	1081

Source: Author's fieldwork (2022)

Notes: n (number of sampled projects) = 40; P.1, P.2, P.3….P.40 represent code numbers of the 40 projects that were sampled.

Table 4.9 presents result on the generation of work durations using conventional man-hour statistics. Output constants were obtained from the Nigerian Institute of Quantity Surveyors databank and construction price book publications and data was used to generate results.

Table 4.9: Man-hour statistics for computing hazard exposure under Fine-Kinney approach

WBS Section	WBS Sub-section	WBS Work Items	Units	Period	Output/ Man/Day	Output/Man/ Hour	Man/Hour
1	2	3	4	5	6	7	8
SUBSTRUCTURE	Excavation and Filling	Trench exc.	M^3	Day	14.40	1.80	0.56
		Laterite filling	M^3	Day	16.80	2.10	0.48
		Hardcore	M^3	Day	16.80	2.10	0.48
	Concrete work	Concrete work	M^3	Day	28.80	3.60	0.28
		Reinforcement	Kg	Day	240.00	30.00	0.03
		Formwork	M^2	Day	36.00	4.50	0.22
	Blockwork	Blockwork	M^2	Day	19.20	2.40	0.42
SUPER STRUCTURE	Frames	Concrete work	M^3	Day	28.80	3.60	0.28
		Reinforcement	Kg	Day	240.00	30.00	0.03
		Formwork	M^2	Day	36.00	4.50	0.22
MASONRY	Concrete work	Concrete work	M^3	Day	28.80	3.60	0.28
		Reinforcement	Kg	Day	240.00	30.00	0.03
		Formwork	M^2	Day	36.00	4.50	0.22
	Blockwork	Blockwork	M^2	Day	19.20	2.40	0.42
ROOF	Covering	Roof covering	M^2	Day	36.00	4.50	0.22
FINISHING	FLOOR	Screeding	M^2	Day	60.00	7.50	0.13
		Tiling	M^2	Day	24.00	3.00	0.33
	Wall	Rendering & Plastering	M^2	Day	43.20	5.40	0.19
		Tiling	M^2	Day	24.00	3.00	0.33
PAINTING& DECORATION		Emulsion	M^2	Day	72.00	9.00	0.11

Source: Author's compilation (2022)

Notes: Period=Working day of 8 hours; Output/Man/Day=Amount of work done by one worker in one work-day of 8 hours; Output/Man/Hour= Amount of work done by one worker in one work-hour; Man/Hour=Time taken by one worker to complete one unit of work (e.g. 1 M^2, 1 M^3, 1 Kg of work)

Table 4.10a and 4.10b presents the result of the period of time in days for a single worker to complete the quantity of work for all of the different work items. The output of the results from NIQS databank and Consol's Nigeria Building price book (Consol Associate, 2019) was utilized, which provided the estimated output and number of worker required for a day's job.

Table 4.10a: Work Programme duration for work items in projects 1 – 20)

WBS Section/ Sub-section	WBS Work Items	P.1	P.2	P.3	P.4	P.5	P.6	P.7	P.8	P.9	P.10	P.11	P.12	P.13	P.14	P.15	P.16	P.17	P.18	P.19	P.20
Substructure	Trench exc.	3	4	5	5	5	6	6	6	8	8	8	9	9	9	10	8	8	8	8	9
(Excavation &	Laterite filling	1	2	2	3	3	3	3	3	4	4	4	4	4	4	5	6	6	6	6	6
Filling)	Hardcore	2	3	3	3	4	4	4	4	5	6	6	6	6	6	7	4	4	4	4	5
Super Structure	Concrete work	4	6	7	8	8	9	9	9	11	13	13	13	13	13	15	15	16	16	16	17
(Frames)	Reinforcement	5	6	8	8	9	10	10	10	13	14	14	15	15	15	17	29	29	30	30	32
	Formwork	10	14	17	19	19	21	21	22	28	31	31	32	32	32	37	35	36	36	36	39
Masonry	Concrete work	1	1	2	2	2	2	2	2	3	3	3	3	3	3	3	1	1	1	1	1
(Concrete Work;	Reinforcement	1	2	2	3	3	3	3	3	4	4	4	4	4	4	5	3	3	3	3	3
Blockwork)	Formwork	1	2	2	3	3	3	3	3	4	4	4	4	4	4	5	3	3	3	3	3
	Blockwork	4	6	7	8	8	9	9	9	11	13	13	13	13	13	15	13	13	13	13	14
Roof (Covering)	Roof covering	2	3	4	4	4	5	5	5	6	7	7	7	7	7	8	4	4	4	4	4
Finishing	Screeding	5	7	9	9	10	11	11	11	14	15	16	16	16	16	19	6	6	6	6	6
(Floor;	Tiling	13	17	21	23	24	26	26	27	34	38	38	39	40	40	46	13	13	13	13	14
Wall)	Rendering	9	11	14	15	16	17	17	18	23	25	25	26	26	27	31	23	24	24	24	26
	Tiling	3	4	6	6	6	7	7	7	9	10	10	10	10	10	12	8	8	8	8	9
Painting& Decoration	Emulsion	7	9	12	13	13	14	15	15	19	21	21	22	22	22	25	18	18	18	18	20

Source: Author's fieldwork (2022)

Notes: n (number of sampled projects) = 40; P.1, P.2, P.3….P.40 represent code numbers of the 40 projects that were sampled.

Table 4.10b: Work Programme duration for work items in projects 21 – 40

WBS Section/ Sub-section	WBS Work Items	P.21	P.22	P.23	P.24	P.25	P.26	P.27	P.28	P.29	P.30	P.31	P.32	P.33	P.34	P.35	P.36	P.37	P.38	P.39	P.40
Substructure	Trench exc.	9	10	11	11	12	13	13	13	13	13	13	13	13	16	17	17	22	25	32	13
(Excavation &	Laterite filling	6	7	7	8	8	9	9	9	9	9	9	9	9	11	12	12	15	17	22	9
Filling)	Hardcore	5	5	5	6	6	6	7	7	7	7	7	7	7	8	8	9	11	12	16	7
Super Structure	Concrete work	17	20	20	21	23	24	25	25	25	25	25	25	25	30	32	32	40	47	60	24
(Frames)	Reinforcement	32	37	37	39	42	45	46	47	47	47	47	47	47	56	59	60	75	87	112	46
	Formwork	40	45	46	48	52	55	57	58	58	58	58	58	58	69	73	74	93	108	138	56
Masonry	Concrete work	1	1	1	1	2	2	2	2	2	2	2	2	2	2	2	2	3	3	4	2
(Concrete Work;	Reinforcement	3	4	4	4	5	5	5	5	5	5	5	5	5	6	6	6	8	9	12	5
Blockwork)	Formwork	3	3	3	4	4	4	4	4	4	4	4	4	4	5	5	5	7	8	10	4
	Blockwork	14	16	17	18	19	20	21	21	21	21	21	21	21	25	26	27	34	39	50	20
Roof (Covering)	Roof covering	4	5	5	5	5	6	6	6	6	6	6	6	6	7	7	7	9	11	14	6
Finishing	Screeding	6	7	7	8	8	9	9	9	9	9	9	9	9	11	12	12	15	17	22	9
(Floor;	Tiling	14	16	17	18	19	20	21	21	21	21	21	21	21	25	26	27	34	39	50	20
Wall)	Rendering	26	29	30	32	34	36	37	38	38	38	38	38	38	45	48	48	61	70	90	37
	Tiling	9	10	10	11	11	12	12	13	13	13	13	13	13	15	16	16	20	23	30	12
Painting& Decoration	Emulsion	20	23	23	25	27	28	29	29	29	29	29	29	29	35	37	37	47	55	70	29

Source: Author's fieldwork (2022)

Notes: n (number of sampled projects) = 40; P.1, P.2, P.3….P.40 represent code numbers of the 40 projects that were sampled.

Table 4.11 presents computation of hazard exposure based on Fine-Kinney classification. The result is the development of a frequency scale for ranking work activity durations as a percentage proportion of the total elemental duration.

Table 4.11: Frequency scale for ranking work activity durations in computing hazard exposure under Fine-Kinney approach

S/No	Work activity duration as % of total elemental duration	Description of frequency	Frequency (exposure) value from Fine-Kinney scale
1	100.0%	Continuous	10
2	14.0%	Frequent (daily)	6
3	3.0%	Occasional (weekly)	3
4	1.6%	Unusual (monthly)	2
5	0.3%	Rare (a few year per year)	1

Source: Author’s fieldwork (2022)

Table 4.12a and 4.12b presents the duration of workers to hazards for individual work activities. Result shows the table generated for the study for the work activity duration replaced with the Fine-Kinney frequency (exposure) value that corresponded to the % value of the work activity duration.

Table 4.12a: Exposure of workers to hazards for individual work activities using the Fine-Kinney frequency scale (Project Nos. 1 – 20)

WBS Section/ Sub-section	WBS Work Items	P.1	P.2	P.3	P.4	P.5	P.6	P.7	P.8	P.9	P.10	P.11	P.12	P.13	P.14	P.15	P.16	P.17	P.18	P.19	P.20
Substructure	Trench exc.	2.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	6.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
(Excavation &	Laterite filling	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	3.0	0.5	1.0	1.0	3.0	1.0	3.0	1.0	1.0	2.0	2.0
Filling)	Hardcore	0.5	2.0	3.0	1.0	1.0	1.0	1.0	1.0	0.5	2.0	0.5	3.0	1.0	2.0	2.0	2.0	3.0	1.0	0.5	1.0
Super Structure	Concrete work	1.0	0.5	0.5	1.0	1.0	1.0	1.0	0.5	1.0	0.5	1.0	0.5	1.0	0.5	0.5	0.5	0.5	1.0	0.5	0.5
(Frames)	Reinforcement	6.0	3.0	3.0	6.0	3.0	6.0	6.0	3.0	6.0	3.0	6.0	3.0	6.0	3.0	3.0	0.5	6.0	6.0	3.0	3.0
	Formwork	3.0	0.5	3.0	3.0	3.0	3.0	3.0	3.0	2.0	0.5	3.0	3.0	3.0	0.5	3.0	0.5	3.0	3.0	3.0	3.0
Masonry	Concrete work	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
(Concrete Work;	Reinforcement	2.0	2.0	2.0	3.0	2.0	1.0	1.0	2.0	2.0	1.0	1.0	1.0	0.5	1.0	1.0	2.0	1.0	1.0	2.0	2.0
Blockwork)	Formwork	2.0	1.0	1.0	2.0	1.0	1.0	1.0	2.0	1.0	1.0	1.0	1.0	0.5	1.0	1.0	1.0	1.0	1.0	1.0	1.0
	Blockwork	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	3.0	6.0	3.0	6.0	6.0	6.0	6.0	3.0	6.0	6.0
Roof (Covering)	Roof covering	2.0	3.0	3.0	3.0	2.0	2.0	3.0	3.0	2.0	3.0	1.0	3.0	2.0	3.0	3.0	3.0	3.0	1.0	3.0	3.0
Finishing	Screeding	3.0	0.5	3.0	0.5	3.0	2.0	1.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
(Floor;	Tiling	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	0.5	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Wall)	Rendering	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	3.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0
	Tiling	3.0	6.0	3.0	3.0	3.0	3.0	2.0	3.0	3.0	3.0	3.0	3.0	1.0	3.0	2.0	3.0	3.0	3.0	3.0	3.0
Painting& Decoration	Emulsion	2.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	2.0	3.0	3.0	2.0	3.0	3.0	2.0	2.0	3.0	3.0	3.0

Source: Author’s fieldwork (2022)

Table 4.12b: Exposure of workers to hazards for individual work activities using the Fine-Kinney frequency scale (Project Nos. 21 – 40)

WBS Section/ Sub-section	WBS Work Items	P.21	P.22	P.23	P.24	P.25	P.26	P.27	P.28	P.29	P.30	P.31	P.32	P.33	P.34	P.35	P.36	P.37	P.38	P.39	P.40
Substructure	Trench exc.	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	6.0	3.0	3.0	3.0	3.0	3.0
(Excavation &	Laterite filling	3.0	2.0	1.0	3.0	1.0	1.0	2.0	1.0	1.0	1.0	1.0	1.0	1.0	2.0	2.0	1.0	1.0	2.0	2.0	2.0
Filling)	Hardcore	2.0	3.0	1.0	2.0	1.0	3.0	2.0	1.0	1.0	1.0	1.0	1.0	1.0	2.0	3.0	1.0	3.0	3.0	2.0	0.5
Super Structure	Concrete work	0.5	0.5	1.0	0.5	1.0	0.5	1.0	0.5	0.5	0.5	0.5	0.5	0.5	0.5	1.0	1.0	0.5	0.5	1.0	0.5
(Frames)	Reinforcement	0.5	3.0	6.0	0.5	3.0	3.0	6.0	3.0	3.0	3.0	3.0	3.0	3.0	6.0	6.0	6.0	6.0	3.0	6.0	6.0
	Formwork	0.5	0.5	3.0	0.5	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Masonry	Concrete work	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
(Concrete Work;	Reinforcement	1.0	1.0	2.0	1.0	2.0	2.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	3.0	1.0	2.0	1.0	1.0	1.0	2.0
Blockwork)	Formwork	1.0	1.0	1.0	1.0	2.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
	Blockwork	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	3.0	6.0	6.0	6.0	6.0	6.0	6.0
Roof (Covering)	Roof covering	6.0	3.0	2.0	3.0	2.0	3.0	2.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	2.0	3.0	3.0	2.0	2.0
Finishing	Screeding	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	2.0	3.0	3.0	3.0	3.0	3.0	3.0
(Floor;	Tiling	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Wall)	Rendering	6.0	6.0	3.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	3.0	6.0	6.0	3.0	6.0	6.0	6.0
	Tiling	3.0	3.0	2.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	1.0	2.0	2.0	2.0	3.0	2.0	3.0
Painting& Decoration	Emulsion	3.0	3.0	2.0	2.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	1.0	2.0	3.0	2.0	3.0	1.0	1.0

Source: Author's fieldwork (2022)

Tables 4.13c and 4.13d presents the computation of exposure of workers to hazards under the Fine-Kinney technique. The exposures average for each Work element in projects was obtained. The resulting values were from now on employed in the determination of the level of risk in work items and projects under the Fine-Kinney approach.

Table 4.13a and 4.13b presents the weightings for excavation work, which is provided to illustrate the data type required for the Fine-Kinney technique. Data on likelihood and severity of hazards in other work items can be found in the Appendix D.

In terms of specifics for hazard likelihood or probability, as presented in Table 4.13a, a weighting of 1 (one) referred to the occurrence of a hazard that was 'conceivable but very unlikely'; a value of 0.5 was attached to such a weighting. A weighting of 3 (three) denoted the occurrence of a hazard that was unusual but possible; a value of 3 was attached to such a weighting. A weighting of 5 (five) denoted the occurrence of a hazard that might well be expected; a value of 10 was attached to such a weighting. Of the 578 weightings in Table 4.8a, it was found that the number of ones (1) exceeded all other weightings (208, compared to 150 threes (3) and 50 fives (5)). This implied that most hazards were considered to be of a rare occurrence, although quite a number of respondents considered that the listed hazards do occasionally occur.

With respect to hazard severity, as presented in Table 4.13b, a weighting of 1 (one) referred to the severity of a hazard that was ‘noticeable, requiring only minor first aid; a value of 1 was attached to such a weighting. A weighting of 3 (three) denoted the severity of a hazard that resulted in serious injury; a value of 7 was attached to such a weighting. A weighting of 5 (five) denoted the severity of a hazard that was a disaster, resulting in a few fatalities; a value of 40 was attached to such a weighting. Of the 591 weightings in Table 4.8b, it was found that the number of ones (1) exceeded all other weightings (178, compared to 98 threes (3) and 109 fives (5)). This implied that quite a number of respondents considered that the listed hazards were severe enough to cause a disaster whenever they might occur.

Hazard frequency, or exposure of workers to hazards, as presented in Table 4.13c and 4.13d, utilised a weighting of 1 (one) for exposure to a hazard that was ‘very rare, only once per year’; a value of 1 was attached to such a weighting. A weighting of 3 (three) denoted the exposure to a hazard that was ‘unusual, only occurring monthly’; a value of 3 was attached to such a weighting. A weighting of 5 (five) denoted exposure to a hazard that was ‘continuous, occurring daily’; a value of 10 was attached to such a weighting. One important assumption made in the computation of exposure was that all of the hazards identified in this study (eighteen (18) in number) had equal opportunity to affect workers during the period that workers were exposed to such hazards in completing certain construction tasks (Bilir and Gurcanli, 2018). This was the reason why all hazards pertaining to a specific work item/element and project had the same exposure (frequency) value.

Table 4.13a: Fine-Kinney weightings for probability of occurrence of different hazards in excavation work

Hazards in Excavation work	P.1	P.2	P.3	P.4	P.5	P.6	P.7	P.8	P.9	P.10	P.11	P.12	P.13	P.14	P.15	P.16	P.17	P.18	P.19	P.20	P.21	P.22	P.23	P.24	P.25	P.26	P.27	P.28	P.29	P.30	P.31	P.32	P.33	P.34	P.35	P.36	P.37	P.38	P.39	P.40
Struck by falling objects	0.5	10		1	0.5	10	1	3	3	3	3	3	1	3	3	3	1	1	1	1	1	3	3	3		3	6	1	1	1	1	1	1		3	1	0.5	3	1	1
Fall from height	0.5	3		3	1	1	0.5	0.5	0.5	1	0.5	1	1	0.5	1	10			1	1	1	1	3	3		0.5	10	3	0.5	6	1	1	1		1	0.5	0.5		10	0.5
Cave –ins / collapses	0.5	10		1	0.5	10	3	3	1	6	10	6	3	0.5	6	10	6	6	1	3	3	3	3	3		1	10	3	3	6	3	3	10	3	1	10	3	3	10	3
Fall to lower level	3	10			0.5	1	0.5	1	1	1	0.5	3	1	0.5	1	10	3	3	1	1			3	3		0.5	6	1	0.5	6	1	1	1		1	3	0.5	6	6	0.5
Fall to the same level	0.5	10		1	0.5	1	1	3	0.5	1	6	1	1	3	1	10	1	1	1	1			3		6	1	3	1	3	3	1	1	1		3	0.5	3	6	3	0.5
Building collapse	0.5	6			1	10	0.5	1	3	3	3	6	3	1	1	3	1	1	1	1		1	3			0.5	6	1	3	6	1	3	1		3	6	0.5	6	6	3
Equipment accidents	3	3	1	1	3	10	1	3	1	1	0.5	1	1	3	1	6	1	1	1	3		1	3			3	6	1	3	3	3	1	3	6	1	1	0.5	10	10	0.5
Struck by vehicles	3	6		3	0.5	1	0.5	0.5	3	1	6	0.5	3	0.5	3	6	1	1	1	1			3		3	1	3	1	0.5	6	1	1	1		1	0.5	3	0.5	10	0.5
achine/tool hazards	6	10	3	1	1	10	0.5	3	3	1	3	3	6	3	3	6	1	1	1	1			3			1	3	1	1	6	1	1	1	6	1	6	0.5	10	10	1
Contact - electricity	1	3	3	1	0.5	6	0.5	1	1	1	3	0.5	0.5	1	3	3			1	1		6	3			0.5	3	1	0.5	1	1	1	1		1	3	0.5	1	10	0.5
Contact - underground lines	6	10	1	1	0.5	10	3	3	3	10	6	0.5	3	0.5	3	10	6	6	3	6	3	10	3		3	3	3	1	6	6	1	6	3	1	10	3	6	10	10	6
Collapse – cavities/pits	3	6	1	1	1	10	3	3	3	6	10	6	6	0.5	6	10	6	6	1	3	3		3		3	1	6	1	3	3	1	6	1		1	6	3	10	10	6
Traffic accident	1	6	1	3	0.5	1	0.5	1	6	1	1	0.5	3	0.5	1	3	1	1	1	1	1		3		3	1	6	1	0.5	6	1	1	1	1	1	0.5	0.5	0.5	10	1
Noise exposure	0.5	1	1	1	1	10	3	1	1	1	3	6	6	0.5	1	10	3	3	1	1			3	3		1	6	3	3	6	3	3	1	6	1	1	0.5	10	6	3
Fire exposure	0.5	1		1	0.5	6	0.5	0.5	6	1	0.5	0.5	0.5	1	1	1	1	1	1	1		1	3	6		0.5	6	3	1		1	3	1	6	1	0.5	0.5	0.5	10	3
Caught between objects									3							10										0.5	3	1	3	1		1			1	3	3	0.5	10	0.5
Exposure - harmful items									6							6										1	3	1	1	3					6	6	0.5	10	10	
Overexertion									1							1										0.5	6	1	6						6	0.5	0.5	0.5	10	
Weighting	*0.1*	*0.2*	*0.5*	*1*	*3*	*6*	*10*																																	
Count (frequency)	*0*	*0*	*90*	*208*	*150*	*80*	*50*																																	

Source: Author’s fieldwork (2022)

Notes: *n (number of sampled projects) = 40; P.1, P.2, P.3….P.40 represent code numbers of the 40 projects that were sampled.*

Weighting followed a 5-item Likert scale approach, with 5 being ‘Might well be expected, *4 being* Quite possible, *3 being* Unusual but possible, *2 being remote and 1 being* ‘Conceivable. *Blank spaces represent missing values, where respondents did not fill in any response*

Table 4.13b: Fine-Kinney weightings for severity of different hazards in excavation work

Hazards in Excavation work	P.1	P.2	P.3	P.4	P.5	P.6	P.7	P.8	P.9	P.10	P.11	P.12	P.13	P.14	P.15	P.16	P.17	P.18	P.19	P.20	P.21	P.22	P.23	P.24	P.25	P.26	P.27	P.28	P.29	P.30	P.31	P.32	P.33	P.34	P.35	P.36	P.37	P.38	P.39	P.40
Struck by falling objects	1	15	1	1	1	3	1	40	7	1	15	3	1	15	15	3	7	3	1	40	3	1	15	15		1	15	1	1	3	1	1	15	3	40	1	1	15	40	7
Fall from height	1	40	1	3	1	3	1	15	1	1	1	1	1	1	1	3	1	1	3		1	1	15	15		1	15	1	1	15	1	15	1		1	1	1	1	40	15
Cave –ins / collapses	40	40	7	1	1	15	1	40	7	40	7	40	40	40	40	40	15	15	3	15	3	40	40	40	3	3	15	7	40	15	1	40	40	15	7	40	15	15	40	40
Fall to lower level	1	15	1	1	3	3	7	15	3	1	1	1	3	3	1	40	3	3	3		1	1	15	15		1	15	3	3	15	1	15	3		1	15	1	1	3	3
Fall to the same level	1	40	1	3	3	7	1	40	1	1	3	1	1	7	3	40	7	7	1	3	1	1	15	15		3	15	3	1	7	1	1	7	40	3	1	7	7	1	1
Building collapse	40	40	1	1	1	7	7	40	7	40	15	15	15	40	40	1	3	3	15			1	40	40	3	1	15	1	40	15	1	40	40		40	15	1	15	40	40
Equipment accidents	40	40	3	1	3	3	7	40	3	1	3	15	15	3	7	40	3	3	7	7		15	40	40		1	15	7	3	7	1	40	3		7	3	1	7	40	3
Struck by vehicles	1	40	1	1	1	3	7	7	7	1	7	40	1	40	1	15			7	40		1	40	40		3	15	3	1	15	1	40	40		7	1	7	3	40	3
achine/tool hazards	3	15	7	1	3	7	3	40	7	1	7	7	7	3	15	7	3	3	7	7		3	15	15	15	1	15	1	7	1	1	1	3		7	3	7	7	1	1
Contact - electricity	1	40	1	1	3	3	7	3	3	1	15	1	1	1	15	7			40	15			15	15		3	15	3	1	3	1	40	1		40	7	7	3	40	1
Contact - underground lines	40	40	7	7	1	15	15	7	7	40	7	40	15	3	15	40	15	15	15	40	7	15	40	40	15	1	15	3	40	15	1	40	3		40	40	15	40	40	3
Collapse – cavities/pits	40	40	15	3	1	15	40	40	7	40	15	40	40	15	15	40	15	15	40	40	3	40	40	40	40	1	15	1	40	7	1	40	15	15	40	15	15	7	40	15
Traffic accident	1	40	1	1	7	3	7	1	15	1	7	3	7	1	7	3	3	3	15				7	7		1	15	7	1	15	3	1	1		7	1	7	3	40	1
Noise exposure	1	40	7	3	7	7	15	7	3	15	3	3	1	1	3	7	7	7	1	1	1	7	7	7		1	15	7	7	15	7	7	1		1	1	7	7	15	1
Fire exposure	1	7		1	1	3	7	1	15	1	7	1	1	1	7	1			1							1	15	3	1	1	1	1	3		40	3	1	3	40	1
Caught between objects									7							15										1	15	1	7	3	1				40	7	1	1	40	
Exposure - harmful items									15							7										1	15	3	3	7	1				7	15	1		40	
Overexertion									3							7										1	15	3	40		1				40	1	1		40	

Weighting	*1*	*3*	*7*	*15*	*40*
Count (frequency)	*178*	*101*	*98*	*105*	*109*

Source: Author's fieldwork (2022)

Notes: *n (number of sampled projects) = 40; P.1, P.2, P.3….P.40 represent code numbers of the 40 projects that were sampled.*
Weighting followed a 5-item Likert scale approach, with 5 being 'disaster, 4 being very serious, 3 being serious, 2 being important and 1 being 'noticeable. Blank spaces represent missing values, where respondents did not fill in any response.

Table 4.13c: Fine-Kinney weightings for frequency (exposure) to different hazards in excavation work (Projects 1 – 20)

Hazards in excavation work	P.1	P.2	P.3	P.4	P.5	P.6	P.7	P.8	P.9	P.10	P.11	P.12	P.13	P.14	P.15	P.16	P.17	P.18	P.19	P.20
Struck by falling objects	1.17	2.00	2.00	1.67	1.67	1.50	1.67	1.67	1.33	2.67	1.00	2.00	2.67	2.67	1.67	2.67	2.00	1.50	1.83	2.00
Fall from height	1.17	2.00	2.00	1.67	1.67	1.50	1.67	1.67	1.33	2.67	1.00	2.00	2.67	2.67	1.67	2.67	2.00	1.50	1.83	2.00
Cave –ins / Trench collapses	1.17	2.00	2.00	1.67	1.67	1.50	1.67	1.67	1.33	2.67	1.00	2.00	2.67	2.67	1.67	2.67	2.00	1.50	1.83	2.00
Lower level fall	1.17	2.00	2.00	1.67	1.67	1.50	1.67	1.67	1.33	2.67	1.00	2.00	2.67	2.67	1.67	2.67	2.00	1.50	1.83	2.00
Fall to the same level/Slips trip	1.17	2.00	2.00	1.67	1.67	1.50	1.67	1.67	1.33	2.67	1.00	2.00	2.67	2.67	1.67	2.67	2.00	1.50	1.83	2.00
Building/structure collapse	1.17	2.00	2.00	1.67	1.67	1.50	1.67	1.67	1.33	2.67	1.00	2.00	2.67	2.67	1.67	2.67	2.00	1.50	1.83	2.00
Equipment accidents	1.17	2.00	2.00	1.67	1.67	1.50	1.67	1.67	1.33	2.67	1.00	2.00	2.67	2.67	1.67	2.67	2.00	1.50	1.83	2.00
Struck by moving vehicles	1.17	2.00	2.00	1.67	1.67	1.50	1.67	1.67	1.33	2.67	1.00	2.00	2.67	2.67	1.67	2.67	2.00	1.50	1.83	2.00
Manual handling of machine/tool hazards	1.17	2.00	2.00	1.67	1.67	1.50	1.67	1.67	1.33	2.67	1.00	2.00	2.67	2.67	1.67	2.67	2.00	1.50	1.83	2.00
Contact with electricity	1.17	2.00	2.00	1.67	1.67	1.50	1.67	1.67	1.33	2.67	1.00	2.00	2.67	2.67	1.67	2.67	2.00	1.50	1.83	2.00
Underground lines contact	1.17	2.00	2.00	1.67	1.67	1.50	1.67	1.67	1.33	2.67	1.00	2.00	2.67	2.67	1.67	2.67	2.00	1.50	1.83	2.00
Underground cavities/pits collapses	1.17	2.00	2.00	1.67	1.67	1.50	1.67	1.67	1.33	2.67	1.00	2.00	2.67	2.67	1.67	2.67	2.00	1.50	1.83	2.00
Traffic accident	1.17	2.00	2.00	1.67	1.67	1.50	1.67	1.67	1.33	2.67	1.00	2.00	2.67	2.67	1.67	2.67	2.00	1.50	1.83	2.00
Noise exposure	1.17	2.00	2.00	1.67	1.67	1.50	1.67	1.67	1.33	2.67	1.00	2.00	2.67	2.67	1.67	2.67	2.00	1.50	1.83	2.00
Fire exposure	1.17	2.00	2.00	1.67	1.67	1.50	1.67	1.67	1.33	2.67	1.00	2.00	2.67	2.67	1.67	2.67	2.00	1.50	1.83	2.00
Caught in between objects/mat	1.17	2.00	2.00	1.67	1.67	1.50	1.67	1.67	1.33	2.67	1.00	2.00	2.67	2.67	1.67	2.67	2.00	1.50	1.83	2.00
Exposure to harmful substance	1.17	2.00	2.00	1.67	1.67	1.50	1.67	1.67	1.33	2.67	1.00	2.00	2.67	2.67	1.67	2.67	2.00	1.50	1.83	2.00
Overexertion	1.17	2.00	2.00	1.67	1.67	1.50	1.67	1.67	1.33	2.67	1.00	2.00	2.67	2.67	1.67	2.67	2.00	1.50	1.83	2.00

Source: Author's fieldwork (2022)

Notes: *n (number of sampled projects) = 40; P.1, P.2, P.3….P.20 represent code numbers of the 40 projects that were sampled.*
Weighting was based on a 5-item scale, with 5 being 'continuous, with a value of 10', 4 being 'frequent, with a value of 6', 3 being 'occasional, with a value of 3', 2 being 'unusual, with a value of 2'and 1 being 'rare, with a value of 1'. Values were then averaged over the different activities in each work item/element.
Blank spaces represent missing values, where respondents did not fill in any response.

Table 4.13d: Fine-Kinney weightings for frequency (exposure) to different hazards in excavation work (Projects 21 – 40)

Hazards in excavation work	P.21	P.22	P.23	P.24	P.25	P.26	P.27	P.28	P.29	P.30	P.31	P.32	P.33	P.34	P.35	P.36	P.37	P.38	P.39	P.40
Struck by falling objects	2.67	2.67	1.67	2.67	1.67	2.33	2.33	1.67	1.67	1.67	1.67	1.67	1.67	1.67	3.33	1.33	2.33	2.00	1.67	1.83
Fall from height	2.67	2.67	1.67	2.67	1.67	2.33	2.33	1.67	1.67	1.67	1.67	1.67	1.67	1.67	3.33	1.33	2.33	2.00	1.67	1.83
Cave –ins / Trench collapses	2.67	2.67	1.67	2.67	1.67	2.33	2.33	1.67	1.67	1.67	1.67	1.67	1.67	1.67	3.33	1.33	2.33	2.00	1.67	1.83
Lower level fall	2.67	2.67	1.67	2.67	1.67	2.33	2.33	1.67	1.67	1.67	1.67	1.67	1.67	1.67	3.33	1.33	2.33	2.00	1.67	1.83
Slips trip/fall to the same level	2.67	2.67	1.67	2.67	1.67	2.33	2.33	1.67	1.67	1.67	1.67	1.67	1.67	1.67	3.33	1.33	2.33	2.00	1.67	1.83
Building/structure collapse	2.67	2.67	1.67	2.67	1.67	2.33	2.33	1.67	1.67	1.67	1.67	1.67	1.67	1.67	3.33	1.33	2.33	2.00	1.67	1.83
Equipment accidents	2.67	2.67	1.67	2.67	1.67	2.33	2.33	1.67	1.67	1.67	1.67	1.67	1.67	1.67	3.33	1.33	2.33	2.00	1.67	1.83
Struck by moving vehicles	2.67	2.67	1.67	2.67	1.67	2.33	2.33	1.67	1.67	1.67	1.67	1.67	1.67	1.67	3.33	1.33	2.33	2.00	1.67	1.83
Manual handling of machine/tool hazards	2.67	2.67	1.67	2.67	1.67	2.33	2.33	1.67	1.67	1.67	1.67	1.67	1.67	1.67	3.33	1.33	2.33	2.00	1.67	1.83
Contact with electricity	2.67	2.67	1.67	2.67	1.67	2.33	2.33	1.67	1.67	1.67	1.67	1.67	1.67	1.67	3.33	1.33	2.33	2.00	1.67	1.83
Underground lines contact	2.67	2.67	1.67	2.67	1.67	2.33	2.33	1.67	1.67	1.67	1.67	1.67	1.67	1.67	3.33	1.33	2.33	2.00	1.67	1.83
Underground cavities /pits collapse	2.67	2.67	1.67	2.67	1.67	2.33	2.33	1.67	1.67	1.67	1.67	1.67	1.67	1.67	3.33	1.33	2.33	2.00	1.67	1.83
Traffic accident	2.67	2.67	1.67	2.67	1.67	2.33	2.33	1.67	1.67	1.67	1.67	1.67	1.67	1.67	3.33	1.33	2.33	2.00	1.67	1.83
Noise exposure	2.67	2.67	1.67	2.67	1.67	2.33	2.33	1.67	1.67	1.67	1.67	1.67	1.67	1.67	3.33	1.33	2.33	2.00	1.67	1.83
Fire exposure	2.67	2.67	1.67	2.67	1.67	2.33	2.33	1.67	1.67	1.67	1.67	1.67	1.67	1.67	3.33	1.33	2.33	2.00	1.67	1.83
Caught in between objects/mat	2.67	2.67	1.67	2.67	1.67	2.33	2.33	1.67	1.67	1.67	1.67	1.67	1.67	1.67	3.33	1.33	2.33	2.00	1.67	1.83
Exposure to harmful substance	2.67	2.67	1.67	2.67	1.67	2.33	2.33	1.67	1.67	1.67	1.67	1.67	1.67	1.67	3.33	1.33	2.33	2.00	1.67	1.83
Overexertion	2.67	2.67	1.67	2.67	1.67	2.33	2.33	1.67	1.67	1.67	1.67	1.67	1.67	1.67	3.33	1.33	2.33	2.00	1.67	1.83

Source: Author’s fieldwork (2022)

Notes: n (number of sampled projects) = 40; P.21, P.22, P.23….P.40 represent code numbers of the 40 projects that were sampled.
Weighting was based on a 5-item scale, with 5 being ‘continuous, with a value of 10’, 4 being ‘frequent, with a value of 6’, 3 being ‘occasional, with a value of 3’, 2 being ‘unusual, with a value of 2’and 1 being ‘rare, with a value of 1’. Values were then averaged over the different activities in each work item/element.
Blank spaces represent missing values, where respondents did not fill in any response.

4.4.1.2 *Severity, likelihood and exposure assessment of safety hazards in work items of building projects using Fine-Kinney approach*

The quantitative assessment of likelihood, severity and exposure to safety hazards in seven (7) work items using Fine-Kinney approach is the force of this section. All assessment was on an individual basis, both for the hazards and the work items.

Excavation: The results presented in Table 4.14 represented assessments of the severity, likelihood and exposure of eighteen (18) hazards in excavation work of building projects using the Fine-Kinney approach. In excavation work the most three severe hazards are 'collapse underground cavities/pits', 'Cave-ins/trench collapse' and 'contact with underground lines'; these had Severity Risk Impact (SRI) scores of 23.65, 22.65 and 20.44 respectively. Two of these three most severe hazards were also the most likely safety hazards; these were 'contact with underground lines', 'Cave-ins/trench collapse' and 'exposure to harmful substance'. These hazards had Probability of Occurrence (PRO) scores of 4.72, 4.47 and 4.46 respectively. The frequency of exposure was the same for all hazards because it was assumed that workers are exposed to all 18 hazards equally for the duration of the work in an activity. In the case of excavation, the exposure frequency of workers to hazards was 'rare'.

Table 4.14: Severity, likelihood and exposure of safety hazards in Excavation using Fine-Kinney approach

Hazard in Excavation work	Severity			Likelihood			Exposure	
	Score	Impact	Rank	Score	Occurrence	Rank	Score	Frequency
Building/structure collapse	19.43	Very Serious	4	2.74	Rem possible	9	1.96	Rare
Caught in between objects/mat	10.69	Serious	8	2.82	Rem possible	8	1.96	Rare
Cave –ins / Trench collapses	22.65	Very Serious	2	4.47	Unusual	2	1.96	Rare
Collapse of underground cavities / pits	23.65	Very Serious	1	4.22	Unusual	4	1.96	Rare
Contact with electricity	10.38	Serious	9	1.79	Rem possible	17	1.96	Rare
Contact with underground lines	20.44	Very Serious	3	4.72	Unusual	1	1.96	Rare
Equipment accidents	12.89	Serious	7	2.66	Rem possible	10	1.96	Rare
Exposure to harmful substance	9.58	Serious	10	4.46	Unusual	3	1.96	Rare
Fall from height	5.97	Important	16	1.94	Rem possible	15	1.96	Rare
Fall to lower level	5.95	Important	17	2.31	Rem possible	11	1.96	Rare
Fall to the same level	7.72	Serious	12	2.30	Rem possible	12	1.96	Rare
Fire exposure	5.67	Important	18	1.85	Rem possible	16	1.96	Rare
Manual handling of machine/tool hazards	6.76	Important	14	3.25	Unusual	5	1.96	Rare
Noise exposure	6.66	Important	15	3.04	Unusual	6	1.96	Rare
Overexertion	13.82	Serious	5	2.91	Rem possible	7	1.96	Rare
Struck by falling objects	9.05	Serious	11	2.23	Rem possible	13	1.96	Rare
Struck by moving vehicles	13.71	Serious	6	2.07	Rem possible	14	1.96	Rare
Traffic accident	6.94	Important	13	1.79	Rem possible	18	1.96	Rare

Source: Author's fieldwork (2022)

Notes: n = 40; Rem possible=Remotely possible

Reinforced Concrete Work: Table 4.15 present the results on reinforced concrete work, the top three most severe hazards were 'Building structure collapses'. 'Stroked by falling objects' and 'Fall from height', which all had Severity Risk Impact (SRI) scores of 23.24, 16.84 and 15.59 respectively. The three hazards that are most likely to be encountered in reinforced concrete work are 'Building/structure collapses', 'Fall from height' and 'overexertion', because these hazards had the highest Probability of Occurrence (PRO) scores of 3.62, 3.35 and 3.27 respectively. In the case of reinforced concrete work, the exposure frequency of workers to hazards was 'Unusual'.

Table 4.15: Severity, likelihood and exposure of safety hazards in Reinforced Concrete using Fine-Kinney approach

Hazard in Reinforced Concrete work	Severity			Likelihood			Exposure	
	Score	Impact	Rank	Score	Occurrence	Rank	Score	Frequency
Building/structure collapse	23.24	Very Serious	1	3.62	Unusual	1	2.31	Unusual
Caught in between objects/mat	12.00	Serious	8	2.11	Rem possible	11	2.31	Unusual
Cave –ins / Trench collapses	9.50	Serious	9	2.00	Rem possible	13	2.31	Unusual
Collapse of underground cavities / pits	12.41	Serious	7	2.46	Rem possible	7	2.31	Unusual
Contact with electricity	8.65	Serious	13	1.14	Rem possible	18	2.31	Unusual
Contact with underground lines	7.34	Serious	15	1.71	Rem possible	14	2.31	Unusual
Equipment accidents	13.65	Serious	5	2.42	Rem possible	8	2.31	Unusual
Exposure to harmful/ chemical substance	9.09	Serious	10	2.09	Rem possible	12	2.31	Unusual
Falling from height	15.59	Very Serious	3	3.27	Unusual	3	2.31	Unusual
Lower level fall	9.00	Serious	11	2.29	Rem possible	10	2.31	Unusual
Fall to the same level	7.21	Serious	16	2.32	Rem possible	9	2.31	Unusual
Fire exposure	5.23	Important	18	1.41	Rem possible	15	2.31	Unusual
Manual handling of machine/tool hazards	9.00	Serious	12	2.64	Rem possible	6	2.31	Unusual
Noise exposure	7.84	Serious	14	3.01	Unusual	4	2.31	Unusual
Overexertion	14.20	Serious	4	3.35	Unusual	2	2.31	Unusual
Struck by falling objects	16.84	Very Serious	2	2.94	Rem possible	5	2.31	Unusual
Struck by moving vehicles	12.68	Serious	6	1.37	Rem possible	16	2.31	Unusual
Traffic accident	5.30	Important	17	1.22	Rem possible	17	2.31	Unusual

Source: Author's fieldwork (2022)

Notes: n = 40; Rem possible=Remotely possible

Masonry: The three most severe hazards that can occur during masonry work are identified in Table 4.16. These hazards are 'building/structure collapses', 'overexertion' and 'fall from height', which had Severity Risk Impact (SRI) scores of 19.57, 12.80 and 12.16 respectively. The three most likely hazards that can occur in masonry work are 'building/structure collapses', 'fall from height' as well as 'hazard due to manual handling of machine/tool', which had Probability of Occurrence (PRO) scores of 3.38, 3.18 and 2.83 respectively. In the case of masonry work, the exposure frequency of workers to hazards was 'rare'.

Table 4.16: Severity, likelihood and exposure of safety hazards in Masonry using Fine-Kinney approach

Hazard in Masonry work	Severity			Likelihood			Exposure	
	Score	Impact	Rank	Score	Occurrence	Rank	Score	Frequency
Building/structure collapse	19.57	Very Serious	1	3.38	Unusual	1	1.97	Rare
Caught in between objects/mat	6.42	Important	11	0.97	Conceivable unlikely	18	1.97	Rare
Cave –ins / Trench collapses	5.32	Important	15	1.76	Rem possible	11	1.97	Rare
Collapse of underground cavities / pits	6.51	Important	10	1.81	Rem possible	10	1.97	Rare
Contact with electricity	6.73	Important	9	1.05	Rem possible	17	1.97	Rare
Contact with underground lines	3.34	Important	17	1.30	Rem possible	13	1.97	Rare
Equipment accidents	8.73	Serious	7	2.31	Rem possible	5	1.97	Rare
Exposure to harmful substance	5.55	Important	13	2.14	Rem possible	8	1.97	Rare
Fall from height	12.16	Serious	3	3.18	Unusual	2	1.97	Rare
Fall to lower level	8.79	Serious	6	2.63	Rem possible	4	1.97	Rare
Fall to the same level	7.13	Serious	8	2.07	Rem possible	9	1.97	Rare
Fire exposure	4.10	Important	16	1.21	Rem possible	15	1.97	Rare
Manual handling of machine/tool hazards	5.43	Important	14	2.83	Rem possible	3	1.97	Rare
Noise exposure	5.56	Important	12	1.74	Rem possible	12	1.97	Rare
Overexertion	12.80	Serious	2	2.20	Rem possible	7	1.97	Rare
Struck by falling objects	9.87	Serious	4	2.28	Rem possible	6	1.97	Rare
Struck by moving vehicles	9.06	Serious	5	1.13	Rem possible	16	1.97	Rare
Traffic accident	2.69	Important	18	1.26	Rem possible	14	1.97	Rare

Source: Author's fieldwork (2022)

Notes: n = 40; Rem possible=Remotely possible

Roof work: The three most severe hazards that can occur during roof work are identified in Table 4.17. These hazards are 'fall from height', 'building/structure collapses', and 'fall to lower level' which had Severity Risk Impact (SRI) scores of 22.08, 20.42 and 17.97 respectively. Two of these hazards also double as part of the three most likely hazards with highest Probability of Occurrence (PRO) scores (4.64, 3.55 and 3.37), which are 'fall from height', 'overexertion' and 'fall to lower level' respectively. Frequency of exposure of workers to hazards for roof work was ranked as 'unusual'.

Table 4.17: Severity, likelihood and exposure of safety hazards in Roof work using Fine-Kinney approach

Hazard in Roof work	Severity			Likelihood			Exposure	
	Score	Impact	Rank	Score	Occurrence	Rank	Score	Frequency
Building/structure collapse	20.42	Very Serious	2	3.05	Unusual	6	2.55	Unusual
Caught in between objects/mat	9.08	Serious	10	1.33	Rem possible	14	2.55	Unusual
Cave –ins / Trench collapses	6.45	Important	13	1.38	Rem possible	13	2.55	Unusual
Collapse of underground cavities / pits	7.00	Serious	12	1.09	Rem possible	17	2.55	Unusual
Contact with electricity	12.30	Serious	6	2.06	Rem possible	9	2.55	Unusual
Contact with underground lines	4.73	Important	16	0.92	Conceivably unlikely	18	2.55	Unusual
Equipment accidents	13.00	Serious	5	2.19	Rem possible	8	2.55	Unusual
Exposure to harmful substance	4.33	Important	17	1.50	Rem possible	12	2.55	Unusual
Fall from height	22.08	Very Serious	1	4.64	Unusual	1	2.55	Unusual
Fall to lower level	17.97	Very Serious	3	3.37	Unusual	3	2.55	Unusual
Fall to the same level	11.42	Serious	8	1.85	Rem possible	11	2.55	Unusual
Fire exposure	6.29	Important	15	1.88	Rem possible	10	2.55	Unusual
Manual handling of machine/tool hazards	11.58	Serious	7	3.36	Unusual	4	2.55	Unusual
Noise exposure	6.42	Important	14	2.64	Rem possible	7	2.55	Unusual
Overexertion	9.64	Serious	9	3.55	Unusual	2	2.55	Unusual
Struck by falling objects	15.82	Very Serious	4	3.17	Unusual	5	2.55	Unusual
Struck by moving vehicles	7.44	Serious	11	1.17	Rem possible	16	2.55	Unusual
Traffic accident	3.82	Important	18	1.32	Rem possible	15	2.55	Unusual

Source: Author’s fieldwork (2022)

Notes: n = 40; Rem possible=Remotely possible

Floor Finishing: The three most severe safety hazards in floor finishing work were identified in Table 4.18 as ‘fall from height’, ‘building/structure collapse’ and ‘struck by falling objects’ that had Severity Risk Impact (SRI) scores of 15.10, 14.42 and 10.74 respectively. In terms of likelihood, the three most likely safety hazards were ‘fall from height’, ‘overexertion’ and ‘fall to lower level’; their Probability of Occurrence (PRO) scores were 2.96, 2.82 and 2.71 respectively. Frequency of exposure of workers to hazards for floor finishing work was ranked as ‘unusual’.

Table 4.18: Severity, likelihood and exposure of safety hazards in Floor Finishing work using Fine-Kinney approach

Hazard in Floor Finishing work	Severity			Likelihood			Exposure	
	Score	Impact	Rank	Score	Occurrence	Rank	Score	Frequency
Building/structure collapse	14.42	Serious	2	1.99	Rem possible	6	2.77	Unusual
Caught in between objects/mat	4.71	Important	17	0.97	Conceivably unlikely	15	2.77	Unusual
Cave –ins / Trench collapses	4.74	Important	16	0.80	Conceivably unlikely	16	2.77	Unusual
Collapse of underground cavities / pits	5.09	Important	13	0.74	Conceivably unlikely	18	2.77	Unusual
Contact with electricity	7.74	Serious	8	1.27	Rem possible	11	2.77	Unusual
Contact with underground lines	4.82	Important	15	1.31	Rem possible	10	2.77	Unusual
Equipment accidents	7.83	Serious	7	1.74	Rem possible	9	2.77	Unusual
Exposure to harmful substance	6.17	Important	11	1.08	Rem possible	13	2.77	Unusual
Fall from height	15.10	Very Serious	1	2.96	Rem possible	1	2.77	Unusual
Fall to lower level	8.24	Serious	5	2.71	Rem possible	3	2.77	Unusual
Fall to the same level	8.13	Serious	6	1.97	Rem possible	7	2.77	Unusual
Fire exposure	3.69	Important	18	1.23	Rem possible	12	2.77	Unusual
Manual handling of machine/tool hazards	6.97	Important	10	2.35	Rem possible	5	2.77	Unusual
Noise exposure	4.83	Important	14	1.82	Rem possible	8	2.77	Unusual
Overexertion	10.45	Serious	4	2.82	Rem possible	2	2.77	Unusual
Struck by falling objects	10.74	Serious	3	2.44	Rem possible	4	2.77	Unusual
Struck by moving vehicles	7.38	Serious	9	0.80	Conceivably unlikely	17	2.77	Unusual
Traffic accident	5.27	Important	12	1.06	Rem possible	14	2.77	Unusual

Source: Author's fieldwork (2022)

Notes: n = 40; Rem possible=Remotely possible

Plastering/Rendering: The three most severe hazards that can occur during plastering /rendering work are identified in Table 4.19. These hazards are 'fall from high level', 'building/structure collapse' and struck /hit by falling objects'; these had Severity Risk Impact (SRI) scores of 15.10, 14.42 and 10.74 respectively. Similarly, the three most likely safety hazards in finishing work in building construction projects are 'fall from height', 'overexertion' and 'fall to lower level', which had Probability of Occurrence (PRO) scores of 2.96, 2.82 and 2.71 respectively. In the case of plastering/rendering work, the exposure frequency of workers to hazards was 'occasional'.

Table 4.19: Severity, likelihood and exposure of safety hazards in Plastering/Rendering work using Fine-Kinney approach

Hazard in Plastering/Rendering work	Severity			Likelihood			Exposure	
	Score	Impact	Rank	Score	Occurrence	Rank	Score	Frequency
Building/structure collapse	14.42	Serious	2	1.99	Rem possible	6	3.80	Occasional
Caught in between objects/mat	4.71	Important	17	0.97	Conceivably unlikely	15	3.80	Occasional
Cave –ins / Trench collapses	4.74	Important	16	0.80	Conceivably unlikely	16	3.80	Occasional
Collapse of underground cavities / pits	5.09	Important	13	0.74	Conceivably unlikely	18	3.80	Occasional
Contact with electricity	7.74	Serious	8	1.27	Rem possible	11	3.80	Occasional
Contact with underground lines	4.82	Important	15	1.31	Rem possible	10	3.80	Occasional
Equipment accidents	7.83	Serious	7	1.74	Rem possible	9	3.80	Occasional
Exposure to harmful substance	6.17	Important	11	1.08	Rem possible	13	3.80	Occasional
Fall from height	15.10	Very Serious	1	2.96	Rem possible	1	3.80	Occasional
Fall to lower level	8.24	Serious	5	2.71	Rem possible	3	3.80	Occasional
Fall to the same level	8.13	Serious	6	1.97	Rem possible	7	3.80	Occasional
Fire exposure	3.69	Important	18	1.23	Rem possible	12	3.80	Occasional
Manual handling of machine/tool hazards	6.97	Important	10	2.35	Rem possible	5	3.80	Occasional
Noise exposure	4.83	Important	14	1.82	Rem possible	8	3.80	Occasional
Overexertion	10.45	Serious	4	2.82	Rem possible	2	3.80	Occasional
Struck by falling objects	10.74	Serious	3	2.44	Rem possible	4	3.80	Occasional
Struck by moving vehicles	7.38	Serious	9	0.80	Conceivably unlikely	17	3.80	Occasional
Traffic accident	5.27	Important	12	1.06	Rem possible	14	3.80	Occasional

Source: Author's fieldwork (2022)

Notes: n = 40; Rem possible=Remotely possible

Painting and decoration: Table 4.20 revealed that among the eighteen (18) hazards identified in this study, three hazards had the most severe impact on safety in painting and decoration work. These were 'fall from height', 'building/structure collapse' and 'struck by falling objects' (Severity Risk Impact (SRI) scores of 15.10, 14.42 and 10.74 respectively). In terms of likelihood, the three most likely safety hazards were 'fall from height', 'overexertion' and 'fall to lower level', which had Probability of Occurrence (PRO) scores of 2.96, 2.82 and 2.71 respectively. In the case of painting and decoration work, the exposure frequency of workers to hazards was 'unusual'.

Table 4.20: Severity, likelihood and exposure of safety hazards in Painting work using Fine-Kinney approach

Hazard in Painting work	Severity			Likelihood			Exposure	
	Score	Impact	Rank	Score	Occurrence	Rank	Score	Frequency
Building/structure collapse	14.42	Serious	2	1.99	Rem possible	6	2.45	Unusual
Caught in between objects/mat	4.71	Important	17	0.97	Conceivably unlikely	15	2.45	Unusual
Cave –ins / Trench collapses	4.74	Important	16	0.80	Conceivably unlikely	16	2.45	Unusual
Collapse of underground cavities / pits	5.09	Important	13	0.74	Conceivably unlikely	18	2.45	Unusual
Contact with electricity	7.74	Serious	8	1.27	Rem possible	11	2.45	Unusual
Contact with underground lines	4.82	Important	15	1.31	Rem possible	10	2.45	Unusual
Equipment accidents	7.83	Serious	7	1.74	Rem possible	9	2.45	Unusual
Exposure to harmful substance	6.17	Important	11	1.08	Rem possible	13	2.45	Unusual
Fall from height	15.10	Very Serious	1	2.96	Rem possible	1	2.45	Unusual
Fall to lower level	8.24	Serious	5	2.71	Rem possible	3	2.45	Unusual
Fall to the same level	8.13	Serious	6	1.97	Rem possible	7	2.45	Unusual
Fire exposure	3.69	Important	18	1.23	Rem possible	12	2.45	Unusual
Manual handling of machine/tool hazards	6.97	Important	10	2.35	Rem possible	5	2.45	Unusual
Noise exposure	4.83	Important	14	1.82	Rem possible	8	2.45	Unusual
Overexertion	10.45	Serious	4	2.82	Rem possible	2	2.45	Unusual
Struck by falling objects	10.74	Serious	3	2.44	Rem possible	4	2.45	Unusual
Struck by moving vehicles	7.38	Serious	9	0.80	Conceivably unlikely	17	2.45	Unusual
Traffic accident	5.27	Important	12	1.06	Rem possible	14	2.45	Unusual

Source: Author’s fieldwork (2022)

Notes: n = 40; Rem possible=Remotely possible

4.4.1.3 *Risk level assessment of safety hazards in different work items using Fine-Kinney approach*

This section extended the work on quantitative assessment the severity, likelihood and exposure of safety hazards in work items by deriving risk scores for each hazard and each one of the seven selected work items. This made it possible to compare risk levels attributable to a particular hazard amongst different work items. Table 4.21 presents the result of all analyses carried out in this section.

Results presented in Table 4.21 can be summarised in two ways. One, excepting roof work, no other work item/element had ‘high’ or ‘very high’ level of risk. Two, a ‘possible risk’ level was the predominant level of risk identified through the Fine-

Kinney approach; at least 48.4% of all potential hazards belonged to this risk class. With respect to safety hazards that were assessed to have the highest risk levels in each work item/element, in excavation ‘cave-ins/trench collapses’, ‘collapse of underground cavities/pits’ and ‘contact with underground lines’ all had substantial risk levels (risk scores for these three hazards were 198.60, 195.44 and 188.97 respectively).

The risk assessment of hazards in reinforced concrete work identified ‘building/structure collapses’, ‘fall from high level’ and ‘struck /hit by falling objects’ all are of substantial risk levels, as the highest ranked hazards (risk score of 194.23, 117.81 and 114.19 respectively). In masonry work the highest ranked safety hazards were identified as ‘building/structure collapses’, ‘fall from height’ and ‘overexertion’, in which two were of a substantial risk level and one was a possible risk. The risk scores of the three were 130.10, 76.27 and 55.48 respectively.

The results presented in Table 4.21 further identified the most important safety hazards in roof work as ‘fall from height’ (which had a high-risk score of 261.46), followed by ‘building/structure collapses’ and ‘fall to lower level’ all of which were of substantial risk level with risk scores of 158.96 and 154.54 respectively. In floor finishing work under the Fine-Kinney approach, the three most risky hazards were identified as ‘fall from height’, ‘overexertion’ and ‘building/structure collapses’, all of which were of substantial risk level and had risk scores of 123.85, 81.61 and 79.32 respectively. The same pattern was observed in plastering/rendering; highest ranked hazards were ‘fall from height’, ‘overexertion’ and ‘building/structure collapses’. These all belonged to substantial risk level and had risk scores of 169.90, 111.96 and 108.82 respectively. Painting work also had the same highest ranked hazards that were observed in plastering/rendering, although the risk scores were different, being 109.54, 72.18 and 70.16 respectively.

Table 4.21: Risk levels of hazards in different work items using Fine-Kinney approach

Risk scores of hazards in Excavation	Excavation			Reinforced Concrete			Masonry			Roof Work			Floor Finishing			Plastering/ Rendering			Painting		
	RS	**RL**	**R**	**RS**	**RL**	**R**	**RS**	**RL**	**R**	**RS**	**RL**	**R**	**RS**	**RL**	**R**	**RS**	**RL**	**R**	**RS**	**RL**	
Building/structure collapse	104.18	Subst	4	194.23	Subst	1	130.1	Subst	1	158.96	Subst	2	79.32	Subst	3	108.82	Subst	3	70.16	Subst	3
Caught in between objects/mat	59.13	Poss	8	58.41	Poss	7	12.22	Risk	15	30.86	Poss	11	12.65	Risk	15	17.35	Risk	15	11.19	Risk	15
Cave –ins / Trench collapses	198.6	Subst	1	43.89	Poss	12	18.43	Risk	13	22.73	Poss	13	10.55	Risk	17	14.47	Risk	17	9.33	Risk	17
Collapse of underground cavities / pits	195.44	Subst	2	70.45	Subst	6	23.17	Poss	10	19.52	Risk	15	10.46	Risk	18	14.35	Risk	18	9.25	Risk	18
Contact with electricity	36.51	Poss	13	22.7	Poss	16	13.86	Risk	14	64.49	Poss	8	27.3	Poss	9	37.45	Poss	9	24.14	Poss	9
Contact with underground lines	188.97	Subst	3	28.98	Poss	15	8.56	Risk	17	11.13	Risk	18	17.44	Risk	12	23.92	Poss	12	15.42	Risk	12
Equipment accidents	67.27	Poss	7	76.33	Subst	5	39.74	Poss	6	72.57	Subst	7	37.63	Poss	8	51.62	Poss	8	33.28	Poss	8
Exposure to harmful substance	83.74	Subst	5	43.91	Poss	11	23.34	Poss	9	16.58	Risk	16	18.4	Poss	11	25.24	Poss	11	16.27	Risk	11
Fall from height	22.73	Poss	17	117.81	Subst	2	76.27	Subst	2	261.46	High	1	123.85	Subst	1	169.9	Subst	1	109.54	Subst	1
Falling to lower level	26.91	Poss	15	47.6	Poss	10	45.45	Poss	4	154.54	Subst	3	61.79	Poss	5	84.77	Subst	5	54.65	Poss	5
Falling to the same level	34.79	Poss	14	38.57	Poss	14	29.05	Poss	8	53.92	Poss	9	44.46	Poss	7	60.99	Poss	7	39.32	Poss	7
Fire exposure	20.52	Poss	18	17.03	Risk	17	9.79	Risk	16	30.08	Poss	12	12.52	Risk	16	17.18	Risk	16	11.07	Risk	16
Manual handling of machine/tool hazards	43.08	Poss	10	54.98	Poss	8	30.28	Poss	7	99.35	Subst	5	45.45	Poss	6	62.35	Poss	6	40.2	Poss	6
Noise exposure	39.68	Poss	11	54.57	Poss	9	19.09	Risk	12	43.18	Poss	10	24.41	Poss	10	33.49	Poss	10	21.59	Poss	10
Overexertion	78.79	Subst	6	109.89	Subst	4	55.48	Poss	3	87.23	Subst	6	81.61	Subst	2	111.96	Subst	2	72.18	Subst	2
Struck by falling objects	39.56	Poss	12	114.19	Subst	3	44.25	Poss	5	127.89	Subst	4	72.45	Subst	4	99.38	Subst	4	64.08	Poss	4
Struck by moving vehicles	55.68	Poss	9	40.18	Poss	13	20.13	Poss	11	22.14	Poss	14	16.41	Risk	13	22.52	Poss	13	14.52	Risk	13
Traffic accident	24.35	Poss	16	14.97	Risk	18	6.66	Risk	18	12.89	Risk	17	15.52	Risk	14	21.29	Poss	14	13.73	Risk	14

Source: Author's fieldwork (2022)

Notes: n = 40; RS=Risk Score; R=Rank; RL=Risk Level; Subst=Substantial; Poss= Possible; V High= Very high

These findings lend support to findings from earlier studies that show how the majority of the work activities/ items in building projects have to contend with ’substantial (average) risk (Gurcanli *et al*., 2015). The findings being presented here are at the level of individual hazards; it was apparent that while the bulk of potential hazards are of ‘substantial risk’ and ‘possible risk’ grouping, only one ‘high risk’ hazard (fall from height) was identified. This finding, obtained through the use of Fine-Kinney risk assessment technique, was largely to a large extent differed from those earlier studied (Gurcanli *et al*., 2015). The main areas of difference had to do with the number of hazards grouped as very low risk, low risk, average risk, high risk and very high risk. A likely reason for this difference in ranking of the risk level in work items might be due to location of study, legislature and the complexity of construction technology.

4.4.1.4 ***Safety risk assessment in work items of building projects using Fine-Kinney approach***

This section focused on the quantitative assessment of safety risk in work items; in this case the risks posed by individual hazards have been condensed into a single risk score for each work item. The results presented in Table 4.22 represented a summary assessment of the safety risk for common work items of building projects using the Fine-Kinney approach. These were the work items for which hazard exposure had been generated earlier in Section 4.4.1.1, and presented in Table 4.13c and 4.13d.

Results on Table 4.22 demonstrates that reinforced concrete work had the highest risk score of 260.75; this translated to a ‘high’ risk level. Roof work, which had an average risk score of 156.30, corresponding to a ‘substantial risk level was the second ranked work item in terms of safety risk. Excavation, which had an average risk score of 46.86 was a distant third, and belonged to a ‘possible’ risk level.

Table 4.22: Safety risk assessment in work items using Fine-Kinney technique

S/N	Work Items in Building projects	Likelihood	Severity	Exposure	RS	RL	Rank
1	Reinforced Concrete work	3.00	9.45	9.20	260.75	High	1
2	Roof work	4.15	14.77	2.55	156.30	Substantial	2
3	Excavation	2.55	9.38	1.96	46.86	Possible	3
4	Plastering / Rendering	1.87	6.38	3.80	45.29	Possible	4
5	Masonry	2.69	8.00	1.97	42.43	Possible	5
6	Painting	1.85	6.79	2.45	30.75	Possible	6
7	Floor Finishing	1.76	5.05	2.77	24.58	Possible	7

Source: Author's fieldwork (2022)

Notes: n = 40; RS= Risk score; RL= Risk level; Risk level interpretation is based on Risk Score (RS): RS<20 = Risk; 20<RS<70 = Possible; 70<RS<200 = Substantial; 200<RS<400 = High risk; RS>400 =Very High.

The implications of these findings are many; the most obvious is that the seven work items examined were spread over three risk levels. This current result, obtained through the use of Fine-Kinney risk assessment technique, is largely in agreement with Gurcanli *et al*., (2015) from those earlier studies. The main areas of agreement centred on the ranking of the risk level in work items, as well as the number of work items that shared similar risk levels. A likely reason for this agreement in ranking of the risk level in work items might be due to the use of similar operational procedure applied in construction. One of the major implication of the study's finding with respect risk levels in work items, based on the Fine-Kinney technique, is that contractors would have to plan for different levels of expenditure for safety risk mitigation in all different elements.

4.4.1.5 *Risk distribution in work items using Fine Kinney approach*

This section provides a summarised view of the risk level of hazards that was provided in section 4.4.1.4, and reported in Table 4.22. All of the 18 hazards have been assigned to specific risk groups based on their risk scores. As explained in Section 4.4.1.1, the risk score is generated from three metrics (likelihood, severity and exposure of a hazard), and is described in five ways – very high, high, substantial, possible, risk. The risk scale of Fine-Kinney runs from 1 to 400; a risk score of less than 20 indicates 'risk (acceptable) risk'. Risk scores greater than 70 but less than 200 denote 'substantial (correction) risk', while values of risk greater than 400 are an indication of 'very high risk'.

Table 4.23 and Figure 4.1 presents the result of the risk grouping carried out and the risk distribution in selected work activities using Fine-Kinney approach. Table 4.23 was based on aggregate risk levels in seven work items for 40 building projects. While the results in Figure 4.1 were based on 18 potential hazards in seven work items,

The main highlight of the result was that 'substantial' and 'possible' risk hazards were more numerous than 'risk' hazards. Of 'very high' and 'high' risk hazards, only one example was found; this was of a 'high' risk hazard in roof. The foregoing was true of projects as well; 'substantial' and 'possible' level risk hazards were identified in more projects than 'risk', 'high' or 'very high' level risk hazards, as is presented in Table 4.23. Only in excavation work and roof work were 'very high' risk hazards found; even then, high risk hazards made up less than 10% of all hazards.

Table 4.23: Risk distribution of Work items

Work Item/ Elements	**Very High**		**High**		**Substantial**		**Possible**		**Risk**	
	fx	**%**	**fx**	**%**	**fx**	**%**	**fx**	**%**	**fx**	**%**
Excavation	0	0.00	0	0.00	6	33.33	12	66.67	0	0.00
Reinforced Concrete	0	0.00	0	0.00	6	33.33	10	55.56	2	11.11
Masonry	0	0.00	0	0.00	2	11.11	9	50.00	7	38.89
Roof Work	0	0.00	1	5.56	6	33.33	7	38.89	4	22.22
Floor Finishing	0	0.00	0	0.00	4	22.22	7	38.89	7	38.89
Plastering /Rendering	0	0.00	0	0.00	5	27.78	9	50.00	4	22.22
Painting	0	0.00	0	0.00	3	16.67	7	38.89	8	44.44

Source: Author's fieldwork (2022)

Notes: n = 18 hazards; fx=frequency

A line graph of the risk distribution of hazards in seven work items was prepared and presented in Figure 4.1. This showed that the safety hazards risk distribution in the sample of building construction projects examined in this study displayed an inverted

'U' shape; only in floor finishing and painting was on the right-hand side of the 'U' much shorter than the left-hand side. Site managers can thus expect to encounter far more 'substantial risk' and 'possible risk' hazards than 'very high risk', 'high risk' and 'risk' hazards.

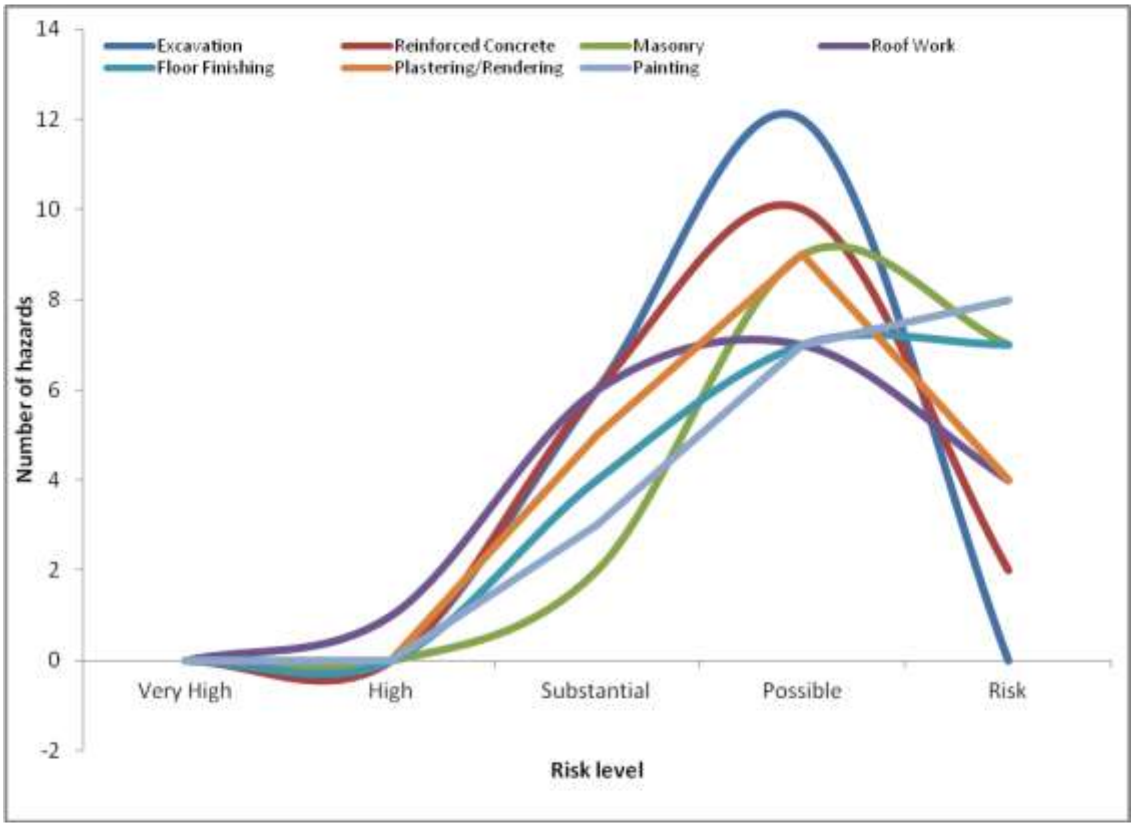

Figure 4.1: Risk distribution in work items using Fine-Kinney technique

4.4.1.6 ***Risk distribution in projects using Fine Kinney approach***

This section provides a summarised view of the risk level of hazards identified by the respondents. This was done by assigning the mean risk score of all of the 18 hazards to specific risk groups for each of the 40 sampled building projects. Table 4.24a and 4.24b presents the result of the risk grouping and the risk distribution in selected work activities across the 40 sampled projects using Fine-Kinney approach.

The main highlight of the result was a preponderance of ‘risk’ hazards; these hazards outnumbered all other groups of hazards by at least 5 to 1. On the average, there were 11 ‘possible’ risk hazards for every 1 ‘very high’ and ‘high’ risk hazards in excavation, reinforced concrete and roof works.

Table 4.24a Risk distribution in projects using Fine Kinney approach

Projects	Excavation					Reinforced Concrete					Masonry					Roof work					Floor finishing					Plastering/Rendering					Painting work				
	VH	**H**	**S**	**P**	**R**	**VH**	**H**	**S**	**P**	**R**	**VH**	**H**	**S**	**P**	**R**	**VH**	**H**	**S**	**P**	**R**	**VH**	**H**	**S**	**P**	**R**	**VH**	**H**	**S**	**P**	**R**	**VH**	**H**	**S**	**P**	**R**
1	0	1	2	3	12	0	0	5	4	9	0	1	0	6	11	2	1	2	1	12	0	1	2	4	11	1	2	3	1	11	0	1	2	3	12
2	7	6	1	0	4	0	4	6	2	6	0	5	5	2	6	7	4	0	0	7	2	3	4	0	9	6	3	0	2	7	2	3	4	0	9
3	0	0	0	1	17	0	0	0	4	14	0	0	1	1	16	0	1	1	3	13	0	1	2	1	14	1	1	2	0	14	0	1	2	1	14
4	0	0	0	0	18	0	0	1	3	14	0	0	0	0	18	0	0	0	3	15	0	0	0	2	16	0	0	2	0	16	0	0	0	2	16
5	0	0	0	0	18	0	0	0	2	16	0	0	0	1	17	0	0	0	0	18	0	0	0	2	16	0	0	2	0	16	0	0	0	2	16
6	0	3	3	4	8	0	3	6	3	6	0	1	4	4	9	1	0	4	3	10	0	0	4	6	8	0	2	8	0	8	0	2	2	6	8
7	0	1	2	0	15	0	0	1	6	11	0	0	0	0	18	0	0	1	1	16	0	0	0	0	18	0	0	0	0	18	0	0	0	0	18
8	0	6	0	3	9	0	4	3	1	10	0	4	2	2	10	0	5	1	3	9	0	1	1	3	13	0	1	1	3	13	0	1	1	3	13
9	0	0	3	7	8	0	9	0	9	0	0	0	0	3	15	0	0	1	6	11	0	1	0	9	8	0	1	0	9	8	0	1	0	9	8
10	3	1	0	1	13	0	2	1	6	9	1	1	2	2	12	2	3	3	4	6	0	3	1	4	10	3	1	4	0	10	0	3	1	4	10
11	0	0	2	6	10	0	1	6	3	8	0	0	0	1	17	0	0	2	5	11	0	0	0	5	13	0	0	0	5	13	0	0	0	4	14
12	2	0	1	5	10	1	0	2	4	11	0	1	2	2	13	0	1	1	5	11	0	1	1	2	14	1	0	3	0	14	0	0	2	2	14
13	1	1	3	2	11	4	0	4	2	8	0	1	2	4	11	1	1	2	4	10	0	0	0	3	15	0	0	0	3	15	0	0	0	3	15
14	0	0	2	6	10	0	0	1	4	13	0	0	2	1	15	0	2	1	7	8	0	0	0	1	17	0	0	1	0	17	0	0	0	1	17
15	1	0	5	1	11	0	0	3	5	10	0	0	2	1	15	1	1	1	2	13	0	0	3	4	11	0	0	6	1	11	0	0	3	4	11
16	7	1	4	3	3	0	3	4	6	5	4	3	3	1	7	8	2	0	2	6	2	2	3	5	6	4	1	7	0	6	2	2	3	5	6
17	0	0	3	1	14	0	1	1	4	12	0	1	3	1	13	0	3	1	3	11	0	1	0	3	14	0	1	0	3	14	0	1	0	2	15
18	0	0	3	1	14	1	1	4	4	8	0	0	2	2	14	0	0	3	2	13	0	1	0	4	13	1	0	3	1	13	0	1	0	3	14
19	0	0	1	2	15	0	0	0	0	18	0	0	0	0	18	0	0	0	4	14	0	0	0	0	18	0	0	0	2	16	0	0	0	0	18
20	1	1	2	3	11	1	0	0	2	15	0	1	2	6	9	0	1	4	2	11	0	1	1	4	12	1	0	5	0	12	0	1	1	4	12
21	0	0	0	3	15	0	0	0	1	17	0	0	0	2	16	0	0	2	1	15	0	0	0	4	14	0	0	3	1	14	0	0	0	4	14
22	1	1	0	1	15	0	1	2	4	11	0	0	0	3	15	2	0	2	2	12	3	0	1	1	13	3	0	2	0	13	3	0	1	1	13
23	0	6	6	2	4	0	0	2	11	5	0	0	0	1	17	0	0	2	5	11	0	0	0	10	8	0	0	0	10	8	0	0	0	10	8
24	0	1	3	1	13	0	0	0	2	16	0	0	0	3	15	0	1	1	7	9	0	0	0	1	17	0	0	1	0	17	0	0	0	1	17
25	0	1	1	0	16	0	0	0	1	17	0	0	0	1	17	0	0	0	1	17	0	0	0	0	18	0	0	0	0	18	0	0	0	0	18
26	0	0	0	0	18	0	1	0	0	17	0	1	0	5	12	0	0	4	4	10	0	0	0	8	10	0	0	3	5	10	0	0	0	8	10
27	0	11	7	0	0	3	5	8	2	0	0	0	1	12	5	0	1	10	6	1	0	0	0	6	12	0	0	0	7	11	0	0	0	7	11
28	0	0	0	2	16	0	0	1	2	15	0	0	0	1	17	0	1	2	4	11	0	0	2	4	12	0	0	5	1	12	0	0	2	3	13
29	2	3	0	2	11	0	2	5	3	8	0	1	1	3	13	0	2	1	5	10	0	0	3	3	12	0	3	3	0	12	0	0	3	3	12
30	0	0	8	4	6	0	0	4	1	13	0	0	2	2	14	0	1	1	6	10	0	2	2	3	11	2	0	5	0	11	0	2	2	3	11
31	0	0	0	1	17	0	0	0	3	15	0	0	0	0	18	0	0	0	0	18	0	0	0	1	17	0	0	1	1	16	0	0	0	1	17

Table 4.24b Risk distribution in projects using Fine Kinney approach

Projects	**Excavation**					**Reinforced Concrete**					**Masonry**					**Roof work**					**Floor finishing**					**Plastering/Rendering**					**Painting work**				
	VH	**H**	**S**	**P**	**R**	**VH**	**H**	**S**	**P**	**R**	**VH**	**H**	**S**	**P**	**R**	**VH**	**H**	**S**	**P**	**R**	**VH**	**H**	**S**	**P**	**R**	**VH**	**H**	**S**	**P**	**R**	**VH**	**H**	**S**	**P**	**R**
32	2	2	0	4	10	0	1	1	2	14	0	1	1	2	14	0	4	0	2	12	0	0	1	1	16	0	1	1	0	16	0	0	1	1	16
33	1	0	0	3	14	0	1	2	4	11	0	1	1	2	14	1	3	1	5	8	0	0	0	3	15	0	0	3	0	15	0	0	0	3	15
34	0	0	1	0	17	1	0	0	0	17	0	0	0	0	18	1	0	0	0	17	0	0	0	0	18	0	0	0	0	18	0	0	0	0	18
35	4	0	2	5	7	1	3	2	2	10	0	2	0	5	11	1	1	3	4	9	1	0	0	3	14	1	0	0	3	14	0	1	0	3	14
36	1	0	4	4	9	2	0	2	3	11	0	0	1	2	15	2	2	3	0	11	0	1	1	1	15	0	0	2	1	15	0	0	2	1	15
37	0	1	2	2	13	0	0	0	0	18	0	0	0	0	18	0	0	2	3	13	0	0	0	1	17	0	0	0	0	18	0	0	0	0	18
38	1	0	8	0	9	0	0	3	4	11	0	0	2	6	10	1	0	1	1	15	0	0	2	0	16	0	0	2	0	16	0	0	2	0	16
39	13	0	1	2	2	5	7	4	1	1	2	1	4	4	7	2	5	3	5	3	0	3	5	5	5	0	3	5	5	5	0	3	5	5	5
40	0	2	1	1	14	0	1	0	4	13	0	1	0	3	14	0	0	3	1	14	0	0	0	0	18	0	0	0	0	18	0	0	0	0	18
	VH	**H**	**S**	**P**	**R**	**VH**	**H**	**S**	**P**	**R**	**VH**	**H**	**S**	**P**	**R**	**VH**	**H**	**S**	**P**	**R**	**VH**	**H**	**S**	**P**	**R**	**VH**	**H**	**S**	**P**	**R**	**VH**	**H**	**S**	**P**	**R**
Sum	*47*	*49*	*81*	*86*	*457*	*19*	*50*	*84*	*124*	*443*	*7*	*27*	*45*	*97*	*544*	*32*	*46*	*69*	*122*	*451*	*8*	*22*	*39*	*117*	*534*	*24*	*20*	*83*	*64*	*529*	*7*	*23*	*39*	*112*	*539*
Average	*1.2*	*1.2*	*2.0*	*2.2*	*11.4*	*0.5*	*1.3*	*2.1*	*3.1*	*11.1*	*0.2*	*0.7*	*1.1*	*2.4*	*13.6*	*0.8*	*1.2*	*1.7*	*3.1*	*11.3*	*0.2*	*0.6*	*1.0*	*2.9*	*13.4*	*0.6*	*0.5*	*2.1*	*1.6*	*13.2*	*0.2*	*0.6*	*1.0*	*2.8*	*13.5*

Source: Author's fieldwork (2022)

Notes: n = 40; R=Risk; P=Possible; S=Substantial; H=High and VH= Very High

4.5 Determination of Safety Cost of Building Projects

The results of the data analysis concerning achieving objective three of the study was reported in this section. The data analysis was carried out using activity-based costing, which generated information for project safety cost under the following categories: costs of PPE, costs of CPM along with the costs of ST. These costs when aggregated gave the cost of safety for the projects concerned.

4.5.1 Computation of the costs of personal protective equipment (PPE)

The procedure explored in deriving the costs of PPE was explained in section 3.8.3 as well as the derivation of the number of workers exposed to hazards during building work activities was presented in Figure 3.1 of Section 3.8.3, with specific reference to Section 3.8.3.3. As explained in Section 3.8.3.3, the number of workers that are required to complete the work, is presented in Table 4.25a and 4.25b

Table 4.25a: Number of skilled and unskilled workers for various work items in project BOQs (Nos. 1 – 20)

WBS Section	WBS Work Items	P.1		P.2		P.3		P.4		P.5		P.6		P.7		P.8		P.9		P.10		P.11		P.12		P.13		P.14		P.15		P.16		P.17		P.18		P.19		P.20	
		Skilled	Unskilled	Skilled	Unskilled	Skilled	Unskilled	Skilled	Unskilled	Skilled	Unskilled	Skilled	Unskilled	Skilled	Unskilled	Skilled	Unskilled	Skilled	Unskilled	Skilled	Unskilled	Skilled	Unskilled	Skilled	Unskilled	Skilled	Unskilled	Skilled	Unskilled	Skilled	Unskilled	Skilled	Unskilled	Skilled	Unskilled	Skilled	Unskilled	Skilled	Unskilled	Skilled	Unskilled
SUBSTRUCTURE	Trench excavation	0	12	0	8	0	15	0	16	0	8	0	39	0	54	0	13	0	23	0	8	0	39	0	11	0	125	0	8	0	15	0	10	0	17	0	54	0	31	0	12
	Laterite filling	0	4	0	2	0	4	0	7	0	5	0	8	0	7	0	3	0	2	0	8	0	6	0	4	0	4	0	8	0	4	0	8	0	3	0	4	0	9	0	7
	Hardcore	0	1	0	3	0	9	0	2	0	2	0	2	0	9	0	2	0	1	0	3	0	2	0	9	0	6	0	3	0	5	0	5	0	14	0	3	0	0	0	3
SUPER STRUCTURE	Concrete work	2	2	0	0	0	0	1	1	1	1	1	1	2	2	0	0	1	1	0	0	5	5	0	0	2	2	0	0	0	0	0	0	0	0	1	1	0	0	0	0
	Reinforcement	36	36	2	2	6	6	14	14	9	9	18	18	36	36	5	5	16	16	1	1	103	103	4	4	38	38	1	1	6	6	0	0	4	4	13	13	3	3	2	2
	Formwork	5	5	0	0	1	1	3	3	3	3	3	3	6	6	1	1	1	1	0	0	16	16	1	1	6	6	0	0	1	1	0	0	1	1	3	3	1	1	1	1
EXTERNAL & INTERNAL WALL (MASONRY)	Concrete work	1	1	0	0	0	0	1	1	0	0	1	1	1	1	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1
	Reinforcement	10	10	2	2	3	3	12	12	4	4	6	6	6	6	2	2	5	5	1	1	7	7	2	2	1	1	1	1	2	2	2	2	4	4	8	8	7	7	4	4
	Formwork	9	9	1	1	2	2	6	6	3	3	6	6	5	5	2	2	3	3	1	1	4	4	1	1	1	1	1	1	2	2	1	1	3	3	5	5	6	6	3	3
	Blockwork	24	24	5	5	11	11	18	18	18	18	31	31	33	33	8	8	22	22	7	7	45	45	12	12	6	6	7	7	12	12	6	6	11	11	21	21	22	22	11	11
ROOF CONSTRUCTION	Roof covering	6	6	3	3	5	5	6	6	4	4	7	7	15	15	4	4	4	4	4	4	6	6	5	5	6	6	4	4	5	5	7	7	12	12	6	6	20	20	14	14
FINISHING	Screeding	6	6	0	0	2	2	0	0	2	2	3	3	2	2	2	2	3	3	2	2	15	15	2	2	8	8	1	1	3	3	3	3	7	7	15	15	7	7	6	6
	Tiling	5	5	1	1	2	2	3	3	2	2	4	4	2	2	1	1	3	3	1	1	14	14	2	2	0	0	1	1	3	3	4	4	8	8	14	14	4	4	7	7
	Rendering	14	14	3	3	7	7	8	8	8	8	13	13	19	19	3	3	7	7	3	3	31	31	5	5	5	5	3	3	7	7	3	3	5	5	21	21	10	10	5	5
	Tiling	15	15	8	8	5	5	4	4	4	4	6	6	5	5	4	4	5	5	2	2	21	21	4	4	2	2	2	2	2	2	5	5	4	4	11	11	9	9	5	5
PAINTING& DECORATION	Emulsion	5	0	2	0	3	0	5	0	5	0	7	0	11	0	2	0	7	0	1	0	14	0	2	0	3	0	2	0	5	0	1	0	2	0	7	0	6	0	3	0

Source: Author's fieldwork (2022)

Table 4.25b: Number of skilled and unskilled workers for various work items in project BOQs (Nos. 21 – 40)

WBS Section	WBS Work Items	P.21		P.22		P.23		P.24		P.25		P.26		P.27		P.28		P.29		P.30		P.31		P.32		P.33		P.34		P.35		P.36		P.37		P.38		P.39		P.40	
		Skilled	Unskilled	Skilled	Unskilled	Skilled	Unskilled	Skilled	Unskilled	Skilled	Unskilled	Skilled	Unskilled	Skilled	Unskilled	Skilled	Unskilled	Skilled	Unskilled	Skilled	Unskilled	Skilled	Unskilled	Skilled	Unskilled	Skilled	Unskilled	Skilled	Unskilled	Skilled	Unskilled	Skilled	Unskilled	Skilled	Unskilled	Skilled	Unskilled	Skilled	Unskilled	Skilled	Unskilled
SUBSTRUCTURE	Trench excavation	0	10	0	9	0	16	0	8	0	15	0	10	0	18	0	12	0	12	0	12	0	12	0	12	0	12	0	19	0	76	0	13	0	19	0	35	0	41	0	24
	Laterite filling	0	8	0	4	0	4	0	8	0	4	0	3	0	11	0	4	0	4	0	4	0	4	0	4	0	4	0	5	0	13	0	4	0	3	0	7	0	11	0	9
	Hardcore	0	5	0	16	0	5	0	5	0	5	0	16	0	16	0	2	0	2	0	2	0	2	0	2	0	2	0	7	0	24	0	5	0	17	0	17	0	15	0	0
SUPER STRUCTURE	Concrete work	0	0	0	0	1	1	0	0	1	1	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	0	0	0	0	1	1	0	0
	Reinforcement	0	0	1	1	14	14	0	0	6	6	3	3	9	9	2	2	2	2	2	2	2	2	2	2	2	2	7	7	9	9	11	11	6	6	4	4	18	18	7	7
	Formwork	0	0	0	0	3	3	0	0	3	3	1	1	2	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	3	3	4	4	2	2	1	1	2	2	2	2
EXTERNAL & INTERNAL WALL (MASONRY)	Concrete work	0	0	0	0	1	1	0	0	3	3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	1	1	2	2	1	1	1	1	3	3	2	2
	Reinforcement	1	1	2	2	8	8	1	1	10	10	6	6	6	6	4	4	4	4	4	4	4	4	4	4	4	4	7	7	6	6	12	12	4	4	4	4	3	3	10	10
	Formwork	1	1	2	2	5	5	1	1	9	9	5	5	4	4	4	4	4	4	4	4	4	4	4	4	4	4	1	1	5	5	8	8	3	3	3	3	11	11	5	5
	Blockwork	5	5	5	5	17	17	6	6	17	17	15	15	19	19	15	15	15	15	15	15	15	15	15	15	15	15	6	6	18	18	22	22	13	13	16	16	28	28	26	26
ROOF CONSTRUCTION	Roof covering	15	15	14	14	10	10	10	10	10	10	12	12	9	9	10	10	10	10	10	10	10	10	10	10	10	10	6	6	15	15	11	11	12	12	12	12	13	13	10	10
FINISHING	Screeding	3	3	4	4	16	16	3	3	11	11	7	7	9	9	6	6	6	6	6	6	6	6	6	6	6	6	3	3	9	9	14	14	8	8	8	8	11	11	10	10
	Tiling	3	3	4	4	15	15	3	3	12	12	8	8	10	10	8	8	8	8	8	8	8	8	8	8	8	8	4	4	10	10	5	5	8	8	9	9	13	13	12	12
	Rendering	3	3	4	4	6	6	3	3	13	13	8	8	9	9	6	6	6	6	6	6	6	6	6	6	6	6	2	2	10	10	9	9	5	5	9	9	15	15	9	9
	Tiling	3	3	2	2	4	4	3	3	9	9	4	4	16	16	8	8	8	8	8	8	8	8	8	8	8	8	1	1	6	6	4	4	3	3	6	6	6	6	6	6
PAINTING& DECORATION	Emulsion	2	0	2	0	3	0	1	0	9	0	4	0	5	0	5	0	5	0	5	0	5	0	5	0	5	0	1	0	4	0	5	0	3	0	4	0	1	0	1	0

Source: Author's fieldwork (2022)

The peculiarities of the building trades concerned determines the type of PPE required. Works where the worker was likely to be hit by moving machinery required the provision of high-visibility clothing, hence the provision of reflective vests for workers in excavation. Where workers operated at considerable heights above ground level, there was the need for safety harness or belts to guard against the possibility of falls from heights. Dust masks were needed where there was the likelihood of inhaling dust or other powdery substances. From the information presented in Table 4.26, it was observed that helmet, protective clothing, protective boot and gloves were needed for each of the building construction trades that were studied.

Table 4.26: PPE items needed for different building construction trades

PPE Items	Substructure (Excavation)	Wall (Masonry)	Concrete work	Roof work	Floor Finishing	Wall Finishing	Painting & Decoration
Dust Mask	√			√	√		
Face Shield		√	√				
Gloves	√	√	√	√	√	√	√
Goggle					√		
Helmet	√	√	√	√	√	√	√
Protective Boot	√	√	√	√	√	√	√
Protective Clothing	√	√	√	√	√	√	√
Reflective Vest	√						
Safety Harness/ Belt		√	√	√			

Source: Author's review (2022)

The breakdown of the costs of PPE items required for different work items in each of the 40 projects that were surveyed was presented in Table 4.27a and 4.27b and 4.28a and 4.28b. The cost of PPE arrived at depended on the number of workers (skilled and unskilled) required for the job, which was determined from the period of time allotted for the completion of the works. It is pertinent to note that the costs reflected here were the purchase costs, which are not affected by how long a period of time the PPE would be needed for; conversely, if the PPE were obtained through rental, the time over which the work would be carried would be a factor in arriving at the total cost of PPE.

Table 4.27a: Costs of PPE components required for excavation, masonry and concrete work (Projects 1 – 20)

Projects			**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
Work item	**PPE Types**	**Rate**	**PPE cost per project – in Thousands of Naira (₦'000)**																			
EXCAVATION	*Number of PPE*		*17*	*13*	*28*	*25*	*15*	*49*	*70*	*18*	*26*	*19*	*47*	*24*	*135*	*19*	*24*	*23*	*34*	*61*	*40*	*22*
	Helmet	5500	93.5	71.5	154	137.5	82.5	269.5	385	99	143	104.5	258.5	132	742.5	104.5	132	126.5	187	335.5	220	121
	Gloves	6500	110.5	84.5	182	162.5	97.5	318.5	455	117	169	123.5	305.5	156	877.5	123.5	156	149.5	221	396.5	260	143
	Protective clothing	20000	340	260	560	500	300	980	1400	360	520	380	940	480	2700	380	480	460	680	1220	800	440
	Reflective vest	5000	85	65	140	125	75	245	350	90	130	95	235	120	675	95	120	115	170	305	200	110
	Protective boot	40000	680	520	1120	1000	600	1960	2800	720	1040	760	1880	960	5400	760	960	920	1360	2440	1600	880
	Dust mask	1000	17	13	28	25	15	49	70	18	26	19	47	24	135	19	24	23	34	61	40	22
MASONRY	*Number of PPE*		*88*	*16*	*32*	*74*	*50*	*88*	*90*	*24*	*60*	*18*	*114*	*30*	*16*	*18*	*32*	*18*	*38*	*70*	*72*	*38*
	Helmet	5500	484	88	176	407	275	484	495	132	330	99	627	165	88	99	176	99	209	385	396	209
	Gloves	6500	572	104	208	481	325	572	585	156	390	117	741	195	104	117	208	117	247	455	468	247
	Protective clothing	20000	1760	320	640	1480	1000	1760	1800	480	1200	360	2280	600	320	360	640	360	760	1400	1440	760
	Protective boot	40000	3520	640	1280	2960	2000	3520	3600	960	2400	720	4560	1200	640	720	1280	720	1520	2800	2880	1520
	Safety harness	40000	3520	640	1280	2960	2000	3520	3600	960	2400	720	4560	1200	640	720	1280	720	1520	2800	2880	1520
	Face shield	10000	880	160	320	740	500	880	900	240	600	180	1140	300	160	180	320	180	380	700	720	380
REINFORCED CONCRETE	*Number of PPE*		*86*	*4*	*14*	*36*	*26*	*44*	*88*	*12*	*36*	*2*	*248*	*10*	*92*	*2*	*14*	*1*	*10*	*34*	*8*	*6*
	Helmet	5500	473	22	77	198	143	242	484	66	198	11	1364	55	506	11	77	0	55	187	44	33
	Gloves	6500	559	26	91	234	169	286	572	78	234	13	1612	65	598	13	91	0	65	221	52	39
	Protective clothing	20000	1720	80	280	720	520	880	1760	240	720	40	4960	200	1840	40	280	0	200	680	160	120
	Protective boot	40000	3440	160	560	1440	1040	1760	3520	480	1440	80	9920	400	3680	80	560	0	400	1360	320	240
	Safety harness	40000	3440	160	560	1440	1040	1760	3520	480	1440	80	9920	400	3680	80	560	0	400	1360	320	240
	Face shield	10000	860	40	140	360	260	440	880	120	360	20	2480	100	920	20	140	0	100	340	80	60

Source: Author's fieldwork (2022)

Table 4.27b: Costs of PPE components required for roof, floor, plastering and painting work (Projects 1 – 20)

Projects			**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
Work item	**PPE Types**	**Rate**	**PPE cost per project – in Thousands of Naira (₦'000)**																			
ROOF WORK	*Number of PPE*		*12*	*6*	*10*	*12*	*8*	*14*	*30*	*8*	*8*	*8*	*12*	*10*	*12*	*8*	*10*	*14*	*24*	*12*	*40*	*28*
	Helmet	5500	66	33	55	66	44	77	165	44	44	44	66	55	66	44	55	77	132	66	220	154
	Gloves	6500	78	39	65	78	52	91	195	52	52	52	78	65	78	52	65	91	156	78	260	182
	Protective cloth	20000	240	120	200	240	160	280	600	160	160	160	240	200	240	160	200	280	480	240	800	560
	Protective boot	40000	480	240	400	480	320	560	1200	320	320	320	480	400	480	320	400	560	960	480	1600	1120
	Safety harness	40000	480	240	400	480	320	560	1200	320	320	320	480	400	480	320	400	560	960	480	1600	1120
	Dust mask	1000	12	6	10	12	8	14	30	8	8	8	12	10	12	8	10	14	24	12	40	28
FLOOR	Number of PPE		*22*	*2*	*8*	*6*	*8*	*14*	*8*	*6*	*12*	*6*	*58*	*8*	*16*	*4*	*12*	*14*	*30*	*58*	*22*	*26*
	Helmet	5500	121	11	44	33	44	77	44	33	66	33	319	44	88	22	66	77	165	319	121	143
	Gloves	6500	143	13	52	39	52	91	52	39	78	39	377	52	104	26	78	91	195	377	143	169
	Protective cloth	20000	440	40	160	120	160	280	160	120	240	120	1160	160	320	80	240	280	600	1160	440	520
	Protective boot	40000	880	80	320	240	320	560	320	240	480	240	2320	320	640	160	480	560	1200	2320	880	1040
	Dust mask	1000	22	2	8	6	8	14	8	6	12	6	58	8	16	4	12	14	30	58	22	26
	Goggle	6500	143	13	52	39	52	91	52	39	78	39	377	52	104	26	78	91	195	377	143	169
PLASTERING	Number of PPE		*58*	*22*	*24*	*24*	*24*	*38*	*48*	*14*	*24*	*10*	*104*	*18*	*14*	*10*	*18*	*16*	*18*	*64*	*38*	*20*
	Helmet	5500	319	121	132	132	132	209	264	77	132	55	572	99	77	55	99	88	99	352	209	110
	Gloves	6500	377	143	156	156	156	247	312	91	156	65	676	117	91	65	117	104	117	416	247	130
	Protective cloth	20000	1160	440	480	480	480	760	960	280	480	200	2080	360	280	200	360	320	360	1280	760	400
	Protective boot	40000	2320	880	960	960	960	1520	1920	560	960	400	4160	720	560	400	720	640	720	2560	1520	800
PAINTING	Number of PPE		*5*	*2*	*3*	*5*	*5*	*7*	*11*	*2*	*7*	*1*	*14*	*2*	*3*	*2*	*5*	*1*	*2*	*7*	*6*	*3*
	Helmet	5500	27.5	11	16.5	27.5	27.5	38.5	60.5	11	38.5	5.5	77	11	16.5	11	27.5	5.5	11	38.5	33	16.5
	Gloves	6500	32.5	13	19.5	32.5	32.5	45.5	71.5	13	45.5	6.5	91	13	19.5	13	32.5	6.5	13	45.5	39	19.5
	Protective cloth	20000	100	40	60	100	100	140	220	40	140	20	280	40	60	40	100	20	40	140	120	60
	Protective boot	40000	200	80	120	200	200	280	440	80	280	40	560	80	120	80	200	40	80	280	240	120

Source: Author's fieldwork (2022)

Table 4.28a: Costs of PPE components required for excavation, masonry and concrete work (Projects 21 – 40)

Projects			**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**31**	**32**	**33**	**34**	**35**	**36**	**37**	**38**	**39**	**40**
Work item	**PPE Types**	**Rate**	**PPE cost per project – in Thousands of Naira (₦'000)**																			
	Number of PPE		*17*	*13*	*28*	*25*	*15*	*49*	*70*	*18*	*26*	*19*	*47*	*24*	*135*	*19*	*24*	*23*	*34*	*61*	*40*	*22*
EXCAVATION	Helmet	5500	126.5	159.5	137.5	115.5	132	159.5	247.5	99	99	99	99	99	99	170.5	621.5	121	214.5	324.5	368.5	181.5
	Gloves	6500	149.5	188.5	162.5	136.5	156	188.5	292.5	117	117	117	117	117	117	201.5	734.5	143	253.5	383.5	435.5	214.5
	Protective cloth	20000	460	580	500	420	480	580	900	360	360	360	360	360	360	620	2260	440	780	1180	1340	660
	Reflective vest	5000	115	145	125	105	120	145	225	90	90	90	90	90	90	155	565	110	195	295	335	165
	Protective boot	40000	920	1160	1000	840	960	1160	1800	720	720	720	720	720	720	1240	4520	880	1560	2360	2680	1320
	Dust mask	1000	23	29	25	21	24	29	45	18	18	18	18	18	18	31	113	22	39	59	67	33
MASONRY	Number of PPE		*14*	*18*	*62*	*16*	*78*	*54*	*60*	*48*	*48*	*48*	*48*	*48*	*48*	*28*	*60*	*88*	*42*	*48*	*90*	*86*
	Helmet	5500	77	99	341	88	429	297	330	264	264	264	264	264	264	154	330	484	231	264	495	473
	Gloves	6500	91	117	403	104	507	351	390	312	312	312	312	312	312	182	390	572	273	312	585	559
	Protective cloth	20000	280	360	1240	320	1560	1080	1200	960	960	960	960	960	960	560	1200	1760	840	960	1800	1720
	Protective boot	40000	560	720	2480	640	3120	2160	2400	1920	1920	1920	1920	1920	1920	1120	2400	3520	1680	1920	3600	3440
	Safety harness	40000	560	720	2480	640	3120	2160	2400	1920	1920	1920	1920	1920	1920	1120	2400	3520	1680	1920	3600	3440
	Face shield	10000	140	180	620	160	780	540	600	480	480	480	480	480	480	280	600	880	420	480	900	860
REINFORCED CONCRETE	Number of PPE		*1*	*2*	*36*	*1*	*20*	*8*	*24*	*6*	*6*	*6*	*6*	*6*	*6*	*16*	*26*	*32*	*16*	*10*	*42*	*18*
	Helmet	5500	0	11	198	0	110	44	132	33	33	33	33	33	33	88	143	176	88	55	231	99
	Gloves	6500	0	13	234	0	130	52	156	39	39	39	39	39	39	104	169	208	104	65	273	117
	Protective cloth	20000	0	40	720	0	400	160	480	120	120	120	120	120	120	320	520	640	320	200	840	360
	Protective boot	40000	0	80	1440	0	800	320	960	240	240	240	240	240	240	640	1040	1280	640	400	1680	720
	Safety harness	40000	0	80	1440	0	800	320	960	240	240	240	240	240	240	640	1040	1280	640	400	1680	720
	Face shield	10000	0	20	360	0	200	80	240	60	60	60	60	60	60	160	260	320	160	100	420	180

Source: Author's fieldwork (2022)

Table 4.28b: Costs of PPE components required for roof, floor, plastering and painting work (Projects 21 – 40)

Projects			**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**31**	**32**	**33**	**34**	**35**	**36**	**37**	**38**	**39**	**40**
Work item	**PPE Types**	**Rate**	**PPE cost per project – in Thousands of Naira (₦'000)**																			
ROOF WORK	Number of PPE		*30*	*28*	*20*	*20*	*20*	*24*	*18*	*20*	*20*	*20*	*20*	*20*	*20*	*12*	*30*	*22*	*24*	*24*	*26*	*20*
	Helmet	5500	165	154	110	110	110	132	99	110	110	110	110	110	110	66	165	121	132	132	143	110
	Gloves	6500	195	182	130	130	130	156	117	130	130	130	130	130	130	78	195	143	156	156	169	130
	Protective cloth	20000	600	560	400	400	400	480	360	400	400	400	400	400	400	240	600	440	480	480	520	400
	Protective boot	40000	1200	1120	800	800	800	960	720	800	800	800	800	800	800	480	1200	880	960	960	1040	800
	Safety harness	40000	1200	1120	800	800	800	960	720	800	800	800	800	800	800	480	1200	880	960	960	1040	800
	Dust mask	1000	30	28	20	20	20	24	18	20	20	20	20	20	20	12	30	22	24	24	26	20
FLOOR	Number of PPE		*12*	*16*	*62*	*12*	*46*	*30*	*38*	*28*	*28*	*28*	*28*	*28*	*28*	*14*	*38*	*38*	*32*	*34*	*48*	*44*
	Helmet	5500	66	88	341	66	253	165	209	154	154	154	154	154	154	77	209	209	176	187	264	242
	Gloves	6500	78	104	403	78	299	195	247	182	182	182	182	182	182	91	247	247	208	221	312	286
	Protective cloth	20000	240	320	1240	240	920	600	760	560	560	560	560	560	560	280	760	760	640	680	960	880
	Protective boot	40000	480	640	2480	480	1840	1200	1520	1120	1120	1120	1120	1120	1120	560	1520	1520	1280	1360	1920	1760
	Dust mask	1000	12	16	62	12	46	30	38	28	28	28	28	28	28	14	38	38	32	34	48	44
	Goggle	6500	78	104	403	78	299	195	247	182	182	182	182	182	182	91	247	247	208	221	312	286
PLASTERING	Number of PPE		*12*	*12*	*20*	*12*	*44*	*24*	*50*	*28*	*28*	*28*	*28*	*28*	*28*	*6*	*32*	*26*	*16*	*30*	*42*	*30*
	Helmet	5500	66	66	110	66	242	132	275	154	154	154	154	154	154	33	176	143	88	165	231	165
	Gloves	6500	78	78	130	78	286	156	325	182	182	182	182	182	182	39	208	169	104	195	273	195
	Protective cloth	20000	240	240	400	240	880	480	1000	560	560	560	560	560	560	120	640	520	320	600	840	600
	Protective boot	40000	480	480	800	480	1760	960	2000	1120	1120	1120	1120	1120	1120	240	1280	1040	640	1200	1680	1200
PAINTING	Number of PPE		*2*	*2*	*3*	*1*	*9*	*4*	*5*	*5*	*5*	*5*	*5*	*5*	*5*	*1*	*4*	*5*	*3*	*4*	*1*	*1*
	Helmet	5500	11	11	16.5	5.5	49.5	22	27.5	27.5	27.5	27.5	27.5	27.5	27.5	5.5	22	27.5	16.5	22	5.5	5.5
	Gloves	6500	13	13	19.5	6.5	58.5	26	32.5	32.5	32.5	32.5	32.5	32.5	32.5	6.5	26	32.5	19.5	26	6.5	6.5
	Protective cloth	20000	40	40	60	20	180	80	100	100	100	100	100	100	100	20	80	100	60	80	20	20
	Protective boot	40000	80	80	120	40	360	160	200	200	200	200	200	200	200	40	160	200	120	160	40	40

Source: Author's fieldwork (2022)

The information presented in Table 4.29 represents the summary of PPE costs for the work items in all of the 40 projects. The 'total PPE cost' shown in Column 9 of Table 4.29 was what contractors would require to provide sufficient workforce safety coverage through PPE.

Table 4.29: Summary of PPE costs for work items in all projects

Project	Excavation	Masonry	Concrete	Roof	Floor	Plaster	Painting	Total PPE
1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*
1	1,326,000	10,824,000	10,578,000	1,356,000	1,749,000	4,234,000	365,000	30,432,000
2	1,014,000	1,968,000	492,000	678,000	159,000	1,606,000	146,000	6,063,000
3	2,184,000	3,936,000	1,722,000	1,130,000	636,000	1,752,000	219,000	11,579,000
4	1,950,000	9,102,000	4,428,000	1,356,000	477,000	1,752,000	365,000	19,430,000
5	1,170,000	6,150,000	3,198,000	904,000	636,000	1,752,000	365,000	14,175,000
6	3,822,000	10,824,000	5,412,000	1,582,000	1,113,000	2,774,000	511,000	26,038,000
7	5,460,000	11,070,000	10,824,000	3,390,000	636,000	3,504,000	803,000	35,687,000
8	1,404,000	2,952,000	1,476,000	904,000	477,000	1,022,000	146,000	8,381,000
9	2,028,000	7,380,000	4,428,000	904,000.00	954,000	1,752,000	511,000	17,957,000
10	1,482,000	2,214,000	246,000	904,000.00	477,000	730,000	73,000	6,126,000
11	3,666,000	14,022,000	30,504,000	1,356,000	4,611,000	7,592,000	1,022,000	62,773,000
12	1,872,000	3,690,000	1,230,000	1,130,000	636,000	1,314,000	146,000	10,018,000
13	10,530,000	1,968,000	11,316,000	1,356,000	1,272,000	1,022,000	219,000	27,683,000
14	1,482,000	2,214,000	246,000	904,000	318,000	730,000	146,000	6,040,000
15	1,872,000	3,936,000	1,722,000	1,130,000	954,000	1,314,000	365,000	11,293,000
16	1,794,000	2,214,000	123,000	1,582,000	1,113,000	1,168,000	73,000	8,067,000
17	2,652,000	4,674,000	1,230,000	2,712,000	2,385,000	1,314,000	146,000	15,113,000
18	4,758,000	8,610,000	4,182,000	1,356,000	4,611,000	4,672,000	511,000	28,700,000
19	3,120,000	8,856,000	984,000	4,520,000	1,749,000	2,774,000	438,000	22,441,000
20	1,716,000	4,674,000	738,000	3,164,000	2,067,000	1,460,000	219,000	14,038,000
21	1,794,000	1,722,000	123,000	3,390,000	954,000	876,000	146,000	9,005,000
22	2,262,000	2,214,000	246,000	3,164,000	1,272,000	876,000	146,000	10,180,000
23	1,950,000	7,626,000	4,428,000	2,260,000	4,929,000	1,460,000	219,000	22,872,000
24	1,638,000	1,968,000	123,000	2,260,000	954,000	876,000	73,000	7,892,000
25	1,872,000	9,594,000	2,460,000	2,260,000	3,657,000	3,212,000	657,000	23,712,000
26	2,262,000	6,642,000	984,000	2,712,000	2,385,000	1,752,000	292,000	17,029,000
27	3,510,000	7,380,000	2,952,000	2,034,000	3,021,000	3,650,000	365,000	22,912,000
28	1,404,000	5,904,000	738,000	2,260,000	2,226,000	2,044,000	365,000	14,941,000
29	1,404,000	5,904,000	738,000	2,260,000	2,226,000	2,044,000	365,000	14,941,000
30	1,404,000	5,904,000	738,000	2,260,000	2,226,000	2,044,000	365,000	14,941,000
31	1,404,000	5,904,000	738,000	2,260,000	2,226,000	2,044,000	365,000	14,941,000
32	1,404,000	5,904,000	738,000	2,260,000	2,226,000	2,044,000	365,000	14,941,000
33	1,404,000	5,904,000	738,000	2,260,000	2,226,000	2,044,000	365,000	14,941,000
34	2,418,000	3,444,000	1,968,000	1,356,000	1,113,000	438,000	73,000	10,810,000
35	8,814,000	7,380,000	3,198,000	3,390,000	3,021,000	2,336,000	292,000	28,431,000
36	1,716,000	10,824,000	3,936,000	2,486,000	3,021,000	1,898,000	365,000	24,246,000
37	3,042,000	5,166,000	1,968,000	2,712,000	2,544,000	1,168,000	219,000	16,819,000
38	4,602,000	5,904,000	1,230,000	2,712,000	2,703,000	2,190,000	292,000	19,633,000
39	5,226,000	11,070,000	5,166,000	2,938,000	3,816,000	3,066,000	73,000	31,355,000
40	2,574,000	10,578,000	2,214,000	2,260,000	3,498,000	2,190,000	73,000	23,387,000

Source: Author (2022)

The amounts of monies indicated in Table 4.29 are gross values, inclusive of any profit to be earned by the contractor. Although the values in Table 4.29 show how the surveyed projects varied in terms of costs of PPE required, it was impossible to compare PPE costs amongst projects owing to variations in size, complexity and type of project. To get around this limitation, further pertinent information was provided in the Table 4.30.

Information on some physical and fiscal characteristics of the surveyed projects with respect to PPE costs was presented in Table 4.30. The total PPE cost was related to the (i) Gross Floor Area (GFA), (ii) preliminaries cost, and (iii) total project cost. The findings of this study revealed that PPE cost per square metre of gross floor area (PPE/M^2) varied between ₦4,406.85 and ₦91,387.39; the average cost of PPE per square metre of gross floor area was ₦16,142.58. In a related study, Gurcanli *et al.* (2015); Yilmaz and Kanit (2018) and Yilmaz and Ugur (2019) had established $49.86, $1198.20 and $1050 as the cost of PPE/$M^2$ for construction projects in Turkey; at an exchange rate of ₦400 to $1, this gives a comparable value of ₦19, 944, 479,280 and ₦420,000. The three projects that had the highest PPE costs per square metre of gross floor area all had gross floor areas that were less than 1000 M^2 (these were Project Nos 1, 7 and 11, which have been highlighted in Table 4.30 in bold face type). This observation suggests that the relationship between PPE cost and gross floor area might not be strictly linear; this inference concurs with Gurcanli *et al.* (2015), with specific reference to concrete work in Turkey however. It was also observed that between 1.09% and 16.99% of the total cost of projects would have to be devoted to providing PPE, although the average value of PPE cost as a proportion of total project cost was 4.38%. This percentage value is lower than what is in previous researches such as the 5.88% and 9.8% established (Ghousi *et al*., 2018; Ahn *et al*., 2021).

Table 4.30: Summary details for PPE costs in all projects

Project	Gross Floor Area (M^2)	Total Project Cost (TPC)	Preliminaries Cost	PPE Cost	PPE Cost/ M^2	PPE Cost (% of TPC)	PPE Cost (% of Prelim Cost)
1	*2*	*3*	*4*	*5*	*6*	*7*	*8*
1	333	179,168,916.18	7,500,000.00	30,432,000.00	**91,387.39**	16.99	405.76
2	440	115,425,377.94	6,759,634.00	6,063,000.00	13,779.55	5.25	89.69
3	553	153,390,480.00	88,334,270.00	11,579,000.00	20,938.52	7.55	13.11
4	593	269,092,892.75	12,000,000.00	19,430,000.00	32,765.60	7.22	161.92
5	593	269,092,892.75	1,236,156.00	14,175,000.00	23,903.88	5.27	1146.70
6	673	263,619,794.82	12,000,000.00	26,038,000.00	38,689.45	9.88	216.98
7	678	647,361,909.45	10,597,345.00	35,687,000.00	**52,635.69**	5.51	336.75
8	700	186,704,270.84	16,400,000.00	8,381,000.00	11,972.86	4.49	51.10
9	884	261,065,710.75	12,950,000.00	17,957,000.00	20,313.35	6.88	138.66
10	980	122,232,133.81	3,927,887.00	6,126,000.00	6,251.02	5.01	155.96
11	990	2,625,326,180.02	101,728,578.00	62,773,000.00	**63,407.07**	2.39	61.71
12	1020	195,950,245.40	30,954,514.00	10,018,000.00	9,821.57	5.11	32.36
13	1030	666,623,420.10	25,825,032.00	27,683,000.00	26,876.70	4.15	107.19
14	1033	125,734,353.21	4,040,430.00	6,040,000.00	5,847.05	4.80	149.49
15	1187	688,126,228.94	45,000,000.00	11,293,000.00	9,513.90	1.64	25.10
16	1253	128,804,911.11	3,568,926.00	8,067,000.00	6,438.15	6.26	226.03
17	1287	228,305,474.78	93,509,989.00	15,113,000.00	11,742.81	6.62	16.16
18	1293	823,679,438.38	31,909,468.00	28,700,000.00	22,196.44	3.48	89.94
19	1293	506,056,330.96	10,739,141.00	22,441,000.00	17,355.76	4.43	208.96
20	1400	243,283,404.79	35,172,475.00	14,038,000.00	10,027.14	5.77	39.91
21	1413	142,043,382.73	4,768,893.00	9,005,000.00	6,372.97	6.34	188.83
22	1607	181,880,725.74	31,258,338.00	10,180,000.00	6,334.79	5.60	32.57
23	1640	982,856,744.36	38,075,917.00	22,872,000.00	13,946.34	2.33	60.07
24	1720	165,821,449.11	5,328,617.00	7,892,000.00	4,588.37	4.76	148.11
25	1860	697,688,335.24	24,064,000.00	23,712,000.00	12,748.39	3.40	98.54
26	1973	255,002,560.40	8,586,021.00	17,029,000.00	8,631.02	6.68	198.33
27	2027	1,253,308,886.37	93,509,989.00	22,912,000.00	11,303.40	1.83	24.50
28	2047	741,404,557.05	76,173,082.00	14,941,000.00	7,298.97	2.02	19.61
29	2047	767,011,860.89	79,240,075.00	14,941,000.00	7,298.97	1.95	18.86
30	2047	631,980,919.67	64,655,757.00	14,941,000.00	7,298.97	2.36	23.11
31	2047	804,083,695.02	76,004,280.00	14,941,000.00	7,298.97	1.86	19.66
32	2047	630,898,120.05	64,544,980.00	14,941,000.00	7,298.97	2.37	23.15
33	2047	805,005,376.95	76,091,400.00	14,941,000.00	7,298.97	1.86	19.64
34	2453	759,955,377.51	31,584,137.00	10,810,000.00	4,406.85	1.42	34.23
35	2593	1,158,850,565.88	32,099,500.00	28,431,000.00	10,964.52	2.45	88.57
36	2627	969,766,039.70	40,180,000.00	24,246,000.00	9,229.54	2.50	60.34
37	3300	1,115,910,245.02	30,954,514.00	16,819,000.00	5,096.67	1.51	54.33
38	3827	1,179,859,664.31	31,258,338.00	19,633,000.00	5,130.13	1.66	62.81
39	4900	2,883,968,720.00	119,859,224.00	31,355,000.00	6,398.98	1.09	26.16
40	2000	896,130,605.85	38,690,860.00	23,387,000.00	11,693.50	2.61	60.45
Average					**16,412.58**	**4.38**	**123.38**

Source: Author's fieldwork (2022)

The results revealed some interesting highlights, mostly in terms of the inadequacy of the funds usually allocated for 'Preliminaries' in building projects. The costs of ensuring workforce and workplace safety are generally included in the preliminaries. In 14 out of the 40 projects that were surveyed (35%), PPE costs were higher than the monies allocated for preliminaries; In 25 out of the 40 projects that were surveyed (62.5%), PPE costs were higher than 50% of the monies allocated for preliminaries. The inference that can be drawn from these results was that the value of the preliminaries of building projects was grossly inadequate and insufficient for providing workforce safety. However, this scenario is moderated by the fact that PPE are sometimes rented, not purchased and that the same PPE are used for more than one work item and project as well. These practices will bring down the cost of such PPE. This inference is particular to the Nigerian construction industry and the use of the BOQ for deriving the cost of building works. This was the reason why researchers like Wells and Hawkins (2009), Smallwood (2011), Smallwood and Emuze (2014), Malam and Smallwood (2015) and Malan and Smallwood (2018) were of the opinion that a separate section be introduced in the Bills of Quantities for safety and health cost so as to allow for adequate apportioning of cost for safety and health in any contract.

4.5.2 Computation of costs of collective protective measures (CPM)

Safety protection goes beyond personal protection only; the entire workplace also needs to be protected from unauthorized incursions and unsafe working practices. Section 3.8.4.2 dealt with how the costs of CPM were derived for the 40 projects that were surveyed. The costs of the CPM components priced in the 40 projects is presented in Table 4.31.

Result in Table 4.31 revealed that only the costs of providing scaffolding, plant and equipment were provided for in all of the 40 projects that were surveyed. In 90% of the projects, provision was made for the costs of first aid and temporary fencing. The rest three items of CPM costs (i) hoarding and barriers, (ii) protection against damage and (iii) other safety measures (such as ‘access for workmen’) were only priced by about half of the sample of 40 projects that were surveyed.

One key point that arises from the data presented in Table 4.31 has to do with the observation that while there was provision for Collective Protective Measures (CPM) in the preliminaries section of the BOQ, there was no special provision for Personal Protective Equipment (PPE). This is a simple observation with far-reaching implications. While the employer takes responsibility for the costs incurred in protecting the workplace (which is owned by the employer, but under temporary control of the contractor), the entire responsibility for workers' personal safety through PPE is left to the contractor. While it may be argued that the workers are retained by the contractor and so workers safety should be the responsibility of the contractor, it should be kept in mind that both workplace safety and workforce safety are geared towards the same goal, which is delivering the project as planned. The case can thus be made for creating special sub-heads under the preliminaries section that will be dedicated to the costs of PPE, just like what obtains for CPM.

Table 4.31: Costs of CPM components priced in sampled projects

Project	Temporary Fencing	First Aid	Hoardings and Barriers	Scaffolding, Plant and Equipment	Other safety measures (Access for Workmen)	Protection Against Damage	Total CPM Cost inserted in Project Preliminaries
1	*2*	*3*	*4*	*5*	*6*	*7*	*8*
1				3,000,000.00			3,000,000.00
2	116,645.97	116,645.97	58,322.99	149,973.39	20,830.00		462,418.32
3	1,766,685.39	2,650,028.09	883,342.70	8,833,426.97		883,342.70	15,016,825.85
4	300,000.00	100,000.00		300,000.00			700,000.00
5		23,802.75		380,844.00			404,646.75
6	200,000.00	120,000.00	250,000.00	312,500.00		62,500.00	945,000.00
7	249,000.00	220,000.00	250,000.00	500,000.00	100,000.00		1,319,000.00
8	200,000.00	1,200,000.00		3,000,000.00			4,400,000.00
9		100,000.00	250,000.00	1,500,000.00			1,850,000.00
10	236,316.00	23,631.60		118,158.00			378,105.60
11	2,117,164.50	446,956.95	1,881,924.00	19,289,721.00	470,481.00	1,505,539.20	25,711,786.65
12	112,000.00	168,000.00		560,000.00		56,000.00	896,000.00
13	537,467.85	113,465.44	477,749.20	4,896,929.30	119,437.30	382,199.36	6,527,248.45
14	243,087.00	24,308.70		121,543.50			388,939.20
15	2,020,000.00	747,000.00		11,720,000.00			14,487,000.00
16	249,024.00	24,902.40		124,512.00			398,438.40
17	119,000.00	178,500.00		595,000.00		59,500.00	952,000.00
18	664,096.50	140,198.15	590,308.00	6,050,657.00	147,577.00	472,246.40	8,065,083.05
19	400,000.00	88,570.00	221,425.00	1,328,550.00			2,038,545.00
20	100,000.00	150,000.00		6,500,000.00			6,750,000.00
21	286,914.00	28,691.40		143,457.00			459,062.40
22	98,708.30	148,062.45		493,541.50		49,354.15	789,666.40
23	792,432.00	167,291.20	704,384.00	7,219,936.00	176,096.00	563,507.20	9,623,646.40
24	320,589.00	32,058.90		160,294.50			512,942.40
25	500,000.00			8,000,000.00	250,000.00	500,000.00	9,250,000.00
26	1,250,000.00	300,000.00	350,000.00	1,500,000.00			3,400,000.00
27	1,870,199.79	2,805,299.68	935,099.89	9,350,998.93		935,099.89	15,896,698.18
28	1,381,067.63	376,015.87	667,698.00	3,935,867.04	344,391.60		6,705,040.14
29	1,436,674.38	391,155.62	694,640.00	4,094,339.20	358,288.00		6,975,097.20
30	2,535,754.29			3,029,050.36		832,353.25	6,397,157.90
31	1,084,296.25	464,260.24		1,993,328.17	2,180,216.94	406,034.44	6,128,136.04
32	2,531,409.68			3,023,860.56		830,927.14	6,386,197.38
33	1,085,539.13	464,792.40		1,995,613.02	2,182,716.01	406,499.86	6,135,160.42
34	900,110.36	22,279.96	89,119.84	3,163,754.25		1,719,557.26	5,894,821.67
35	641,990.00	962,985.00	320,995.00	3,209,950.00		320,995.00	5,456,915.00
36		50,000.00	55,000.00	3,000,000.00			3,105,000.00
37	619,090.29	928,635.43	309,545.14	3,095,451.44		309,545.14	5,262,267.44
38	625,166.76	937,750.14	312,583.38	3,125,833.80		312,583.38	5,313,917.46
39	3,415,845.48	84,550.63	338,202.52	12,006,189.53		422,753.15	16,267,541.31
40	1,102,643.54	27,293.16	109,172.63	3,875,628.26		136,465.78	5,251,203.37

Source: Author's fieldwork (2022)

The costs of CPM as indicated in Table 4.31 are gross values, inclusive of any profit which may have been built in by the contractor. Although the values in Table 4.31 show how the surveyed projects varied in terms of costs of CPM required, it was impossible to compare CPM costs amongst projects owing to variations in size, complexity and type of project. To get around this limitation, further pertinent information was provided in the next table (Table 4.32).

Information on some physical and fiscal characteristics of the surveyed projects with respect to CPM costs was presented in Table 4.32. The total CPM cost was related to the (i) gross floor area, (ii) preliminaries cost, and (iii) total project cost. The findings of this study revealed that CPM cost per square metre of construction area (CPM/M^2) varied between ₦298.22 and ₦27,155.20; the average cost of CPM per square metre of construction area was ₦4,142.80. In Turkey, Yilmaz and Kanit (2018) and Yilmaz *et al*. (2019) had established $1,198 and $65 as the cost of CPM/$M^2$; at an exchange rate of ₦400 to $1, this gives a comparable value of ₦479, 200 and ₦26, 000. The three projects that had the highest CPM costs per square metre of gross floor area all had gross floor areas that were between 500 and 1200 M^2 (these were Project Nos 3, 11 and 15, which have been highlighted in Table 5.32 in bold face type). It was also observed that between 0.15% and 9.79% of the total cost of projects would have to be devoted to providing CPM, although the average value of CPM cost as a proportion of total project cost was 1.02%. This percentage value is lower than what is in previous researches such as the1.11%, 7.11% and 49.5% established (Ghousi *et al*., 2018; Yilmaz and Kanit, 2018; Ahn *et al*., 2021).

Table 4.32: Summary details for CPM costs in all projects

Project	Gross Floor Area (M^2)	Total CPM Cost	CPM Cost/ M^2	Total Project Cost (TPC)	CPM Cost As % Of TPC	Preliminaries Cost	CPM Cost as % of Preliminaries Cost
1	*2*	*3*	*4*	*5*	*6*	*7*	*8*
1	333	3,000,000.00	9,009.01	179,168,916.18	1.67	7,500,000.00	40.00
2	440	462,418.32	1,050.95	115,425,377.94	0.40	6,759,634.00	6.84
3	553	15,016,825.85	27,155.20	153,390,480.00	9.79	88,334,270.00	17.00
4	593	700,000.00	1,180.44	269,092,892.75	0.26	12,000,000.00	5.83
5	593	404,646.75	682.37	269,092,892.75	0.15	1,236,156.00	32.73
6	673	945,000.00	1,404.16	263,619,794.82	0.36	12,000,000.00	7.88
7	678	1,319,000.00	1,945.43	647,361,909.45	0.20	10,597,345.00	12.45
8	700	4,400,000.00	6,285.71	186,704,270.84	2.36	16,400,000.00	26.83
9	884	1,850,000.00	2,092.76	261,065,710.75	0.71	12,950,000.00	14.29
10	980	378,105.60	385.82	122,232,133.81	0.31	3,927,887.00	9.63
11	990	25,711,786.65	25,971.50	2,625,326,180.02	0.98	101,728,578.00	25.27
12	1020	896,000.00	878.43	195,950,245.40	0.46	30,954,514.00	2.89
13	1030	6,527,248.45	6,337.13	666,623,420.10	0.98	25,825,032.00	25.27
14	1033	388,939.20	376.51	125,734,353.21	0.31	4,040,430.00	9.63
15	1187	14,487,000.00	12,204.72	688,126,228.94	2.11	45,000,000.00	32.19
16	1253	398,438.40	317.99	128,804,911.11	0.31	3,568,926.00	11.16
17	1287	952,000.00	739.70	228,305,474.78	0.42	93,509,989.00	1.02
18	1293	8,065,083.05	6,237.50	823,679,438.38	0.98	31,909,468.00	25.27
19	1293	2,038,545.00	1,576.60	506,056,330.96	0.40	10,739,141.00	18.98
20	1400	6,750,000.00	4,821.43	243,283,404.79	2.77	35,172,475.00	19.19
21	1413	459,062.40	324.88	142,043,382.73	0.32	4,768,893.00	9.63
22	1607	789,666.40	491.39	181,880,725.74	0.43	31,258,338.00	2.53
23	1640	9,623,646.40	5,868.08	982,856,744.36	0.98	38,075,917.00	25.27
24	1720	512,942.40	298.22	165,821,449.11	0.31	5,328,617.00	9.63
25	1860	9,250,000.00	4,973.12	697,688,335.24	1.33	24,064,000.00	38.44
26	1973	3,400,000.00	1,723.26	255,002,560.40	1.33	8,586,021.00	39.60
27	2027	15,896,698.18	7,842.48	1,253,308,886.37	1.27	93,509,989.00	17.00
28	2047	6,705,040.14	3,275.54	741,404,557.05	0.90	76,173,082.00	8.80
29	2047	6,975,097.20	3,407.47	767,011,860.89	0.91	79,240,075.00	8.80
30	2047	6,397,157.90	3,125.14	631,980,919.67	1.01	64,655,757.00	9.89
31	2047	6,128,136.04	2,993.72	804,083,695.02	0.76	76,004,280.00	8.06
32	2047	6,386,197.38	3,119.78	630,898,120.05	1.01	64,544,980.00	9.89
33	2047	6,135,160.42	2,997.15	805,005,376.95	0.76	76,091,400.00	8.06
34	2453	5,894,821.67	2,403.11	759,955,377.51	0.78	31,584,137.00	18.66
35	2593	5,456,915.00	2,104.48	1,158,850,565.88	0.47	32,099,500.00	17.00
36	2627	3,105,000.00	1,181.96	969,766,039.70	0.32	40,180,000.00	7.73
37	3300	5,262,267.44	1,594.63	1,115,910,245.02	0.47	30,954,514.00	17.00
38	3827	5,313,917.46	1,388.53	1,179,859,664.31	0.45	31,258,338.00	17.00
39	4900	16,267,541.31	3,319.91	2,883,968,720.00	0.56	119,859,224.00	13.57
40	2000	5,251,203.37	2,625.60	896,130,605.85	0.59	38,690,860.00	13.57
Average			**4,142.80**		**1.02**		**16.11**

Source: Author's fieldwork (2022)

The results revealed some interesting contrasts with that of the PPE. Unlike the case with PPE where the funds allocated for 'preliminaries' in building projects would be inadequate for providing PPE, the costs of ensuring workplace safety (through CPM) were wholly catered for in the Preliminaries. In none of the 40 projects that were surveyed (0%) were CPM costs higher than the monies allocated for preliminaries. In none of the 40 projects that were surveyed (0%), were CPM costs higher than 40% of the monies allocated for preliminaries. The inference that can be drawn from these results was that the value of the preliminaries of building projects was quite adequate and sufficient for providing workplace safety through CPM.

4.5.3 Computation of costs for safety training (ST)

The costs of ST were derived for the 40 projects that were surveyed in this study as presented in Section 3.8.4.3. Information from the market survey, which was reported in Table 4.33, enabled the cost of the ST package for each project to be determined. It was observed that the ‘safety staff salary’ component was the costliest, followed by ‘safety education and training’, then ‘safety promotion’. Safety staff salary refers mainly to a Safety Officer, who is employed to oversee and coordinate safety activities in a project. The level of qualification and experience is a determining factor when considering safety staff salaries, these vary widely, so the ₦100,000 per month included in Table 4.33 is a very conservative estimate. There are no standard fees for such training; an Institute of Safety Professionals of Nigeria (ISPON) is only now coming into being across Nigeria. The ₦22,916.67 per month computed from the market survey is thus a conservative estimate as well. So also is the ₦10,000.00 per month allocated for safety promotion, which has to do with visual signs and warnings placed at prominent locations throughout the project site. By multiplying the figures for daily cost of ST components by the duration (in days) of each of the 40 projects that were employed for this study, the cost of ST components per project was arrived at; this was presented in Table 4.33.

Table 4.33: Average costs of Safety Training components

Cost type	Safety Education and Training	Safety Promotion	Safety Staff Salary	Total Safety Training Costs
1	*2*	*3*	*4*	*5*
Monthly costs	22,916.67	10,000.00	100,000.00	132,916.67
Daily costs	753.00	33.00	3,288.00	4,074.00

Source: Market Survey by Author (2021)

The costs of ST as indicated in Table 4.34 are gross values, inclusive of profit which may accrue to the contractor. Safety training costs depend on the durations of the surveyed projects; breakdown of these durations have earlier been presented in Table 4.10a and 4.10b. The total time duration each project was reproduced in Column 3 of Table 4.34. Result in Table 4.34 revealed that project 39 had ST cost of ₦2, 978,094.00 which was the highest while Project 1 had the lowest ST cost of ₦297,402.00. Although the values in Table 4.34 show how the surveyed projects varied in terms of gross floor area and ST costs, further analysis of ST costs amongst projects was impossible. To get around this limitation, further pertinent information about ST specific to each project was provided in the Table 4.35.

Table 4.34: Costs of Safety Training components for all projects

Project	Gross Floor Area (M^2)	Project Duration (Days)	Total Project Cost (TPC)	Safety Training Costs Components			
				Education & Training	Safety Promotion	Safety Staff Salary	Total ST Costs
1	*2*	*3*	*4*	*5*	*6*	*7*	*8*
1	333	73	179,168,916.18	54,969.00	2,409.00	240,024.00	297,402.00
2	440	97	115,425,377.94	73,041.00	3,201.00	318,936.00	395,178.00
3	553	122	153,390,480.00	91,866.00	4,026.00	401,136.00	497,028.00
4	593	130	269,092,892.75	97,890.00	4,290.00	427,440.00	529,620.00
5	593	135	269,092,892.75	101,655.00	4,455.00	443,880.00	549,990.00
6	673	148	263,619,794.82	111,444.00	4,884.00	486,624.00	602,952.00
7	678	149	647,361,909.45	112,197.00	4,917.00	489,912.00	607,026.00
8	700	154	186,704,270.84	115,962.00	5,082.00	506,352.00	627,396.00
9	884	194	261,065,710.75	146,082.00	6,402.00	637,872.00	790,356.00
10	980	216	122,232,133.81	162,648.00	7,128.00	710,208.00	879,984.00
11	990	218	2,625,326,180.02	164,154.00	7,194.00	716,784.00	888,132.00
12	1020	224	195,950,245.40	168,672.00	7,392.00	736,512.00	912,576.00
13	1030	227	666,623,420.10	170,931.00	7,491.00	746,376.00	924,798.00
14	1033	227	125,734,353.21	170,931.00	7,491.00	746,376.00	924,798.00
15	1187	261	688,126,228.94	196,533.00	8,613.00	858,168.00	1,063,314.00
16	1253	187	128,804,911.11	140,811.00	6,171.00	614,856.00	761,838.00
17	1287	192	228,305,474.78	144,576.00	6,336.00	631,296.00	782,208.00
18	1293	193	823,679,438.38	145,329.00	6,369.00	634,584.00	786,282.00
19	1293	193	506,056,330.96	145,329.00	6,369.00	634,584.00	786,282.00
20	1400	209	243,283,404.79	157,377.00	6,897.00	687,192.00	851,466.00
21	1413	211	142,043,382.73	158,883.00	6,963.00	693,768.00	859,614.00
22	1607	240	181,880,725.74	180,720.00	7,920.00	789,120.00	977,760.00
23	1640	245	982,856,744.36	184,485.00	8,085.00	805,560.00	998,130.00
24	1720	257	165,821,449.11	193,521.00	8,481.00	845,016.00	1,047,018.00
25	1860	278	697,688,335.24	209,334.00	9,174.00	914,064.00	1,132,572.00
26	1973	294	255,002,560.40	221,382.00	9,702.00	966,672.00	1,197,756.00
27	2027	302	1,253,308,886.37	227,406.00	9,966.00	992,976.00	1,230,348.00
28	2047	305	741,404,557.05	229,665.00	10,065.00	1,002,840.00	1,242,570.00
29	2047	305	767,011,860.89	229,665.00	10,065.00	1,002,840.00	1,242,570.00
30	2047	305	631,980,919.67	229,665.00	10,065.00	1,002,840.00	1,242,570.00
31	2047	305	804,083,695.02	229,665.00	10,065.00	1,002,840.00	1,242,570.00
32	2047	305	630,898,120.05	229,665.00	10,065.00	1,002,840.00	1,242,570.00
33	2047	305	805,005,376.95	229,665.00	10,065.00	1,002,840.00	1,242,570.00
34	2453	366	759,955,377.51	275,598.00	12,078.00	1,203,408.00	1,491,084.00
35	2593	387	1,158,850,565.88	291,411.00	12,771.00	1,272,456.00	1,576,638.00
36	2627	392	969,766,039.70	295,176.00	12,936.00	1,288,896.00	1,597,008.00
37	3300	492	1,115,910,245.02	370,476.00	16,236.00	1,617,696.00	2,004,408.00
38	3827	571	1,179,859,664.31	429,963.00	18,843.00	1,877,448.00	2,326,254.00
39	4900	731	2,883,968,720.00	550,443.00	24,123.00	2,403,528.00	2,978,094.00
40	2000	298	896,130,605.85	224,394.00	9,834.00	979,824.00	1,214,052.00

Source: Author’s fieldwork (2022)

Information on some physical and fiscal characteristics of the surveyed projects with respect to ST costs was presented in Table 4.35. The total ST cost was related to the (i) gross floor area, (ii) preliminaries cost, and (iii) total project cost. The findings of this study revealed that ST cost per square metre of gross floor area varied between ₦606.97 and ₦926.95; the average cost of ST per square metre of gross floor area was ₦716.53. By comparison, Yilmaz and Kanit (2018) and Yilmaz and Ugur(2019) had established $4429.29 and $3050 as the cost of ST/$M^2$ for construction work in Turkey; at an exchange rate of ₦400 to $1, this gives a comparable value of ₦1771,716 and ₦1220000. It was also observed that ST only required between 0.03% and 0.74% of total project costs, although the average value of the cost of ST as a proportion of total project cost was 0.27%. This percentage value is lower than what is in previous researches such as the 1.98%, 16.78%, 1.85% and 3.9% established by Ghousi *et al*., (2018), Yilmaz and Kanit (2018), Yilmaz and Ugur (2019) and Ahn *et al*., (2021) respectively.

Table 4.35: Summary details for Safety Training costs in all projects

Project	Construction Area (M^2)	ST Costs	ST Costs /M^2	Total Project Cost	ST Cost (% of Project Cost)	Preliminaries Cost	ST Cost (% of Preliminaries Cost)
1	*2*	*3*	*4*	*5*	*6*	*7*	*8*
1	333	297,402.00	892.21	179,168,916.18	0.17	7,500,000.00	3.97
2	440	395,178.00	898.13	115,425,377.94	0.34	6,759,634.00	5.85
3	553	497,028.00	898.24	153,390,480.00	0.32	88,334,270.00	0.56
4	593	529,620.00	892.62	269,092,892.75	0.20	12,000,000.00	4.41
5	593	549,990.00	926.95	269,092,892.75	0.20	1,236,156.00	44.49
6	673	602,952.00	895.47	263,619,794.82	0.23	12,000,000.00	5.02
7	678	607,026.00	894.97	647,361,909.45	0.09	10,597,345.00	5.73
8	700	627,396.00	896.28	186,704,270.84	0.34	16,400,000.00	3.83
9	884	790,356.00	894.07	261,065,710.75	0.30	12,950,000.00	6.10
10	980	879,984.00	897.94	122,232,133.81	0.72	3,927,887.00	22.40
11	990	888,132.00	897.10	2,625,326,180.02	0.03	101,728,578.00	0.87
12	1020	912,576.00	894.68	195,950,245.40	0.47	30,954,514.00	2.95
13	1030	924,798.00	897.86	666,623,420.10	0.14	25,825,032.00	3.58
14	1033	924,798.00	894.97	125,734,353.21	0.74	4,040,430.00	22.89
15	1187	1,063,314.00	896.05	688,126,228.94	0.15	45,000,000.00	2.36
16	1253	761,838.00	607.85	128,804,911.11	0.59	3,568,926.00	21.35
17	1287	782,208.00	607.93	228,305,474.78	0.34	93,509,989.00	0.84
18	1293	786,282.00	607.95	823,679,438.38	0.10	31,909,468.00	2.46
19	1293	786,282.00	607.95	506,056,330.96	0.16	10,739,141.00	7.32
20	1400	851,466.00	608.19	243,283,404.79	0.35	35,172,475.00	2.42
21	1413	859,614.00	608.22	142,043,382.73	0.61	4,768,893.00	18.03
22	1607	977,760.00	608.56	181,880,725.74	0.54	31,258,338.00	3.13
23	1640	998,130.00	608.62	982,856,744.36	0.10	38,075,917.00	2.62
24	1720	1,047,018.00	608.73	165,821,449.11	0.63	5,328,617.00	19.65
25	1860	1,132,572.00	608.91	697,688,335.24	0.16	24,064,000.00	4.71
26	1973	1,197,756.00	606.97	255,002,560.40	0.47	8,586,021.00	13.95
27	2027	1,230,348.00	607.08	1,253,308,886.37	0.10	93,509,989.00	1.32
28	2047	1,242,570.00	607.12	741,404,557.05	0.17	76,173,082.00	1.63
29	2047	1,242,570.00	607.12	767,011,860.89	0.16	79,240,075.00	1.57
30	2047	1,242,570.00	607.12	631,980,919.67	0.20	64,655,757.00	1.92
31	2047	1,242,570.00	607.12	804,083,695.02	0.15	76,004,280.00	1.63
32	2047	1,242,570.00	607.12	630,898,120.05	0.20	64,544,980.00	1.93
33	2047	1,242,570.00	607.12	805,005,376.95	0.15	76,091,400.00	1.63
34	2453	1,491,084.00	607.78	759,955,377.51	0.20	31,584,137.00	4.72
35	2593	1,576,638.00	607.96	1,158,850,565.88	0.14	32,099,500.00	4.91
36	2627	1,597,008.00	608.00	969,766,039.70	0.16	40,180,000.00	3.97
37	3300	2,004,408.00	607.40	1,115,910,245.02	0.18	30,954,514.00	6.48
38	3827	2,326,254.00	607.91	1,179,859,664.31	0.20	31,258,338.00	7.44
39	4900	2,978,094.00	607.77	2,883,968,720.00	0.10	119,859,224.00	2.48
40	2000	1,214,052.00	607.03	896,130,605.85	0.14	38,690,860.00	3.14
Average			**716.53**		**0.27**		**6.91**

Source: Author's fieldwork (2022)

The results revealed an interesting contrast of ST costs with that of PPE costs. Unlike the case with PPE where the funds allocated for 'Preliminaries' in building projects would be inadequate for providing PPE, the costs of developing a pro-safety mind-set in workers (through ST) were wholly catered for in the preliminaries. In none of the 40 projects that were surveyed (0%) were ST costs higher than the monies allocated for preliminaries. In only one of the 40 projects that were surveyed (2.5%), were CPM costs higher than 40% of the monies allocated for preliminaries. The inference that can be drawn from these results was that the value of the preliminaries of building projects was quite adequate and sufficient for providing ST in building construction projects.

4.5.4 Aggregation of PPE, CPM and ST costs (safety cost)

The result of aggregating the costs items in arriving at the safety cost for the 40 projects that were surveyed in this study was reported in this section. The following are the costs items that directly constitutes the safety cost of building projects: costs of PPE, costs of CPM and cost of ST. Owing to the form of data available, it has not been feasible to derive the safety cost for each of the major work elements in building projects; only the cost of PPE has been derived at that level of detail. CPM and ST costs have only been derived at the project level, not the elemental level. Thus the safety cost for building construction works has been aggregated at the project level; this was reported in Table 4.36.

The values of the three main safety cost components (PPE, CPM and ST costs) are presented in Table 4.36. In addition, the total project cost and gross floor area for each of the 40 surveyed projects was also presented. The seventh column of Table 4.36 contained the safety cost for each project, which was arrived at as the sum of the costs of PPE, CPM and ST. the highest and lowest safety costs were observed in Project 11 (₦89,372,918.65) and Project 2 (₦6,920,596.32) respectively. More detailed information as well as proportion analysis of safety costs was provided in Table 4.36.

Table 4.36: Safety Costs components computed for all projects

Project	Total Project Cost	GFA	PPE Cost	CPM Cost	ST Cost	Safety Cost of Project
1	*2*	*3*	*4*	*5*	*6*	*7*
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
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

Source: Author’s fieldwork (2022)

Proportion analysis of safety cost using some physical and fiscal characteristics of the surveyed projects was presented in Table 4.37a and 4.37b. Safety cost was related to the (i) gross floor area, (ii) total project cost, and (iii) preliminaries cost. The findings of this analysis revealed that safety cost per square metre of gross floor area varied between ₦5,495.33 and ₦101,289.50; the average safety cost per square metre of gross floor area was ₦21,271.98 while the median value was ₦13,383.67. The median value is the midpoint of the data (Safety Cost per square metre of gross floor area) when the data is arranged in ascending order of size. 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 4.37a 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. It was also observed that safety cost fluctuated between 1.75% and 18.83% of the total projects cost, although the average value cost of safety as a proportion of total project cost was 5.67%, while the median value was 5.13%. This percentage value is lower than what is in previous researches such as the 5.15%, 1-10% established by Yilmaz and Kanit (2018) and Adekunle *et al*., (2020) for construction work in Turkey and Nigeria.

Table 4.37a: Proportion analysis of Safety Cost for all projects (Projects 1 – 29)

Project	Gross floor Area	Total Project cost (TPC)	Preliminaries Cost	Safety Cost of Project	Safety Cost per M^2	Safety Cost (% of TPC)	Safety Cost (% of Prelims)
1	*2*	*3*	*4*	*5*	*6*	*7*	*8*
1	333	179,168,916.18	7,500,000.00	33,729,402.00	**101,289.50**	18.83	449.73
2	440	115,425,377.94	6,759,634.00	6,920,596.32	15,728.63	6.00	102.38
3	553	153,390,480.00	88,334,270.00	27,092,853.85	48,992.50	17.66	30.67
4	593	269,092,892.75	12,000,000.00	20,659,620.00	34,839.16	7.68	172.16
5	593	269,092,892.75	1,236,156.00	15,129,636.75	25,513.72	5.62	1223.93
6	673	263,619,794.82	12,000,000.00	27,585,952.00	40,989.53	10.46	229.88
7	678	647,361,909.45	10,597,345.00	37,613,026.00	**55,476.44**	5.81	354.93
8	700	186,704,270.84	16,400,000.00	13,408,396.00	19,154.85	7.18	81.76
9	884	261,065,710.75	12,950,000.00	20,597,356.00	23,300.18	7.89	159.05
10	980	122,232,133.81	3,927,887.00	7,384,089.60	7,534.79	6.04	187.99
11	990	2,625,326,180.02	101,728,578.00	89,372,918.65	**90,275.68**	3.40	87.85
12	1020	195,950,245.40	30,954,514.00	11,826,576.00	11,594.68	6.04	38.21
13	1030	666,623,420.10	25,825,032.00	35,135,046.45	34,111.70	5.27	136.05
14	1033	125,734,353.21	4,040,430.00	7,353,737.20	7,118.82	5.85	182.00
15	1187	688,126,228.94	45,000,000.00	26,843,314.00	22,614.42	3.90	59.65
16	1253	128,804,911.11	3,568,926.00	9,227,276.40	7,364.15	7.16	258.54
17	1287	228,305,474.78	93,509,989.00	16,847,208.00	13,090.29	7.38	18.02
18	1293	823,679,438.38	31,909,468.00	37,551,365.05	29,042.05	4.56	117.68
19	1293	506,056,330.96	10,739,141.00	25,265,827.00	19,540.47	4.99	235.27
20	1400	243,283,404.79	35,172,475.00	21,639,466.00	15,456.76	8.89	61.52
21	1413	142,043,382.73	4,768,893.00	10,323,676.40	7,306.21	7.27	216.48
22	1607	181,880,725.74	31,258,338.00	11,947,426.40	7,434.62	6.57	38.22
23	1640	982,856,744.36	38,075,917.00	33,493,776.40	20,423.03	3.41	87.97
24	1720	165,821,449.11	5,328,617.00	9,451,960.40	5,495.33	5.70	177.38
25	1860	697,688,335.24	24,064,000.00	34,094,572.00	18,330.42	4.89	141.68
26	1973	255,002,560.40	8,586,021.00	21,626,756.00	10,961.36	8.48	251.88
27	2027	1,253,308,886.37	93,509,989.00	40,039,046.18	19,752.86	3.19	42.82
28	2047	741,404,557.05	76,173,082.00	22,888,610.14	11,181.54	3.09	30.05
29	2047	767,011,860.89	79,240,075.00	23,158,667.20	11,313.47	3.02	29.23

Table 4.37b: Proportion analysis of Safety Cost for all projects (Projects 30 – 40)

Project	Constr. Area	Total Project cost (TPC)	Preliminaries Cost	Safety Cost of Project	Safety Cost per M^2	Safety Cost (% of TPC)	Safety Cost (% of Prelims)
1	*2*	*3*	*4*	*5*	*6*	*7*	*8*
30	2047	631,980,919.67	64,655,757.00	22,580,727.90	11,031.13	3.57	34.92
31	2047	804,083,695.02	76,004,280.00	22,311,706.04	10,899.71	2.77	29.36
32	2047	630,898,120.05	64,544,980.00	22,569,767.38	11,025.78	3.58	34.97
33	2047	805,005,376.95	76,091,400.00	22,318,730.42	10,903.14	2.77	29.33
34	2453	759,955,377.51	31,584,137.00	18,195,905.67	7,417.82	2.39	57.61
35	2593	1,158,850,565.88	32,099,500.00	35,464,553.00	13,677.04	3.06	110.48
36	2627	969,766,039.70	40,180,000.00	28,948,008.00	11,019.42	2.99	72.05
37	3300	1,115,910,245.02	30,954,514.00	24,085,675.44	7,298.69	2.16	77.81
38	3827	1,179,859,664.31	31,258,338.00	27,273,171.46	7,126.51	2.31	87.25
39	4900	2,883,968,720.00	119,859,224.00	50,600,635.31	10,326.66	1.75	42.22
40	2000	896,130,605.85	38,690,860.00	29,852,255.37	14,926.13	3.33	77.16
Mean					**21,271.98**	**5.67**	**146.40**
Median					**13,383.67**	**5.13**	**87.55**
Minimum					**5,495.33**	**1.75**	**18.02**
Maximum					**101,289.50**	**18.83**	**1,223.93**

Source: Author’s fieldwork (2022)

As has been noted earlier, the results revealed some interesting highlights, mostly in terms of the inadequacy of the funds usually allocated for ‘Preliminaries’ in building projects. In 12 out of the 40 projects that were surveyed (30%), Safety costs were less than 50% of the monies allocated for Preliminaries; In 10 out of the 40 projects that were surveyed (25%), Safety costs ranged between 50% and 100% of the monies allocated for Preliminaries. The rest of the sample (45%) had Safety costs that were more than 100% of the monies allocated for preliminaries. The inference that can be drawn from these results was that the costs of ensuring that construction workplaces are safe (that is Safety cost) are far heavier than the provisions that are usually made for safety under conventional systems of pricing construction works.

4.6 Development of Activity-Based Cost Model for Health and Safety Cost

Costs data generated in respect of H&S for building projects were employed in the development of a Simple Regression Analysis (SRA) model so as to achieve the study’s fourth objective. Where the gross floor area or duration of a building project is known, the developed model could be used to predict the proportion of the total project cost that would be needed to provide adequate safety on the project site.

4.6.1 Data employed for modelling safety cost

The main focus of the work carried out in furtherance of developing the model for the study was concerned with the use of the Gross Floor Area (GFA)(also known as the construction area) and Project Duration (also known as project completion time) in the prediction of the Safety cost of a project. There were thus two independent variables (Gross Floor Area and Project Duration), while the dependent variable was the Safety Cost of either the entire project, a part of the project such as a work element or a part of the safety cost like PPE cost. The data collected from forty (40) projects for this purpose is presented in Table 4.38a and 4.38b.

Table 4.38a and 4.38b consists of thirteen columns and forty rows of data. The first nine columns represent the dependent variables; column 1 is the total cost of safety for the entire project, while column 2 displayed the total cost of PPE for each project. Columns 3 through 9 contain the PPE costs for each of seven work elements (excavation, masonry, reinforced concrete, roofing, flooring, plastering and painting). The two independent variables employed in the study are presented in columns 10 and 11. The last two columns in Table 4.38 contain information that identified the projects being referenced and what the project data was used for. The project ID number is displayed in column 12, while the data in column 13 indicated whether the project concerned was assigned to either the model development group (model) or the model validation group (holdout).

Table 4.38a: Data to be employed for modelling safety cost of sampled projects (Projects 1 – 28)

Dependent variables (y)									Independent variables (x)		Project ID Number	Data Used As
Project Safety Cost % TCS	Project PPE Cost % TCS	Excavation PPE Cost % TCS	Masonry PPE Cost % TCS	Concrete PPE Cost % TCS	Roof PPE Cost % TCS	Floor PPE Cost % TCS	Plaster PPE Cost % TCS	Painting PPE Cost % TCS	Gross Floor Area	Duration		
1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*
18.83	**16.99**	**0.74**	**6.04**	**5.90**	**0.76**	**0.98**	**2.36**	**0.20**	**333**	**73**	**1**	**Holdout**
6.00	5.25	0.88	1.70	0.43	0.59	0.14	1.39	0.13	440	97	2	Model
17.66	**7.55**	**1.42**	**2.57**	**1.12**	**0.74**	**0.41**	**1.14**	**0.14**	**553**	**122**	**3**	**Model**
7.68	7.22	0.72	3.38	1.65	0.50	0.18	0.65	0.14	593	130	4	Holdout
5.62	5.27	0.43	2.29	1.19	0.34	0.24	0.65	0.14	593	135	5	Model
10.46	**9.88**	**1.45**	**4.11**	**2.05**	**0.60**	**0.42**	**1.05**	**0.19**	**673**	**148**	**6**	**Model**
5.81	5.51	0.84	1.71	1.67	0.52	0.10	0.54	0.12	678	149	7	Model
7.18	4.49	0.75	1.58	0.79	0.48	0.26	0.55	0.08	700	154	8	Holdout
7.89	6.88	0.78	2.83	1.70	0.35	0.37	0.67	0.20	884	194	9	Model
6.04	5.01	1.21	1.81	0.20	0.74	0.39	0.60	0.06	980	216	10	Model
3.40	2.39	0.14	0.53	1.16	0.05	0.18	0.29	0.04	990	218	11	Model
6.04	5.11	0.96	1.88	0.63	0.58	0.32	0.67	0.07	1020	224	12	Holdout
5.27	4.15	1.58	0.30	1.70	0.20	0.19	0.15	0.03	1030	227	13	Model
5.85	4.80	1.18	1.76	0.20	0.72	0.25	0.58	0.12	1033	227	14	Model
3.90	1.64	0.27	0.57	0.25	0.16	0.14	0.19	0.05	1187	261	15	Model
7.16	6.26	1.39	1.72	0.10	1.23	0.86	0.91	0.06	1253	187	16	Holdout
7.38	6.62	1.16	2.05	0.54	1.19	1.04	0.58	0.06	1287	192	17	Model
4.56	3.48	0.58	1.05	0.51	0.16	0.56	0.57	0.06	1293	193	18	Holdout
4.99	4.43	0.62	1.75	0.19	0.89	0.35	0.55	0.09	1293	193	19	Model
8.89	5.77	0.71	1.92	0.30	1.30	0.85	0.60	0.09	1400	209	20	Model
7.27	6.34	1.26	1.21	0.09	2.39	0.67	0.62	0.10	1413	211	21	Model
6.57	5.60	1.24	1.22	0.14	1.74	0.70	0.48	0.08	1607	240	22	Model
3.41	2.33	0.20	0.78	0.45	0.23	0.50	0.15	0.02	1640	245	23	Model
5.70	4.76	0.99	1.19	0.07	1.36	0.58	0.53	0.04	1720	257	24	Holdout
4.89	3.40	0.27	1.38	0.35	0.32	0.52	0.46	0.09	1860	278	25	Model
8.48	6.68	0.89	2.60	0.39	1.06	0.94	0.69	0.11	1973	294	26	Model
3.19	1.83	0.28	0.59	0.24	0.16	0.24	0.29	0.03	2027	302	27	Model
3.09	2.02	0.19	0.80	0.10	0.30	0.30	0.28	0.05	2047	305	28	Holdout

Table 4.38b: Data to be employed for modelling safety cost of sampled projects (Projects 29 – 40)

Dependent variables (y)									Independent variables (x)		Project ID Number	Data Used As
Project Safety Cost % TCS	**Project PPE Cost % TCS**	**Excavation PPE Cost % TCS**	**Masonry PPE Cost % TCS**	**Concrete PPE Cost % TCS**	**Roof PPE Cost % TCS**	**Floor PPE Cost % TCS**	**Plaster PPE Cost % TCS**	**Painting PPE Cost % TCS**	**Gross Floor Area**	**Duration**		
1	***2***	***3***	***4***	***5***	***6***	***7***	***8***	***9***	***10***	***11***	***12***	***13***
3.02	1.95	0.18	0.77	0.10	0.29	0.29	0.27	0.05	2047	305	29	Model
3.57	2.36	0.22	0.93	0.12	0.36	0.35	0.32	0.06	2047	305	30	Model
2.77	1.86	0.17	0.73	0.09	0.28	0.28	0.25	0.05	2047	305	31	Model
3.58	2.37	0.22	0.94	0.12	0.36	0.35	0.32	0.06	2047	305	32	Model
2.77	1.86	0.17	0.73	0.09	0.28	0.28	0.25	0.05	2047	305	33	Model
2.39	1.42	0.32	0.45	0.26	0.18	0.15	0.06	0.01	2453	366	34	Model
3.06	2.45	0.76	0.64	0.28	0.29	0.26	0.20	0.03	2593	387	35	Model
2.99	2.50	0.18	1.12	0.41	0.26	0.31	0.20	0.04	2627	392	36	Holdout
2.16	1.51	0.27	0.46	0.18	0.24	0.23	0.10	0.02	3300	492	37	Model
2.31	1.66	0.39	0.50	0.10	0.23	0.23	0.19	0.02	3827	571	38	Model
1.75	1.09	0.18	0.38	0.18	0.10	0.13	0.11	0.00	4900	731	39	Holdout
3.33	2.61	0.29	1.18	0.25	0.25	0.39	0.24	0.01	2000	298	40	Model

Source: Author’s fieldwork (2022)

Note: TCS = Total Contract Sum; PPE = Personal Protective Equipment

4.6.2 *Apriori* expectations of models to be developed

Researchers often have a preconceived expectation of the characteristics of the results that they may obtain from their research work. These *apriori* expectations may be based on the results from previous research works, or simply on the properties of the variables being studied.

The researcher's expectations of the results from the regression modelling exercise in this study were based on the discoveries made in a previous research by Gurcanli *et al*. (2015). This was a study that built up an activity-based cost for safety in the construction of residential building and then developed a statistical model for this cost using simple regression analysis. However, the activity-based costing and model development activities were limited to only reinforced concrete work. In this study, the expectation is that while results should be similar in some respects to that obtained by Gurcanli *et al*. (2015), there would be some differences. Such differences would arise from the wider scope of this study (seven work elements compared to the single one covered by Gurcanli *et al*. (2015), and the differences in the sizes of projects considered in the two studies. The expected results from the regression modelling exercise in this study are presented in Table 4.39; these show that the best performing regression model would probably be a logarithmic transformation. The relationship between the dependent and independent variables would most likely, an inverse one, and range from weak to fairly strong.

Table 4.39: Basis of *apriori* expectations of models

Model Number	Dependent variable (y)	Independent Variable(s) (x)	Type of regression model / relationship amongst variables	Strength of relationship (as indicated by Coefficient of Determination (R^2))	Source of information
1	Cost of safety as % proportion of total project cost (TPC) of projects.	Gross Floor Area (GFA) (also known as construction Area, measured in square meters).	Logarithmic / Inverse proportionality	0.67 (can also be expressed in percentage as 67%)	Gurcanli *et al*. (2015)
2	Cost of safety as % proportion of total project cost (TPC) of projects	Construction Duration (also known as Project Completion Time, measured in days).	-	-	-
3	Cost of PPE as % proportion of total project cost (TPC) of projects	Gross floor area (GFA) (also known as construction area, measured in square meters).	-	-	-
4	Cost of PPE as % proportion of total project cost (TPC) of projects	Construction Duration (also known as Project Completion Time, measured in days).	-	-	-

Source: Author (2022)

Notes: A dash (-) indicates that the relationship between the variables concerned was not found to have been tested/determined in the literature that was reviewed.

4.6.3 Results of the preliminary tests of data for linear regression modelling

There are four fundamental conditions that must be satisfied in order for the findings of a linear regression to be reliable. The results that were carried out to test these assumptions are presented in this section.

4.6.3.1 *Test of normality of variables*

The test of normality was conducted by using skewness and kurtosis of variables. Table 4.40 reveals the following: the skewness of all of the four variables being tested had asymmetrical distributions, since their skewness values were more than twice the standard errors. Result of kurtosis which was used as a second measure of a distribution's shape revealed that the distributions of the four variables were leptokurtic. This was the case due to the fact that the kurtosis values was positive, indicating that the observation were more concentrated near the centre of the distribution, presenting tails that were thinner than those of a normal distribution, but thicker than those of a normal distribution at the extremes. An opposite observation to this would be a platykurtic distribution.

Table 4.40: Descriptive statistics of regression variables

Statistic	Construction Area	Duration	Safety Cost as % of Project Cost	PPE Cost As % of Project Cost
N	40	40	40	40
Range	4567.00	658.00	17.08	15.90
Minimum	333.00	73.00	1.75	1.09
Maximum	4900.00	731.00	18.83	16.99
Mean	1610.87	261.08	5.67	4.38
Std. Error of Mean	149.29	19.92	0.57	0.47
Std. Deviation	944.16	126.01	3.61	2.96
Variance	891438.83	15878.79	13.05	8.74
Skewness	**1.40**	**1.72**	**2.19**	**2.12**
Std. Error of Skewness	**0.37**	**0.37**	**0.37**	**0.37**
Kurtosis	**2.90**	**4.47**	**5.98**	**7.39**
Std. Error Kurtosis	**0.73**	**0.73**	**0.73**	**0.73**

Source: Author (2022)

The asymmetry of the distributions was confirmed from the histograms of the dependent variables, which are resented in Figure 4.2 and Figure 4.3. Both histograms showed the distributions being clustered about the left tail rather than the middle.

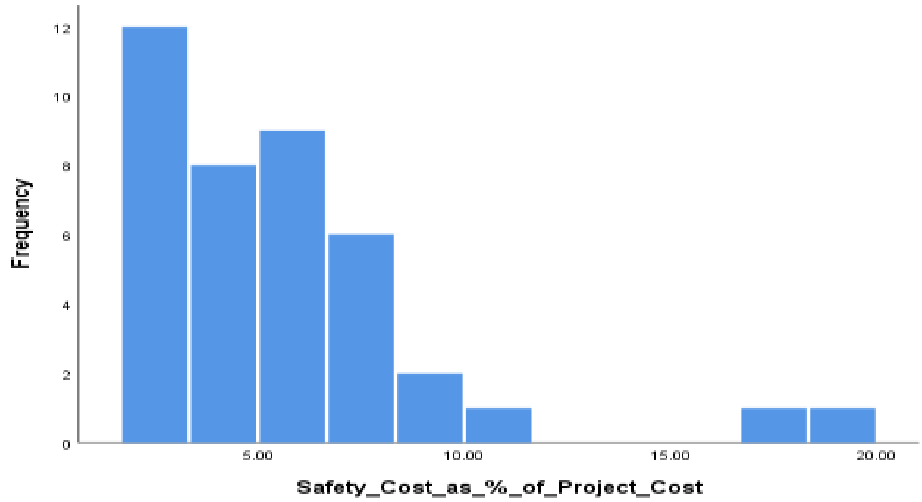

Figure 4.2: Histogram of Safety Cost

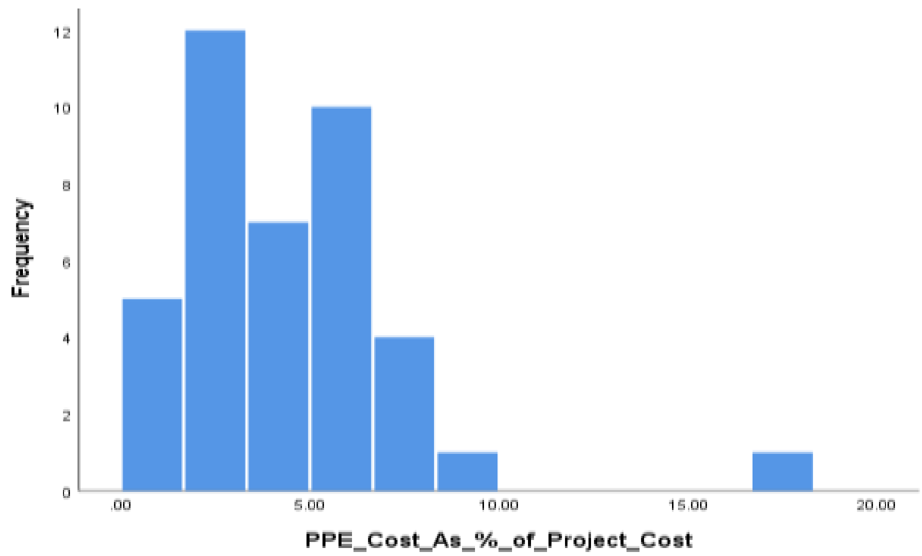

Figure 4.3: Histogram of PPE Cost

A further analysis of the variables' normality was conducted using Shapiro-Wilk test, Table 4.41 presents the result. The result shows the null hypotheses were to be disregarded, based on the 'Sig" value, which was 0.00 for both dependent variables. This meant rejection of the presumption that the variables are from a normal distribution. This provides confirmation that the dependent variables of the study are not normally distributed. This finding has to be taken into consideration when deciding the most effective type of regression to be employed.

Table 4.41: Tests of Normality of regression variables

	Shapiro-Wilk		
	Statistic	**df**	**Sig.**
Safety Cost as % of Project Cost	.778	40	.000
PPE Cost as % of Project Cost	.811	40	.000

Source: Author (2022)

4.6.3.2 ***Test of linearity of variables***

The scatter plots were used to investigate the relationship between the variables in order to ascertain the linearity of assumption. Figure 4.4 and Figure 4.5 presents the plots for the cost of safety; these plots revealed that the majority of the data was clustered in 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 meaning that if one variable increased, the other would decrease.

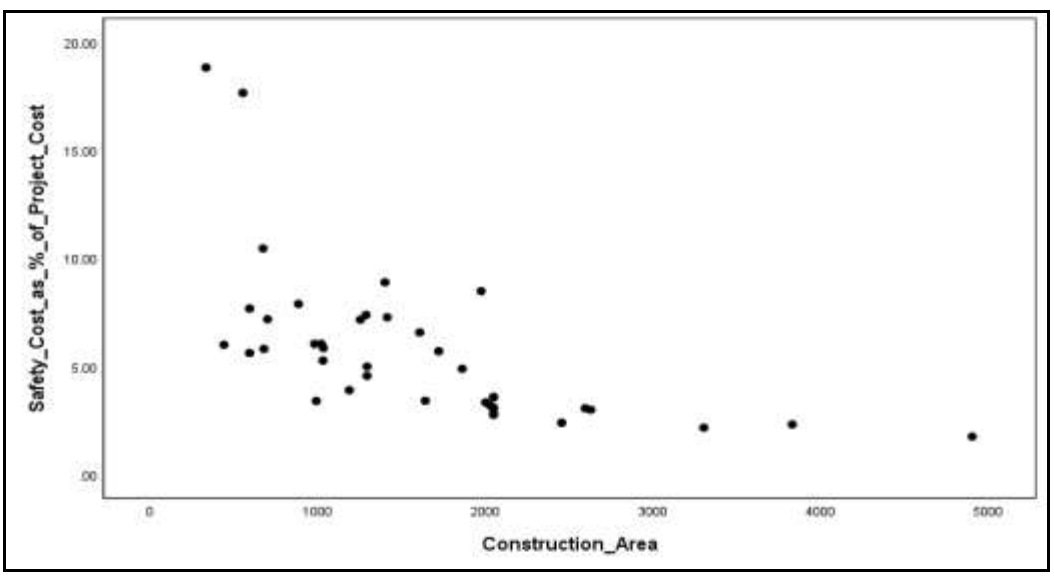

Figure 4.4: Scatter plot of Safety Cost and Construction Area

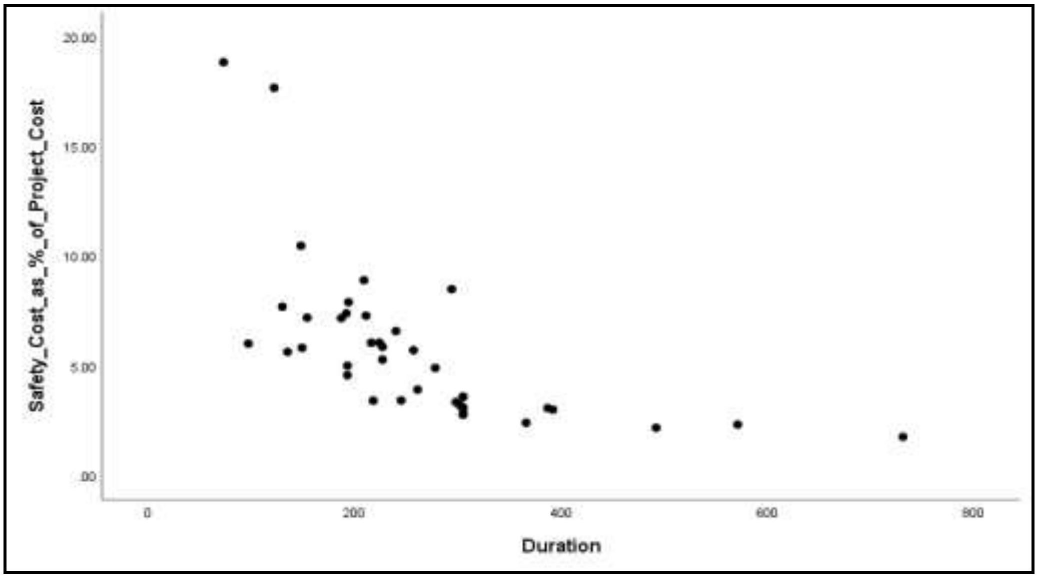

Figure 4.5: Scatter plot of Safety Cost and Project Duration

The plots for PPE cost are presented in Figure 4.6 and Figure 4.7; the presentation of the relation between PPE cost and gross floor area as well as PPE cost and project duration was similar to that of Safety cost. The data was mostly clustered within the lower left quadrant; only one data point that appeared to be an outlier.

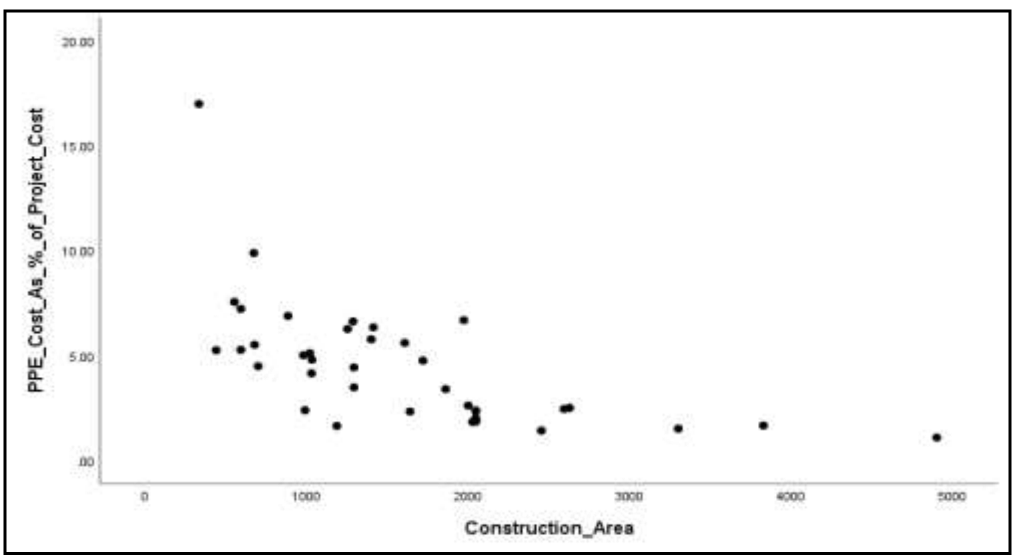

Figure 4.6: Scatterplot of PPE Cost and Construction Area

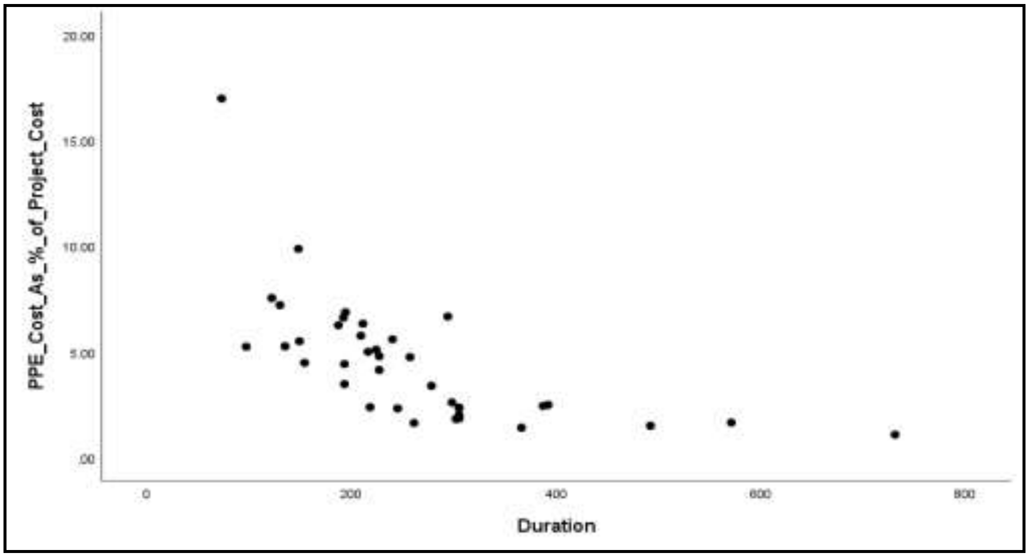

Figure 4.7: Scatterplot of PPE Cost and Project Duration

The inference drawn from the scatter plots was that a check had to be made for outliers; in addition, based only on the spread of the points in the plots, a linear relation between the dependent and independent variables cannot be ruled out.

4.6.3.3 *Test of equality of variances*

The box plots was used to determine the equality of variance as presented in Figure 4.8, the median of Safety Cost sits almost midway between the interquartile range (between the first and third quartiles). The observation that the upper whisker is longer than the lower one is indicative of a preponderance of sample elements having smaller values. This is also the case for PPE Costs.

Both of the dependent variables were similar in terms of their range; however, the box plot identified two outliers in Safety Cost as compared to one outlier in PPE Cost. This confirms what was earlier observed in when the scatter plots of the two variables were reviewed.

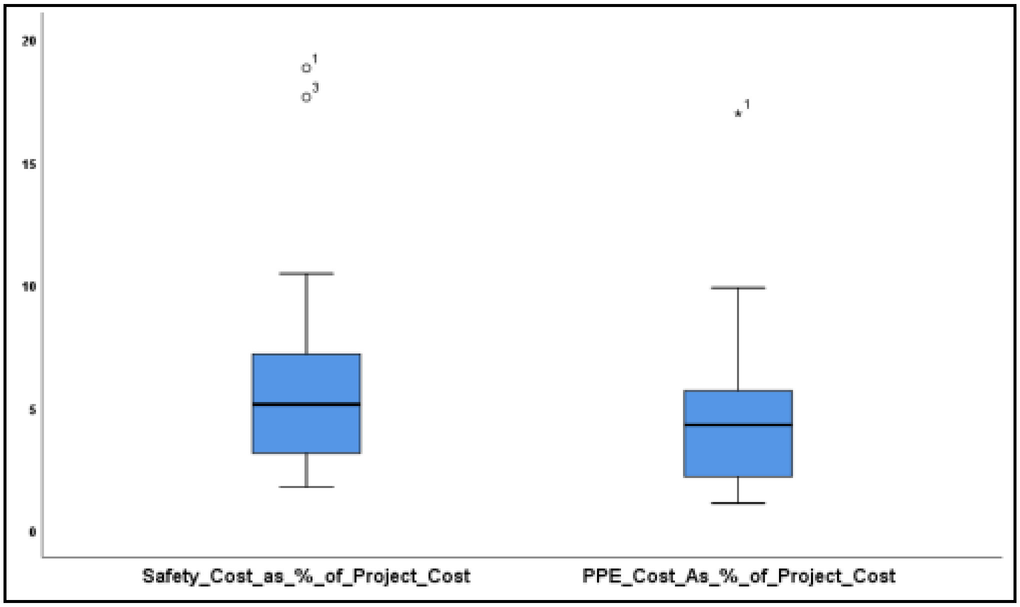

Figure 4.8: Box plot of the dependent variables

As a follow-up on the outliers identified in the scatter plots as well as the box plots, a table was generated which displayed the highest and lowest values in the dependent variables as presented in Table 4.42. Based on the contents of this table, three projects having Project ID Numbers 1, 3 and 6 (indicated as Case numbers in the statistical analysis result in Table 4.42) were removed from the data on Safety Cost. All of the removals were effected and reflected in Section 4.6.1.

Table 4.42: Identification of outliers in dependent variables

Case description	Rank of cases	Safety Cost (% of Project Cost)		PPE Cost (% of Project Cost)	
		Case Number	Value	Case Number	Value
Highest	1	**1**	**18.83**	1	16.99
	2	**3**	**17.66**	6	9.88
	3	**6**	**10.46**	3	7.55
	4	20	8.89	4	7.22
	5	26	8.48	9	6.88
Lowest	1	39	1.75	39	1.09
	2	37	2.16	34	1.42
	3	38	2.31	37	1.51
	4	34	2.39	15	1.64
	5	33	2.77	38	1.66

Source: Author’s fieldwork (2022)

4.6.3.4 *Test of independence of variables*

The correlation coefficient (r) was used to determine whether or not variables are independent of one another. Table 4.43 revealed that each of the independent variable had very strong relationships with the dependent variables; in all cases the correlations were negative, indicating that increases in the construction areas or project durations would be associated with a decrease in the values of Safety and PPE costs. The two independent variables had a strong and positive correlation.

Table 4.43: Correlation coefficients of research variables

	Construction Area	Duration	Safety Cost as % of Project Cost	PPE Cost as % of Project Cost
Construction Area	1	.982**	-.611**	-.625**
Duration	.982**	1	-.624**	-.641**
Safety Cost as % of Project Cost	-.611**	-.624**	1	.909**
PPE Cost As % of Project Cost	-.625**	-.641**	.909**	1

Source: Author’s fieldwork (2022)

Note: **. Correlation is significant at the 0.01 level (2-tailed).

Nonetheless, determining if any of the independent variable was a linear function was needed, this unwanted circumstance is called collinearity. Table 4.44 presents the diagnostics of the collinearity, which datasets demonstrated a multicollinearity issues were limited to interactions between the independent variables. The predictors were probably correlated with one another**,** and little changes in the values of the data might result in huge changes in the coefficients estimates, according to the close proximity of the Eigen values under Dimension 3 were close to 0.

In addition, condition indices were calculated using the square roots of the ratios between the highest and subsequent eigenvalues. Any condition index value larger than 15 suggests potential collinearity challenge, and any value greater than 30 suggests a consequential challenge. Under Dimension 3, an Eigen value of 27.536 portended a serious collinearity problem between the independent variables. The issue of collinearity was circumvented, though, because of the none inclusion of the independent variables in a singular regression analysis.

Table 4.44: Collinearity Diagnostics of the research variables

Model	Dimension	Eigen value	Condition Index	Variance Proportions (Constant)	Variance Proportions Construction Area	Variance Proportions Duration
Safety Cost as % of Project Cost	1	2.842	1.000	.01	.00	.00
	2	.154	4.290	.51	.01	.00
	3	.004	27.536	.48	.98	1.00
PPE Cost As % of Project Cost	1	2.842	1.000	.01	.00	.00
	2	.154	4.290	.51	.01	.00
	3	.004	27.536	.48	.98	1.00

Source: Author's fieldwork (2022)

4.6.3.5 *Partitioning of the data*

The following two tables present different combinations of the research data. Table 4.45 contained all the research data that were used for model development only; this was presented in the 28 rows displayed. In Table 4.46 the 9 projects that were set aside for validating the developed model are presented. Partitioning of data involves the dividing of datasets into diverse subsets that are then applied to various purposes during the models development. Commonly dataset are grouped into two, in order to use part for model development; while the rest of the data is then used to validate the predictive ability of the model.

The choices of data splitting into development sets and validation sets varies from researcher to researcher. Most research studies have divided datasets in the ratio 60:40 or 70:30 (Chaphalkar *et al*., 2015; Juszczyk and Lesniak, 2016; Husin, 2017) based on the belief that the more the data used to develop the model, the better will be the model performance. The study split the entire 40 projects employed for model development roughly in the ratio 75:25 for development and validation respectively. This meant that 28 of the projects were employed for the development of the regression model, whereas nine of the projects were applied to validate the model developed.

Table 4.45: Data used for developing ABC model (28 projects)

Dependent variables (y)									Independent variables (x)		Project ID Number	Data Used As	S/Nr
Project Safety Cost % TCS	Project PPE Cost % TCS	Excavation PPE Cost % TCS	Masonry PPE Cost % TCS	Concrete PPE Cost % TCS	Roof PPE Cost % TCS	Floor PPE Cost % TCS	Plaster PPE Cost % TCS	Painting PPE Cost % TCS	Construction Area	Duration			
1	***2***	***3***	***4***	***5***	***6***	***7***	***8***	***9***	***10***	***11***	***12***	***13***	***14***
6.00	5.25	0.88	1.70	0.43	0.59	0.14	1.39	0.13	440	97	2	Model	1
5.62	5.27	0.43	2.29	1.19	0.34	0.24	0.65	0.14	593	135	5	Model	2
5.81	5.51	0.84	1.71	1.67	0.52	0.10	0.54	0.12	678	149	7	Model	3
7.89	6.88	0.78	2.83	1.70	0.35	0.37	0.67	0.20	884	194	9	Model	4
6.04	5.01	1.21	1.81	0.20	0.74	0.39	0.60	0.06	980	216	10	Model	5
3.40	2.39	0.14	0.53	1.16	0.05	0.18	0.29	0.04	990	218	11	Model	6
5.27	4.15	1.58	0.30	1.70	0.20	0.19	0.15	0.03	1030	227	13	Model	7
5.85	4.80	1.18	1.76	0.20	0.72	0.25	0.58	0.12	1033	227	14	Model	8
3.90	1.64	0.27	0.57	0.25	0.16	0.14	0.19	0.05	1187	261	15	Model	9
7.38	6.62	1.16	2.05	0.54	1.19	1.04	0.58	0.06	1287	192	17	Model	10
4.99	4.43	0.62	1.75	0.19	0.89	0.35	0.55	0.09	1293	193	19	Model	11
8.89	5.77	0.71	1.92	0.30	1.30	0.85	0.60	0.09	1400	209	20	Model	12
7.27	6.34	1.26	1.21	0.09	2.39	0.67	0.62	0.10	1413	211	21	Model	13
6.57	5.60	1.24	1.22	0.14	1.74	0.70	0.48	0.08	1607	240	22	Model	14
3.41	2.33	0.20	0.78	0.45	0.23	0.50	0.15	0.02	1640	245	23	Model	15
4.89	3.40	0.27	1.38	0.35	0.32	0.52	0.46	0.09	1860	278	25	Model	16
8.48	6.68	0.89	2.60	0.39	1.06	0.94	0.69	0.11	1973	294	26	Model	17
3.19	1.83	0.28	0.59	0.24	0.16	0.24	0.29	0.03	2027	302	27	Model	18
3.02	1.95	0.18	0.77	0.10	0.29	0.29	0.27	0.05	2047	305	29	Model	19
3.57	2.36	0.22	0.93	0.12	0.36	0.35	0.32	0.06	2047	305	30	Model	20
2.77	1.86	0.17	0.73	0.09	0.28	0.28	0.25	0.05	2047	305	31	Model	21
3.58	2.37	0.22	0.94	0.12	0.36	0.35	0.32	0.06	2047	305	32	Model	22
2.77	1.86	0.17	0.73	0.09	0.28	0.28	0.25	0.05	2047	305	33	Model	23
2.39	1.42	0.32	0.45	0.26	0.18	0.15	0.06	0.01	2453	366	34	Model	24
3.06	2.45	0.76	0.64	0.28	0.29	0.26	0.20	0.03	2593	387	35	Model	25
2.16	1.51	0.27	0.46	0.18	0.24	0.23	0.10	0.02	3300	492	37	Model	26
2.31	1.66	0.39	0.50	0.10	0.23	0.23	0.19	0.02	3827	571	38	Model	27
3.33	2.61	0.29	1.18	0.25	0.25	0.39	0.24	0.01	2000	298	40	Model	28

Source: Author's fieldwork (2022

Table 4.46: Data used for validating ABC model (9 projects)

Dependent variables (y)									Independent variables (x)		Project ID Number	Data Used As	S/Nr
Project Safety Cost % TCS	Project PPE Cost % TCS	Excavation PPE Cost % TCS	Masonry PPE Cost % TCS	Concrete PPE Cost % TCS	Roof PPE Cost % TCS	Floor PPE Cost % TCS	Plaster PPE Cost % TCS	Painting PPE Cost % TCS	Construction Area	Duration			
1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	
7.68	7.22	0.72	3.38	1.65	0.50	0.18	0.65	0.14	593	130	4	Holdout	1
7.18	4.49	0.75	1.58	0.79	0.48	0.26	0.55	0.08	700	154	8	Holdout	2
6.04	5.11	0.96	1.88	0.63	0.58	0.32	0.67	0.07	1020	224	12	Holdout	3
7.16	6.26	1.39	1.72	0.10	1.23	0.86	0.91	0.06	1253	187	16	Holdout	4
4.56	3.48	0.58	1.05	0.51	0.16	0.56	0.57	0.06	1293	193	18	Holdout	5
5.70	4.76	0.99	1.19	0.07	1.36	0.58	0.53	0.04	1720	257	24	Holdout	6
3.09	2.02	0.19	0.80	0.10	0.30	0.30	0.28	0.05	2047	305	28	Holdout	7
2.99	2.50	0.18	1.12	0.41	0.26	0.31	0.20	0.04	2627	392	36	Holdout	8
1.75	1.09	0.18	0.38	0.18	0.10	0.13	0.11	0.00	4900	731	39	Holdout	9

Source: Author's fieldwork (2022)

4.6.4 Development of regression models

The outcomes of the regression analysis which resulted in models development for the prediction of safety cost as well as PPE cost is presented. Although a wide range of different types of regression models are available and can be used, the research was guided by the *apriori* expectations detailed in Section 4.6.2.1. The nature of the variables under consideration made some types of regression models (such as cubic or moving averages) unsuitable. Three types of regressions were employed throughout the modelling exercise; these were the linear, logarithmic and quadratic regressions.

The regression modelling exercise was executed in stages. The first stage, safety cost was modelled using first, gross floor area, and then Project duration. The results were reported in Sections 4.6.4.1 and 4.6.4.2. The second phase comprised the modelling of PPE cost using the same independent variables (gross floor area and project duration). The results for the second phase were reported in Sections 4.6.4.3 and 4.6.4.4. In the third which was the final stage, the costs of PPE for seven different work elements were modelled using one independent variable only, which was gross floor area. The results for the third phase were reported in Section 4.6.4.5.

4.6.4.1 Prediction of safety cost using gross floor area

The result of the first phase of model development, where safety cost was modelled using gross floor area is reported in Table 4.46. For each of the three types of regression employed - linear, logarithmic and quadratic regressions – the following information were provided; the linear regression denotes model 1, logarithmic regression denotes model 2, while quadratic regression denotes model 3, 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).

The enter procedure was utilized by the study, for the selection of variable in where all the variable in block are recorded in singular stride, since the independent variable was one. Generally, for a dependent variable to be a good predictor, the R^2 value of the variable must be large. However, in this case using gross floor area only gave an R^2 value of 0.392 for model 3 (quadratic), 0.391 for model 2 (logarithmic) and 0.354 for model 1(linear). 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 is presented in Table 4.47. In all three types of regression, 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 were all larger than the critical value of $F_{0.05}$. In addition, the probability values (P) were all much smaller than 0.05. Taken together, these meant that in each of the three models gross floor area was significantly but weakly related to safety cost.

Table 4.47: Regression model results for Safety Cost and GFA

Variable	**Model 1**			**Model 2**			**Model 3**		
	B	β	SEB	B	β	SEB	B	β	SEB
Constant	7.33		.735	20.608		4.767	7.307		1.410
GFA	-.002	-.600	.000	-2.166	-.547	0.651	-.001	-.588	-.002
							(.000)	(-.013)	(.000)
R	.600			.547			.600		
R^2	.354			.391			.392		
ΔF	14.625			11.074			7.031		
P	.001			.003			.004		

Source: Author's fieldwork (2022)

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 4.9. The three trend lines of linear, logarithmic and quadratic regressions displayed great similarity, which might account for the closeness of the r^2 values of the three types of regressions. This similarity of appearance introduced some difficulty into the selection of the best performing model. For this reason, consistency in predictions, as indicated by the lowest observed error level, was the criteria adopted for selection of the best performing model. This was treated in the fifth objective of this study, which involve the validation of the models developed in the study.

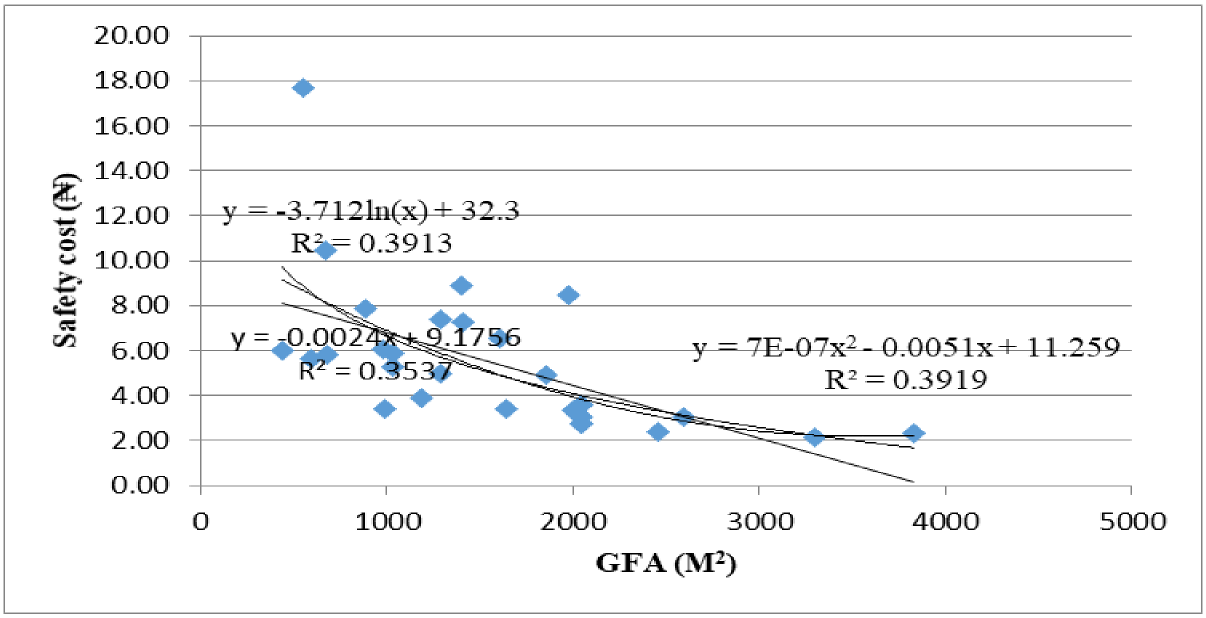

Figure 4.9: Scatter plot with trend lines (Safety cost & GFA)

4.6.4.2 Prediction of safety cost using duration of projects

The result of the modelling of safety cost using project duration is reported in this section in Table 4.48. Using project duration gave an R^2 value of 0.381 for the model 1 (linear), 0.436 for the model 2 (logarithmic) and 0.46 for the model 3 (quadratic). The inference is that only 38% to 46% of the change in safety cost is accounted for by the projects duration. Table 4.48 presents the regression model coefficients; these show that all the regression coefficients (B) were 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 values of the F statistic were all larger than the critical value of $F_{0.05}$. In addition, the probability values (P) were all much smaller than 0.05. When all of these observations were taken together, the inference was that the duration of projects was significantly but weakly related to safety cost.

Table 4.48: Regression model results for Safety Cost and Duration

Variable	Model 1			Model 2			Model 3		
	B	β	SEB	B	β	SEB	B	β	SEB
Constant	8.185		.866	23.240		.841	9.508		2.001
Duration	-.013	-.635	.003	-3.338	-.614	.841	-.022	-1.099	.013
							(1.427E-5)	(.478)	(.000)
R	.617			.601			.630		
R^2	.381			.436			.46		
ΔF	17.536			15.772			8.883		
P	.000			.001			.002		

Source: Author's fieldwork (2022)

The result presented in Table 4.48 was supported by the visual representation of the trend showing the relation between the cost of safety and projects duration, as displayed Figure 4.10. The three trend lines of linear, logarithmic and quadratic regressions displayed great similarity, which might account for the closeness of the r^2 values of the three types of regressions. Only the trend line for linear regression indicated that when duration of projects keeps increasing, safety cost would at some point become a negative value. This is a clearly impossible scenario, which shows the limits of the linear regression model.

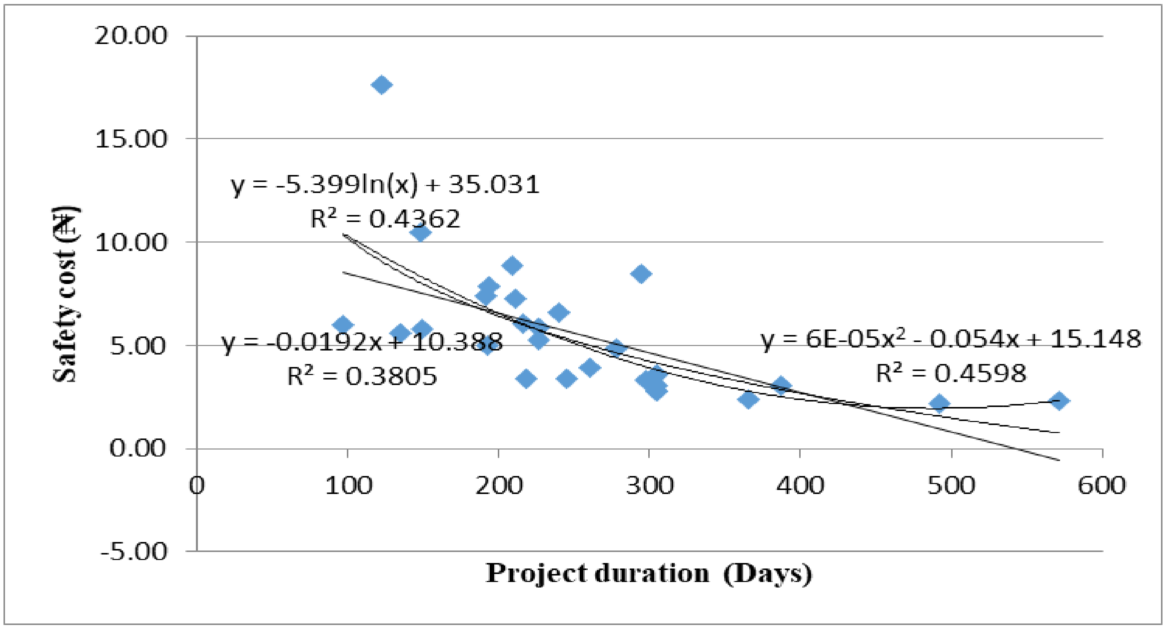

Figure 4.10: Scatter plot with trend lines (Safety cost & Project duration)

4.6.4.3 Prediction of PPE cost of projects using gross floor area

This point marks the beginning of the second phase of regression modelling, which focused on PPE cost as the dependent variable. The result of the modelling of PPE cost using Gross Floor Area as the independent variable is reported in Table 4.49. Using gross floor area gave an R^2 value of 0.439 for the model 1(linear), 0.46 for the model 2 (logarithmic) and 0.476 for the model 3 (quadratic). This inferred that only 44% to 48% of the change in PPE cost is accounted for by the gross floor area of projects. The regression coefficients (B) were negative in all three types of regression, which was an indication of negative linearity. This meant that larger projects would be associated with smaller PPE costs, and vice versa. In all of the three types of regression**,** the critical value of $F_{0.05}$ were smaller than the F statistic value. In addition, the probability values (P) were all much smaller than 0.05. It was inferred from these that the gross floor area of projects was significantly but weakly related to PPE cost.

Table 4.49: Regression model results for PPE Cost and GFA

Variable	Model 1			Model 2			Model 3		
	B	*β*	SEB	B	*β*	SEB	B	*β*	SEB
Constant	6.210		.680	20.277		4.278	6.978		1.291
GFA	-.001	-.621	.000	-2.267	-.606	.584	-.002 (2.39E-7)	-1.013 (.407)	-.002 (.000)
R	.621			.606			.631		
R^2	.386			.367			.398		
ΔF	16.356			15.063			8.265		
P	.000			.001			.002		

Source: Author's fieldwork (2022)

The convergence of the results presented in Table 4.49 was confirmed by the visual representation of the trend of the relation between PPE cost and gross floor area of buildings, as displayed in Figure 4.11. The three trend lines of linear, logarithmic and quadratic regressions displayed great similarity and convergence, which was expected, given the closeness of the r^2 values observed in the three types of regressions. Only the trend line for linear regression indicated that when the gross floor area of projects keeps increasing, safety cost would at some point become a negative value. This impossible scenario, which limited the (GFA) size of projects that can be effectively modelled to 4000 square meters, showed the limits of the linear regression model.

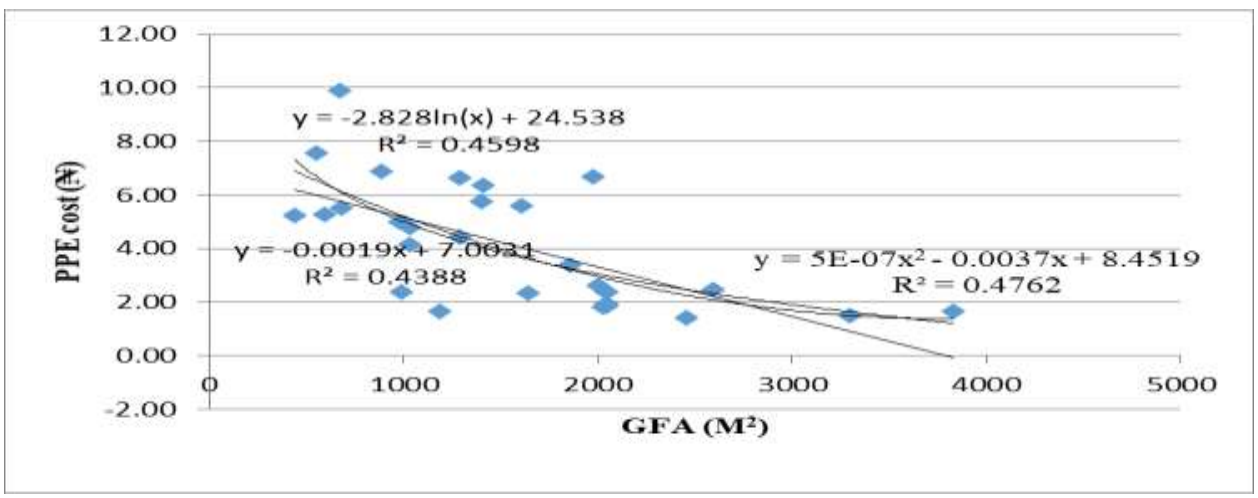

Figure 4.11: Scatter plot with trend lines (PPE cost & GFA)

4.6.4.4 ***Prediction of PPE cost of projects using duration (completion time)***

The result of the modelling of PPE cost using project duration as the independent variable is reported in Table 4.50. Observed R^2 values were 0.473 for the model 1 (linear), 0.518 for the model 2 (logarithmic) and 0.555 for the model 3 (quadratic). This inferred that only 47% to 56% of the change in PPE cost is accounted for by the duration of projects. Negative linearity was observed in all three types of regression, which meant that longer project durations would be associated with smaller PPE costs, and vice versa. In all of the three types of regression, the critical value of the $F_{0.05}$ were smaller than the F statistic value. In addition, the probability values (P) were all much smaller than 0.05. It was inferred from these that the duration of projects was significantly but weakly related to PPE cost.

Table 4.50: Regression model results for PPE Cost and Duration

Variable	**Model 1**			**Model 2**			**Model 3**		
	B	β	SEB	B	β	SEB	B	β	SEB
Constant	7.048		.796	22.754		4.133	9.617		1.771
GFA	-.012	-.658	.003	-3.443	-.671		-.030	-1.613	.011
							(2.8E-5)	(-.983)	(.000)
R	.658			.671			.698		
R^2	.433			.450			.487		
ΔF	19.879			21.312			11.852		
P	.000			.000			.000		

Source: Author's fieldwork (2022)

The convergence of the results presented in Table 4.50 was confirmed by the visual representation of the trend of the relation between PPE cost and duration of building projects, as displayed in Figure 4.12. The three trend lines of linear, logarithmic and quadratic regressions displayed the expected similarity and convergence, given the closeness of the observed r^2 values. The limit of the linear regression model was indicated by its trend line, which showed that when the duration of projects keeps increasing, PPE cost would at some point become a negative value.

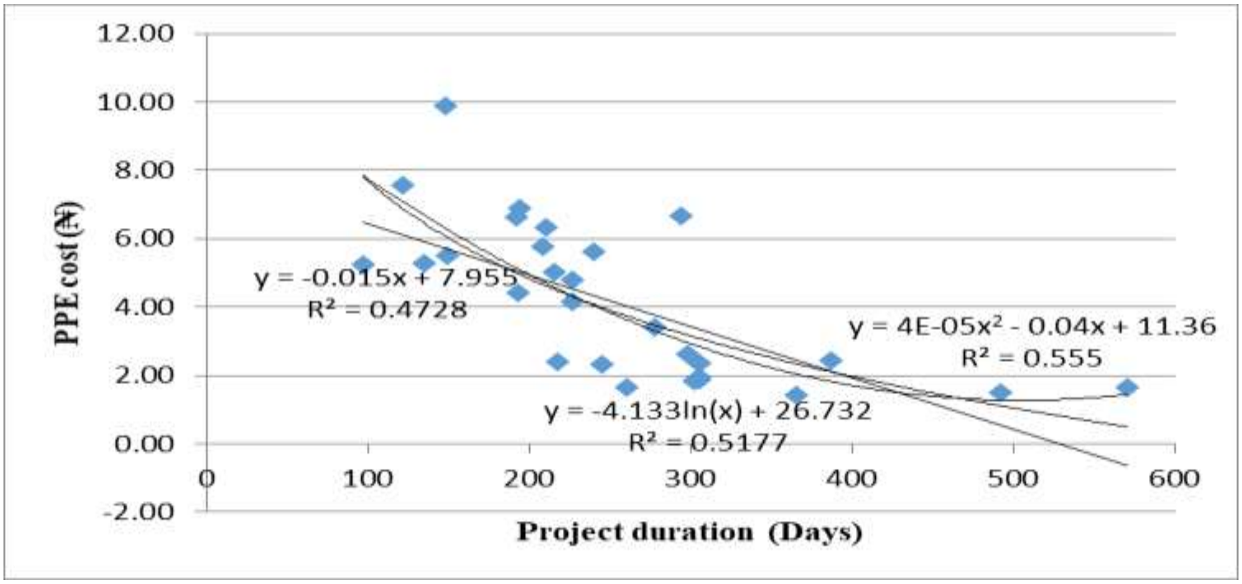

Figure 4.12: Scatter plot with trend lines (PPE cost & Project duration)

4.6.4.5 ***Prediction of PPE cost of work elements using GFA***

This section reported the results of the third and last phase of model development, where PPE cost for seven work elements was modelled using gross floor area (or construction area). Three types of regression were employed (linear, logarithmic and quadratic), and fourteen pieces of information was provided on each model. The enter procedure was employed for the selection of variable where all the variables in block are recorded in a singular stride, since there was only one independent variable.

Excavation: The result of PPE cost modelling for excavation work using gross floor area as the independent variable, which is reported in Table 4.51. It was observed that R^2 values across the three regression models ranged from 0.267 to 0.314. It was inferred that only 27% to 31% of the change in PPE cost in excavation is accounted for by the gross floor area of projects. All three types of regression exhibited negative linearity; this meant that larger projects would be associated with smaller PPE costs in excavation, and vice versa. The critical value of $F_{0.05}$ was smaller than the F statistic values, while probability values were smaller than 0.05 for the linear and logarithmic models. In the case of quadratic model however, the F statistic was smaller than $F_{0.05}$, and the probability value (P) was higher than the 0.05. The inference drawn from these observations was that using linear and logarithmic regression, there is a very weak statistical significant relationship between projects gross floor area and PPE cost in excavation has been established.

Table 4.51: Regression model results for PPE (Excavation) and GFA

Variable	Model 1			Model 2			Model 3		
	B	***β***	SEB	B	***β***	SEB	B	***β***	SEB
Constant	1.004		.178	3.263		1.110	1.236		.337
GFA	-.000	-.435	.000	-.364	-.426	.152	-.000	-.954	-.000
							(7.23E-8)	(.539)	(.000)
R	.435			.426			.458		
R^2	. 267			. 286			. 314		
ΔF	6.068			5.760			3.324		
P	.021			.024			.052		

Source: Author's fieldwork (2022)

A visual representation of the results presented in Table 4.51 was displayed in Figure 4.13, being the trend of the relation between PPE cost in excavation and gross floor area of buildings. The three trend lines of linear, logarithmic and quadratic regressions displayed great similarity and convergence, which was expected, given the closeness of the r^2 values observed in the three types of regressions. However, the dispersal of scatter points over a wide area of the plot reinforced the observed weak relationship between the variables.

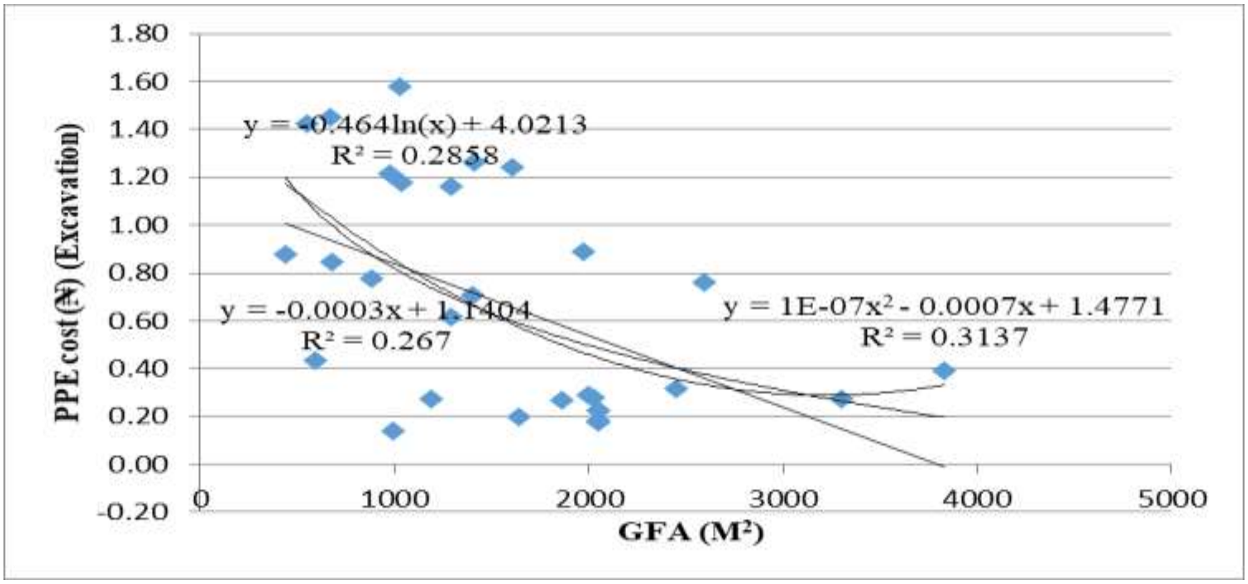

Figure 4.13: Scatter plot with trend lines (PPE Excavation cost & GFA)

Masonry: The result of PPE cost modelling for masonry work using gross floor area as the independent variable was reported in Table 4.52. It was observed that R^2 values across the three regression models ranged from 0.343 to 0.381. From the observed R^2 values it was inferred that only 34% to 38% of the change in PPE cost in masonry is accounted for by the gross floor area of projects. Negative linearity was observed in all of the three types of regression; this meant that larger projects would be associated with smaller PPE costs in excavation, and vice versa. The critical value of $F_{0.05}$ was smaller than the F statistics values, while probability values were smaller than 0.05 for the three models. From this, inference was drawn that, a weak statistical significant relationship existed between projects gross floor area as well as PPE cost in masonry work.

Table 4.52: Regression model results for PPE (Masonry) and GFA

Variable	Model 1			Model 2			Model 3		
	B	*β*	SEB	B	*β*	SEB	B	*β*	SEB
Constant	2.036		.274	6.730		1.696	2.287		.521
GFA	.000	-. 539	.000	-. 753	-. 538	. 232	-.001	-. 880	.001
							(7.8E-8)	(. 355)	(.000)
R	.539			.538			.547		
R^2	.343			.379			.381		
ΔF	10.625			10.580			5.335		
P	.003			.003			.011		

Source: Author's fieldwork (2022)

The trend of the relation between PPE cost in masonry and gross floor area of buildings was presented as a visual representation using a scatter plot chart in Figure 4.14. The three trend lines of linear, logarithmic and quadratic regressions were both similar and convergent. This was expected, given the closeness of the r^2 values observed in Table 4.52. It was however observed that the dispersal of scatter points over a wide area of the plot suggested that PPE cost in masonry cannot be effectively modelled with regression.

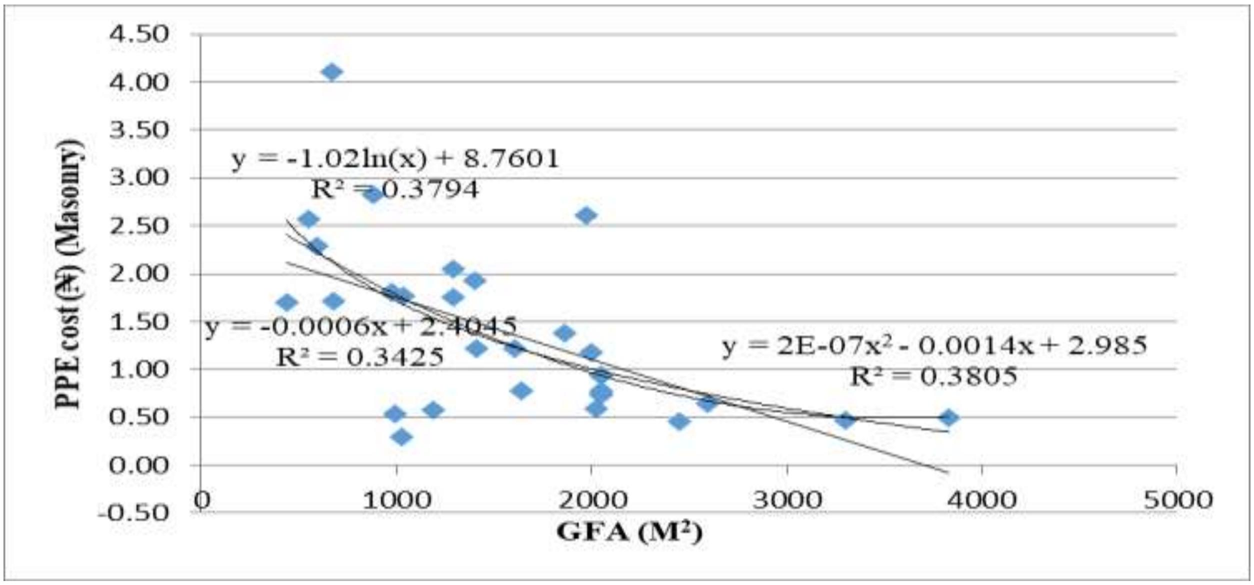

Figure 4.14: Scatter plot with trend lines (PPE Masonry cost & GFA)

Concrete: The result of PPE cost modelling for reinforced concrete work using gross floor area as the independent variable was reported in Table 4.53. It was observed that R^2 values across the three regression models ranged from 0.355 to 0.478; it was thus inferred that only 36% to 48% of changes in PPE cost in reinforced concrete is accounted for by the gross floor area of projects. The negative linearity observed in all three models meant that larger projects would be associated with smaller PPE costs in reinforced concrete. The critical value of $F_{0.05}$ was smaller than the F statistics values, while probability values were smaller than 0.05 for the three models. From this, inferred that, a weak statistical significant relationship existed between projects gross floor area as well as PPE cost in reinforced concrete work.

Table 4.53: Regression model results for PPE (Concrete) and GFA

Variable	Model 1			Model 2			Model 3		
	B	β	SEB	B	β	SEB	B	β	SEB
Constant	1. 054		.198	4. 934		1.170	1. 684		.349
GFA	.000	-.621	.000	-. 613	-.606	.584	-.001	-1. 729	.000
							(1. 96E -7)	(1. 227)	(.000)
R	. 547			.601			. 638		
R^2	. 355			. 433			. 478		
ΔF	11.095			14.729			8.584		
P	.003			.001			.001		

Source: Author's fieldwork (2022)

Figure 4.15 provided a visual representation of the relationship between PPE cost in reinforced concrete and gross floor area of buildings with the aid of a scatter plot chart. The three trend lines of linear, logarithmic and quadratic regressions exhibited similar patterns. The low r^2 values observed in the results in Table 4.53 might however be attributable to the dispersal of scatter points over a wide area of the plot. This might also be a subtle signal that some other variable or variables as yet undiscovered might be contributing more to the variation in PPE cost in reinforced concrete work than the gross floor area of buildings.

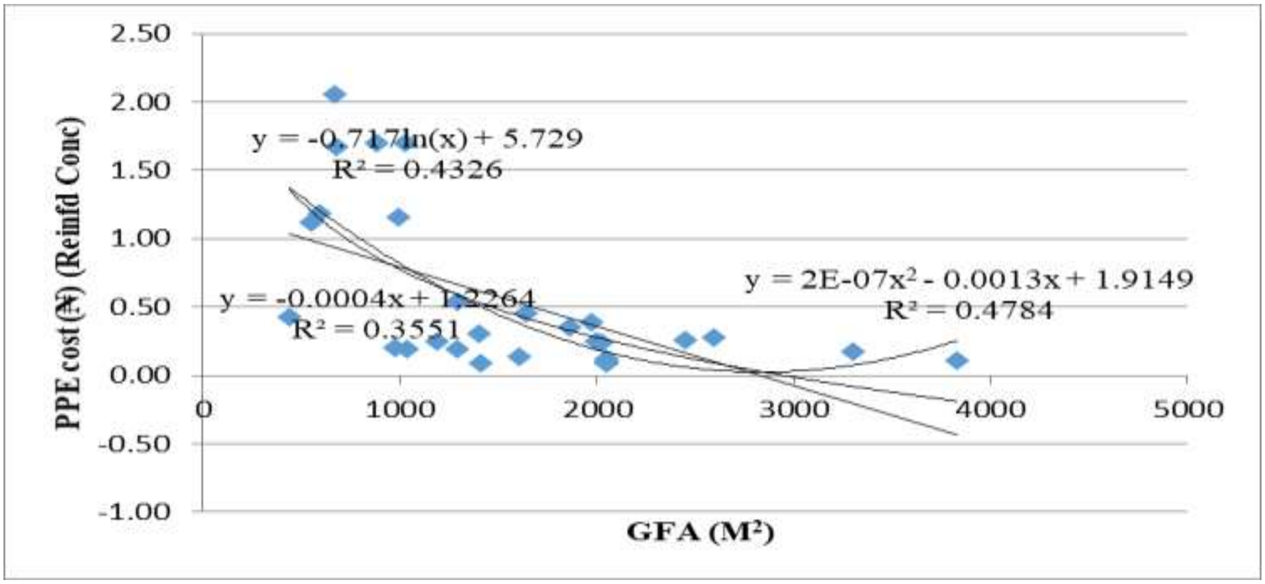

Figure 4.15: Scatter plot with trend lines (PPE Concrete cost & GFA**)**

Roof: Gross floor area was employed as the independent variable in the modelling of PPE cost for roof work. Results in Table 4.54 revealed that the R^2 values across the three regression models ranged from 0.023 to 0.074; it was thus inferred that only 2% to 7% of changes in PPE cost in roof is accounted for by the construction area of projects. The negative linearity observed in all three models meant that larger projects would be associated with smaller PPE costs in roof. The values of the F statistic were smaller than the critical values of $F_{0.05}$, and the probability values (P) were larger than 0.05 in all of the three models. From this, the inference drawn is that a weak statistical non-significant relationship existed between projects gross floor area as well as PPE cost in roof work.

Table 4.54: Regression model results for PPE (Roof) and GFA

Variable	Model 1			Model 2			Model 3		
	B	*β*	SEB	B	*β*	SEB	B	*β*	SEB
Constant	. 816		.243	1. 662		1.526	. 502		.459
GFA	-.000	-.221	.000	-. 151	-. 140	. 208	.000	.339	.000
							(.000)	(-.580)	(.000)
R	. 221			. 140			. 270		
R^2	. 051			. 023			. 074		
ΔF	1.331			.522			.983		
P	.259			.476			.388		

Source: Author's fieldwork (2022)

A scatter plot was employed to provide a visual representation of the relationship between PPE cost in roof and gross floor area of buildings; this was displayed in Figure 4.16. The three trend lines of linear, logarithmic and quadratic regressions converged in a similar pattern. For the first time in the study however, the quadratic regression model had a downward facing curve.

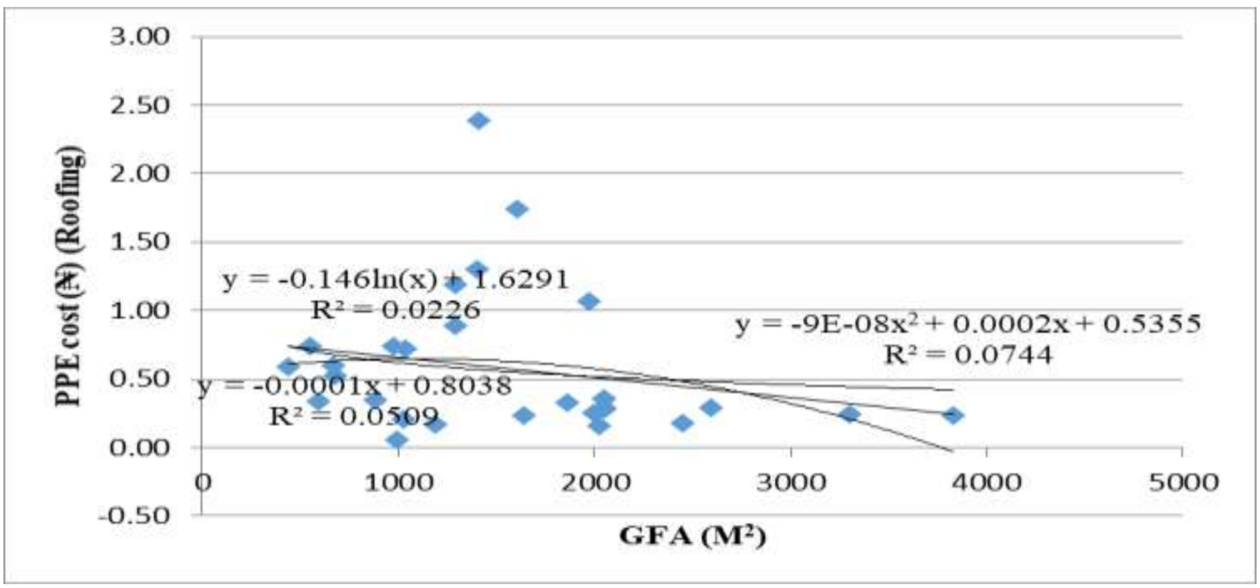

Figure 4.16: Scatter plot with trend lines (PPE Roofing cost & GFA**)**

Floor Finishing: Table 4.55 contained the results of regression modelling of PPE cost for floor finishing, using gross floor area as the independent variable. The observed R^2 values for the three regression models ranged from 0.001 to 0.126. From this observation it was inferred that not more than 13% of changes in PPE cost in floor finishing is accounted for by the gross floor area of projects. The positive linearity observed in all three models meant that larger projects would be associated with larger PPE costs in floor finishing. The values of the F statistic were smaller than the critical values of $F_{0.05}$, and the probability values (P) were larger than 0.05 in all of the three models. Based on this, the inference drawn is that a weak statistical non-significant relationship existed between projects gross floor area as well as PPE cost in floor finishing.

Table 4.55: Regression model results for PPE (Floor) and GFA

Variable	**Model 1**			**Model 2**			**Model 3**		
	B	***β***	SEB	B	***β***	SEB	B	***β***	SEB
Constant	.391		. 114	-.045		. 705	. 035		.203
GFA	.000	-. 023	.000	. 058	. 117	. 096	.000	1. 355	.000
							(.000)	(-1.430)	(.000)
R	. 023			. 117			. 384		
R^2	. 001			. 008			. 126		
ΔF	.014			.363			2.161		
P	.906			.552			.136		

Source: Author's fieldwork (2022)

A scatter plot was used to provide a visual representation of the relationship between PPE cost in floor finishing and gross floor area of buildings. This was presented in Figure 4.17. The linear and logarithmic trend lines exhibited similar patterns. The quadratic regression model however had a downward facing curve. This was unlike what was observed for total safety cost and the total PPE cost for projects. Only in the case of roof work had a similar trend been observed. As in all of the work elements that had been modelled so far (excavation, masonry, concrete and roof), a wide dispersal of scatter points was also observed.

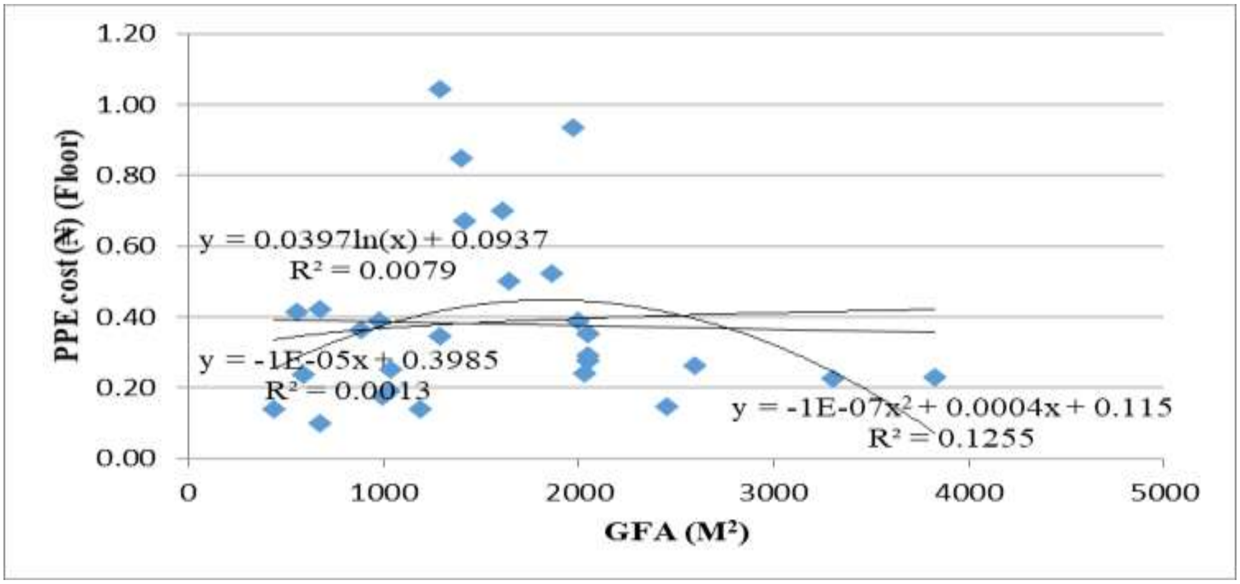

Figure 4.17: Scatter plot with trend lines (PPE Floor cost & GFA**)**

Plastering/Rendering: The result of PPE cost modelling for plastering/rendering work using gross floor area as the independent variable, which is reported in Table 4.56. It was observed that R^2 values across the three regression models ranged from 0.455 to 0.593, it was inferred that only 46% to 59% of the change in PPE cost in plastering/rendering is accounted for by the gross floor area of projects. Two out of the three types of regression exhibited negative linearity; this meant that larger projects would be associated with smaller PPE costs in plastering/rendering, and vice versa. The critical value of $F_{0.05}$ was smaller than the F statistic values, while probability values were smaller than 0.05 for the three models. The inference was drawn that, a weak statistical significant relationship existed between projects gross floor area as well as PPE cost in plastering/rendering work has been established.

Table 4.56: Regression model results for PPE (Plastering) and GFA

Variable	Model 1			Model 2			Model 3		
	B	*β*	SEB	B	*β*	SEB	B	*β*	SEB
Constant	. 780		.098	3. 228		.549	1. 068		.176
GFA	.000	-.623	.000	-. 385	-. 709	. 075	-.001 (8. 96E -8)	-1. 637 (1. 052)	.000 (.000)
R	.623			. 710			. 684		
R^2	. 455			. 593			. 566		
ΔF	16.482			26.332			10.973		
P	.000			.000			.000		

Source: Author's fieldwork (2022)

A visual representation of the results presented in Table 4.56 was displayed in Figure 4.18, being the trend of the relation between PPE cost in plastering/rendering and construction area of buildings. The three trend lines of linear, logarithmic and quadratic regressions displayed great similarity and convergence, which was expected, given the closeness of the r^2 values observed in the three types of regressions. However the dispersal of scatter points over a wide area of the plot reinforced the observed

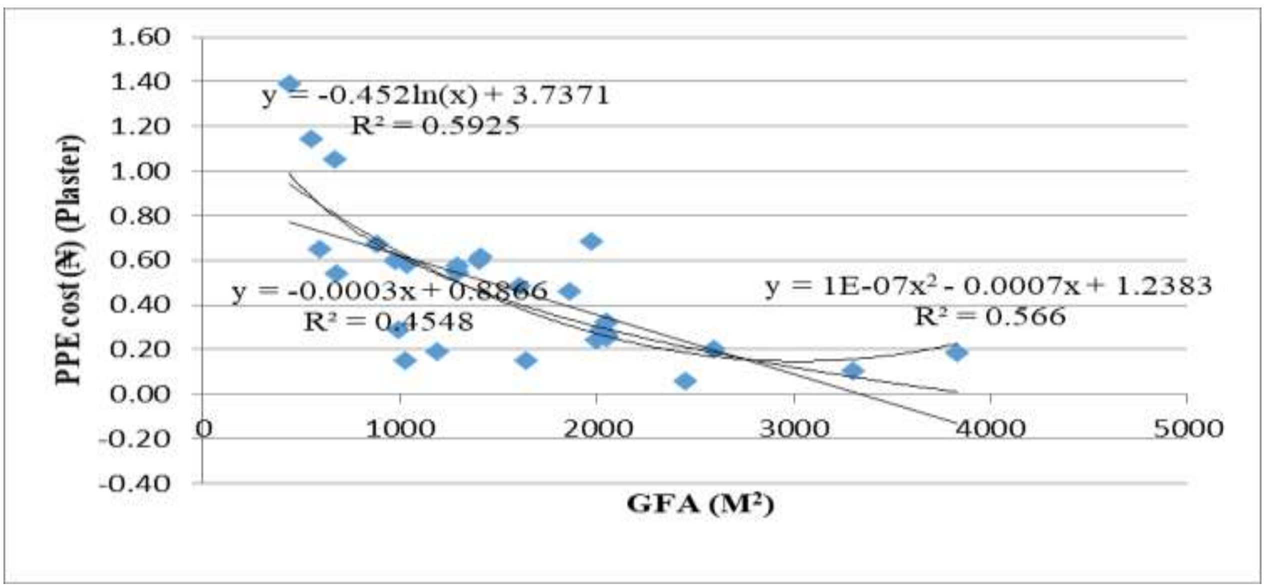

Figure 4.18: Scatter plot with trend lines (PPE Plaster cost & GFA**)**

Painting: Gross Floor area was employed as the independent variable in the modelling of PPE cost for painting work. Results in Table 4.57 revealed that R^2 values for the three regression models ranged from 0.449 to 0.52; it was thus inferred that only 45% to 52% of changes in PPE cost in painting is accounted for by the gross floor area of projects. The negative linearity observed in all three models meant that larger projects would be associated with smaller PPE costs in painting. The values of the F statistic were larger than the critical values of $F_{0.05}$, and the probability values (P) were smaller than 0.05 in all of the three models. From this, it was inferred that a weak statistical significant relationship existed between projects gross floor area as well as PPE cost in painting work.

Table 4.57: Regression model results for PPE (Painting) and GFA

Variable	Model 1			Model 2			Model 3		
	B	***β***	SEB	B	***β***	SEB	B	***β***	SEB
Constant	.129		.016	.505		.097	.166		.300
GFA	.000	-. 627	.000	-. 060	-. 664	. 013	-.000	-1. 424	.000
							(1. 169E -8)	(0.827)	(.000)
R	.627			.664			.665		
R^2	. 449			. 517			. 520		
ΔF	16.805			20.484			9.890		
P	.000			.000			.001		

Source: Author's fieldwork (2022)

Figure 4.19 provided a visual representation of the relationship between PPE cost in painting and gross floor area of buildings with the aid of a scatter plot chart. The three trend lines of linear, logarithmic and quadratic regressions exhibited similar patterns. The low r^2 values observed in the results in Table 4.57 might however be attributable to the dispersal of scatter points over a wide area of the plot. As has been pointed out earlier, low observed r^2 values might also be an indication that some other variable or variables that have not yet; 'been undiscovered might be contributing more to the variation in PPE cost in painting than the gross floor area of buildings.

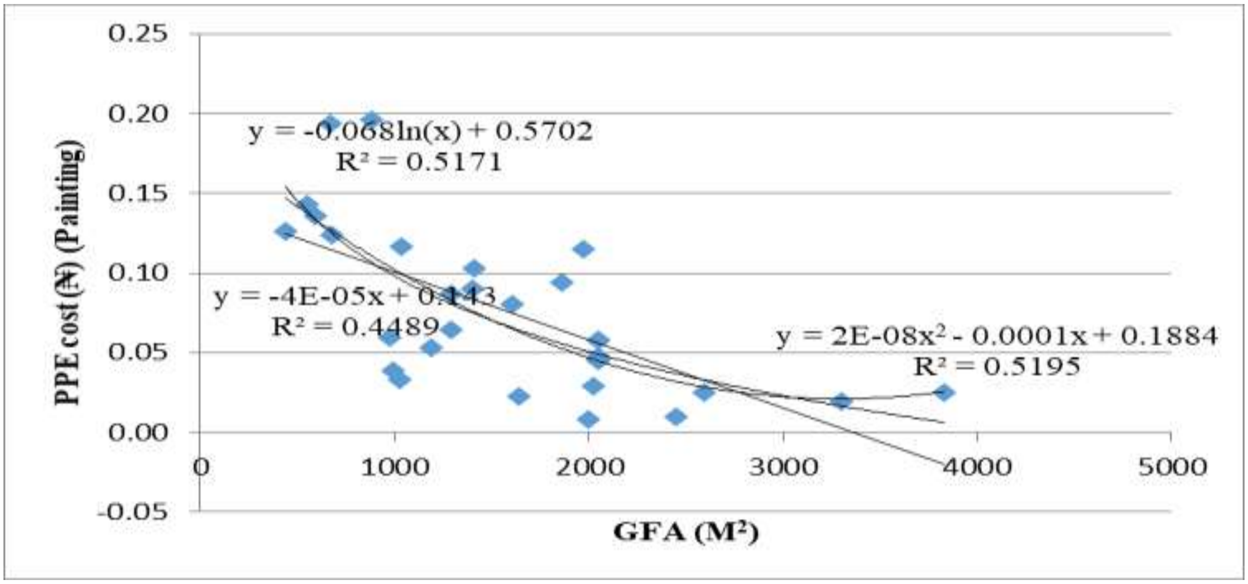

Figure 4.19: Scatter plot with trend lines (PPE Painting cost & GFA**)**

4.6.5 Discussion of results of development of regression models

This section brought together the findings of the various sections in which the results of regression model development for safety cost was presented, and then attempted to explain the findings in the light of knowledge drawn from the literature on health and safety. The section is structured in like manner to that on the development of models for safety cost; this means it comprises three main subsections, which correspond to the three phases of model development.

4.6.5.1 *Discussion of results of safety cost modelling*

The results from the modelling of safety cost may be recapped briefly as follows. The dependent variable was the total safety cost of building projects; two independent variables were employed, the first was Gross Floor Area (GFA) (or construction area), while the second was project duration (or project completion time). A study of the developed models revealed that the performance of the independent variables was poor, since they accounted for only 35% to 46% of the changes in safety cost. It was found that an inverse proportional association existed between the dependent and independent variables. However, both independent variables had a significant but weak relationship with the cost of safety.

Lopez-Alonso *et al*. (2013) 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 scope and project 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. Hadwiansyah and Latief (2022) studied the safety cost in low-cost apartments, using Structural Equation Model (SEM) to investigate the relationship between work breakdown structures (WBS), work methods along with risk. They worked at a more aggregate level, unlike this study which pinpointed the relationship between safety cost and two factors affecting safety cost.

Purwanti and Latief (2021) used Work Breakdown Structure (WBS) to analyse the safety cost structure for mechanical works. The work only analysed the WBS structure for mechanical services; it did not proceed to discover the relationship between safety cost and its influencing factors. Lee *et al*. (2021) developed a framework for estimating losses associated to fatality in project construction in Korea. This work on cost of accidents was of a necessity carried out at a macro level; this was the level of an entire industry, not individual projects. In terms of the quality of the models, based only on the r^2 values, Gurcanli *et al*. (2015) work is the closest study with which comparison can be made. The study modelled cost of safety for reinforced concrete construction, an r^2 value of 67% was obtained from a logarithmic regression. This is comparable to the 46% r^2 value that was obtained in this study; this study has thus confirmed the position of influence occupied by construction area and project duration with regards to safety cost.

4.6.5.2 *Discussion of results of total PPE cost modelling*

The results from the second phase of regression model development – the modelling of total PPE cost for individual projects - may be recapped briefly as follows. The dependent variable was the total PPE cost of building projects; two independent variables - construction area and project duration - were employed. The performance of the independent variables was however observed to be poor, since they accounted for only 44% to 56% of the changes in total PPE cost. All of the models developed displayed an inverse proportionality between variables. Both construction area and project duration had a significant but weak relationship with safety cost.

Hadwiansyah and Latief (2022) identified PPE (Personal Protective Equipment) as components of health and safety cost as applicable to Indonesia public works. Although they described the following as- helmets, boots, vests, mask, hat, rain jackets, eye protectors and safety glove as Personal Protective Equipment– their study did not focus on identifying factors that influence the cost of PPE in projects. The influence of construction area and project duration on the PPE cost of projects was not highlighted in the study by Gurcanli *et al*., (2015). That study modelled only the total safety cost of reinforced concrete construction; however, PPE is a principal component of total cost of safety.

The expectation that the behaviours of the total safety cost as well as the total cost for PPE will be similar when juxtaposed with construction area and project duration is thus not unreasonable. This expectation is supported by the results of this study, where total safety cost has a maximum r^2 value of 46% compared to the 56% of total PPE cost. This study has thus confirmed the similarity of behaviour of total safety cost and total PPE cost.

4.6.5.3 *Discussion of results of elemental PPE cost modelling*

The results from the third phase of regression model development – the modelling of PPE costs for seven different elements of building projects - may be recapped briefly as follows. The dependent variable was the elemental PPE costs, while the independent variable was the construction area of projects. The observed performance of the predictor variable (construction area) was poor, accounting for only a maximum of 59% of the changes in elemental PPE cost. In five (5) elements (excavation, masonry, reinforced concrete, plastering/rendering and painting), construction area had a statistically significant but weak relationship with elemental PPE cost. The relationship of construction area with PPE cost in two elements (roofing and flooring) was statistically non-significant.

In recent Occupational Safety and Health (OSH) literature, Gurcanli *et al*. (2015) worked on reinforced concrete construction in residential buildings in Turkey. Within this single element of a building, his study established that 67% of the variations in safety cost (comprising the costs of PPE, the costs of CPM as well as the cost of ST) are due to variations of the construction area of buildings. While the findings from Gurcanli *et al*. (2015) cannot be applied to all of the seven elements considered in this study, it is possible to assert that construction area cannot be used to satisfactorily predict the changes in PPE cost in roofing and flooring works.

4.7 Validation of Regression Models Developed for the Study

The results of works concerned with achieving the fifth objective of the study is reported in this section, which was the validation of the regression models that was developed in section 4.6. The validation was carried out by using statistical tools that measures the error level in the application of the developed models. The error was symbolised by the variation between the actual value of the dependent variable (y) and the expected y value, which is obtained from computing for y using the developed regression model. Works carried out in this section involved using holdout data to test the three variants (linear, logarithmic and quadratic) of each of the eleven models developed, and computing the MSE of each in order to validate the choice of the most effective model for predicting either Project Safety cost, Project PPE cost or Elemental PPE cost.

A final point needs to be brought up here regarding the independent variables employed in this study, which are Gross Floor Area (GFA) (or construction area) and project duration (or project completion time). The sample of 40 projects that were collected during fieldwork had gross floor areas ranging from $333M^2$ to $4900M^2$ and project durations ranging from 73 to 731 days. To test the efficacy of the models developed, this GFA range was split into three (0 – $1100M^2$; 0 – $2700M^2$; and 0 – $4900M^2$). With respect to project duration, a three way spilt was also carried out. Thus models were evaluated based on effects on projects with completion periods ranging from 0 – 200 days; 0 – 400 days; and 0 – 800 days. The splitting of the GFA and duration ranges was carried out in order to discover if the models had equal predictive effect on all of the projects within the sample, irrespective of differences in GFA and duration.

4.7.1 Validation of regression models for safety cost

The report of the validation of the six regression models which were 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 was employed using three different regression models – linear, logarithmic and quadratic, as presented in Table 4.58 and 4.59. A choice was made between the two predictors as to which performed best, in Table 4.60. Using the MSE as a measure of model performance, a cursory examination revealed that the logarithmic model was better than the quadratic model, which in turn was better than the linear model. However, when the MAPD in Table 4.58 was considered, only two models (logarithmic and quadratic) passed general acceptability threshold, since some of their MAPD values were below 5.0%, which is the acceptable level of error in most scientific experiments. It was observed that projects with smaller gross floor areas (the 0 – 1100M^2 range) appeared to be associated with smaller levels of error. Although this range had the lowest observed MSE value (0.44 in quadratic regression model), the decision on which model performed best was made using the (the 0 – 4900M^2 range), which was the largest, containing all of the 40 projects that were surveyed in the study.

Table 4.58: Validation of Safety Cost and Gross Floor Area model

Type of regression model	GFA range (M^2)	MSE	MAPD	MAE
Linear	0 – 1100 (593-1020)	1.48	16.54	1.17
	0 – 2700 (593-2626)	1.76	16.89	1.03
	0 – 4900 (593-4900)	3.54	41.75	1.38
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
Quadratic	0 – 1100 (593-1020)	0.44	5.39	0.42
	0 – 2700 (593-2626)	1.58	-16.16	-0.37
	0 – 4900 (593-4900)	1.48	-19.69	-0.42

Source: Author's analysis of fieldwork data (2022)

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

Figure 4.20 was a line graph depiction of the three models MSE values in Table 4.58. The displayed results in the chart showed clearly that for the largest range (0 – 4900M^2), the logarithmic model had the lowest MSE value. The logarithmic and quadratic models exhibited similar trends; the highest MSE values belonged to the middle range of GFA (0 – 2700M^2), while the lowest MSE belonged to the smallest range of GFA (the 0 – 1100M^2).

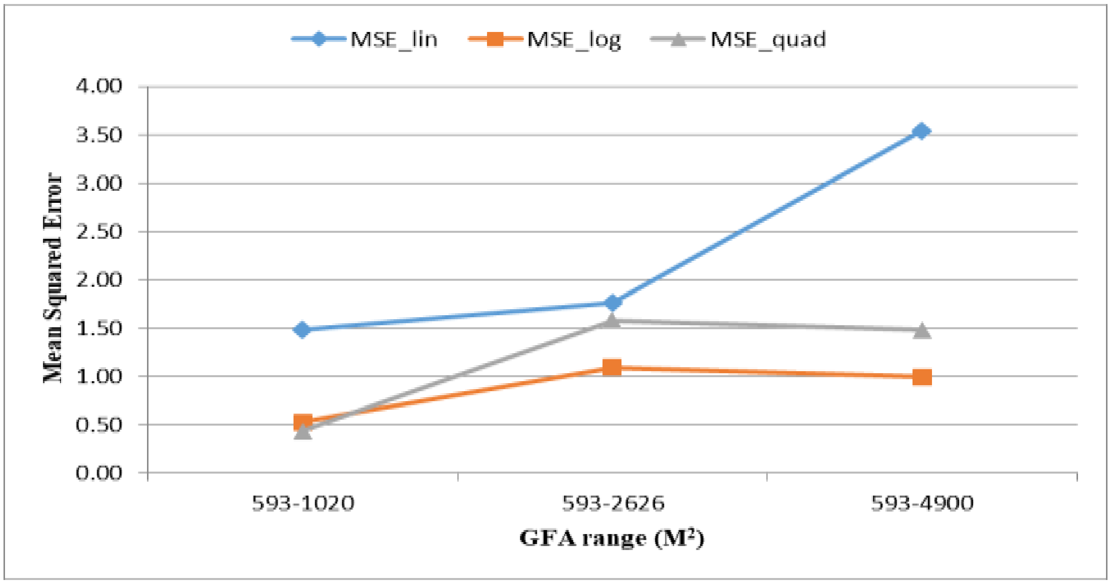

Figure 4.20: Comparison of MSE for Safety cost & GFA

The report of the validation of the three regression models which were developed for safety cost using project duration as predictor was provided in Table 4.59. 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 the quadratic model was better than the logarithmic model, which in turn was better than the linear model.

Table 4.59: Validation of Safety Cost and Duration model

Type of regression model	Duration range (Days)	MSE	MAPD	MAE
Linear	0 - 200 (130-193)	1.41	6.12	0.62
	0 - 400 (130-392)	1.03	1.50	0.36
	0 - 800 (130-731)	1.96	20.79	0.66
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
Quadratic	0 - 200 (130-193)	1.07	2.75	0.39
	0 - 400 (130-392)	0.84	0.30	0.26
	0 - 800 (130-731)	0.80	4.72	0.31

Source: Author's analysis of fieldwork data (2022)

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

Unlike what obtained with gross floor area, it was also observed that projects with the smallest project durations (the 0 – 200 days range) appeared to be associated with the highest levels of error. The lowest observed MSE value (0.80 in quadratic regression model) belonged in the largest duration range (0 – 800 days). When the MAPD in Table 4.59 was considered, the MAPD values for logarithmic model was lower than that of the quadratic model (3.42% compared to 4.72%). This was why the logarithmic model was chosen as the best performing model.

To serve as a visual aid in the determination of the best performing model, a line graph depiction of the MSE values of the three models in Table 4.59 was presented as Figure 4.21. The results in the chart showed clearly that the logarithmic and quadratic models exhibited similar trends; 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).

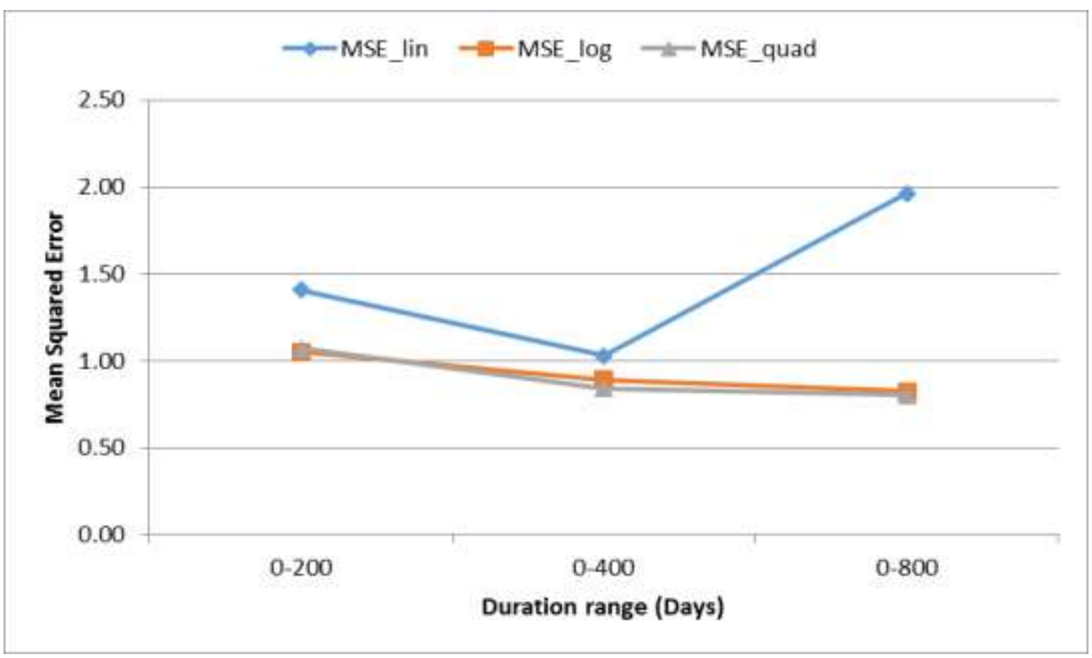

Figure 4.21: Comparison of MSE for Safety cost & Duration

4.7.1.1 *Regression model adjudged most effective for predicting safety cost*

The choice of the predictor which performed best, in terms of being in a statistically significant regression model and having the lowest MSE as provided in Table 4.60. The choice of most effective predictor was a straightforward one from the results shown in Table 4.60. 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; the logarithmic model was chosen as the best performing model. Table 4.60 provides the formula for the logarithmic regression model, alongside with the model's coefficient of determinant (R^2) of 0.436. 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 4.60: 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.

Source: Author's analysis of fieldwork data (2022)

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

4.7.2 Validation of regression models for PPE cost for projects

This section reported the validation of the six regression models which were developed for PPE cost for projects, using two independent variables as predictors (gross floor area and project duration). Each predictor was employed in three different regression models – linear, logarithmic and quadratic. The result for gross floor area is provided in Table 4.61, while Table 4.62

contained results for project duration. The final table in the section, Table 4.63 provided details of the most effective or best performing predictor and model.

Using the MSE as the main measure of model performance, an examination of results in Table 4.61 revealed that the logarithmic model was better than the quadratic model, which in turn was better than the linear model. It was observed that projects with smaller gross floor areas (the 0 – 1100M^2 range) appeared to be associated with smaller levels of error. Although the 0 – 1100M^2 range had the lowest observed MSE value (1.06 in logarithmic regression model), the decision on which model performed best was made using the largest range (0 – 4900M^2), which contained all of the 40 projects that were surveyed in the study. All of the MAPD values for the logarithmic model in Table 4.61 were below 5.0%, which is the acceptable level of error in most scientific experiments.

Table 4.61: Validation of Project PPE Cost and Gross Floor Area model

Type of regression model	GFA range (M^2)	MSE	MAPD	MAE
Linear	0 – 1100 (593-1020)	1.21	-0.68	0.17
	0 – 2700 (593-2626)	1.66	-20.83	-0.32
	0 – 4900 (593-4900)	1.48	-20.76	-0.31
Logarithmic	0 – 1100 (593-1020)	1.06	3.12	0.34
	0 – 2700 (593-2626)	1.37	1.39	0.39
	0 – 4900 (593-4900)	1.22	2.01	0.35
Quadratic	0 – 1100 (593-1020)	1.09	-3.24	0.02
	0 – 2700 (593-2626)	1.44	-17.72	-0.26
	0 – 4900 (593-4900)	1.65	-34.42	-0.43

Source: Author's analysis of fieldwork data (2022)

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

Figure 4.22 is a line graph depiction of the MSE values of the three models in Table 4.61; it serves as a visual aid in the determination of the best performing model. The results in the chart showed clearly that for the largest range of gross floor area (0 – 4900M^2), the logarithmic model had the lowest MSE value (1.22). Generally, all of the three models exhibited similar trends; the highest MSE values belonged to the middle range of GFA (0 – 2700M^2). In the case of quadratic regression the highest MSE belonged to the largest range of GFA (the 0 – 4900M^2).

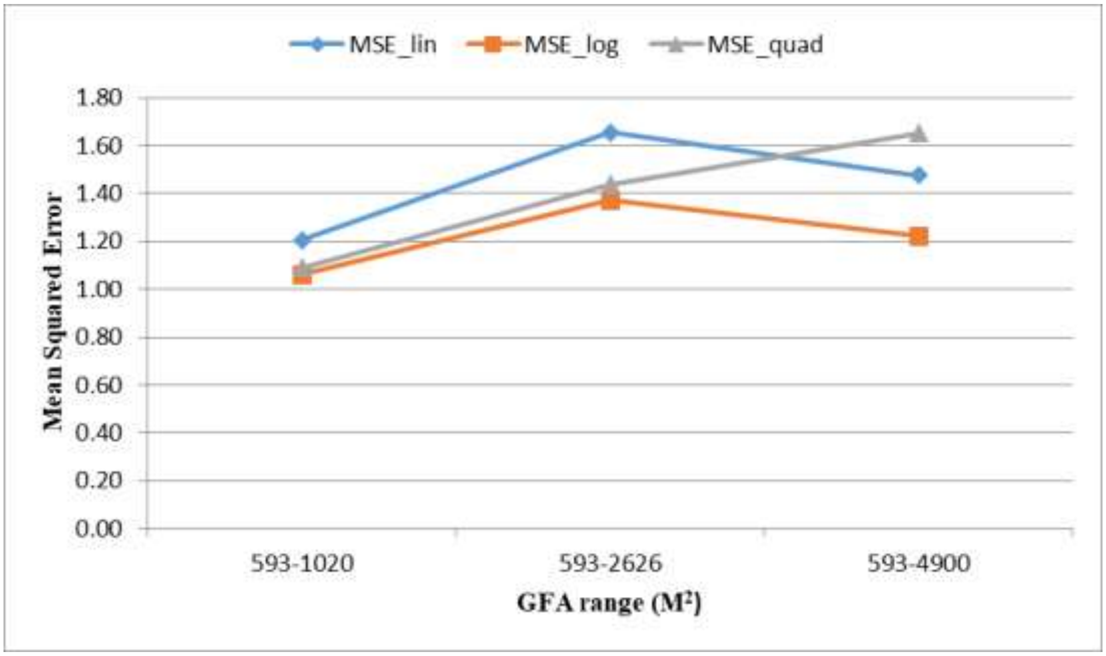

Figure 4.22: Comparison of MSE for PPE cost & GFA

The report of the validation of the three regression models which were developed for PPE cost for projects using project duration as predictor was provided in Table 4.62. 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 the logarithmic model was better than the quadratic model, which in turn was better than the linear model. Unlike what obtained with gross floor area, it was also observed that projects with the smallest project durations (the 0 – 200 days range) appeared to be associated with the highest levels of error. The lowest observed MSE value (1.11 in quadratic regression model) occurred in the medium duration range (0 – 400 days). However, since the focus was on the largest duration range (0 – 800 days) as a determinant of best performing model/predictor, this value was rejected and the 1.16 MSE of the logarithmic model was chosen as the best performing model instead.

Table 4.62: Validation of Project PPE Cost and Duration model

Type of regression model	Duration range	MSE	MAPD	MAE
Linear	0 - 200 (130-193)	1.80	-1.09	0.31
	0 - 400 (130-392)	1.29	-4.35	0.20
	0 - 800 (130-731)	2.02	24.82	0.49
Logarithmic	0 - 200 (130-193)	1.50	-3.08	0.17
	0 - 400 (130-392)	1.17	-1.15	0.25
	0 - 800 (130-731)	1.16	9.59	0.34
Quadratic	0 - 200 (130-193)	1.50	-7.81	-0.06
	0 - 400 (130-392)	1.11	-4.14	0.11
	0 - 800 (130-731)	1.26	-19.57	-0.08

Source: Author's analysis of fieldwork data (2022)

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

When a line graph of the MSE values of the models in Table 4.62 was produced as a visual aid, it was observed that the three models exhibited similar trends. The highest MSE values generally belonged to the smallest range of project duration (0 – 200 days); the only exception was the linear regression model, where the largest project duration range (0 – 800 days) also had the highest MSE. Figure 4.23 reveals the results.

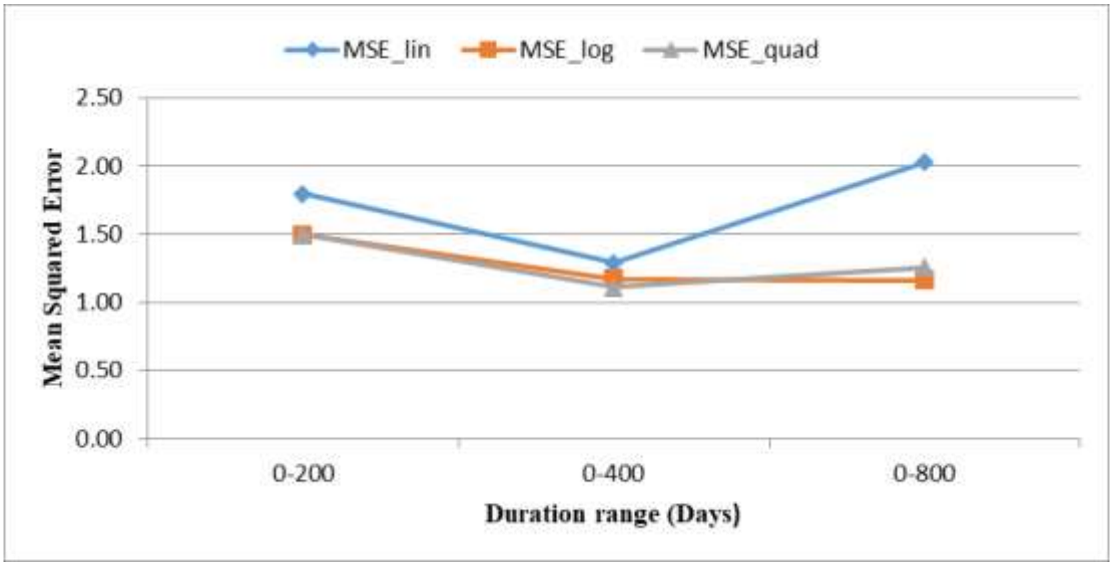

Figure 4.23: Comparison of MSE for PPE cost & Duration

4.7.2.1 *Regression model adjudged most effective for predicting PPE cost for projects*

The choice of the predictor which performed best, in terms of being in a statistically significant regression model and having the lowest MSE as provided in Table 4.63. The results revealed that the second predictor, Project Duration, had an MSE of 1.16, compared to 1.22 for GFA. Project duration was thus adjudged the most effective predictor, alongside the logarithmic model, which was chosen as the best performing model. Table 4.63 provides the formula for the logarithmic regression model, alongside with the model's coefficient of determinant (R^2) of 0.518. Although this R^2 value is low, the logarithmic regression model that has been developed in this study represents a scientific way through which the PPE cost for building 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 4.63: Most effective predictor of PPE Cost

Measure / Model	MSE of Predictors		Model structure	R^2 (%)	Remark
	x1 (GFA)	x2 (Duration)			
MSE / Logarithmic	1.22	1.16	PPE cost = 22.754 + (-3.443 * ln(Duration))	51.8%	Using **Project Duration as predictor** returned the lowest error in prediction of PPE cost.

Source: Author's analysis of fieldwork data (2022)

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

4.7.3 Validation of regression models for PPE cost for elements

This section dealt with the validation of the regression models for the PPE cost of seven elements of building projects. Only one independent variable (GFA) was employed as predictor, in three different regression models – linear, logarithmic and quadratic. Each model was validated thrice, with different groups of the holdout data corresponding to different ranges of GFA as explained in section 4.6. The results for each element consist of a table and a line chart of MSE values. At the end of this section (4.7.3), details of the best performing models for the prediction of PPE cost in each of the seven elements were provided using a tabular format.

4.7.3.1 *Validation of regression models for PPE cost (Excavation)*

The validation of PPE cost prediction for excavation used MSE as the sole measure of model performance, and the results as shown in Table 4.64. It was revealed that the logarithmic model stood a better chance than the linear and quadratic models. When the MAPD the models was considered, none of the three models' MAPD values that were below 5.0%, which is the acceptable level of error in most scientific experiments. It was also observed that projects with smaller GFA (within 0 – 1100 M^2 range) appeared to be associated with smaller levels of error. However, as stated earlier in section 4.7.3 and 4.7.4, the decision on which model performed best was made using the (the 0 – 4900M^2 range).

Table 4.64: Validation of PPE Cost (Excavation) and GFA model

Type of regression model	GFA range (M^2)	MSE	MAPE	MAE
Linear	0 – 1100 (593-1020)	0.05	-25.72	-0.19
	0 – 2700 (593-2626)	0.23	-127.78	-0.28
	0 – 4900 (593-4900)	0.28	-164.45	-0.34
Logarithmic	0 – 1100 (593-1020)	0.04	-7.99	-0.04
	0 – 2700 (593-2626)	0.12	-27.89	0.06
	0 – 4900 (593-4900)	0.11	-24.18	0.05
Quadratic	0 – 1100 (593-1020)	0.16	33.76	0.30
	0 – 2700 (593-2626)	0.70	172.82	0.72
	0 – 4900 (593-4900)	1.12	283.79	0.87

Source: Author's analysis of fieldwork data (2022)

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

Figure 4.24 was a line graph depiction of the three models, MSE values in Table 4.64. The displayed results in the chart showed clearly that the linear and logarithmic models exhibited similar trends; MSE values increased as the range of GFA covered by the holdout data increased. Thus, the largest range (0 – 4900 M^2) had higher MSE values than the other two ranges. The MSE value of the quadratic model were much higher than those of the two other models.

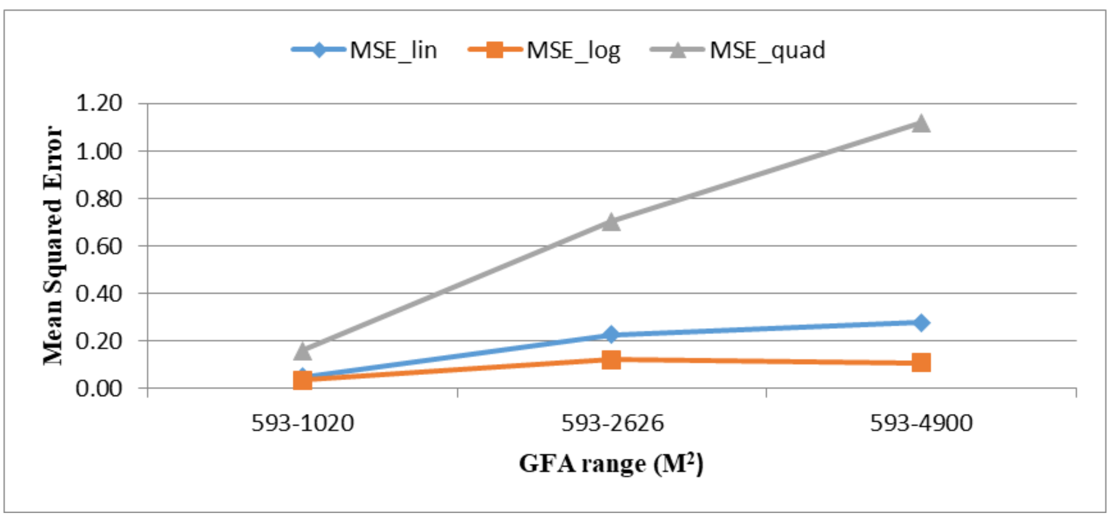

Figure 4.24: Comparison of MSE for PPE cost (Excavation) & GFA

4.7.3.2 *Validation of regression models for PPE cost (Masonry)*

The validation of PPE cost prediction for Masonry used MSE as the sole measure of model performance as provided in Table 4.65. It was revealed that the logarithmic model was the better than the quadratic and the linear model. When the MAPD of the models was considered, only one of the three linear models' MAPD values was below the acceptable error level of 5.0%.

Table 4.65: Validation of PPE Cost (Masonry) and GFA model

Type of regression model	GFA range (M^2)	MSE	MAPD	MAE
Linear	0 – 1100 (593-1020)	0.68	0.97	0.25
	0 – 2700 (593-2626)	0.78	-52.49	-0.45
	0 – 4900 (593-4900)	1.00	-95.08	-0.58
Logarithmic	0 – 1100 (593-1020)	0.77	16.38	0.54
	0 – 2700 (593-2626)	0.33	6.50	0.23
	0 – 4900 (593-4900)	0.30	7.18	0.21
Quadratic	0 – 1100 (593-1020)	1.02	24.91	0.72
	0 – 2700 (593-2626)	0.55	30.45	0.52
	0 – 4900 (593-4900)	0.63	59.82	0.59

Source: Author's analysis of fieldwork data (2022)

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

A line graph chart of the MSE values of the three models in Table 4.65 was displayed in Figure 4.25. The chart showed clearly that the logarithmic model had the lowest MSE (for the largest range of gross floor area covered by the holdout data). While the logarithmic and quadratic models exhibited a descending trend, with MSE values decreasing as the size of the range of GFA covered increased, a different trend was observed for the linear model. In this case, the MSE values kept increasing as the size of the range of GFA covered increased.

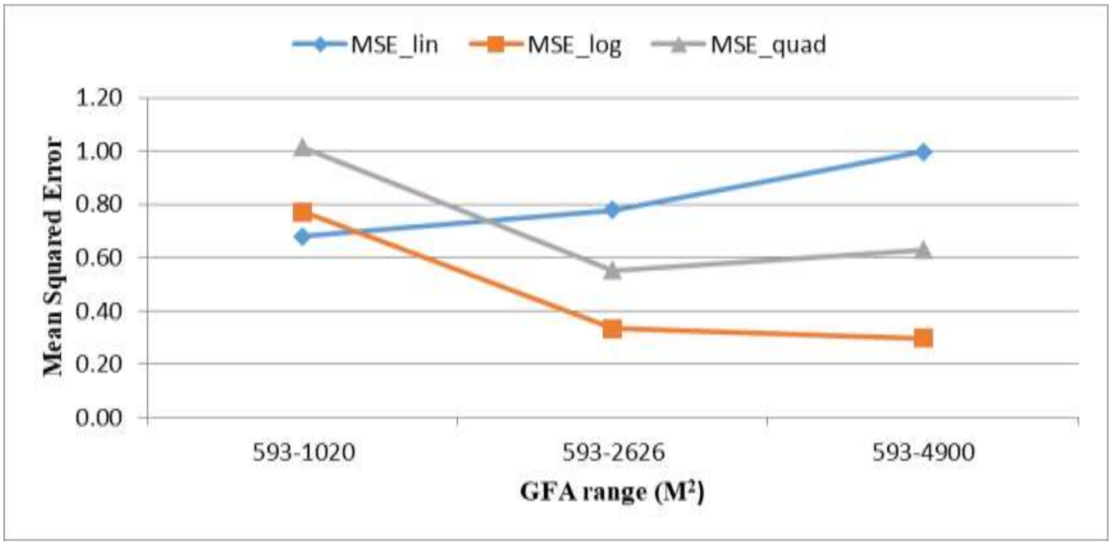

Figure 4.25: Comparison of MSE for PPE cost (Masonry) & GFA

4.7.3.3 *Validation of regression models for PPE cost (Concrete)*

MSE was used as the sole measure of model performance in the validation of PPE cost prediction for Concrete. Table 4.66 presents the results which reveals that the logarithmic model was better than the quadratic and the linear model. When the MAPD of the models was considered, only one of the three logarithmic models' MAPD values was below 5.0%, which is the acceptable level of error in most scientific experiments. It was also observed that projects with smaller GFA (within 0 – 1100 M^2 range) appeared to be associated with smaller levels of error. However, the decision on which model performed best was made using the largest GFA range (0 – 4900 M^2 range).

Table 4.66: Validation of PPE Cost (Concrete) and GFA model

Type of regression model	GFA range (M^2)	MSE	MAPD	MAE
Linear	0 – 1100 (593-1020)	0.20	-21.76	-0.03
	0 – 2700 (593-2626)	0.51	-452.01	-0.52
	0 – 4900 (593-4900)	0.54	-455.74	-0.56
Logarithmic	0 – 1100 (593-1020)	0.14	4.12	0.15
	0 – 2700 (593-2626)	0.10	-120.69	-0.03
	0 – 4900 (593-4900)	0.12	-79.22	0.03
Quadratic	0 – 1100 (593-1020)	0.13	-15.16	-0.01
	0 – 2700 (593-2626)	0.15	-220.01	-0.22
	0 – 4900 (593-4900)	0.33	-277.02	-0.34

Source: Author's analysis of fieldwork data (2022)

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

In Figure 4.26, which was a line graph depiction of the MSE values of the three models in Table 4.66, it was observed clearly that none of the three models exhibited similar trends. The logarithmic model was the only one in which MSE values fell then increased very slightly as the range of GFA covered by the holdout data increased. The other two models, the linear and quadratic, had MSE values that followed a rising trend.

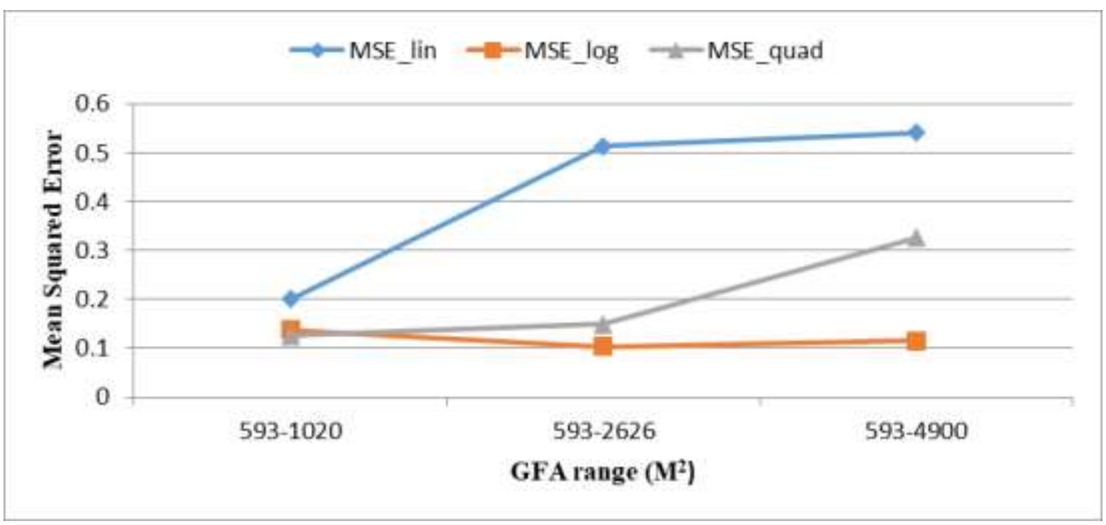

Figure 4.26: Comparison of MSE for PPE cost (Concrete) & GFA

4.7.3.4 *Validation of regression models for PPE cost (Roof)*

The PPE cost for roof was predicted with three regression models (linear, logarithmic and quadratic). To validate the performance of these models, MSE was employed, and the results are provided Table in 4.67. It was revealed that the logarithmic model had a better chance than the linear and quadratic model. When the MAPD of the models was considered, none of the three models had MAPD values that were below 5.0%, which is the acceptable level of error in most scientific experiments. It was also observed that projects with smaller gross floor area (within 0 – 1100 M^2 range) were associated with smaller levels of error.

Table 4.67: Validation of PPE Cost (Roof) and GFA model

Type of regression model	GFA range (M^2)	MSE	MAPD	MAE
Linear	0 – 1100 (593-1020)	0.09	-57.32	-0.29
	0 – 2700 (593-2626)	0.22	-109.99	-0.21
	0 – 4900 (593-4900)	0.25	-177.33	-0.26
Logarithmic	0 – 1100 (593-1020)	0.02	-28.08	-0.14
	0 – 2700 (593-2626)	0.18	-46.98	0.03
	0 – 4900 (593-4900)	0.17	-72.75	-0.01
Quadratic	0 – 1100 (593-1020)	0.16	70.36	0.37
	0 – 2700 (593-2626)	0.85	-61.00	0.11
	0 – 4900 (593-4900)	20.11	-1520.58	-1.37

Source: Author's analysis of fieldwork data (2022)

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

A line graph of the MSE values of the three models in Table 4.67 was presented in Figure 4.27. The results displayed in the chart showed clearly that the linear and logarithmic models exhibited similar trends; MSE values remained within a narrow band that was less than 1.0. By contrast, the quadratic model had one MSE value (for the 0 – 4900 M^2 GFA range) that was markedly higher than any other MSE value in Table 4.67.

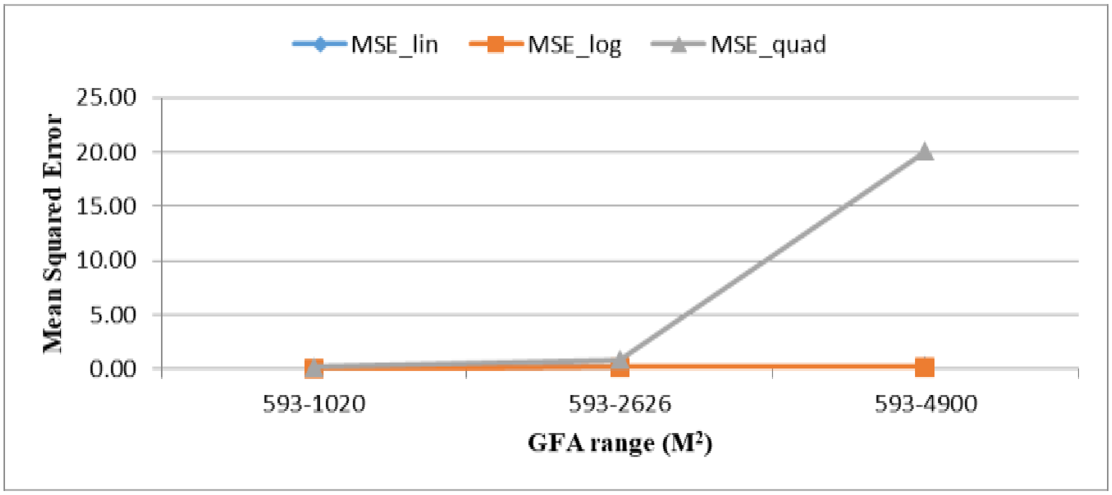

Figure 4.27: Comparison of MSE for PPE cost (Roof) & GFA

4.7.3.5 *Validation of regression models for PPE cost (Floor)*

The validation of PPE cost prediction for floor used MSE as the sole measure of model performance, and the results as shown in Table 4.68. It was revealed that the logarithmic model was a better choice than the linear and the quadratic model. When the MAPD of the models was considered, none of the three models had MAPD values that were below 5.0%, which is the acceptable level of error in most scientific experiments. It was also observed that projects with smaller gross floor area (within 0 – 1100 M^2 range) were associated with smaller levels of error. Table 4.68 presents the results which shows that using the MAPD values, it was observed that the linear model out-performed the logarithmic model in the 0 – 2700 M^2 range of GFA.

Table 4.68: Validation of PPE Cost (Floor) and GFA model

Type of regression model	GFA range (M^2)	MSE	MAPD	MAE
Linear	0 – 1100 (593-1020)	0.02	-62.42	-0.13
	0 – 2700 (593-2626)	0.05	-13.72	0.04
	0 – 4900 (593-4900)	0.05	-31.41	0.01
Logarithmic	0 – 1100 (593-1020)	0.01	-41.52	-0.09
	0 – 2700 (593-2626)	0.05	-8.14	0.05
	0 – 4900 (593-4900)	0.05	-34.40	0.01
Quadratic	0 – 1100 (593-1020)	0.09	111.53	0.29
	0 – 2700 (593-2626)	0.52	163.22	0.65
	0 – 4900 (593-4900)	1.31	380.78	0.89

Source: Author's analysis of fieldwork data (2022)

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

Figure 4.28 was a line graph depiction of the three models MSE values in Table 4.68. The displayed results in the chart showed clearly that the linear and logarithmic models exhibited similar trends; MSE values were the same for the medium and largest ranges of gross floor area covered by the holdout data (0 – 2700 M^2 and 0 – 4900 M^2). The MSE values of the quadratic model were much higher than those of the two other models.

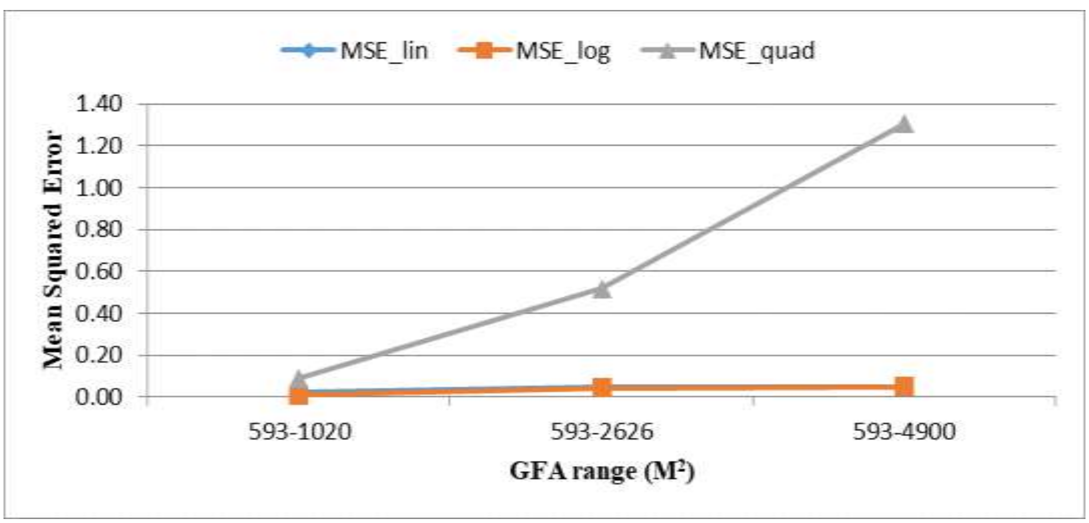

Figure 4.28: Comparison of MSE for PPE cost (Floor) & GFA

4.7.3.6 *Validation of regression models for PPE cost (Plastering)*

The PPE cost for plastering was predicted with three regression models (linear, logarithmic and quadratic). MSE was employed as a performance metric in the validation of these models and the results as shown in Table 4.69. It was revealed that the logarithmic model out-perform the linear and quadratic model. When the MAPD of the models was considered, none of the three models had MAPD values that were below 5.0%, which is the acceptable level of error in most scientific experiments. It was also observed that projects with smaller gross floor areas (within 0 – 1100 M^2 range) were associated with smaller levels of error.

Table 4.69: Validation of PPE Cost (Plastering) and GFA model

Type of regression model	GFA range (M^2)	MSE	MAPD	MAE
Linear	0 – 1100 (593-1020)	0.03	-26.20	-0.16
	0 – 2700 (593-2626)	0.10	-78.91	-0.24
	0 – 4900 (593-4900)	0.14	-137.82	-0.29
Logarithmic	0 – 1100 (593-1020)	0.02	-10.27	-0.06
	0 – 2700 (593-2626)	0.03	7.30	0.06
	0 – 4900 (593-4900)	0.03	21.98	0.07
Quadratic	0 – 1100 (593-1020)	0.11	41.96	0.27
	0 – 2700 (593-2626)	0.57	177.03	0.67
	0 – 4900 (593-4900)	0.86	338.22	0.79

Source: Author’s analysis of fieldwork data (2022)

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

Figure 4.29 was a line graph depiction of the three models MSE values in Table 4.69. The displayed results in the chart showed clearly that the linear and logarithmic models exhibited similar trends; MSE values increased only very slightly as the range of GFA covered by the holdout data increased. Thus, the largest range (0 – 4900 M^2) had higher MSE values than the other two ranges. The MSE values of the quadratic model were much higher than those of the two other models.

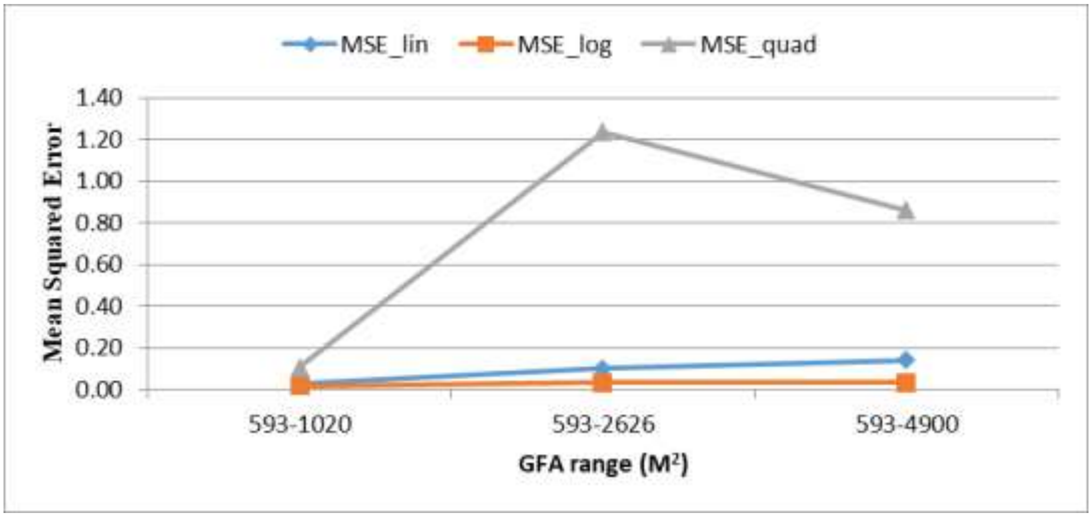

Figure 4.29: Comparison of MSE for PPE cost (Plastering) & GFA

4.7.3.7 *Validation of regression models for PPE cost (Painting)*

The PPE cost for painting was predicted with three regression models (linear, logarithmic and quadratic). MSE was employed as a performance metric in the validation of these models and the results as shown in Table 4.70. It was revealed that the logarithmic model out-perform the linear and quadratic model. When the MAPD of the models was considered, none of the three models' MAPD values were below 5.0%, which is the acceptable level of error in most scientific experiments. The validation of the prediction model for painting was marked by very low MSE values. The MAPE values were also quite low, relative to other elements in this study.

Table 4.70: Validation of PPE Cost (Painting) and GFA model

Type of regression model	GFA range (M^2)	MSE	MAPD	MAE
Linear	0 – 1100 (593-1020)	0.0006	-11.7241	-0.0049
	0 – 2700 (593-2626)	0.0004	-20.8564	-0.0107
	0 – 4900 (593-4900)	0.0007	173.3906	-0.0038
Logarithmic	0 – 1100 (593-1020)	0.0005	-17.6392	-0.0116
	0 – 2700 (593-2626)	0.0003	-15.6107	-0.0094
	0 – 4900 (593-4900)	0.0003	15.0847	-0.0075
Quadratic	0 – 1100 (593-1020)	0.0006	-20.4793	-0.0137
	0 – 2700 (593-2626)	0.0004	-17.4079	-0.0108
	0 – 4900 (593-4900)	0.0005	-162.5882	-0.0140

Source: Author's analysis of fieldwork data (2022)

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

Figure 4.30 was a line graph depiction of the three models MSE values in Table 4.70. The displayed results in the chart showed clearly that all of the three models (linear, logarithmic and quadratic) exhibited similar trends; MSE values first decreased, then increased as the range of gross floor area covered by the holdout data increased. Only the logarithmic model differed in this respect, since MSE values did not increase, remaining constant instead.

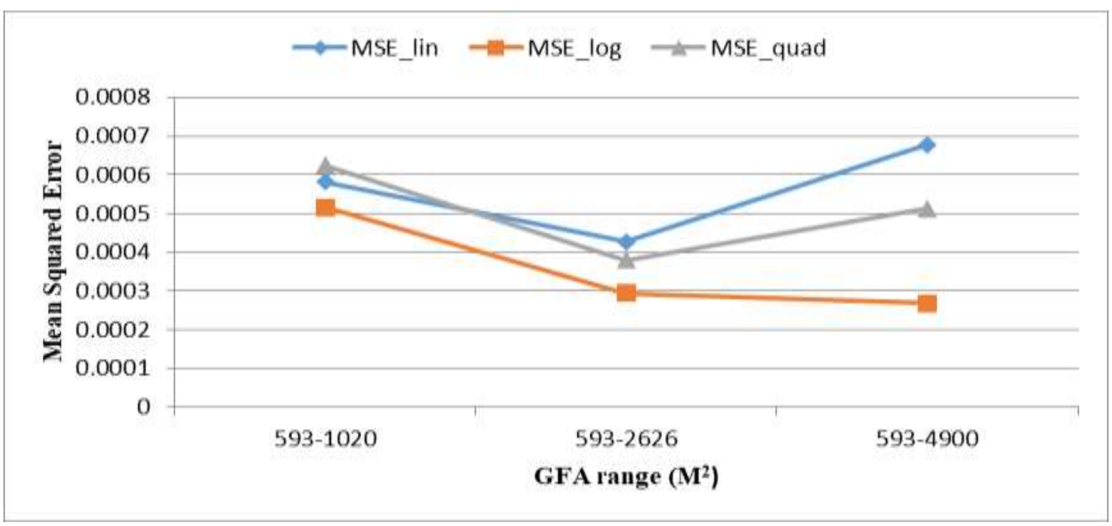

Figure 4.30: Comparison of MSE for PPE cost (Painting) & GFA

4.7.3.8 *Regression models adjudged most effective for predicting PPE cost for elements*

The choice of the model which most effectively enabled the prediction of PPE cost for each of seven elements of building projects using gross floor area as the predictor, in terms of being a statistically significant regression model and having the lowest MSE is presented in Table 4.71. Each of the seven rows in the table represents data about an element of a building. It was possible to effectively model only five elements; for two of the elements – Roof and Floor – the regressions models that were developed, between the independent variables and the dependent variable a non-significant relationship existed. This might be as a result of some other variables that have not yet; ‘been undiscovered might be contributing more to the variation in the cost of safety, total PPE cost and elemental PPE cost, than the gross floor area and project duration of buildings.

The most effective predictive regression model for PPE cost for excavation, using gross floor area as predictor was found to be the logarithmic regression model, which had an MSE of 0.11, compared to 0.28 for linear and 1.12 for the quadratic models. The logarithmic regression model, the formula for which is provided in Table 4.64, had a coefficient of determination (R^2) value of 0.286. This R^2 value is very low for reliable prediction purposes, since this implies that using the developed logarithmic regression model that has been developed in this study will only predict 28.6% of the variations in the PPE cost for excavation.

The regression model that most effectively predicted PPE cost for masonry, using gross floor area as predictor was found to be the logarithmic regression model, which had an MSE of 0.30, compared to 1.00 for linear and 0.63 for the quadratic models. The logarithmic regression model, the formula for which is provided in Table 4.65, had a coefficient of determination (R^2) value of 0.379. This R^2 value is very low for reliable prediction purposes, since this implies that using the developed logarithmic regression model that has been developed in this study will only predict 37.9% of the variations in the PPE cost for masonry.

Table 4.71: Models adjudged most effective for Elemental PPE Cost prediction

Element	MSE of Models			Model with lowest MSE	Model structure	R^2 (%)	Remark
	Model1 (Lin)	Model2 (Log)	Model3 (Quad)				
Excavation	0.28	0.11	1.12	Logarithmic	PPE cost (Excavation) = 3.623+ (-0.364 * ln(GFA))	28.6%	Logarithmic model selected.
Masonry	1.00	0.30	0.63	Logarithmic	PPE cost (Masonry) = 6.73 + (-0.753 * ln(GFA))	37.9%	Logarithmic model selected.
Concrete	0.54	0.12	0.33	Logarithmic	PPE cost (Concrete) = 4.934 + (-0.613 * ln(GFA))	43.3%	Logarithmic model selected.
Roof	0.25	0.17	20.11				No model selected because relationship between variables was non-significant.
Floor	0.05	0.05	1.31				No model selected because relationship between variables was non-significant.
Plastering	0.14	0.03	0.86	Logarithmic	PPE cost (Plastering) = 26.332 + (-0.385 * ln(GFA))	59.3%	Logarithmic model selected.
Painting	0.0007	0.0003	0.0005	Logarithmic	PPE cost (Painting) = 20.484 + (-0.06 * ln(GFA))	51.7%	Logarithmic model selected.

Source: Author's analysis of fieldwork data (2022)

Notes: GFA=Gross floor area; MSE=Mean squared error; ln=natural log; Lin=Linear regression; Log=Logarithmic regression; Quad=Quadratic regression

The regression model that most effectively predicted PPE cost for reinforced concrete work, using gross floor area as predictor was found to be the logarithmic regression model, which had an MSE of 0.12, compared to 0.54 for linear and 0.33 for the quadratic models. The logarithmic regression model, the formula for which is provided in Table 4.66, had a coefficient of determination (R^2) value of 0.433. This R^2 value is very low for reliable prediction purposes, since this implies that using the developed logarithmic regression model that has been developed in this study will only predict 43.3% of the variations in the PPE cost for reinforced concrete.

The regression model that most effectively predicted PPE cost for plastering/rendering, using gross floor area as predictor was found to be the logarithmic regression model, which had an MSE of 0.03, compared to 0.14 for linear and 0.86 for the quadratic models. The logarithmic regression model, the formula for which is provided in Table 4.69, had a coefficient of determination (R^2) value of 0.593. This R^2 value is low for reliable prediction purposes, since this implies that using the developed logarithmic regression model that has been developed in this study will only predict 59.3% of the variations in the PPE cost for plastering/rendering.

The regression model that most effectively predicted PPE cost for painting, using gross floor area as predictor was found to be the logarithmic regression model, which had an MSE of 0.0003, compared to 0.0007 for linear and 0.0005 for the quadratic models. The logarithmic regression model, the formula for which is provided in Table 4.70, had a coefficient of determination (R^2) value of 0.517. This R^2 value is low for reliable prediction purposes, since this implies that using the developed logarithmic regression model that has been developed in this study will only predict 51.7% of the variations in the PPE cost for painting.

4.7.4 Discussion of results of model validation

The identification and computation of a suitable performance measure is the only possible way to validate statistical models. Only then can a successful comparison be undertaken. The following performance measures have been found in literature R^2, MSE. RMSE, MAE and Percentage Error (PE).

The results of the developed validation models in this study can be compared with findings from construction management literature, where parallels cannot be found in health and safety literature. As part of their research into pre-project planning in the USA, Wang and Gibson (2010) reported an R value (coefficient of correlation) of 0.475 for a linear regression model. This translates to an R^2 (coefficient of determination) of 22.6%. After eliminating the outliers in the pre-project planning data, they obtained a RMSE of 0.086 for the linear regression model. Gulcicek *et al*. (2013) researched on the assessment of construction projects cost, multiple regression model was employed and obtained MSE values of 0.02210.

Regression modelling has been employed in Hong Kong in forecasting the cost of operation and maintenance of condominium properties by Tu and Huang (2013). The regression model developed by the authors predicted operation and maintenance costs with an average absolute error (also referred to as Mean Absolute Error – MAE) of 26.8%. In their study of safety costs of reinforced concrete work using activity-based costing, Gurcanli *et al*. (2015) reported an R^2 value of 0.67 from a logarithmic regression model. It can thus be observed that regression modelling has been applied to diverse research purposes with varying levels of prediction effectiveness. This study joins the wide and diverse body of literature on the use of regression modelling in construction, having employed duration to predict the safety cost of projects as recommended by Gurcanli *et al*. (2015), and obtained an R^2 value of 0.436 and MSE of 0.82 from a logarithmic regression model.

4.8 Summary of Findings

In this section the key findings are brought together and are reported for all of the five objectives of the study. Being a summary, most of the detail has been omitted; only the bare outlines of the findings can be found in the section. For ease of reference, the findings have been numbered in the same order as the objectives of the study.

i. Eighteen potential hazards were identified on building construction sites. The severity of eleven (11) of these hazards was described as 'high risk. 'Falls from height', 'building structure collapse' and workers being 'struck or hit by falling objects', were ranked as the hazards with the top most safety risk in construction projects.
ii. The levels of risk was determined using the Fine-Kinney method in seven work elements of buildings projects. Reinforced concrete was classified as work item with 'high' risk; roof work classified as 'medium' risk work while the remaining five elements (excavation, masonry, floor, plastering and painting) were classified as 'low' risk.
iii. The cost of safety of construction projects was synthesized using activity-based costing approach and was found to lie between 1.75% and 18.83% of the total cost of projects, with an average value of 5.67%. In relation to the gross floor area of building projects, main contractors will need to spend ₦21, 271.98 per square meter as Safety Cost. The main component of safety cost is the cost of PPE, which was an average of ₦16, 142.58 per square meter or 4.38% of the total project cost.
iv. Seven (7) logarithmic regression models have been developed in this study. Project duration was employed by two models to predict the total safety cost as well as the PPE cost of building projects. In the five other models' gross floor area was used as a predictor of the PPE cost of the excavation, masonry, reinforced concrete, plastering and painting elements of building projects. The predictive strength of the seven models was low, based on maximum observed R^2 of 59%. The study was unable to satisfactorily predict the changes in PPE cost in roof and floor works.

v. The study has successfully validated the logarithmic regression model that was developed by the study. The cost of safety of building projects model was validated by employing duration of the project, by using this formula: Safety cost = 23.24 + (-3.338 * ln(Duration), with an R^2 value of 0.436 and MSE of 0.82.

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

This study aim was to employ activity-based costing to develop a safety cost model for building construction projects. The procedure adopted for achieving this aim involved identifying hazards and determining the level of risk in building construction works. Thereafter the cost of safety was synthesised and modelled using regression; the models that were developed were then validated. Certain findings have been made from the results of the study, which is now being concluded in this section.

It was inferred that among the potential hazard, fall from height which has being tagged as the big four hazard in the construction industry was prominent in all the work items sampled. It was discovered that significant variations emerged in the classification of construction work items according to the level of risk, it was concluded that contractors would have to plan for different levels of expenditure for safety risk mitigation in all different elements. And thus, expect to encounter far more ‘substantial risk’ and ‘possible risk’ hazards than ‘very high risk’, ‘high risk’ and ‘risk’ hazards.

In determining safety cost of building projects, inference drawn from these results was that the value of the preliminaries of building projects was quite adequate and sufficient for providing workplace safety through CPM and ST. Although, there was no special provision for PPE. The conclusion that can be drawn from these results was that the costs of ensuring that construction workplaces are safe (that is Safety cost) are far heavier than the provisions that are usually made for safety under conventional systems of pricing construction works.

In determining the performance of the independent variables in elemental PPE cost, five (5) elements (excavation, masonry, reinforced concrete, plastering/rendering and painting). Gross floor area had a statistically significant but weak relationship with elemental PPE cost. The relationship of gross floor area with PPE cost in two elements (roofing and flooring) was statistically non-significant. It is possible to assert that gross floor area cannot be used to satisfactorily predict the changes in PPE cost in roofing and flooring works. It can be concluded that some other variable or variables that have not yet; 'been undiscovered might be contributing more to the variation in the cost of safety, total PPE cost and elemental PPE cost, than the gross floor area and project duration of buildings.

In the validation of model using gross floor area and project duration, the duration of project was adjudged the most effective predictor for safety cost of projects and the cost of PPE. In addition the logarithmic model was chosen as the best performing model, as well as in the prediction of elemental PPE cost using construction area as the predictor. It was concluded that logarithmic regression model was validated as suitable for predicting safety cost as well as PPE cost of building project by employing the project duration and the cost of PPE of building work elements by employing construction area. It was concluded that the cost of safety is predictable before execution of project by construction firms by employing the information from the BOQ and by using project duration so as to reduce the rate of accident on sites.

5.2 Recommendations

The suggested measures that should be implemented to improve the study's achievements is detailed, centred on the findings from the study. The recommendations made for both policy and strategy stakeholders are as follow:

i) Hazard identification is an important feature of safety in construction; unless potential hazards are correctly identified, effective measures to mitigate such hazards cannot be designed. Construction site managers should focus attention on the critical hazards identified, to ensure the safety of the workforces as well as the work space.

ii) During project planning stage special attention should be paid to safety in terms of construction work elements/items such as roof work that was ranked as 'high risk'.

iii) Adequate provision should be made for safety measures such as collective protective measures to arrest fall in project sites in order to abate accidents on site.

iv) The levels of risk in building construction work depends on the correct identification of potential hazards, it is recommended that in the management of risks throughout building activities the Fine-Kinney methodology be employed. In other words for an effective risk control, appropriate identification of risk along with prioritization of risk should be a prerequisite.

v) It is recommended that it would be advantageous for a specialized agency to be set up to handle issues relating to risk, hazards, and accidents in the construction industry. Such a body could be called the Construction Safety Board, and would be responsible for the promotion of methodologies for the analysis and management of risk in construction that would be tailored specifically to the peculiarities of the construction sector in Nigeria.

vi) The research has recommended that a separate section be apportioned for health and safety in the BOQ to aid the detailed estimation of the H&S cost items, to aid proper utilization of the approximately 6% estimated for cost of safety in this study.

vii) It was also recommended that a special sub-heads should be created under the preliminaries section that will be dedicated to the costs of personal protective equipment, just like what obtains for collective protective equipment.

viii) It was recommended that the duration of projects should be well estimated for proper projection of cost of safety of project.

5.3 Contribution to Knowledge and Practical Implication of the Research

In this study activity-based costing was utilised to develop regression models for safety cost in building construction projects. The process of carrying out this study, the following contributions were made to the body of knowledge existing:

i. The study has provided researchers as well as stakeholders within the construction sector a perception of hazards in construction activities from the point of view of site managers, work supervisors and project managers. This group of stakeholders viewed eleven (11) hazards as being of such severity as to justify their description as ‘highly critical’. The presence of these critical hazards can be employed to rank work items in terms of how hazardous they are likely to be.

ii. The study has added a practical citable example of a situation that proves that perceptions of risk levels in building work elements depend not on who perceives the risk, but more on the work item that is been analysed. The Fine-Kinney approach was utilized in the determination of the level of risk, this study has empirically confirmed the assertion by other researchers that several parameters do affect risk level results. This has led to the important caveats that have been highlighted regarding comparability of risk levels computed with different parameters and methodologies. All of these are important additions to the theoretical literature on risk analysis.

iii. The study has provided and proved a method by which the well-known, common bills of quantities can be used as the basic and main source of data for the synthesis of safety cost for building projects through the usage of ABC methodology. An approach for determining the number of workers required for work items using the BOQ and the construction programme has been demonstrated in this study.

iv. Discovery of the findings will help main contractors during the bidding for projects, since they are now aware of how much it will cost them to ensure adequate safety on the project site.

v. The logarithmic regression models that has been developed in this study represents a scientific way through which the safety cost along with the cost of PPE of building projects can be determined as a percentage of the proportion of the total contract sum even before work has commenced on the project site.

vi. This study joins the wide and diverse body of literature on the use of regression modelling in construction, having employed duration to predict the safety cost of projects.

vii. The research has developed the predictive mathematical model for estimating the cost of safety using projects duration (applicable to projects costing between ₦0.15b and ₦2.88b), by using the formula:

Safety cost = - 3.338 ln(Duration) +23.24) $R^2 = 0.436$

vi. The practical implication of the result of the model validation is that at duration of 100 days, health and safety cost will average 7.66%; this drops to 2.49% when duration increases to 500 days. The implication of this for clients and contractors alike in the Nigerian Construction Industry is that it provides a benchmark to make provision for health and safety cost under conditions of unstable project duration of building construction projects.

5.4 Areas for Further Study

The following are suggestions for further development of the research work, which was based on the limitations the study encountered.

i) Computing risk exposure scores of all individual work items in building projects for risk level categorisation using the Fine-Kinney risk analysis approach.

ii) Development of regression models for activity-based cost of safety of building projects using project risk level as predictor.

iii) Development of regression models for activity-based cost of safety of individual work items in building projects using duration as predictor.

iv) Prediction of activity-based cost of safety of building projects using artificial neural networks and regression analysis.

ix) It has been pointed out that the predictive strength of the models developed in this study is low, since the maximum observed R^2 was 0.59. It was recommended that to improve upon the predictive strength of the models, a much larger sample of projects should be taken. Secondly, with a larger sample of projects, it becomes possible to develop several subcategories out of the data. Developing models for each subcategory might lead to significant improvement in the predictive strength of the models as indicated by the R^2 values.

x) It was suggested that more efforts should be devoted to identifying and eliminating outliers and extreme values in the data.

xi) In validating future versions of this study, more performance measurement metrics could be employed. It is suggested that the MAPE and MAE should be considered.

xii) Given the performance of the models developed in this study on projects within a narrow band of gross floor area, it was also recommended that models should be developed for projects grouped according to similarity in gross floor area.

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APPENDIX A

SURVEY QUESTIONNAIRE

Federal University of Technology, Minna

School of Environmental Technology,

Department of Quantity Surveying,

PMB 65 Minna, Niger state

DEVELOPMENT OF ACTIVITY BASED COST MODEL FOR HEALTH AND SAFETY IN BUILDING CONSTRUCTION PROJECTS IN ABUJA, NIGERIA

Dear respondent,

I am currently undertaking a PhD research study in Quantity Surveying at the School of Environmental Technology, Federal University of Technology, Minna, under the supervision of Dr Y.D. Mohammed, Dr A.A. Shittu and Dr A.D. Adamu. I am writing to request you to take part in the above- titled PhD research, which aim is to develop an Activity Based Cost (ABC) model for health and safety risks in building construction projects in Abuja with a view to reducing accident rate and cost in construction sites in Nigeria.

You are one of the few stakeholders selected for the purpose of this study. Your organisation has been adjudged to be one of the best placed to provide information relevant to this research. Sincere responses are thus required as a way of improving health and safety in the Nigeria construction industry. Please be assured that full confidentiality of responses would also be maintained; all findings the process of findings and conclusions would only be disseminated in an aggregated form which makes it impossible to identify individual respondents. To this end an ethical consent form is included for your perusal and completion.

Thank you in anticipation for your response.

Mamman, Ekemena Juliet.

08036633146, 08058211197, 07081320228 ekemenajuliet@gmail.com

ETHICAL CONSENT FORM

Title of the Research Project

Development of Activity Based **Cost Model for Health and Safety Risk in Building Construction Projects in Abuja, Nigeria**

Name of the Researcher

Mamman, Ekemena Juliet PhD candidate,

Department of Quantity Surveying, School of Environmental Technology,

Federal University of Technology, Minna

Please respond to the following:

1. I have read Mrs Mamman's covering letter and understand what kind of information she is seeking from me. Please tick ☐
2. I agree to answer the questions posed in this study, and to provide accurate information to the best of my ability. Please tick ☐
3. I understand that my participation is voluntary and that I am free to withdraw at any time without offering reasons. Please tick ☐
4. I agree to take part in this study. Please tick ☐

Name of the respondent and organisation……………………………………………………

…………………………………………………………………………………………………

………

………………………………………………

Phone number/ Email address………………………………………………………

Signature/Date……………………………………………………………………………

SECTION A: General Information

Please complete the following questions by ticking and fill in the blanks as may be applicable.

1. **Gender of respondent ____**

2. **Highest Academic qualification of Respondent. ____________________________**

3. **Profession of respondent**: **_________________________**

4. **Professional membership of respondent**: **_________________________**

5. **Position &Year of experience in construction industry____________________**

6. **Number of employees in Respondent's company?**(a) 0-49 ( )(b) 50-249 ( )(c) >250 ( )

7. **Which of the following are included in the OHSM system** (a) **Safety Officer** ( ) (b) **Written Health & Safety policy** ( ) (c) **Accident reporting system** ( ) (d) **Safety audit** ( ) (e) **Documented risk assessment** ( ) (f) **Insurance cover for sites** ( ) (g) Others Please specify**____**

8.	**Which health and safety programme do you assign cost to and how?**	**Location of H&S cost in contract document**			**Type of pricing**		
		Prelims	**Body of BOQ**	**Contingency**	**%**	**Lump**	
1	**Health &Safety manager/officer**						
2	**Safety audit by external consultant**						
3	**Staff Safety training**						
4	**Site Safety incentive scheme**						
5	**First aid**						
6	**Personal Protective Equipment (PPE)**						
7a	**Fire points (temporary fire alarm)**						
7b	**Fire extinguishers**						
8	**Statutory Safety signage/ promotion**						
9	**Nurse**						
10	**Traffic marshals**						
11	**Mobile clinic**						
12	**Insurance of workers**						

Activity-Based Costing (ABC) is a system of calculating the cost of individual activities & assigning these costs to cost objects on the basis of activities undertaken to produce each task.

9. **What type of costing system do you use to allocate OHS cost to projects**
(a) Insurance premium ( ) (b) Traditional costing ( ) (c) Job based costing ( ) (d) Activity-Based costing ( ) (e) Others please specify ____________________

10. **Have your company applied the use of Activity Based costing (ABC) to estimate cost for any construction project?** (a) Yes ( ) (b) No ( ). If Yes please state the area ____

SECTION B: DETERMINATION OF POTENTIAL HAZARDS IN BUILDING CONSTRUCTION PROJECTS.

Please from your wealth of experience tick according to preference the riskiest hazard in building construction project.

S/N	HAZARD/ LEVEL OF RISK FACTOR	**Very Low risk** 1	**Low risk** 2	**Moderate risk 3**	**High Risk** 4	**Very High risk** 5
1	**Struck by falling objects**					
2	**Fall from height**					
3	**Cave- ins /trench collapses**					
4	**Fall to lower level**					
5	**Fall to the same level / Slips trips and falls**					
6	**Building/structure collapse**					
7	**Equipment accidents**					
8	**Struck by moving vehicles**					
9	**Machine/tool handling & usage hazards**					
10	**Contact with electricity**					
11	**Contact with underground lines**					
12	**Collapse of underground cavities / pits**					
13	**Traffic accident**					
14	**Exposure to noise**					
15	**Exposure to fire**					
16	**Caught in-between Objects or Materials**					
17	**Exposure to harmful substance**					
18	**Overexertion**					

SECTION C: DETERMINATION OF THE LEVEL OF RISK FOR EACH WORK ITEM IN BUILDING CONSTRUCTION PROJECTS.

Based on your wealth of experience please rank the following building construction work items of their level of risk.

(a) **SEVERITY where: 1- Noticeable, 2- Important, 3- Serious, 4- Very serious, 5- Disaster**

(b) LIKELIHOOD where: 1- Rare, 2- Remote, 3- Occasional, 4-Frequent, 5-Almost

S/N	WORK ITEM IN BUILDING CONSTRUCTION PROJECTS.	SEVERITY					LIKELIHOOD				
		1	2	3	4	5	1	2	3	4	5
1	**Substructure /Excavation**										
2	**Reinforced Concrete work**										
3	**Masonry (block/ brick)**										
4	**Roof work (carcass & covering**										
5	**Floor Finishing**										
6	**Painting work**										
7	**Plastering / Rendering**										

SECTION D: DETERMINATION OF THE LEVEL OF SEVERITY OF HAZARD FOR EACH WORK ITEM IN BUILDING CONSTRUCTION.

Severity or Consequence means the degree of impact an accident or hazard might have on the workers.

LEVEL	SEVERITY/ Consequence	DESCRIPTION
5	**Disaster**	Fatality/death, fatal diseases or multiple major injuries (permanent disability)
4	**Very serious**	Serious injuries / life-threatening occupational disease (temporary disability) & absenteeism from work
3	**Serious**	Injury requiring medical treatment or ill-health leading to temporary disability or loss of working days
2	**Important**	Injury or ill-health requiring first-aid only.
1	**Noticeable**	Not likely to cause injury or ill-health, minor first aid

Please rate the impact of risk that can occur in each of the hazards listed below, using a scale of 1-5.

SN	Severity or Consequence of Possible Hazard/ Work Item	Substructure/ Excavation	Reinforced Concrete	Masonry (block/ brick)	Roof work	Finishing
1	Struck by falling objects					
2	Fall from height					
3	Cave –ins / Trench collapses					
4	Fall to lower level					
5	Fall to the same level / Slips' trips and falls					
6	Building/structure collapse					
7	Equipment accidents					
8	Struck by moving vehicles					
9	Machine/tool handling & usage hazards					
10	Contact with electricity					
11	Contact with underground lines					
12	Collapse of underground cavities / pits					
13	Traffic accident					
14	Noise exposure					
15	Fire exposure					
16	Caught in-between Objects or Materials					
17	Exposure to harmful substance					
18	Overexertion					

SECTION E: DETERMINATION OF THE LEVEL OF LIKELIHOOD OF HAZARD FOR EACH WORK ITEM IN BUILDING CONSTRUCTION.

Likelihood or Probability means how likely an accident or hazard will occur during work.

Where: 1- Rare, 2- Remote, 3- Occasional, 4-Frequent, 5-Almost

LEVEL	LIKELIHOOD	DESCRIPTION
5	**Almost**	Certain Continual or repeating experience.
4	**Frequent**	Common occurrence.
3	**Occasional**	Possible or known to occur.
2	**Remote**	Not likely to occur under normal circumstances.
1	**Rare**	Not expected to occur but still possible.

Please rate the level of risk that can occur in each of the hazards listed below, using a scale of 1-5.

SN	LIKELIHOOD OR PROBABILITY of Possible Hazard/ Work Item	Substructure/ Excavation	Reinforced Concrete	Masonry (block/ brick)	Roof work	Finishing
1	Struck by falling objects					
2	Fall from height					
3	Cave –ins / Trench collapses					
4	Fall to lower level					
5	Fall to the same level / Slips’ trips and falls					
6	Building/structure collapse					
7	Equipment accidents					
8	Struck by moving vehicles					
9	Machine/tool handling & usage hazards					
10	Contact with electricity					
11	Contact with underground lines					
12	Collapse of underground cavities / pits					
13	Traffic accident					
14	Noise exposure					
15	Fire exposure					
16	Caught in-between Objects or Materials					
17	Exposure to harmful substance					
18	Overexertion					

SECTION F: DETERMINATION OF PERSONAL PROTECTIVE EQUIPMENT (PPE) FOR CONTROLLING CONSTRUCTION ACTIVITIES IN BUILDING CONSTRUCTION PROJECTS.

Please tick the safety program required for each work item listed (multiple selection is allowed)

SN	Personal Protective Equipment (PPE)/ Work Item	Substructure /Excavation	Reinforced Concrete work	Masonry (block/ brick)	Roof works	Finishing
1	Helmet					
2	Gloves					
3	Protective clothing					
4	Reflective vest					
5	Goggle					
6	Protective boot					
7	Dust mask respirator					
8	Safety harness/ belt					
9	Face shield					
10	Ear plug					

SECTION G: COST ESTIMATION OF SAFETY PROGRAM FOR CONSTRUCTION PROJECT: Please help to provide the cost estimated for these safety items by your company.

S/N	SAFETY PROGRAM/ WORK ITEM	UNIT RATE (N)
A	PERSONAL PROTECTIVE EQUIPMENT (PPE)	
1	Helmet	
2	Gloves	
3	Protective clothing	
4	Reflective vest	
5	Goggle	
6	Protective boot	
7	Dust mask respirator	
8	Safety harness/ belt	
9	Face shield	
10	Ear plug	
B	COLLECTIVE PROTECTIVE MEASURES (CPM)	
1	First aid tool box	
2	Safety net	
3	Scaffold	
4	Warning signs	
5	Fire extinguisher	
6	Fire Blanket	
7	Safety tapes	
8	Fence	
9	Safety switch	
10	Radio	
C	SAFETY TRAINING & EDUCATION	
D	SAFETY PROMOTION	
E	SAFETY STAFFING/ PERSONEL SALARY	

APPENDIX B:

A detailed breakdown of the archival data collected is given in Appendix B of this research.

Project	Project description	Total Project Cost	Cost of Prelims
1	Education facility office	421,900,658.55	7,000,000.00
2	Education facility Lecture hall	271,783,781.85	7,000,000.00
3	Education facility office	263,619,794.82	12,000,000.00
4	Education facility Clinic	295,671,087.96	30,377,717.16
5	Education facility Hostel	741,404,557.05	76,173,081.74
6	Education facility Hostel	767,011,860.89	79,240,074.72
7	Education facility Studio	225,757,397.25	10,000,000.00
8	Education facility Workshop	125,394,507.00	6,000,000.00
9	Residential building	261,065,710.75	12,950,000.00
10	Education facility office	391,433,539.89	24,250,000.00
11	Education facility office	697,688,335.24	24,064,000.00
12	Education facility School	243,283,404.79	35,172,475.10
13	Office complex	186,704,270.84	16,400,000.00
14	Office complex	1,350,517,336.75	74,600,000.00
15	Education facility hostel	217,791,870.49	7,549,970.00
16	Office complex	969,766,039.70	40,180,000.00
17	Commercial complex	269,092,892.75	12,000,000.00
18	Residential building	169,840,969.00	29,960,000.00
19	Education facility office	2,625,326,180.02	101,728,578.02
20	Education facility conference hall	982,856,744.36	38,075,917.36
21	Education facility office	823,679,438.38	31,909,467.88
22	Education facility office	666,623,420.10	25,825,032
23	Education facility	115,425,377.94	6,759,633.96
24	Education facility Hostel	269,092,892.75	1,236,156.15
25	Education facility Clinic	353,727,445.95	12,200,000.00
26	Education facility building	1,274,776,759.63	88,334,269.71
27	Education facility building	228,305,474.78	5,950,000.00
28	Education facility building	195,950,245.40	5,600,000.00
29	Education facility building	181,880,725.74	4,935,415.00
30	Education facility building	1,183,939,020.82	32,099,500.00
31	Health facility	142,043,382.73	4,768,893.23
32	Health facility	122,232,133.81	3,927,887.01
33	Health facility	125,734,353.21	4,040,430.06
34	Health facility	165,821,449.11	5,328,616.63
35	Health facility	128,804,911.11	4,139,110.91
36	Education facility	255,002,560.40	8,586,021.00
37	Education facility building	179,168,916.18	7,500,000.00
38	Office complex	688,126,228.94	45,000,000.00
39	Education facility	506,056,330.96	10,739,112.50
40	Education facility	647,361,909.45	10,597,345.16
41	Education facility	631,980,919.67	64,655,757.27
42	Education facility	759,955,377.51	31,584,136.55
43	Education facility	212,307,474.46	21,720,435.08
44	Education facility	1,253,308,886.37	93,509,989.33
45	Education facility	804,083,695.02	76,004,280.00
46	Education facility	1,115,910,245.02	30,954,514.43
47	Education facility	630,898,120.05	64,544,979.82

48	Education facility	268,173,831.31	25,348,554.00
49	Education facility	1,179,859,664.31	31,258,338.00
50	Education facility	805,005,376.95	76,091,400.00
51	Education facility	1,158,850,565.88	32,099,500.00
52	Education facility	2,883,968,720.00	119,859,224.00
53	Education facility	896,130,605.85	38,690,859.79
54	Residential building	604,091,112.70	8,465,579.39
55	Commercial complex	550,338,584.08	10,225,967.90
56	Commercial complex	290,965,712.50	12,957,628.69
57	Worship building	6,154,978,335.00	466,146,000
58	Sport facility Stadium	147,161,090.08	3,424,900.00
59	Residential building	21,003,138.24	2,009,000.00
60	Education facility Lecture hall	203,253,400.30	9,500,000.00
61	Renovation Residential building	150,995,092.50	7,000,000.00
62	Commercial complex	445,065,149.00	29,252,651.00
63	Commercial complex	535,288,090.00	29,252,651.00
64	Poultry farm	34,743,203.25	2,500,000.00
65	Poultry farm	44,249,698.50	4,500,000.00
66	Hostel	1,350,517,336.75	74,600,000.00
67	Residential building duplex	66,522,532.76	2,179,572.96
68	Residential building duplex	111,823,855.50	3,960,000.00
69	Education facility workshop	91,097,871.70	2,896,888.48
70	Poultry farm	28,688,058.00	2,750,000.00
71	Residential building duplex	29,047,136.68	830,000.00
72	Office complex	19,043,804.50	541,489.99
73	Office complex	62,678,076.25	1,782,437.88
74	Education facility office	169,493,751.00	2,930,000.00
75	Residential building	31,851,627.16	788,742.90
76	Remodelling of Auditorium	13,974,534.00	500,000.00

APPENDIX C

Sources of Constant use for the research (output of the results from QS databank and Consol's Nigeria Building price book)

GROUNDWORK (Manual excavations in normal soil soft laterite)

S/N	**Description**	**Output /man day**
1	Trench excavation for foundation n.e. 1.50m deep	4m3(unskilled)6m3
2	Pit excavation for foundation n.e. 1.50m deep	3.5m3 (unskilled) 4.5m3
3	Basement excavation for ground tanks n.e. 1.50m deep	3.0 m3 (unskilled) 3.5m3
4	Basement excavation for ground tanks 1.50m- 3.00m deep	1.75m3 (unskilled)
5	Remove surplus excavated material	5m3 (unskilled)

FILLING

S/N	Description	Output /man day
1	Backfill sides of excavation	8m3 (unskilled) 10m3
2	Imported filling to makeup level	5m3 (unskilled) 7m3
3	Hardcore filling	7m3(unskilled)

CONCRETE WORK

S/N	Description	Output /man day
1	Hand mixing and placing (height n.e.3.0 above ground	0.5m3(unskilled)
2	mixing and placing (height n.e.3.0 above ground	0.6m3(Unskilled)
3	Spreading and tampering of concrete in columns, walls & beams	10m3(skilled)
4	Spreading and tampering of concrete in floor or roof slabs	80m3(skilled)

IRON BENDER (Skilled Labour)

S/N	Description	Output /man day
1	Cutting, bending and fixing of iron rods 16mm and below	100kg
2	Machine bending and cutting plus fixing 20-25mm diameter	60kg
3	Cutting, bending and fixing of iron of fabric mesh reinforcement	100m2 (120M2)

FORMWORK (CARPENTER)

S/N	Description	Output/ man day
1	Fabricating and installing formwork for ground beams or bases n.e. 1.0m high	12m2
2	Fabricating and installing formwork for columns or walls	8m2
3	Fabricating and installing formwork for beams	5m2
4	Fabricating and installing formwork for lintels	6m2
5	Fabricating and installing formwork for floor slab n.e. 3.50m high	15m2
6	Dismantling of formwork and setting aside; beams or columns	16m2
7	Dismantling of formwork and setting aside; for floor slab	30m2

BLOCKWORK (GANG STRENGHT= 1no mason + 1no labour)

S/N	Description	Output /man day
1	Laying 100mm blockwork	8m2
2	Laying 150mm blockwork	8m2
3	Laying 230mm blockwork	7m2
4	Laying Pre-cast concrete screenwall	10m2
5	Laying clay block screenwall	12m2
6	Laying glass block	10m2

PAINTING

S/N	Description	Output /man day
1	Emulsion paint to wall	30m2(skilled)
2	Emulsion paint to soffits	27.5m2(skilled)
3	Gloss paint on wood work	25m2(skilled)
4	Gloss paint on metal work	25m2(skilled)
5	Texcote paint to walls	22.5m2 (skilled)
6	Texcote paint to soffits	20m2 (skilled)

FINISHING (**PLASTERING**)

S/N	Description	Output /man day
A	Plastering wall (skilled)	18m2
B	Plastering ceiling soffit not exceeding 3.5m high	10m2
C	Plastering 4sided column 600-1000mm girth	6m
D	Plastering 3sided beams n.e 3.5m high	6m
E	Floor screeding 50mm thick	25m2
F	Floor tiling with screed bed 300mmx300mm	10m2
G	Wall tiling with screed backing 300mmx300mm	8m2
H	Building-in and dressing of single door frame	2NO
I	Building-in and dressing of single door frame	1NO
J	Building-in and dressing of window frame 1200mm x 1200mm	2NO
L	Building-in and dressing of window frame 1800mm x 1200mm	1NO

CARPENTRY/**ROOFING**/CEILING (**GANG STRENGHT= 2Nr carpenters + 1nr labour)**

S/N	Description	Output /man day
1	Gable roof structure for bungalow at 3.5m above ground	25m2
2	Gable roof structure for 2-storey at 6.5m above ground	15m2
3	Gable roof structure for 3-storey at 9.5m above ground	9m2
4	Ceiling noggins	30m2
5	Asbestos ceiling with cover battens	60m2
6	Chipboard ceiling boards	50m2
7	Portioning carcass un boarded both sides	40m2
8	Roof covering with SLW Asbestos on bungalow	80m2
9	Roof covering with S7 Asbestos on bungalow	60m2
10	Roof covering with Aluminum on bungalow	130m2

APPENDIX D

LIKELIHOOD, SEVERITY AND EXPOSURE OF WORK ITEMS MASONRY

MASONRY WORK LIKELIHOOD	P.1	P.2	P.3	P.4	P.5	P.6	P.7	P.8	P.9	P.10	P.11	P.12	P.13	P.14	P.15	P.16	P.17	P.18	P.19	P.20	P.21	P.22	P.23	P.24	P.25	P.26	P.27	P.28	P.29	P.30	P.31	P.32	P.33	P.34	P.35	P.36	P.37	P.38	P.39	P.40
Struck by falling objects	1	6	1	1	1	3	1	3	1	6	1	6	3	3	6	6	3	3	1	3	3	1	1	1		3	3	1	3	1	1	3	1		1	1	1	3	1	3
Fall from height	3	6	3	1	1	3	0.5	3	3	6	6	6	6	0.5	3	10	3	3	1	3	3	1	1	1		6	1	1	3	6	1	3	3		3	3	1	10	1	3
Cave ins/ trench collapses	1	1	1	1	1	6	0.5	0.5	0.5	0.5	3	1	1	0.5	1	6			1	1		1	1	1		0.5	1	1	1	6	1	0.5	6		6	1	1	1	10	0.5
Fall to lower level	3	10	1	1	3	3	0.5	3	0.5	3	6	3	1	0.5	3	10	6	6	1	3			1	1		1	1	1	1	1	1	3	3		1	3	1	6	1	3
Fall to the same level	1	6	3	1	1	0.5	0.5	3	1	1	1	0.5	6	3	3	10	1	1	1	1			1	1	6	1	1	3	3	1	1	0.5	1		3	1	1	6	3	0.5
Building structure / collapse	3	3	1	1	3	10	1	3	3	1	3	3	6	1	6	10	6	6	1	3	3	3	1	1	3	0.5	3	1	1	3	1	3	3	10	6	3	3	6	6	3
Equipment accidents	3	3		1	3	10	0.5	1	1	0.5	1	1	1	3	1	6	1	1	1	3		3	1	1		1	3	1	3	1	1	0.5	3	3	3	1	1	10	10	0.5
Struck by moving objects	1	3		1	1	3	0.5	0.5	1	0.5	0.5	0.5	3	0.5	0.5	6	1	0.5	1	1			1	1		0.5	3	1	1	1	1	0.5	1		0.5	1	1	1	6	0.5
Manual handling of machine/tool hazards	6	6	3	1	3	10	0.5	3	3	0.5	3	10	3	3	0.5	3	3	3	1	3			1	1	1	1	1	1	3	1	1	1	3	3	0.5	1	1	10	10	1
Contact with electricity	1	1		1	1	6	0.5	0.5	1	0.5	0.5	0.5	0.5	1	1	6			1	1			1	1		0.5	1	1	1	1	1	1	1		0.5	1	1	1	3	1
Contact with underground lines	3	3		1	1	6	0.5	0.5	1	0.5	0.5	0.5	1	0.5	0.5	3	1	1	1	6			1			0.5	1	1	1	1	1	1	1	0.5	0.5	1	1	1	6	1
Collapse of underground cavities / pits	3	6		1	1	10	0.5	0.5	1	0.5	0.5	0.5	1	0.5	1	6	1	1	1	3		3	1	1		1	1	1	1	1	1	1	1		1	1	1	10	3	1
Traffic accident	1	6		1	1	1	0.5	0.5	1	0.5	3	0.5	3	0.5	0.5	3	1	0.5	1	1	1		1			3	3	1	1	1	1	1	1		0.5	1	1	1	6	1
Noise exposure	1	6		1	1	1	0.5	1	1	1	1	0.5	1	0.5	0.5	3	3	3	1	3		3	1			0.5	3	1	3	1	1	3	1		0.5	1	1	10	1	3
Fire exposure	1	1		1	1	0.5	0.5	0.5	1	0.5	0.5	0.5	0.5	1	0.5	1	1	1	1	1			1			0.5	3	1	1		1	3	1		0.5	1	1	3	10	3
Caught in between objects/mat									1							3							1			1	1	1	3	1		0.5			1	1	1	1	1	0.5
Exposure to harmful substance									3							1										1	1	1	1	6					6	3	1		1	
Overexertion									1							6										0.5	1	1	3						6	1	1		3	

SEVERITY OF MASONRY WORK	P.1	P.2	P.3	P.4	P.5	P.6	P.7	P.8	P.9	P.10	P.11	P.12	P.13	P.14	P.15	P.16	P.17	P.18	P.19	P.20	P.21	P.22	P.23	P.24	P.25	P.26	P.27	P.28	P.29	P.30	P.31	P.32	P.33	P.34	P.35	P.36	P.37	P.38	P.39	P.40
Struck by falling objects	15	15	3	3	3	15	1	15	3	15	7	3	15	15	7	40	40	40	1	15	7	3	7	7		3	15	7	7	3	3	7	15		7	3	1	3	3	3
Fall from height	7	40	15	1	7	7	1	40	7	40	1	7	15	15	7	7	15	15	3	7	3	3	15	15		15	7	3	15	15	1	15	15		15	7	7	7	40	7
Cave –ins / Trench collapses	1	40	1	1	3	3	1	1	1	3	1	3	1	3	1	1	3	3	1			40	7	7	3	1	15	7	1	15	1	1	3		1	1	1	7	7	7
Fall to lower level	7	15	7	1	3	3	1	40	1	40	3	7	40	3	3	40	7	7	3	15	7	3	3	3		15	7	3	15	3	1	1	3		1	3	3	7	7	3
Fall to the same level	3	40	7	3	40	3	1	40	3	7	7	3	15	7	3	15	7	7	1	3	1	3	3	3		3	7	1	7	3	3	1	7		3	1	1	7	1	1
Building/structure collapse	40	40	7	1	1	15	3	40	7	40	1	40	40	40	15	15	15	15	15	40	15	15			3	40	15	7	3	7	1	40	40		40	15	3	3	7	40
Equipment accidents	7	40	3	1	3	3	3	15	3	40	3	7	15	3	1	40	3	3	1	3		15	15	7		15	40	3	3	1	1	1	3		7	1	1	3	7	3
Struck by moving objects	7	40	1	1	1	3	3	3	7	3	3	15	15	15	1	40			3	40	7	1	3	3		15	15	1	1	1	1	1	15		15	1	1	1	40	3
Manual handling of machine/tool hazards	3	15	3	3	3	7	1	15	3	7	3	7	7	3	7	15	3	3	1	3		3	7	15		7	15	1	3	1	1	15	3		3	7	1	3	3	1
Contact with electricity	1	40	1	1	1	7	1	1	7	1	3	1	1	1	7	1			3	3			7	7		7	15	1	1	3	1	1			40	15	1	1	40	1
Contact with underground lines	1		1	1	3	7	3	1	3	1	1	1	40	3	3	1			3	3	3					1	7	1	1	1	1	1	3		3	1	1	1	3	3
Collapse of underground cavities / pits	7	40	1	1	3	3	3	7	3	7	3	1	15	15	3	1		3	7	3			15	15		7	7	1	1	1	1	1	15		15	1	1	7	7	7
Traffic accident	3		1	1	1	3	3	1	3	1	1	7	7	1	1	1	3	7	3							3	15	3	1	1	1	1	1		7	1	1	1	1	1
Noise exposure	3	40	7	1	7	7	3	15	3	15	3	1	7	1	3	7	7		1	1	1					3	7	15	3	3	7	1	1		7	1	1	3	3	1
Fire exposure	1		3	1	7	7	7	3	3	1	3	1	1	3	1	1			1							3	15	7	1	1	1	1	3		3	1	1	1	40	1
Caught in between objects/mat									3							40										3	15	3	1	1					3	1	3	1	3	
Exposure to harmful substance									7							7										1	15	1	7	3					3	1	1		15	
Overexertion									3							15										7	15	3	40						40	1	1		3	

MASONRY WORK EXPOSURE	P.1	P.2	P.3	P.4	P.5	P.6	P.7	P.8	P.9	P.10	P.11	P.12	P.13	P.14	P.15	P.16	P.17	P.18	P.19	P.20	P.21	P.22	P.23	P.24	P.25	P.26	P.27	P.28	P.29	P.30	P.31	P.32	P.33	P.34	P.35	P.36	P.37	P.38	P.39	P.40
Struck by falling objects	2.63	1.63	2.13	2.88	2.13	2.12	2.12	2.12	2.12	2.12	1.25	2.12	0.88	2.12	2.12	2.12	2.12	1.38	2.12	2.38	1.38	1.38	1.38	2.12	2.38	2.38	1.38	2.12	2.12	2.12	2.12	2.12	2.12	1.5	1.38	2.38	2.12	1.38	2.12	2.38
Fall from height	2.63	1.63	2.13	2.88	2.13	2.12	2.12	2.12	2.12	2.12	1.25	2.12	0.88	2.12	2.12	2.12	2.12	1.38	2.12	2.38	1.38	1.38	1.38	2.12	2.38	2.38	1.38	2.12	2.12	2.12	2.12	2.12	2.12	1.5	1.38	2.38	2.12	1.38	2.12	2.38
Cave ins/ trench collapses	2.63	1.63	2.13	2.88	2.13	2.12	2.12	2.12	2.12	2.12	1.25	2.12	0.88	2.12	2.12	2.12	2.12	1.38	2.12	2.38	1.38	1.38	1.38	2.12	2.38	2.38	1.38	2.12	2.12	2.12	2.12	2.12	2.12	1.5	1.38	2.38	2.12	1.38	2.12	2.38
Fall to lower level	2.63	1.63	2.13	2.88	2.13	2.12	2.12	2.12	2.12	2.12	1.25	2.12	0.88	2.12	2.12	2.12	2.12	1.38	2.12	2.38	1.38	1.38	1.38	2.12	2.38	2.38	1.38	2.12	2.12	2.12	2.12	2.12	2.12	1.5	1.38	2.38	2.12	1.38	2.12	2.38
Fall to the same level	2.63	1.63	2.13	2.88	2.13	2.12	2.12	2.12	2.12	2.12	1.25	2.12	0.88	2.12	2.12	2.12	2.12	1.38	2.12	2.38	1.38	1.38	1.38	2.12	2.38	2.38	1.38	2.12	2.12	2.12	2.12	2.12	2.12	1.5	1.38	2.38	2.12	1.38	2.12	2.38
Building structure / collapse	2.63	1.63	2.13	2.88	2.13	2.12	2.12	2.12	2.12	2.12	1.25	2.12	0.88	2.12	2.12	2.12	2.12	1.38	2.12	2.38	1.38	1.38	1.38	2.12	2.38	2.38	1.38	2.12	2.12	2.12	2.12	2.12	2.12	1.5	1.38	2.38	2.12	1.38	2.12	2.38
Equipment accidents	2.63	1.63	2.13	2.88	2.13	2.12	2.12	2.12	2.12	2.12	1.25	2.12	0.88	2.12	2.12	2.12	2.12	1.38	2.12	2.38	1.38	1.38	1.38	2.12	2.38	2.38	1.38	2.12	2.12	2.12	2.12	2.12	2.12	1.5	1.38	2.38	2.12	1.38	2.12	2.38
Struck by moving objects	2.63	1.63	2.13	2.88	2.13	2.12	2.12	2.12	2.12	2.12	1.25	2.12	0.88	2.12	2.12	2.12	2.12	1.38	2.12	2.38	1.38	1.38	1.38	2.12	2.38	2.38	1.38	2.12	2.12	2.12	2.12	2.12	2.12	1.5	1.38	2.38	2.12	1.38	2.12	2.38
Manual handling of machine/tool hazards	2.63	1.63	2.13	2.88	2.13	2.12	2.12	2.12	2.12	2.12	1.25	2.12	0.88	2.12	2.12	2.12	2.12	1.38	2.12	2.38	1.38	1.38	1.38	2.12	2.38	2.38	1.38	2.12	2.12	2.12	2.12	2.12	2.12	1.5	1.38	2.38	2.12	1.38	2.12	2.38
Contact with electricity	2.63	1.63	2.13	2.88	2.13	2.12	2.12	2.12	2.12	2.12	1.25	2.12	0.88	2.12	2.12	2.12	2.12	1.38	2.12	2.38	1.38	1.38	1.38	2.12	2.38	2.38	1.38	2.12	2.12	2.12	2.12	2.12	2.12	1.5	1.38	2.38	2.12	1.38	2.12	2.38
Contact with underground lines	2.63	1.63	2.13	2.88	2.13	2.12	2.12	2.12	2.12	2.12	1.25	2.12	0.88	2.12	2.12	2.12	2.12	1.38	2.12	2.38	1.38	1.38	1.38	2.12	2.38	2.38	1.38	2.12	2.12	2.12	2.12	2.12	2.12	1.5	1.38	2.38	2.12	1.38	2.12	2.38
Collapse of underground cavities / pits	2.63	1.63	2.13	2.88	2.13	2.12	2.12	2.12	2.12	2.12	1.25	2.12	0.88	2.12	2.12	2.12	2.12	1.38	2.12	2.38	1.38	1.38	1.38	2.12	2.38	2.38	1.38	2.12	2.12	2.12	2.12	2.12	2.12	1.5	1.38	2.38	2.12	1.38	2.12	2.38
Traffic accident	2.63	1.63	2.13	2.88	2.13	2.12	2.12	2.12	2.12	2.12	1.25	2.12	0.88	2.12	2.12	2.12	2.12	1.38	2.12	2.38	1.38	1.38	1.38	2.12	2.38	2.38	1.38	2.12	2.12	2.12	2.12	2.12	2.12	1.5	1.38	2.38	2.12	1.38	2.12	2.38
Noise exposure	2.63	1.63	2.13	2.88	2.13	2.12	2.12	2.12	2.12	2.12	1.25	2.12	0.88	2.12	2.12	2.12	2.12	1.38	2.12	2.38	1.38	1.38	1.38	2.12	2.38	2.38	1.38	2.12	2.12	2.12	2.12	2.12	2.12	1.5	1.38	2.38	2.12	1.38	2.12	2.38
Fire exposure	2.63	1.63	2.13	2.88	2.13	2.12	2.12	2.12	2.12	2.12	1.25	2.12	0.88	2.12	2.12	2.12	2.12	1.38	2.12	2.38	1.38	1.38	1.38	2.12	2.38	2.38	1.38	2.12	2.12	2.12	2.12	2.12	2.12	1.5	1.38	2.38	2.12	1.38	2.12	2.38
Caught in between objects/mat	2.63	1.63	2.13	2.88	2.13	2.12	2.12	2.12	2.12	2.12	1.25	2.12	0.88	2.12	2.12	2.12	2.12	1.38	2.12	2.38	1.38	1.38	1.38	2.12	2.38	2.38	1.38	2.12	2.12	2.12	2.12	2.12	2.12	1.5	1.38	2.38	2.12	1.38	2.12	2.38
Exposure to harmful substance	2.63	1.63	2.13	2.88	2.13	2.12	2.12	2.12	2.12	2.12	1.25	2.12	0.88	2.12	2.12	2.12	2.12	1.38	2.12	2.38	1.38	1.38	1.38	2.12	2.38	2.38	1.38	2.12	2.12	2.12	2.12	2.12	2.12	1.5	1.38	2.38	2.12	1.38	2.12	2.38
Overexertion	2.63	1.63	2.13	2.88	2.13	2.12	2.12	2.12	2.12	2.12	1.25	2.12	0.88	2.12	2.12	2.12	2.12	1.38	2.12	2.38	1.38	1.38	1.38	2.12	2.38	2.38	1.38	2.12	2.12	2.12	2.12	2.12	2.12	1.5	1.38	2.38	2.12	1.38	2.12	2.38

REINFORCED CONCRETE WORK LIKELIHOOD	P.1	P.2	P.3	P.4	P.5	P.6	P.7	P.8	P.9	P.10	P.11	P.12	P.13	P.14	P.15	P.16	P.17	P.18	P.19	P.20	P.21	P.22	P.23	P.24	P.25	P.26	P.27	P.28	P.29	P.30	P.31	P.32	P.33	P.34	P.35	P.36	P.37	P.38	P.39	P.40
Struck by falling objects	1	6	3	1	1	6	1	3	3	6	1	3	1	3	1	6	3	3	0.5	3	3	10	1	1	6	1	3	3	3	6	3	3	1		3	1	1	3	6	3
Fall from height	1	6	3	1	3	3	1	3	3	6	0.5	6	6	0.5	3	10	3	3	0.5	3	3	10	1	1		1	6	1	3	3	3	3	1		3	3	1		10	3
Cave ins/ trench collapses	1	3	1	3	3	6	1	0.5	6	0.5	3	1	1	0.5	1	6			0.5	1		0.5	1	1	3	1	6	3	0.5	1	0.5	1	6		3	1	1	3	3	1
Fall to lower level	1	6	3	1	3	1	0.5	3	6	0.5	3	1	1	0.5	3	10	1	1	0.5	1		3	1	0.5	3	0.5	3	1	3	1	0.5	3	3		1	3	1	6	6	3
Fall to the same level	1	6	3	1	1	1	1	3	3	0.5	3	1	1	3	3	10	1	1	0.5	1		6	1	1	6	1	3	3	3	1	1	1	1		1	1	1	6	10	1
Building/structure collapse	1	3	1	1	3	10	3	3	6	1	10	6	6	1	3	10	6	6	0.5	3		6	1	1		3	3	1	3	6	0.5	3	3	10	3	6	1	1	1	3
Equipment accidents	3	3	1	3	3	10	1	3	6	3	3	1	1	3	1	6	1	1	0.5	3		3	1	1		1	6	1	3	1	1	1	3	6	1	1	1	3	3	1
Struck by moving vehicles	3	3		1	1	3	0.5	0.5	3	0.5	1	0.5	3	0.5	0.5	10	0.5	1	0.5	1			1	0.5		0.5	3	1	0.5	1	0.5	1	1		1	1	1	1	6	1
Manual handling of machine/tool hazards	1	6		1	1	10	1	3	6	0.5	3	3	3	3	3	6	3	3	1	1	3		1	1	3	1	1	1	3	1	1	1	1	6	1	6	1	1	10	1
Contact with electricity	6	1		1	1	6	0.5	0.5	3	0.5	0.5	0.5	0.5	1	0.5	3			0.5	1			1	1		0.5	1	1	1	1	0.5	1	1		1	1	1	1	1	1
Contact with underground lines	1	3		1	1	10	1	0.5	3	0.5	0.5	0.5	1	0.5	0.5	6	3	3	0.5	6			1	1		0.5	3	1	1	1	0.5	3	1	1	1	1	1	1	3	3
Collapse of underground cavities / pits	3	6		3	3	10	0.5	0.5	6	1	3	6	3	0.5	3	6	1	1	0.5	3		3	1	1		1	3	1	0.5	1	0.5	3	3		1	1	1	1	6	3
Traffic accident	3	6		1	1	1	0.5	1	6	1	0.5	0.5	3	0.5	0.5	3	0.5	1	0.5	1	0.5		1			0.5	3	1	0.5	1	1	1	1	1	1	1	1	1	1	1
Noise exposure	1	1		1	3	10	0.5	1	3	1	1	6	6	0.5	0.5	10	3	3	0.5	1		3	1			0.5	6	6	3	6	3	3	3	6	1	1	1	10	1	3
Fire exposure	3	1		3	1	3	0.5	0.5	6	0.5	0.5	0.5	0.5	1	0.5	1	1	1	0.5	1			1			0.5	6	1	1		0.5	3	1		1	1	1	1	3	3
Caught in between objects/mat									3							6										1	3	1	3	1		1			1	3	1	1	6	1
Exposure to harmful substance									6							1										0.5	3	1	1	3					6	1	1		1	
Overexertion									3							3										0.5	3	1	6						6	1	1		10	

SEVERITY OF REINFORCED CONC	P.1	P.2	P.3	P.4	P.5	P.6	P.7	P.8	P.9	P.10	P.11	P.12	P.13	P.14	P.15	P.16	P.17	P.18	P.19	P.20	P.21	P.22	P.23	P.24	P.25	P.26	P.27	P.28	P.29	P.30	P.31	P.32	P.33	P.34	P.35	P.36	P.37	P.38	P.39	P.40
Struck by falling objects	1	15	7	7	7	15	7	40	7	40	7	7	1	40	15	15	40	40	7		15	7	40	40		1	40	7	15	15	7	1	40		40	7	1	7	15	7
Fall from height	7	40	7	7	1	7	7	40	7	40	7	15	40	15	15	40	7	7	7		7	15	40	40		7	15	7	15	15	7	15	15		40	1	1	7	7	7
Cave –ins / Trench collapses	1	40	1	7	1	7	7	1	15	7	7	1	7	7	1	1	7	7	1			40	15	15		1	15	1	1	1	1	1	7		15	40	1	7	40	15
Fall to lower level	1	15	7	7	7	7	7	15	15	40	7	7	1	7	7	15	7	7	7		7	1	7	7		7	15	7	15	1	1	1	7		1	40	1	7	15	7
Fall to the same level	7	40	7	1	1	7	1	40	7	7	7	7	7	7	7	15	7	7	1	1	7	7	7	7		7	7	7	7	1	7	1	7		1	1	1	7	7	1
Building/structure collapse	40	40	7	1	1	15	7	40	15	40	7	40	40	40	15	40	15	15	7		15	15	7	7		40	15	7	40	15	1	40	40	40	40	40	1	15	40	40
Equipment accidents	15	40	1	1	1	7	15	15	15	40	7	15	40	7	7	40	7	7	7	7		15	7	7		7	15	7	40	7	7	40	7		15	7	1	7	15	7
Struck by moving vehicles	7	40	1	7	1	7	7	7	7	40	7	40	40	15	1	40	7	7	7	40	7	7	1	1		7	40	7	1	1	1	1	15		15	1	1	1	40	7
Manual handling of machine/tool hazards	7	40	7	1	7	7	1	15	15	40	7	7	7	7	7	15	7	7	1	7	7	7	7	7	7	7	15	7	15	7	1	7	7		7	7	1	7	15	1
Contact with electricity	1	40	1	7	7	7	7	1	7	1	7	1	1	7	40	1			7	15			7	7		7	7	1	1	7	1	1	7		40	7	1	1	40	1
Contact with underground lines	7		1	7	1	7	7	1	7	1	7	1	1	15	7	15	7	7	7	40			7	7		1	15	1	7	7	1	1	7		7	1	1	1	40	7
Collapse of underground cavities / pits	15	40	7	1	1	7	15	7	15	40	15	1	40	7	15	7	7	7	7		7		7	7	40	1	15	7	1	7	1	7	15		40	1	1	7	40	1
Traffic accident	7		1	7	7	7	7	1	15	7	7	15	7	1	1	1	7	7	7				7			7	7	7	1	7	7	1	1		7	1	1	1	7	1
Noise exposure	7	40	7	7	7	15	7	15	7	15	7	7	7	1	1	15	7	7	1	1	1	7	7			1	15	15	7	15	7	1	1		7	1	1	7	15	1
Fire exposure	1		1	1	1	7	7		15	1	7	1	1	7	1	1			1				7			1	15	7	1	7	1	1	7		7	1	1	7	40	1
Caught in between objects/mat									7							7										7	40	7	7	7					7	7	7	1	40	
Exposure to harmful substance									15							7										1	7	7	7	7					7	1	1		40	
Overexertion									7							15										1	15	7	15						40	1	1		40	

REINFORCED CONCRETE WORK EXPOSURE	P.1	P.2	P.3	P.4	P.5	P.6	P.7	P.8	P.9	P.10	P.11	P.12	P.13	P.14	P.15	P.16	P.17	P.18	P.19	P.20	P.21	P.22	P.23	P.24	P.25	P.26	P.27	P.28	P.29	P.30	P.31	P.32	P.33	P.34	P.35	P.36	P.37	P.38	P.39	P.40
Struck by falling objects	3.33	1.33	2.17	3.33	2.33	2.33	3.33	2.17	3	1.33	3.33	2.17	3.33	1.33	2.17	0.5	2.17	3.33	1.83	2.17	0.5	1.33	3.33	0.5	2.33	2.17	3.33	2.17	2.17	2.17	2.17	2.17	2.17	3.17	2.33	3.33	3.17	1.83	3	2.17
Fall from height	3.33	1.33	2.17	3.33	2.33	2.33	3.33	2.17	3	1.33	3.33	2.17	3.33	1.33	2.17	0.5	2.17	3.33	1.83	2.17	0.5	1.33	3.33	0.5	2.33	2.17	3.33	2.17	2.17	2.17	2.17	2.17	2.17	3.17	2.33	3.33	3.17	1.83	3	2.17
Cave ins/ trench collapses	3.33	1.33	2.17	3.33	2.33	2.33	3.33	2.17	3	1.33	3.33	2.17	3.33	1.33	2.17	0.5	2.17	3.33	1.83	2.17	0.5	1.33	3.33	0.5	2.33	2.17	3.33	2.17	2.17	2.17	2.17	2.17	2.17	3.17	2.33	3.33	3.17	1.83	3	2.17
Fall to lower level	3.33	1.33	2.17	3.33	2.33	2.33	3.33	2.17	3	1.33	3.33	2.17	3.33	1.33	2.17	0.5	2.17	3.33	1.83	2.17	0.5	1.33	3.33	0.5	2.33	2.17	3.33	2.17	2.17	2.17	2.17	2.17	2.17	3.17	2.33	3.33	3.17	1.83	3	2.17
Fall to the same level	3.33	1.33	2.17	3.33	2.33	2.33	3.33	2.17	3	1.33	3.33	2.17	3.33	1.33	2.17	0.5	2.17	3.33	1.83	2.17	0.5	1.33	3.33	0.5	2.33	2.17	3.33	2.17	2.17	2.17	2.17	2.17	2.17	3.17	2.33	3.33	3.17	1.83	3	2.17
Building/structure collapse	3.33	1.33	2.17	3.33	2.33	2.33	3.33	2.17	3	1.33	3.33	2.17	3.33	1.33	2.17	0.5	2.17	3.33	1.83	2.17	0.5	1.33	3.33	0.5	2.33	2.17	3.33	2.17	2.17	2.17	2.17	2.17	2.17	3.17	2.33	3.33	3.17	1.83	3	2.17
Equipment accidents	3.33	1.33	2.17	3.33	2.33	2.33	3.33	2.17	3	1.33	3.33	2.17	3.33	1.33	2.17	0.5	2.17	3.33	1.83	2.17	0.5	1.33	3.33	0.5	2.33	2.17	3.33	2.17	2.17	2.17	2.17	2.17	2.17	3.17	2.33	3.33	3.17	1.83	3	2.17
Struck by moving vehicles	3.33	1.33	2.17	3.33	2.33	2.33	3.33	2.17	3	1.33	3.33	2.17	3.33	1.33	2.17	0.5	2.17	3.33	1.83	2.17	0.5	1.33	3.33	0.5	2.33	2.17	3.33	2.17	2.17	2.17	2.17	2.17	2.17	3.17	2.33	3.33	3.17	1.83	3	2.17
Manual handling of machine/tool hazards	3.33	1.33	2.17	3.33	2.33	2.33	3.33	2.17	3	1.33	3.33	2.17	3.33	1.33	2.17	0.5	2.17	3.33	1.83	2.17	0.5	1.33	3.33	0.5	2.33	2.17	3.33	2.17	2.17	2.17	2.17	2.17	2.17	3.17	2.33	3.33	3.17	1.83	3	2.17
Contact with electricity	3.33	1.33	2.17	3.33	2.33	2.33	3.33	2.17	3	1.33	3.33	2.17	3.33	1.33	2.17	0.5	2.17	3.33	1.83	2.17	0.5	1.33	3.33	0.5	2.33	2.17	3.33	2.17	2.17	2.17	2.17	2.17	2.17	3.17	2.33	3.33	3.17	1.83	3	2.17
Contact with underground lines	3.33	1.33	2.17	3.33	2.33	2.33	3.33	2.17	3	1.33	3.33	2.17	3.33	1.33	2.17	0.5	2.17	3.33	1.83	2.17	0.5	1.33	3.33	0.5	2.33	2.17	3.33	2.17	2.17	2.17	2.17	2.17	2.17	3.17	2.33	3.33	3.17	1.83	3	2.17
Collapse of underground cavities / pits	3.33	1.33	2.17	3.33	2.33	2.33	3.33	2.17	3	1.33	3.33	2.17	3.33	1.33	2.17	0.5	2.17	3.33	1.83	2.17	0.5	1.33	3.33	0.5	2.33	2.17	3.33	2.17	2.17	2.17	2.17	2.17	2.17	3.17	2.33	3.33	3.17	1.83	3	2.17
Traffic accident	3.33	1.33	2.17	3.33	2.33	2.33	3.33	2.17	3	1.33	3.33	2.17	3.33	1.33	2.17	0.5	2.17	3.33	1.83	2.17	0.5	1.33	3.33	0.5	2.33	2.17	3.33	2.17	2.17	2.17	2.17	2.17	2.17	3.17	2.33	3.33	3.17	1.83	3	2.17
Noise exposure	3.33	1.33	2.17	3.33	2.33	2.33	3.33	2.17	3	1.33	3.33	2.17	3.33	1.33	2.17	0.5	2.17	3.33	1.83	2.17	0.5	1.33	3.33	0.5	2.33	2.17	3.33	2.17	2.17	2.17	2.17	2.17	2.17	3.17	2.33	3.33	3.17	1.83	3	2.17
Fire exposure	3.33	1.33	2.17	3.33	2.33	2.33	3.33	2.17	3	1.33	3.33	2.17	3.33	1.33	2.17	0.5	2.17	3.33	1.83	2.17	0.5	1.33	3.33	0.5	2.33	2.17	3.33	2.17	2.17	2.17	2.17	2.17	2.17	3.17	2.33	3.33	3.17	1.83	3	2.17
Caught in between objects/mat	3.33	1.33	2.17	3.33	2.33	2.33	3.33	2.17	3	1.33	3.33	2.17	3.33	1.33	2.17	0.5	2.17	3.33	1.83	2.17	0.5	1.33	3.33	0.5	2.33	2.17	3.33	2.17	2.17	2.17	2.17	2.17	2.17	3.17	2.33	3.33	3.17	1.83	3	2.17
Exposure to harmful substance	3.33	1.33	2.17	3.33	2.33	2.33	3.33	2.17	3	1.33	3.33	2.17	3.33	1.33	2.17	0.5	2.17	3.33	1.83	2.17	0.5	1.33	3.33	0.5	2.33	2.17	3.33	2.17	2.17	2.17	2.17	2.17	2.17	3.17	2.33	3.33	3.17	1.83	3	2.17
Overexertion	3.33	1.33	2.17	3.33	2.33	2.33	3.33	2.17	3	1.33	3.33	2.17	3.33	1.33	2.17	0.5	2.17	3.33	1.83	2.17	0.5	1.33	3.33	0.5	2.33	2.17	3.33	2.17	2.17	2.17	2.17	2.17	2.17	3.17	2.33	3.33	3.17	1.83	3	2.17

ROOF WORK LIKELIHOOD	P.1	P.2	P.3	P.4	P.5	P.6	P.7	P.8	P.9	P.10	P.11	P.12	P.13	P.14	P.15	P.16	P.17	P.18	P.19	P.20	P.21	P.22	P.23	P.24	P.25	P.26	P.27	P.28	P.29	P.30	P.31	P.32	P.33	P.34	P.35	P.36	P.37	P.38	P.39	P.40
Struck by falling objects	6	6		1	3	1	0.5	3	1	10	1	6	1	3	1	10	3	3	1	6	3	10	1	1	3	1	6	6	3	3	1	3	3		3	1	3	1	1	3
Fall from height	6	10	6	1	3	10	3	3	3	10	10	6	6	0.5	6	10	6	6	1	3	3	10	3	3		3	3	3	3	6	1	3	3		1	6	3	10	1	3
Cave ins/ trench collapses	1	6	3	1	1	6	1	0.5	1	0.5	1	1	1	0.5	0.5	1			1	0.5		0.5	3	3		1	3	1	1	1	1	1	1		1	1	1		3	3
Fall to lower level	3	10	1	3	3	10	1	3	1	3	10	3	3	0.5	0.5	10	6	6	1	3		3	3	3	3	1	3	6	1	1	1	3	3	6	3	6	1	1	1	3
Fall to the same level	1	6		1	1	0.5	1	3	1	3	3	3	6	3	0.5	3	1	1	1	1		6	1	1	6	1	1	3	3	1	1	1	1		1	1	1	1	3	0.5
Building/structure collapse	3	3		1	1	10	1	1	3	3	3	0.5	1	1	1	10	6	6	1	3	3	0.5	3	3		1	1	1	1	1	1	3	6	6	1	10	3	6	6	3
Equipment accidents	3	3	3	1	1	10	0.5	0.5	3	3	0.5	1	1	3	0.5	3	1	1	1	1		3	1	1		3	6	1	3	1	1	1	3	3	1	1	3		10	0.5
Struck by moving vehicles	1	3		3	1	0.5	0.5	3	1	0.5	0.5	0.5	1	0.5	0.5	3	0.5	1	1	0.5						6	3	1	1	1	1	1	1		1	1	1	1	3	0.5
Manual handling of machine/tool hazards	3	6	3	1	6	10	0.5	3	1	1	3	3	3	3	3	10	3	3	1	3		3	3	6		3	3	1	1	3	1	1	6	3	10	3	3		6	1
Contact with electricity	3	6		1	1	3	0.5	0.5	1	0.5	3	0.5	0.5	1	3	1	1	1	1	1		1	6	10		1	3	1	1	3	1	3	1		1	1	1	1	10	3
Contact with underground lines	1	1		3	1	0.5	0.5	0.5	1	0.5	0.5	0.5	0.5	0.5	0.5	1			1	0.5		6				1	1	1	1	1	1	1	1		3	1	1	1	1	0.5
Collapse of underground cavities / pits	1	1		1	1	0.5	0.5	0.5	3	0.5	0.5	0.5	0.5	0.5	0.5	1			1	1	3					1	1	1	1	1	1	1	1		3	1	1	1	10	0.5
Traffic accident	1	6		1	1	0.5	0.5	3	1	0.5	0.5	0.5	3	0.5	0.5	1	0.5	1	1	0.5	0.5					1	6	1	1	1	1	1	1	1	1	1	1		10	1
Noise	3	6		1	1	1	0.5	1	3	3	3	0.5	6	0.5	0.5	10	1	1	1	1		3	3	6		1	3	6	3	3	1	3	1		1	6	1	10	1	3
Fire	3	1		1	3	0.5	0.5	0.5	6	0.5	0.5	0.5	0.5	1	0.5	10	3	3	1	0.5						3	3	1	1		6	1	3		1	3	1	1	1	1
Caught in between objects/mat									1							1										1	3	1	3	3	1	1			1	1	1	1	3	1
Exposure to harmful substance									3							1										1	1	1	1	3	1				6	1	1		1	
Overexertion									1							10										1	1	1	6						6	1	1		10	

ROOF WORK SEVERITY	P.1	P.2	P.3	P.4	P.5	P.6	P.7	P.8	P.9	P.10	P.11	P.12	P.13	P.14	P.15	P.16	P.17	P.18	P.19	P.20	P.21	P.22	P.23	P.24	P.25	P.26	P.27	P.28	P.29	P.30	P.31	P.32	P.33	P.34	P.35	P.36	P.37	P.38	P.39	P.40
Struck by falling objects	40	15	15	3	3	40	7	40	7	40	3	3	7	40	3	40	15	15	3		15	15	15	15	7	3	7	7	3	15	3	40	40		7	7	15	1	40	7
Fall from height	40	40	15	1	3	40	15	40	7	40	15	3	15	15	40	40	15	15	15	40	7	15	15	15	7	15	40	7	40	15	1	40	15	40	7	40	15	40	40	15
Cave ins /Trench collapses	1	40	7	3	3	3	3	40	1	3	3	1	1	3	1	1	3	3	1	15		1	7	7	3	3	15	1	1	1	1	1	3		7	1	1	1	40	15
Fall to lower level	15	15	15	3	3	3	3	40	3	40	15	40	40	40	40	40	15	15	7		15	15	7	7		15	15	15	40	3	1	1	40	40	1	15	3	15	40	3
Fall to the same level	3	40	15	7	3	3	15	40	1	15	7	15	40	7	7	40	15	7	3	40	3	7	7	7		7	7	7	3	3	1	1	7		1	1	1	7	40	1
Building/structure collapse	40	40	7	1	1	7	3	40	7	40	15	15	15	40	40	40	15	15	15	15	15	40	7	32		15	15	3	3	15	1	40	40		40	40	3	1	40	15
Equipment accidents	15	40	7	7	7	3	7	40	7	40	3	7	7	40	3	40	3	3	1	40		3	3	7		15	15	3	3	1	3	3	40		40	7	7	7	1	3
Struck by moving vehicles	3	40		3	1	3	1	1	1	40	7	3	15	15	1	3			1	3	7	1		7		7	15	3	1	1	1	1	15		7	1	1	1	40	3
Manual handling of machine/tool hazards	7	40	15	1	1	7	3	40	7	40	15	7	7	3	7	40	7	7	1	7		1	7	3	3	15	15	7	7	3	1	15	3		3	40	7	7	40	1
Contact with electricity	1	40	3	7	1	15	7	7	3	40	15	1	3	7	40	1			1	40			7			3	15	1	1	7	1	40	7		40	40	1	7	3	1
Contact with underground lines	1		1	1	3	3	1	1	3	1	3	1	3	3	3	1			1							1	15	3	1	1	1	1	3		40	1	1	1	40	3
Collapse of underground cavities / pits	3		1	1	3	3	3	1	7	40	3	1	1	15	3	1			3							40	15	1	1	1	1	15	15		15	7	1	1	1	7
Traffic accident	7		3	1	3	3	1	1	1	40	1	7	7	1	1	1	3	3	1	1						7	15	3	1	1	1	1	1		3	1	1	1	3	1
Noise	1	40	15	1	3	7	3	15	7	15	7	7	7	1	7	15	3	3	1		1		3	3		1	7	7	7	7	7	1	1		1	15	1	7	3	1
Fire	3		7	1	3	7	1	3	15	1	7	1	1	1	1	15	3		40							1	15	3	3	3	1	1	3		7	40	1	3	3	1
caught in between									3							15										1	15	7	7	7	1				7	7	7	1	40	
Exposure to harmful substance									7							3										1	15	1	3	7	1				7	3	1		3	
Overexertion									1							15										1	15	1	15		1				40	1	1		15	

ROOF WORK EXPOSURE	P.1	P.2	P.3	P.4	P.5	P.6	P.7	P.8	P.9	P.10	P.11	P.12	P.13	P.14	P.15	P.16	P.17	P.18	P.19	P.20	P.21	P.22	P.23	P.24	P.25	P.26	P.27	P.28	P.29	P.30	P.31	P.32	P.33	P.34	P.35	P.36	P.37	P.38	P.39	P.40
Struck by falling objects	2.00	3.00	3.00	3.00	2.00	2.00	3.00	3.00	2.00	3.00	1.00	3.00	2.00	3.00	3.00	3.00	3.00	1.00	3.00	3.00	3.00	3.00	2.00	3.00	2.00	3.00	2.00	3.00	3.00	3.00	3.00	3.00	3.00	2.00	2.00	2.00	3.00	2.00	2.00	2.00
Fall from height	2.00	3.00	3.00	3.00	2.00	2.00	3.00	3.00	2.00	3.00	1.00	3.00	2.00	3.00	3.00	3.00	3.00	1.00	3.00	3.00	3.00	3.00	2.00	3.00	2.00	3.00	2.00	3.00	3.00	3.00	3.00	3.00	3.00	2.00	2.00	2.00	3.00	2.00	2.00	2.00
Cave ins/ trench collapses	2.00	3.00	3.00	3.00	2.00	2.00	3.00	3.00	2.00	3.00	1.00	3.00	2.00	3.00	3.00	3.00	3.00	1.00	3.00	3.00	3.00	3.00	2.00	3.00	2.00	3.00	2.00	3.00	3.00	3.00	3.00	3.00	3.00	2.00	2.00	2.00	3.00	2.00	2.00	2.00
Fall to lower level	2.00	3.00	3.00	3.00	2.00	2.00	3.00	3.00	2.00	3.00	1.00	3.00	2.00	3.00	3.00	3.00	3.00	1.00	3.00	3.00	3.00	3.00	2.00	3.00	2.00	3.00	2.00	3.00	3.00	3.00	3.00	3.00	3.00	2.00	2.00	2.00	3.00	2.00	2.00	2.00
Fall to the same level	2.00	3.00	3.00	3.00	2.00	2.00	3.00	3.00	2.00	3.00	1.00	3.00	2.00	3.00	3.00	3.00	3.00	1.00	3.00	3.00	3.00	3.00	2.00	3.00	2.00	3.00	2.00	3.00	3.00	3.00	3.00	3.00	3.00	2.00	2.00	2.00	3.00	2.00	2.00	2.00
Building/structure collapse	2.00	3.00	3.00	3.00	2.00	2.00	3.00	3.00	2.00	3.00	1.00	3.00	2.00	3.00	3.00	3.00	3.00	1.00	3.00	3.00	3.00	3.00	2.00	3.00	2.00	3.00	2.00	3.00	3.00	3.00	3.00	3.00	3.00	2.00	2.00	2.00	3.00	2.00	2.00	2.00
Equipment accidents	2.00	3.00	3.00	3.00	2.00	2.00	3.00	3.00	2.00	3.00	1.00	3.00	2.00	3.00	3.00	3.00	3.00	1.00	3.00	3.00	3.00	3.00	2.00	3.00	2.00	3.00	2.00	3.00	3.00	3.00	3.00	3.00	3.00	2.00	2.00	2.00	3.00	2.00	2.00	2.00
Struck by moving vehicles	2.00	3.00	3.00	3.00	2.00	2.00	3.00	3.00	2.00	3.00	1.00	3.00	2.00	3.00	3.00	3.00	3.00	1.00	3.00	3.00	3.00	3.00	2.00	3.00	2.00	3.00	2.00	3.00	3.00	3.00	3.00	3.00	3.00	2.00	2.00	2.00	3.00	2.00	2.00	2.00
Manual handling of machine/tool hazards	2.00	3.00	3.00	3.00	2.00	2.00	3.00	3.00	2.00	3.00	1.00	3.00	2.00	3.00	3.00	3.00	3.00	1.00	3.00	3.00	3.00	3.00	2.00	3.00	2.00	3.00	2.00	3.00	3.00	3.00	3.00	3.00	3.00	2.00	2.00	2.00	3.00	2.00	2.00	2.00
Contact with electricity	2.00	3.00	3.00	3.00	2.00	2.00	3.00	3.00	2.00	3.00	1.00	3.00	2.00	3.00	3.00	3.00	3.00	1.00	3.00	3.00	3.00	3.00	2.00	3.00	2.00	3.00	2.00	3.00	3.00	3.00	3.00	3.00	3.00	2.00	2.00	2.00	3.00	2.00	2.00	2.00
Contact with underground lines	2.00	3.00	3.00	3.00	2.00	2.00	3.00	3.00	2.00	3.00	1.00	3.00	2.00	3.00	3.00	3.00	3.00	1.00	3.00	3.00	3.00	3.00	2.00	3.00	2.00	3.00	2.00	3.00	3.00	3.00	3.00	3.00	3.00	2.00	2.00	2.00	3.00	2.00	2.00	2.00
Collapse of underground cavities / pits	2.00	3.00	3.00	3.00	2.00	2.00	3.00	3.00	2.00	3.00	1.00	3.00	2.00	3.00	3.00	3.00	3.00	1.00	3.00	3.00	3.00	3.00	2.00	3.00	2.00	3.00	2.00	3.00	3.00	3.00	3.00	3.00	3.00	2.00	2.00	2.00	3.00	2.00	2.00	2.00
Traffic accident	2.00	3.00	3.00	3.00	2.00	2.00	3.00	3.00	2.00	3.00	1.00	3.00	2.00	3.00	3.00	3.00	3.00	1.00	3.00	3.00	3.00	3.00	2.00	3.00	2.00	3.00	2.00	3.00	3.00	3.00	3.00	3.00	3.00	2.00	2.00	2.00	3.00	2.00	2.00	2.00
Noise	2.00	3.00	3.00	3.00	2.00	2.00	3.00	3.00	2.00	3.00	1.00	3.00	2.00	3.00	3.00	3.00	3.00	1.00	3.00	3.00	3.00	3.00	2.00	3.00	2.00	3.00	2.00	3.00	3.00	3.00	3.00	3.00	3.00	2.00	2.00	2.00	3.00	2.00	2.00	2.00
Fire	2.00	3.00	3.00	3.00	2.00	2.00	3.00	3.00	2.00	3.00	1.00	3.00	2.00	3.00	3.00	3.00	3.00	1.00	3.00	3.00	3.00	3.00	2.00	3.00	2.00	3.00	2.00	3.00	3.00	3.00	3.00	3.00	3.00	2.00	2.00	2.00	3.00	2.00	2.00	2.00
Caught in between objects/mat	2.00	3.00	3.00	3.00	2.00	2.00	3.00	3.00	2.00	3.00	1.00	3.00	2.00	3.00	3.00	3.00	3.00	1.00	3.00	3.00	3.00	3.00	2.00	3.00	2.00	3.00	2.00	3.00	3.00	3.00	3.00	3.00	3.00	2.00	2.00	2.00	3.00	2.00	2.00	2.00
Exposure to harmful substance	2.00	3.00	3.00	3.00	2.00	2.00	3.00	3.00	2.00	3.00	1.00	3.00	2.00	3.00	3.00	3.00	3.00	1.00	3.00	3.00	3.00	3.00	2.00	3.00	2.00	3.00	2.00	3.00	3.00	3.00	3.00	3.00	3.00	2.00	2.00	2.00	3.00	2.00	2.00	2.00
Overexertion	2.00	3.00	3.00	3.00	2.00	2.00	3.00	3.00	2.00	3.00	1.00	3.00	2.00	3.00	3.00	3.00	3.00	1.00	3.00	3.00	3.00	3.00	2.00	3.00	2.00	3.00	2.00	3.00	3.00	3.00	3.00	3.00	3.00	2.00	2.00	2.00	3.00	2.00	2.00	2.00

FLOOR FINISHING LIKELIHOOD	P.1	P.2	P.3	P.4	P.5	P.6	P.7	P.8	P.9	P.10	P.11	P.12	P.13	P.14	P.15	P.16	P.17	P.18	P.19	P.20	P.21	P.22	P.23	P.24	P.25	P.26	P.27	P.28	P.29	P.30	P.31	P.32	P.33	P.34	P.35	P.36	P.37	P.38	P.39	P.40
Struck by falling objects	3	6	6	0.5	3	3	0.5	3	3	3	0.5	0.5	0.5	3	3	3	3	3	0.5	0.5	3	10	3	0.5		0.5	0.5	3	3	6	1	0.5	3	10	0.5	1	0.5	1	0.5	1
Fall from height	3	6	3	0.5	0.5	3	0.5	3	0.5	6	3	6	0.5	0.5	3	10	3	3	0.5	3	3	10	3	0.5		0.5	0.5	6	3	6	1	0.5	3		3	3	0.5	10	0.5	1
Cave ins/ trench collapses	1	1	3	0.5	0.5	3		0.5	3	0.5	0.5	0.5	0.5	0.5	0.5	1			0.5	0.5		1		0.5		0.5	0.5	1	1	0.5	1	0.5	0.5		0.5	1	0.5	1	3	1
Fall to lower level	3	10	3	0.5	3	3		3	3	3	3	6	0.5	0.5	6	6	1	1	0.5	3			3	0.5		0.5	3	3	3	0.5	6	3	3	3	0.5	3	0.5	1	6	1
Fall to the same level	1	6	6	3	0.5	0.5		0.5	6	3	0.5	0.5	0.5		0.5	6	1	1	0.5	0.5	3	6	3	0.5	6	0.5	3	1	3	0.5	1	0.5	0.5	6	0.5	1	0.5	1	3	1
Building/structure collapse	3	3		0.5	3	6		0.5	0.5	0.5	0.5	0.5	0.5		3	10	1	1	0.5	3	0.5	6	3	0.5		0.5	0.5	1	1	6	1	0.5	0.5		0.5	6	0.5	6	0.5	1
Equipment accidents	3	3		0.5	3	10		0.5	0.5	0.5	0.5	0.5	0.5		3	6	1	1	0.5	0.5	3	3	3	0.5		0.5	0.5	1	1	0.5	1	0.5	0.5		0.5	1	0.5		10	1
Struck by moving vehicles	1	3		0.5	0.5	3		0.5	0.5	0.5	0.5	0.5	0.5		0.5	3	1	1	0.5	0.5			3	0.5		0.5	0.5	1	1	0.5	1	0.5	0.5		0.5	1	0.5	1	0.5	1
Manual handling of machine/tool hazards	3	6		0.5	0.5	10		0.5	0.5	3	3	3	3	3	3	3	3	3	0.5	0.5			3	0.5		0.5	3	3	1	6	3	3	0.5	3	0.5	1	0.5		3	1
Contact with electricity	1	3		3	0.5	3		0.5	3	0.5	0.5	0.5	0.5		3	3	1	1	0.5	0.5			3	0.5		0.5	3	1	1	0.5	1	0.5	0.5		0.5	1	0.5	1	6	1
Contact with underground lines	1	3		0.5	0.5	0.5		0.5	3	0.5	0.5	0.5	0.5		0.5	3			0.5	6			3	0.5		0.5	0.5	1	1	0.5	1	0.5	0.5		0.5	1	0.5	1	10	1
Collapse of underground cavities / pits	1	1		0.5	0.5	3		0.5	0.5	0.5	0.5	0.5	0.5		0.5	1	1		0.5	0.5				0.5		0.5	0.5	1	1	0.5	1	0.5	0.5		3	1	0.5	3	0.5	1
Traffic accident	1	6		0.5	0.5	0.5		0.5	3	0.5	0.5	0.5	3		0.5	1	3	1	0.5	0.5	0.5			0.5		0.5	0.5	1	1	3	1	0.5	0.5		0.5	1	0.5		3	1
Noise	1	1		0.5	0.5	0.5		0.5	3	0.5	3	0.5	3	0.5	0.5	3	1	3	0.5	0.5		3		3		0.5	3	1	3	3	3	0.5	0.5		0.5	1	0.5	10	6	3
Fire exposure	1	1		0.5	3	0.5		0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	1		1	0.5	0.5				0.5		0.5	3	6	1		1	0.5	3		0.5	1	0.5	1	10	1
Caught in between objects/mat									0.5							3								0.5		0.5	0.5	3	1	0.5	1	0.5			0.5	1	0.5	1	3	1
Exposure to harmful substance									3							3										0.5	0.5	1	1	3	1	0.5			0.5	1	0.5		0.5	
Overexertion									0.5							3										0.5	0.5	1	3			6			6	1	0.5		10	

FLOOR FINISHING SEVERITY	P.1	P.2	P.3	P.4	P.5	P.6	P.7	P.8	P.9	P.10	P.11	P.12	P.13	P.14	P.15	P.16	P.17	P.18	P.19	P.20	P.21	P.22	P.23	P.24	P.25	P.26	P.27	P.28	P.29	P.30	P.31	P.32	P.33	P.34	P.35	P.36	P.37	P.38	P.39	P.40
Struck by falling objects	7	15	7	7	7	15	7	7	7	15	7	7	7	7	7	15	40	40	7		7	40	7	1	7	15	7	7	7	7	1	1	7	1	7	7	7	1	40	1
Fall from height	40	40	15	7	7	7	7	40	1	15	7	7	7	7	15	40	7	7	7	40	7	40	7	7	7	15	7	7	15	15	1	40	7	1	7	15	15	7	40	7
Cave ins /Trench collapses	1	15	1	1	7	7	7	1	7	1	7	1	1	7	1	1	7		1			1		7	7	40	7	1	1	1	1	1	7		7	1	1	1	1	7
Fall to lower level	15	15	7	1	1	7	7	15	7	40	7	15	7	7		7	7	7	7	7	7	15	7	7	7	15	7	7	15	1	1	1	7	1	1	7	1	7	7	7
Fall to the same level	7	40	15	7	7	7	1	40	15	7	7	7	7	1	7	7	7	7	7	40	7	7	7	1		7	7	7	7	1	1	1	1	1	1	1	1	1	7	1
Building/structure collapse	15	40	1	7	1	7	7	40	7	40	7	40	15	7	7	40	7	7	7		15	40	7	7	7	40	15	15	7	7	1	7	7		40	15	1	1	7	7
Equipment accidents	7	15	1	1	7	7	7	7	7	40	7	7	7	7	15	15	7		1			7	7	1		7	7	7	7	1	1	7	7		7	7	7	7	15	7
Struck by moving vehicles	7	15		1	7	7	1	1	15	40	7	7	15	7	7	1	15	7	1	40	7	1	7	1		7	7	7	1	1	1	1	7		1	1	1	7	7	7
Manual handling of machine/tool hazards	7	7	1	1	1	7	1	7	7	40	7	7	7	1	7	7		7	7	7	15	1	7	7		15	7	7	7	15	1	15	1		1	7	1	7	7	1
Contact with electricity	7	40	1	7	7	7	7	1	7	7	15	1	1	1	15	7		15	15	7			7	1		40	7	7	7	7	1	1	1		7	1	1	7	7	1
Contact with underground lines	1		1	1	7	7	1	1	7	1	7	1	7	7	15	1			15	7			7	1		7	7	7	1	1	1	1	7		7	1	1	1	15	7
Collapse of underground cavities / pits	1		1	7	7	7	7	1	7	7	7	1	1	7	1	1	7		7	40				1		1	7	7	1	7	1	1	7		7	1	1	1	1	7
Traffic accident	7		1	7	7	7	1	1	7	1	7	7	7	1	7	1	7	7	7					1		7	7	7	1	7	7	1	1		1	1	1	1	40	1
Noise	7	7	1	1	7	7	1	7	7	7	7	1	7	7	7	7	7	7	1	1	1			7		7	7	7	7	7	7	1	1		1	1	1	7	7	1
Fire exposure	15		1	1	1	7	1	1	7	7	7	1	1	1	1	1		7	7					1		7	7	7	1	7	1	1	1		7	1	1	1	7	1
Caught in betwen objects/mat									7							7								1		15	7	1	1	1	1				7	1	1	1	15	
Exposure to harmful substance									7							7										7	7	7	7	7	1				7	1	1		15	
Overexertion									1							40										1	7	7	15		1				40	1	1		1	

FLOOR FINISHINGEXPOSURE	P.1	P.2	P.3	P.4	P.5	P.6	P.7	P.8	P.9	P.10	P.11	P.12	P.13	P.14	P.15	P.16	P.17	P.18	P.19	P.20	P.21	P.22	P.23	P.24	P.25	P.26	P.27	P.28	P.29	P.30	P.31	P.32	P.33	P.34	P.35	P.36	P.37	P.38	P.39	P.40
Struck by falling objects	3.00	1.75	3.00	1.75	2.50	2.50	1.50	3.00	3.00	3.00	3.00	3.00	1.75	3.00	3.00	3.00	3.00	3.00	2.50	3.00	3.00	3.00	3.00	3.00	3.00	3.00	2.50	3.00	3.00	3.00	3.00	3.00	3.00	2.50	2.50	3.00	3.00	2.50	2.50	3.00
Fall from height	3.00	1.75	3.00	1.75	2.50	2.50	1.50	3.00	3.00	3.00	3.00	3.00	1.75	3.00	3.00	3.00	3.00	3.00	2.50	3.00	3.00	3.00	3.00	3.00	3.00	3.00	2.50	3.00	3.00	3.00	3.00	3.00	3.00	2.50	2.50	3.00	3.00	2.50	2.50	3.00
Cave ins/ trench collapses	3.00	1.75	3.00	1.75	2.50	2.50	1.50	3.00	3.00	3.00	3.00	3.00	1.75	3.00	3.00	3.00	3.00	3.00	2.50	3.00	3.00	3.00	3.00	3.00	3.00	3.00	2.50	3.00	3.00	3.00	3.00	3.00	3.00	2.50	2.50	3.00	3.00	2.50	2.50	3.00
Fall to lower level	3.00	1.75	3.00	1.75	2.50	2.50	1.50	3.00	3.00	3.00	3.00	3.00	1.75	3.00	3.00	3.00	3.00	3.00	2.50	3.00	3.00	3.00	3.00	3.00	3.00	3.00	2.50	3.00	3.00	3.00	3.00	3.00	3.00	2.50	2.50	3.00	3.00	2.50	2.50	3.00
Fall to the same level	3.00	1.75	3.00	1.75	2.50	2.50	1.50	3.00	3.00	3.00	3.00	3.00	1.75	3.00	3.00	3.00	3.00	3.00	2.50	3.00	3.00	3.00	3.00	3.00	3.00	3.00	2.50	3.00	3.00	3.00	3.00	3.00	3.00	2.50	2.50	3.00	3.00	2.50	2.50	3.00
Building/structure collapse	3.00	1.75	3.00	1.75	2.50	2.50	1.50	3.00	3.00	3.00	3.00	3.00	1.75	3.00	3.00	3.00	3.00	3.00	2.50	3.00	3.00	3.00	3.00	3.00	3.00	3.00	2.50	3.00	3.00	3.00	3.00	3.00	3.00	2.50	2.50	3.00	3.00	2.50	2.50	3.00
Equipment accidents	3.00	1.75	3.00	1.75	2.50	2.50	1.50	3.00	3.00	3.00	3.00	3.00	1.75	3.00	3.00	3.00	3.00	3.00	2.50	3.00	3.00	3.00	3.00	3.00	3.00	3.00	2.50	3.00	3.00	3.00	3.00	3.00	3.00	2.50	2.50	3.00	3.00	2.50	2.50	3.00
Struck by moving vehicles	3.00	1.75	3.00	1.75	2.50	2.50	1.50	3.00	3.00	3.00	3.00	3.00	1.75	3.00	3.00	3.00	3.00	3.00	2.50	3.00	3.00	3.00	3.00	3.00	3.00	3.00	2.50	3.00	3.00	3.00	3.00	3.00	3.00	2.50	2.50	3.00	3.00	2.50	2.50	3.00
Manual handling of machine/tool hazards	3.00	1.75	3.00	1.75	2.50	2.50	1.50	3.00	3.00	3.00	3.00	3.00	1.75	3.00	3.00	3.00	3.00	3.00	2.50	3.00	3.00	3.00	3.00	3.00	3.00	3.00	2.50	3.00	3.00	3.00	3.00	3.00	3.00	2.50	2.50	3.00	3.00	2.50	2.50	3.00
Contact with electricity	3.00	1.75	3.00	1.75	2.50	2.50	1.50	3.00	3.00	3.00	3.00	3.00	1.75	3.00	3.00	3.00	3.00	3.00	2.50	3.00	3.00	3.00	3.00	3.00	3.00	3.00	2.50	3.00	3.00	3.00	3.00	3.00	3.00	2.50	2.50	3.00	3.00	2.50	2.50	3.00
Contact with underground lines	3.00	1.75	3.00	1.75	2.50	2.50	1.50	3.00	3.00	3.00	3.00	3.00	1.75	3.00	3.00	3.00	3.00	3.00	2.50	3.00	3.00	3.00	3.00	3.00	3.00	3.00	2.50	3.00	3.00	3.00	3.00	3.00	3.00	2.50	2.50	3.00	3.00	2.50	2.50	3.00
Collapse of underground cavities / pits	3.00	1.75	3.00	1.75	2.50	2.50	1.50	3.00	3.00	3.00	3.00	3.00	1.75	3.00	3.00	3.00	3.00	3.00	2.50	3.00	3.00	3.00	3.00	3.00	3.00	3.00	2.50	3.00	3.00	3.00	3.00	3.00	3.00	2.50	2.50	3.00	3.00	2.50	2.50	3.00
Traffic accident	3.00	1.75	3.00	1.75	2.50	2.50	1.50	3.00	3.00	3.00	3.00	3.00	1.75	3.00	3.00	3.00	3.00	3.00	2.50	3.00	3.00	3.00	3.00	3.00	3.00	3.00	2.50	3.00	3.00	3.00	3.00	3.00	3.00	2.50	2.50	3.00	3.00	2.50	2.50	3.00
Noise	3.00	1.75	3.00	1.75	2.50	2.50	1.50	3.00	3.00	3.00	3.00	3.00	1.75	3.00	3.00	3.00	3.00	3.00	2.50	3.00	3.00	3.00	3.00	3.00	3.00	3.00	2.50	3.00	3.00	3.00	3.00	3.00	3.00	2.50	2.50	3.00	3.00	2.50	2.50	3.00
Fire exposure	3.00	1.75	3.00	1.75	2.50	2.50	1.50	3.00	3.00	3.00	3.00	3.00	1.75	3.00	3.00	3.00	3.00	3.00	2.50	3.00	3.00	3.00	3.00	3.00	3.00	3.00	2.50	3.00	3.00	3.00	3.00	3.00	3.00	2.50	2.50	3.00	3.00	2.50	2.50	3.00
Caught in between objects/mat	3.00	1.75	3.00	1.75	2.50	2.50	1.50	3.00	3.00	3.00	3.00	3.00	1.75	3.00	3.00	3.00	3.00	3.00	2.50	3.00	3.00	3.00	3.00	3.00	3.00	3.00	2.50	3.00	3.00	3.00	3.00	3.00	3.00	2.50	2.50	3.00	3.00	2.50	2.50	3.00
Exposure to harmful substance	3.00	1.75	3.00	1.75	2.50	2.50	1.50	3.00	3.00	3.00	3.00	3.00	1.75	3.00	3.00	3.00	3.00	3.00	2.50	3.00	3.00	3.00	3.00	3.00	3.00	3.00	2.50	3.00	3.00	3.00	3.00	3.00	3.00	2.50	2.50	3.00	3.00	2.50	2.50	3.00
Overexertion	3.00	1.75	3.00	1.75	2.50	2.50	1.50	3.00	3.00	3.00	3.00	3.00	1.75	3.00	3.00	3.00	3.00	3.00	2.50	3.00	3.00	3.00	3.00	3.00	3.00	3.00	2.50	3.00	3.00	3.00	3.00	3.00	3.00	2.50	2.50	3.00	3.00	2.50	2.50	3.00

PLASTERING/RENDERING LIKELIH(	P.1	P.2	P.3	P.4	P.5	P.6	P.7	P.8	P.9	P.10	P.11	P.12	P.13	P.14	P.15	P.16	P.17	P.18	P.19	P.20	P.21	P.22	P.23	P.24	P.25	P.26	P.27	P.28	P.29	P.30	P.31	P.32	P.33	P.34	P.35	P.36	P.37	P.38	P.39	P.40
Struck by falling objects	3	6	6	0.5	3	3	0.5	3	3	3	0.5	0.5	0.5	3	3	3	3	3	0.5	0.5	3	10	3	0.5		0.5	0.5	3	3	6	1	0.5	3	10	0.5	1	0.5	1	0.5	1
Fall from height	3	6	3	0.5	0.5	3	0.5	3	0.5	6	3	6	0.5	0.5	3	10	3	3	0.5	3	3	10	3	0.5		0.5	0.5	6	3	6	1	0.5	3		3	3	0.5	10	0.5	1
Cave ins/ trench collapses	1	1	3	0.5	0.5	3		0.5	3	0.5	0.5	0.5	0.5	0.5	0.5	1			0.5	0.5		1		0.5		0.5	0.5	1	1	0.5	1	0.5	0.5		0.5	1	0.5	1	3	1
Fall to lower level	3	10	3	0.5	3	3		3	3	3	3	6	0.5	0.5	6	6	1	1	0.5	3			3	0.5		0.5	3	3	3	0.5	6	3	3	3	0.5	3	0.5	1	6	1
Fall to the same level	1	6	6	3	0.5	0.5		0.5	6	3	0.5	0.5	0.5		0.5	6	1	1	0.5	0.5	3	6	3	0.5	6	0.5	3	1	3	0.5	1	0.5	0.5	6	0.5	1	0.5	1	3	1
Building/structure collapse	3	3		0.5	3	6		0.5	0.5	0.5	0.5	0.5	0.5		3	10	1	1	0.5	3	0.5	6	3	0.5		0.5	0.5	1	1	6	1	0.5	0.5		0.5	6	0.5	6	0.5	1
Equipment accidents	3	3		0.5	3	10		0.5	0.5	0.5	0.5	0.5	0.5		3	6	1	1	0.5	0.5	3	3	3	0.5		0.5	0.5	1	1	0.5	1	0.5	0.5		0.5	1	0.5		10	1
Struck by moving vehicles	1	3		0.5	0.5	3		0.5	0.5	0.5	0.5	0.5	0.5		0.5	3	1	1	0.5	0.5			3	0.5		0.5	0.5	1	1	0.5	1	0.5	0.5		0.5	1	0.5	1	0.5	1
Manual handling of machine/tool hazards	3	6		0.5	0.5	10		0.5	0.5	3	3	3	3	3	3	3	3	3	0.5	0.5			3	0.5		0.5	3	3	1	6	3	3	0.5	3	0.5	1	0.5		3	1
Contact with electricity	1	3		3	0.5	3		0.5	3	0.5	0.5	0.5	0.5		3	3	1	1	0.5	0.5			3	0.5		0.5	3	1	1	0.5	1	0.5	0.5		0.5	1	0.5	1	6	1
Contact with underground lines	1	3		0.5	0.5	0.5		0.5	3	0.5	0.5	0.5	0.5		0.5	3			0.5	6			3	0.5		0.5	0.5	1	1	0.5	1	0.5	0.5		0.5	1	0.5	1	10	1
Collapse of underground cavities / pits	1	1		0.5	0.5	3		0.5	0.5	0.5	0.5	0.5	0.5		0.5	1	1		0.5	0.5				0.5		0.5	0.5	1	1	0.5	1	0.5	0.5		3	1	0.5	3	0.5	1
Traffic accident	1	6		0.5	0.5	0.5		0.5	3	0.5	0.5	0.5	3		0.5	1	3	1	0.5	0.5	0.5			0.5		0.5	0.5	1	1	3	1	0.5	0.5		0.5	1	0.5		3	1
Noise	1	1		0.5	0.5	0.5		0.5	3	0.5	3	0.5	3	0.5	0.5	3	1	3	0.5	0.5		3		3		0.5	3	1	3	3	3	0.5	0.5		0.5	1	0.5	10	6	3
Fire exposure	1	1		0.5	3	0.5		0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	1		1	0.5	0.5				0.5		0.5	3	6	1		1	0.5	3		0.5	1	0.5	1	10	1
Caught in between objects/mat									0.5							3								0.5		0.5	0.5	3	1	0.5	1	0.5			0.5	1	0.5	1	3	1
Exposure to harmful substance									3							3										0.5	0.5	1	1	3	1	0.5			0.5	1	0.5		0.5	
Overexertion									0.5							3										0.5	0.5	1	3			6			6	1	0.5		10	

PLASTERING/RENDERING SEVEF	P.1	P.2	P.3	P.4	P.5	P.6	P.7	P.8	P.9	P.10	P.11	P.12	P.13	P.14	P.15	P.16	P.17	P.18	P.19	P.20	P.21	P.22	P.23	P.24	P.25	P.26	P.27	P.28	P.29	P.30	P.31	P.32	P.33	P.34	P.35	P.36	P.37	P.38	P.39	P.40
Struck by falling objects	7	15	7	7	7	15	7	7	7	15	7	7	7	7	7	15	40	40	7		7	40	7	1	7	15	7	7	7	7	1	1	7		7	7	7	1	40	1
Fall from height	40	40	15	7	7	7	7	40	1	15	7	7	7	7	15	40	7	7	7	40	7	40	7	7	7	15	7	7	15	15	1	40	7		7	15	15	7	40	7
Cave ins /Trench collapses	1	15	1	1	7	7	7	1	7	1	7	1	1	7	1	1	7		1			1		7	7	40	7	1	1	1	1	1	7	1	7	1	1	1	1	7
Fall to lower level	15	15	7	1	1	7	7	15	7	40	7	15	7	7		7	7	7	7	7	7	15	7	7	7	15	7	7	15	1	1	1	7		1	7	1	7	7	7
Fall to the same level	7	40	15	7	7	7	1	40	15	7	7	7	7	1	7	7	7	7	7	40	7	7	7	1		7	7	7	7	1	1	1	1	1	1	1	1	1	7	1
Building/structure collapse	15	40	1	7	1	7	7	40	7	40	7	40	15	7	7	40	7	7	7		15	40	7	7	7	40	15	15	7	7	1	7	7		40	15	1	1	7	7
Equipment accidents	7	15	1	1	7	7	7	7	7	40	7	7	7	7	15	15	7		1			7	7	1		7	7	7	7	1	1	7	7		7	7	7	7	15	7
Struck by moving vehicles	7	15		1	7	7	1	1	15	40	7	7	15	7	7	1	15	7	1	40	7	1	7	1		7	7	7	1	1	1	1	7		1	1	1	7	7	7
Manual handling of machine/tool hazards	7	7	1	1	1	7	1	7	7	40	7	7	7	1	7	7		7	7	7	15	1	7	7		15	7	7	7	15	1	15	1		1	7	1	7	7	1
Contact with electricity	7	40	1	7	7	7	7	1	7	7	15	1	1	1	15	7		15	15	7			7	1		40	7	7	7	7	1	1	1	1	7	1	1	7	7	1
Contact with underground lines	1		1	1	7	7	1	1	7	1	7	1	7	7	15	1			15	7			7	1		7	7	7	1	1	1	1	7		7	1	1	1	15	7
Collapse of underground cavities / pits	1		1	7	7	7	7	1	7	7	7	1	1	7	1	1	7		7	40				1		1	7	7	1	7	1	1	7		7	1	1	1	1	7
Traffic accident	7		1	7	7	7	1	1	7	1	7	7	7	1	7	1	7	7	7					1		7	7	7	1	7	7	1	1		1	1	1	1	40	1
Noise	7	7	1	1	7	7	1	7	7	7	7	1	7	7	7	7	7	7	1	1	1			7		7	7	7	7	7	7	1	1		1	1	1	7	7	1
Fire exposure	15		1	1	1	7	1	1	7	7	7	1	1	1	1	1		7	7					1		7	7	7	1	7	1	1	1	1	7	1	1	1	7	1
Caught in betwen objects/mat									7							7								1		15	7	1	1	1	1				7	1	1	1	15	
Exposure to harmful substance									7							7										7	7	7	7	7	1				7	1	1		15	
Overexertion									1							40										1	7	7	15		1				40	1	1		1	

PLASTERING RENDERING EXPOSU	P.1	P.2	P.3	P.4	P.5	P.6	P.7	P.8	P.9	P.10	P.11	P.12	P.13	P.14	P.15	P.16	P.17	P.18	P.19	P.20	P.21	P.22	P.23	P.24	P.25	P.26	P.27	P.28	P.29	P.30	P.31	P.32	P.33	P.34	P.35	P.36	P.37	P.38	P.39	P.40
Struck by falling objects	4.50	6.00	4.50	4.00	4.50	4.00	4.00	3.00	3.00	4.50	3.00	4.50	2.00	4.50	4.00	4.50	3.00	4.50	4.50	4.50	4.50	4.00	2.50	4.50	4.50	4.50	3.00	4.50	4.50	4.50	4.50	4.50	4.50	2.00	2.50	2.00	2.50	2.50	2.50	2.50
Fall from height	4.50	6.00	4.50	4.00	4.50	4.00	4.00	3.00	3.00	4.50	3.00	4.50	2.00	4.50	4.00	4.50	3.00	4.50	4.50	4.50	4.50	4.00	2.50	4.50	4.50	4.50	3.00	4.50	4.50	4.50	4.50	4.50	4.50	2.00	2.50	2.00	2.50	2.50	2.50	2.50
Cave ins/ trench collapses	4.50	6.00	4.50	4.00	4.50	4.00	4.00	3.00	3.00	4.50	3.00	4.50	2.00	4.50	4.00	4.50	3.00	4.50	4.50	4.50	4.50	4.00	2.50	4.50	4.50	4.50	3.00	4.50	4.50	4.50	4.50	4.50	4.50	2.00	2.50	2.00	2.50	2.50	2.50	2.50
Fall to lower level	4.50	6.00	4.50	4.00	4.50	4.00	4.00	3.00	3.00	4.50	3.00	4.50	2.00	4.50	4.00	4.50	3.00	4.50	4.50	4.50	4.50	4.00	2.50	4.50	4.50	4.50	3.00	4.50	4.50	4.50	4.50	4.50	4.50	2.00	2.50	2.00	2.50	2.50	2.50	2.50
Fall to the same level	4.50	6.00	4.50	4.00	4.50	4.00	4.00	3.00	3.00	4.50	3.00	4.50	2.00	4.50	4.00	4.50	3.00	4.50	4.50	4.50	4.50	4.00	2.50	4.50	4.50	4.50	3.00	4.50	4.50	4.50	4.50	4.50	4.50	2.00	2.50	2.00	2.50	2.50	2.50	2.50
Building/structure collapse	4.50	6.00	4.50	4.00	4.50	4.00	4.00	3.00	3.00	4.50	3.00	4.50	2.00	4.50	4.00	4.50	3.00	4.50	4.50	4.50	4.50	4.00	2.50	4.50	4.50	4.50	3.00	4.50	4.50	4.50	4.50	4.50	4.50	2.00	2.50	2.00	2.50	2.50	2.50	2.50
Equipment accidents	4.50	6.00	4.50	4.00	4.50	4.00	4.00	3.00	3.00	4.50	3.00	4.50	2.00	4.50	4.00	4.50	3.00	4.50	4.50	4.50	4.50	4.00	2.50	4.50	4.50	4.50	3.00	4.50	4.50	4.50	4.50	4.50	4.50	2.00	2.50	2.00	2.50	2.50	2.50	2.50
Struck by moving vehicles	4.50	6.00	4.50	4.00	4.50	4.00	4.00	3.00	3.00	4.50	3.00	4.50	2.00	4.50	4.00	4.50	3.00	4.50	4.50	4.50	4.50	4.00	2.50	4.50	4.50	4.50	3.00	4.50	4.50	4.50	4.50	4.50	4.50	2.00	2.50	2.00	2.50	2.50	2.50	2.50
Manual handling of machine/tool hazards	4.50	6.00	4.50	4.00	4.50	4.00	4.00	3.00	3.00	4.50	3.00	4.50	2.00	4.50	4.00	4.50	3.00	4.50	4.50	4.50	4.50	4.00	2.50	4.50	4.50	4.50	3.00	4.50	4.50	4.50	4.50	4.50	4.50	2.00	2.50	2.00	2.50	2.50	2.50	2.50
Contact with electricity	4.50	6.00	4.50	4.00	4.50	4.00	4.00	3.00	3.00	4.50	3.00	4.50	2.00	4.50	4.00	4.50	3.00	4.50	4.50	4.50	4.50	4.00	2.50	4.50	4.50	4.50	3.00	4.50	4.50	4.50	4.50	4.50	4.50	2.00	2.50	2.00	2.50	2.50	2.50	2.50
Contact with underground lines	4.50	6.00	4.50	4.00	4.50	4.00	4.00	3.00	3.00	4.50	3.00	4.50	2.00	4.50	4.00	4.50	3.00	4.50	4.50	4.50	4.50	4.00	2.50	4.50	4.50	4.50	3.00	4.50	4.50	4.50	4.50	4.50	4.50	2.00	2.50	2.00	2.50	2.50	2.50	2.50
Collapse of underground cavities / pits	4.50	6.00	4.50	4.00	4.50	4.00	4.00	3.00	3.00	4.50	3.00	4.50	2.00	4.50	4.00	4.50	3.00	4.50	4.50	4.50	4.50	4.00	2.50	4.50	4.50	4.50	3.00	4.50	4.50	4.50	4.50	4.50	4.50	2.00	2.50	2.00	2.50	2.50	2.50	2.50
Traffic accident	4.50	6.00	4.50	4.00	4.50	4.00	4.00	3.00	3.00	4.50	3.00	4.50	2.00	4.50	4.00	4.50	3.00	4.50	4.50	4.50	4.50	4.00	2.50	4.50	4.50	4.50	3.00	4.50	4.50	4.50	4.50	4.50	4.50	2.00	2.50	2.00	2.50	2.50	2.50	2.50
Noise	4.50	6.00	4.50	4.00	4.50	4.00	4.00	3.00	3.00	4.50	3.00	4.50	2.00	4.50	4.00	4.50	3.00	4.50	4.50	4.50	4.50	4.00	2.50	4.50	4.50	4.50	3.00	4.50	4.50	4.50	4.50	4.50	4.50	2.00	2.50	2.00	2.50	2.50	2.50	2.50
Fire exposure	4.50	6.00	4.50	4.00	4.50	4.00	4.00	3.00	3.00	4.50	3.00	4.50	2.00	4.50	4.00	4.50	3.00	4.50	4.50	4.50	4.50	4.00	2.50	4.50	4.50	4.50	3.00	4.50	4.50	4.50	4.50	4.50	4.50	2.00	2.50	2.00	2.50	2.50	2.50	2.50
Caught in between objects/mat	4.50	6.00	4.50	4.00	4.50	4.00	4.00	3.00	3.00	4.50	3.00	4.50	2.00	4.50	4.00	4.50	3.00	4.50	4.50	4.50	4.50	4.00	2.50	4.50	4.50	4.50	3.00	4.50	4.50	4.50	4.50	4.50	4.50	2.00	2.50	2.00	2.50	2.50	2.50	2.50
Exposure to harmful substance	4.50	6.00	4.50	4.00	4.50	4.00	4.00	3.00	3.00	4.50	3.00	4.50	2.00	4.50	4.00	4.50	3.00	4.50	4.50	4.50	4.50	4.00	2.50	4.50	4.50	4.50	3.00	4.50	4.50	4.50	4.50	4.50	4.50	2.00	2.50	2.00	2.50	2.50	2.50	2.50
Overexertion	4.50	6.00	4.50	4.00	4.50	4.00	4.00	3.00	3.00	4.50	3.00	4.50	2.00	4.50	4.00	4.50	3.00	4.50	4.50	4.50	4.50	4.00	2.50	4.50	4.50	4.50	3.00	4.50	4.50	4.50	4.50	4.50	4.50	2.00	2.50	2.00	2.50	2.50	2.50	2.50

PAINTING LIKELIHOOD	P.1	P.2	P.3	P.4	P.5	P.6	P.7	P.8	P.9	P.10	P.11	P.12	P.13	P.14	P.15	P.16	P.17	P.18	P.19	P.20	P.21	P.22	P.23	P.24	P.25	P.26	P.27	P.28	P.29	P.30	P.31	P.32	P.33	P.34	P.35	P.36	P.37	P.38	P.39	P.40
Struck by falling objects	3	6	6	0.5	3	3	0.5	3	3	3	0.5	0.5	0.5	3	3	3	3	3	0.5	0.5	3	10	3	0.5		0.5	0.5	3	3	6	1	0.5	3	10	0.5	1	0.5	1	0.5	1
Fall from height	3	6	3	0.5	0.5	3	0.5	3	0.5	6	3	6	0.5	0.5	3	10	3	3	0.5	3	3	10	3	0.5		0.5	0.5	6	3	6	1	0.5	3		3	3	0.5	10	0.5	1
Cave ins/ trench collapses	1	1	3	0.5	0.5	3		0.5	3	0.5	0.5	0.5	0.5	0.5	0.5	1			0.5	0.5		1		0.5		0.5	0.5	1	1	0.5	1	0.5	0.5		0.5	1	0.5	1	3	1
Fall to lower level	3	10	3	0.5	3	3		3	3	3	3	6	0.5	0.5	6	6	1	1	0.5	3			3	0.5		0.5	3	3	3	0.5	6	3	3	3	0.5	3	0.5	1	6	1
Fall to the same level	1	6	6	3	0.5	0.5		0.5	6	3	0.5	0.5	0.5		0.5	6	1	1	0.5	0.5	3	6	3	0.5	6	0.5	3	1	3	0.5	1	0.5	0.5	6	0.5	1	0.5	1	3	1
Building/structure collapse	3	3		0.5	3	6		0.5	0.5	0.5	0.5	0.5	0.5		3	10	1	1	0.5	3	0.5	6	3	0.5		0.5	0.5	1	1	6	1	0.5	0.5		0.5	6	0.5	6	0.5	1
Equipment accidents	3	3		0.5	3	10		0.5	0.5	0.5	0.5	0.5	0.5		3	6	1	1	0.5	0.5	3	3	3	0.5		0.5	0.5	1	1	0.5	1	0.5	0.5		0.5	1	0.5		10	1
Struck by moving vehicles	1	3		0.5	0.5	3		0.5	0.5	0.5	0.5	0.5	0.5		0.5	3	1	1	0.5	0.5			3	0.5		0.5	0.5	1	1	0.5	1	0.5	0.5		0.5	1	0.5	1	0.5	1
Manual handling of machine/tool hazards	3	6		0.5	0.5	10		0.5	0.5	3	3	3	3	3	3	3	3	3	0.5	0.5			3	0.5		0.5	3	3	1	6	3	3	0.5	3	0.5	1	0.5		3	1
Contact with electricity	1	3		3	0.5	3		0.5	3	0.5	0.5	0.5	0.5		3	3	1	1	0.5	0.5			3	0.5		0.5	3	1	1	0.5	1	0.5	0.5		0.5	1	0.5	1	6	1
Contact with underground lines	1	3		0.5	0.5	0.5		0.5	3	0.5	0.5	0.5	0.5		0.5	3			0.5	6			3	0.5		0.5	0.5	1	1	0.5	1	0.5	0.5		0.5	1	0.5	1	10	1
Collapse of underground cavities / pits	1	1		0.5	0.5	3		0.5	0.5	0.5	0.5	0.5	0.5		0.5	1	1		0.5	0.5				0.5		0.5	0.5	1	1	0.5	1	0.5	0.5		3	1	0.5	3	0.5	1
Traffic accident	1	6		0.5	0.5	0.5		0.5	3	0.5	0.5	0.5	3		0.5	1	3	1	0.5	0.5	0.5			0.5		0.5	0.5	1	1	3	1	0.5	0.5		0.5	1	0.5		3	1
Noise	1	1		0.5	0.5	0.5		0.5	3	0.5	3	0.5	3	0.5	0.5	3	1	3	0.5	0.5		3		3		0.5	3	1	3	3	3	0.5	0.5		0.5	1	0.5	10	6	3
Fire exposure	1	1		0.5	3	0.5		0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	1		1	0.5	0.5				0.5		0.5	3	6	1		1	0.5	3		0.5	1	0.5	1	10	1
Caught in between objects/mat									0.5							3								0.5		0.5	0.5	3	1	0.5	1	0.5			0.5	1	0.5	1	3	1
Exposure to harmful substance									3							3										0.5	0.5	1	1	3	1	0.5			0.5	1	0.5		0.5	
Overexertion									0.5							3										0.5	0.5	1	3			6			6	1	0.5		10	

PAINTING SEVERITY	P.1	P.2	P.3	P.4	P.5	P.6	P.7	P.8	P.9	P.10	P.11	P.12	P.13	P.14	P.15	P.16	P.17	P.18	P.19	P.20	P.21	P.22	P.23	P.24	P.25	P.26	P.27	P.28	P.29	P.30	P.31	P.32	P.33	P.34	P.35	P.36	P.37	P.38	P.39	P.40
Struck by falling objects	7	15	7	7	7	15	7	7	7	15	7	7	7	7	7	15	40	40	7		7	40	7	1	7	15	7	7	7	7	1	1	7		7	7	7	1	40	1
Fall from height	40	40	15	7	7	7	7	40	1	15	7	7	7	7	15	40	7	7	7	40	7	40	7	7	7	15	7	7	15	15	1	40	7		7	15	15	7	40	7
Cave ins /Trench collapses	1	15	1	1	7	7	7	1	7	1	7	1	1	7	1	1	7		1			1		7	7	40	7	1	1	1	1	1	7		7	1	1	1	1	7
Fall to lower level	15	15	7	1	1	7	7	15	7	40	7	15	7	7		7	7	7	7	7	7	15	7	7	7	15	7	7	15	1	1	1	7		1	7	1	7	7	7
Fall to the same level	7	40	15	7	7	7	1	40	15	7	7	7	7	1	7	7	7	7	7	40	7	7	7	1		7	7	7	7	1	1	1	1		1	1	1	1	7	1
Building/structure collapse	15	40	1	7	1	7	7	40	7	40	7	40	15	7	7	40	7	7	7		15	40	7	7	7	40	15	15	7	7	1	7	7		40	15	1	1	7	7
Equipment accidents	7	15	1	1	7	7	7	7	7	40	7	7	7	7	15	15	7		1			7	7	1		7	7	7	7	1	1	7	7		7	7	7	7	15	7
Struck by moving vehicles	7	15		1	7	7	1	1	15	40	7	7	15	7	7	1	15	7	1	40	7	1	7	1		7	7	7	1	1	1	1	7		1	1	1	7	7	7
Manual handling of machine/tool hazards	7	7	1	1	1	7	1	7	7	40	7	7	7	1	7	7		7	7	7	15	1	7	7		15	7	7	7	15	1	15	1		1	7	1	7	7	1
Contact with electricity	7	40	1	7	7	7	7	1	7	7	15	1	1	1	15	7		15	15	7			7	1		40	7	7	7	7	1	1	1		7	1	1	7	7	1
Contact with underground lines	1		1	1	7	7	1	1	7	1	7	1	7	7	15	1			15	7			7	1		7	7	7	1	1	1	1	7		7	1	1	1	15	7
Collapse of underground cavities / pits	1		1	7	7	7	7	1	7	7	7	1	1	7	1	1	7		7	40				1		1	7	7	1	7	1	1	7		7	1	1	1	1	7
Traffic accident	7		1	7	7	7	1	1	7	1	7	7	7	1	7	1	7	7	7					1		7	7	7	1	7	7	1	1		1	1	1	1	40	1
Noise	7	7	1	1	7	7	1	7	7	7	7	1	7	7	7	7	7	7	1	1	1			7		7	7	7	7	7	7	1	1		1	1	1	7	7	1
Fire exposure	15		1	1	1	7	1	1	7	7	7	1	1	1	1	1		7	7					1		7	7	7	1	7	1	1	1		7	1	1	1	7	1
Caught in betwen objects/mat									7							7								1		15	7	1	1	1	1				7	1	1	1	15	
Exposure to harmful substance									7							7										7	7	7	7	7	1				7	1	1		15	
Overexertion									1							40										1	7	7	15		1				40	1	1		1	

PAINTING EXPOSURE	P.1	P.2	P.3	P.4	P.5	P.6	P.7	P.8	P.9	P.10	P.11	P.12	P.13	P.14	P.15	P.16	P.17	P.18	P.19	P.20	P.21	P.22	P.23	P.24	P.25	P.26	P.27	P.28	P.29	P.30	P.31	P.32	P.33	P.34	P.35	P.36	P.37	P.38	P.39	P.40
Struck by falling objects	2.00	2.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	2.00	2.00	2.00	1.00	3.00	3.00	2.00	2.00	2.00	3.00	3.00	3.00	3.00	2.00	2.00	3.00	3.00	2.00	3.00	3.00	3.00	3.00	3.00	3.00	1.00	2.00	2.00	2.00	2.00	1.00
Fall from height	2.00	2.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	2.00	2.00	2.00	1.00	3.00	3.00	2.00	2.00	2.00	3.00	3.00	3.00	3.00	2.00	2.00	3.00	3.00	2.00	3.00	3.00	3.00	3.00	3.00	3.00	1.00	2.00	2.00	2.00	2.00	1.00
Cave ins/ trench collapses	2.00	2.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	2.00	2.00	2.00	1.00	3.00	3.00	2.00	2.00	2.00	3.00	3.00	3.00	3.00	2.00	2.00	3.00	3.00	2.00	3.00	3.00	3.00	3.00	3.00	3.00	1.00	2.00	2.00	2.00	2.00	1.00
Fall to lower level	2.00	2.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	2.00	2.00	2.00	1.00	3.00	3.00	2.00	2.00	2.00	3.00	3.00	3.00	3.00	2.00	2.00	3.00	3.00	2.00	3.00	3.00	3.00	3.00	3.00	3.00	1.00	2.00	2.00	2.00	2.00	1.00
Fall to the same level	2.00	2.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	2.00	2.00	2.00	1.00	3.00	3.00	2.00	2.00	2.00	3.00	3.00	3.00	3.00	2.00	2.00	3.00	3.00	2.00	3.00	3.00	3.00	3.00	3.00	3.00	1.00	2.00	2.00	2.00	2.00	1.00
Building/structure collapse	2.00	2.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	2.00	2.00	2.00	1.00	3.00	3.00	2.00	2.00	2.00	3.00	3.00	3.00	3.00	2.00	2.00	3.00	3.00	2.00	3.00	3.00	3.00	3.00	3.00	3.00	1.00	2.00	2.00	2.00	2.00	1.00
Equipment accidents	2.00	2.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	2.00	2.00	2.00	1.00	3.00	3.00	2.00	2.00	2.00	3.00	3.00	3.00	3.00	2.00	2.00	3.00	3.00	2.00	3.00	3.00	3.00	3.00	3.00	3.00	1.00	2.00	2.00	2.00	2.00	1.00
Struck by moving vehicles	2.00	2.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	2.00	2.00	2.00	1.00	3.00	3.00	2.00	2.00	2.00	3.00	3.00	3.00	3.00	2.00	2.00	3.00	3.00	2.00	3.00	3.00	3.00	3.00	3.00	3.00	1.00	2.00	2.00	2.00	2.00	1.00
Manual handling of machine/tool hazards	2.00	2.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	2.00	2.00	2.00	1.00	3.00	3.00	2.00	2.00	2.00	3.00	3.00	3.00	3.00	2.00	2.00	3.00	3.00	2.00	3.00	3.00	3.00	3.00	3.00	3.00	1.00	2.00	2.00	2.00	2.00	1.00
Contact with electricity	2.00	2.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	2.00	2.00	2.00	1.00	3.00	3.00	2.00	2.00	2.00	3.00	3.00	3.00	3.00	2.00	2.00	3.00	3.00	2.00	3.00	3.00	3.00	3.00	3.00	3.00	1.00	2.00	2.00	2.00	2.00	1.00
Contact with underground lines	2.00	2.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	2.00	2.00	2.00	1.00	3.00	3.00	2.00	2.00	2.00	3.00	3.00	3.00	3.00	2.00	2.00	3.00	3.00	2.00	3.00	3.00	3.00	3.00	3.00	3.00	1.00	2.00	2.00	2.00	2.00	1.00
Collapse of underground cavities / pits	2.00	2.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	2.00	2.00	2.00	1.00	3.00	3.00	2.00	2.00	2.00	3.00	3.00	3.00	3.00	2.00	2.00	3.00	3.00	2.00	3.00	3.00	3.00	3.00	3.00	3.00	1.00	2.00	2.00	2.00	2.00	1.00
Traffic accident	2.00	2.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	2.00	2.00	2.00	1.00	3.00	3.00	2.00	2.00	2.00	3.00	3.00	3.00	3.00	2.00	2.00	3.00	3.00	2.00	3.00	3.00	3.00	3.00	3.00	3.00	1.00	2.00	2.00	2.00	2.00	1.00
Noise	2.00	2.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	2.00	2.00	2.00	1.00	3.00	3.00	2.00	2.00	2.00	3.00	3.00	3.00	3.00	2.00	2.00	3.00	3.00	2.00	3.00	3.00	3.00	3.00	3.00	3.00	1.00	2.00	2.00	2.00	2.00	1.00
Fire exposure	2.00	2.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	2.00	2.00	2.00	1.00	3.00	3.00	2.00	2.00	2.00	3.00	3.00	3.00	3.00	2.00	2.00	3.00	3.00	2.00	3.00	3.00	3.00	3.00	3.00	3.00	1.00	2.00	2.00	2.00	2.00	1.00
Caught in between objects/mat	2.00	2.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	2.00	2.00	2.00	1.00	3.00	3.00	2.00	2.00	2.00	3.00	3.00	3.00	3.00	2.00	2.00	3.00	3.00	2.00	3.00	3.00	3.00	3.00	3.00	3.00	1.00	2.00	2.00	2.00	2.00	1.00
Exposure to harmful substance	2.00	2.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	2.00	2.00	2.00	1.00	3.00	3.00	2.00	2.00	2.00	3.00	3.00	3.00	3.00	2.00	2.00	3.00	3.00	2.00	3.00	3.00	3.00	3.00	3.00	3.00	1.00	2.00	2.00	2.00	2.00	1.00
Overexertion	2.00	2.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	2.00	2.00	2.00	1.00	3.00	3.00	2.00	2.00	2.00	3.00	3.00	3.00	3.00	2.00	2.00	3.00	3.00	2.00	3.00	3.00	3.00	3.00	3.00	3.00	1.00	2.00	2.00	2.00	2.00	1.00

WORK ITEM

LIKELIHOOD

LIKELIHOOD OF WORK ITEMS IN BUILD	P.1	P.2	P.3	P.4	P.5	P.6	P.7	P.8	P.9	P.10	P.11	P.12	P.13	P.14	P.15	P.16	P.17	P.18	P.19	P.20	P.21	P.22	P.23	P.24	P.25	P.26	P.27	P.28	P.29	P.30	P.31	P.32	P.33	P.34	P.35	P.36	P.37	P.38	P.39	P.40
Excavation	3	1	1	0.5	0.5	6	3	6	1	3	3	6	3	0.5	1	6	1	1	1	1	3	3	1	3	0.5	3	3	0.5	3	3	0.5	3	0.5	3	3	1	0.5	6	10	3
Reinforced Concrete work	3	3	3	6	0.5	6	1	1	1	6	3	3	6	6	1	1	3	3	0.5	3	3	6	1	0.5	1		6	1	3	6	1	1	6	6		3	1	3	3	3
Masonry	0.5	3	1	3	3	10	1	6	1	1	1	3	3	1	1	6	6	6		3	0.5	3	1	1	3	3	1	1	0.5	6	3	1	3	1	0.5	3	1	6	6	1
Roof work	6	3	3	0.5	3	10	3	6	6	10	6	6	3	0.5	3	6	6	6	1	6	3	6	3	1	6	3	3	6	6	6	3	3	3	6	0.5	3	6	3	1	0.5
Finishings floor	0.5	0.5	0.5	0.5	3		1	0.5	1	6	0.5	3	3	1	0.5	6	1	1	0.5	0.5	0.5	0.5	0.5	3	3	3	1	0.5	3	3	3	3	0.5	1	3	0.5	0.5	3	3	3
Painting	3	3	0.5	0.5		6			6					0.5		6							1			0.5	1	1	0.5	3		3	0.5	0.5	3	0.5	0.5	1	0.5	0.5
Plastering / Rendering	3	3	0.5	1	3	6	1		6		0.5	1	1	0.5	1	3	1	1	0.5	6	1	1	1	0.5	1	3	1	1	0.5	3	0.5	3	3	1	3	0.5	3	1	3	1

SEVERITY

SEVERITY OFWORK ITEMS IN BUILD	P.1	P.2	P.3	P.4	P.5	P.6	P.7	P.8	P.9	P.10	P.11	P.12	P.13	P.14	P.15	P.16	P.17	P.18	P.19	P.20	P.21	P.22	P.23	P.24	P.25	P.26	P.27	P.28	P.29	P.30	P.31	P.32	P.33	P.34	P.35	P.36	P.37	P.38	P.39	P.40
Excavation	15	3	1	3	3	40	3	40	7	7	3	1	7	3	7	15	7	7	7	7	3	7	7	3	1	15	15	1	3	7	3	15	3	7	7	40	7	15	15	15
Reinforced Concrete work	1	7	7	1	7	15	1	7	7	15	3	3	7	40	7	7	7	7	1	7	7	15	7	3	3		40	7	3	15	7	7	3	15		40	1	7	7	15
Masonry	7	3	7	7	15	15		1	7	7	1	1	7	3	3	15	40	15		15	3	7	7	1	15	7	7	15	1	15	3	7	3	3	3	15	1		7	7
Roof work	7	40	3	7	3	40	3	40	15	40	7	7	3	3	15	40	15	15	3	40	7	15		3	40	15	15	15	15	15	1	15	1	15	3	15	15	15	7	3
Finishings floor	1	1	3	3	3		3	3	7	7	1	1	7	3	3	15	15	3	1	1	1	3		3	7	7	7	7	3	7	3	15	3	7	7	1	1	7	7	15
Painting	7	15	7	1		40			15			1		3	1	7			1							7	7	3	3	15		15	1	3	3	1	1	3		3
Plastering / Rendering	7	15	7	1	3	40	3		15		7	1	15	3	1	7	7	3	1	7	1	3		1	7	7	7	7	3	15	1	15	3	7	3	1	3	3	3	3

EXPOSURE

EXPOSURE OF WORK ITEMS IN BU	P1	P2	P3	P4	P5	P6	Q7	Q8	Q9	P10	P11	P12	P13	P14	P15	P16	P17	P18	P19	P20	P21	P22	P23	P24	P25	P26	P27	P28	P29	P3(	P31	P3	P33	P34	P35	P36	P37	P38	P39	P40
Excavation	3	1	1	0.5	0.5	6	3	6	1	3	3	6	3	0.5	1	6	1	1	1	1	3	3	1	3	0.5	3	3	0.5	3	3	0.5	3	0.5	3	3	1	0.5	6	10	3
Reinforced Concrete work	3	3	3	6	0.5	6	1	1	1	6	3	3	6	6	1	1	3	3	0.5	3	3	6	1	0.5	1		6	1	3	6	1	1	6	6		3	1	3	3	3
Masonry	0.5	3	1	3	3	10	1	6	1	1	1	3	3	1	1	6	6	6		3	0.5	3	1	1	3	3	1	1	0.5	6	3	1	3	1	0.5	3	1	6	6	1
Roof work	6	3	3	0.5	3	10	3	6	6	10	6	6	3	0.5	3	6	6	6	1	6	3	6	3	1	6	3	3	6	6	6	3	3	3	6	0.5	3	6	3	1	0.5
Finishings floor	0.5	0.5	0.5	0.5	3		1	0.5	1	6	0.5	3	3	1	0.5	6	1	1	0.5	0.5	0.5	0.5	0.5	3	3	3	1	0.5	3	3	3	3	0.5	1	3	0.5	0.5	3	3	3
Painting	3	3	0.5	0.5		6			6					0.5		6							1			0.5	1	1	0.5	3		3	0.5	0.5	3	0.5	0.5	1	0.5	0.5
Plastering / Rendering	3	3	0.5	1	3	6	1		6		0.5	1	1	0.5	1	3	1	1	0.5	6	1	1	1	0.5	1	3	1	1	0.5	3	0.5	3	3	1	3	0.5	3	1	3	1

APPENDIX E

Table 4.28: Result of Market Survey of PPE prices

PPE items	Unit cost
Dust mask	1,000.00
Face shield	10,000.00
Gloves	6,500.00
Goggle	6,500.00
Helmet	5,500.00
Protective boot	40,000.00
Protective clothing	20,000.00
Reflective vest	5,000.00
Safety harness/ belt	40,000.00

Source: Market Survey by Author (2022)

APPENDIX F FOR REGRESSION

COST OF SAFETY USING CONSTRUCTION AREA

Correlations

		COST OF SAFETY IN PROJECTAS % OF TOTAL COST	CONSTRUCTION AREA
Pearson Correlation	COST OF SAFETY IN PROJECTAS % OF TOTAL COST	1.000	-.600
	CONSTRUCTION AREA	-.600	1.000
Sig. (1-tailed)	COST OF SAFETY IN PROJECTAS % OF TOTAL COST	.	.000
	CONSTRUCTION AREA	.000	.
N	COST OF SAFETY IN PROJECTAS % OF TOTAL COST	28	28
	CONSTRUCTION AREA	28	28

Linear

Model Summary

R	R Square	Adjusted R Square	Std. Error of the Estimate
.600	.360	.335	1.627

The independent variable is CONSTRUCTION AREA.

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Regression	38.719	1	38.719	14.625	.001
Residual	68.834	26	2.647		
Total	107.553	27			

The independent variable is CONSTRUCTION AREA.

Coefficients

	Unstandardized Coefficients		Standardized Coefficients		
	B	Std. Error	Beta	t	Sig.
CONSTRUCTION AREA	-.002	.000	-.600	-3.824	.001
(Constant)	7.333	.735		9.976	.000

Logarithmic

Model Summary

R	R Square	Adjusted R Square	Std. Error of the Estimate
.547	.299	.272	1.703

The independent variable is CONSTRUCTION AREA.

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Regression	32.126	1	32.126	11.074	.003
Residual	75.426	26	2.901		
Total	107.553	27			

The independent variable is CONSTRUCTION AREA.

Coefficients

	Unstandardized Coefficients		Standardized Coefficients		
	B	Std. Error	Beta	t	Sig.
ln(CONSTRUCTION AREA)	-2.166	.651	-.547	-3.328	.003
(Constant)	20.608	4.767		4.323	.000

Quadratic

Model Summary

R	R Square	Adjusted R Square	Std. Error of the Estimate
.600	.360	.309	1.659

The independent variable is CONSTRUCTION AREA.

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Regression	38.720	2	19.360	7.031	.004
Residual	68.833	25	2.753		
Total	107.553	27			

The independent variable is CONSTRUCTION AREA.

Coefficients

	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
CONSTRUCTION AREA	-.001	.002	-.588	-.984	.334
CONSTRUCTION AREA ** 2	-7.868E-9	.000	-.013	-.021	.983
(Constant)	7.307	1.410		5.184	.000

COST OF SAFETY USING DURATION

Correlations

		COST OF SAFETY IN PROJECTAS % OF TOTAL COST	DURATION
Pearson Correlation	COST OF SAFETY IN PROJECTAS % OF TOTAL COST	1.000	-.635
	DURATION	-.635	1.000
Sig. (1-tailed)	COST OF SAFETY IN PROJECTAS % OF TOTAL COST	.	.000
	DURATION	.000	.
N	COST OF SAFETY IN PROJECTAS % OF TOTAL COST	28	28
	DURATION	28	28

Linear

Model Summary

R	R Square	Adjusted R Square	Std. Error of the Estimate
.635	.403	.380	1.572

The independent variable is DURATION.

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Regression	43.321	1	43.321	17.536	.000
Residual	64.231	26	2.470		
Total	107.553	27			

The independent variable is DURATION.

Coefficients

	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
DURATION	-.013	.003	-.635	-4.188	.000
(Constant)	8.185	.866		9.455	.000

Logarithmic

Model Summary

R	R Square	Adjusted R Square	Std. Error of the Estimate
.614	.378	.354	1.605

The independent variable is DURATION.

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Regression	40.609	1	40.609	15.772	.001
Residual	66.944	26	2.575		
Total	107.553	27			

The independent variable is DURATION.

Coefficients

	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
ln(DURATION)	-3.338	.841	-.614	-3.971	.001
(Constant)	23.240	4.658		4.989	.000

Quadratic

Model Summary

R	R Square	Adjusted R Square	Std. Error of the Estimate
.645	.415	.369	1.586

The independent variable is DURATION.

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Regression	44.680	2	22.340	8.883	.001
Residual	62.873	25	2.515		
Total	107.553	27			

The independent variable is DURATION.

Coefficients

	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
DURATION	-.022	.013	-1.099	-1.690	.103
DURATION ** 2	1.427E-5	.000	.478	.735	.469
(Constant)	9.508	2.001		4.752	.000

COST OF PPE USING CONSTRUCTION AREA

Linear

Model Summary

R	R Square	Adjusted R Square	Std. Error of the Estimate
.621	.386	.363	1.505

The independent variable is CONSTRUCTION AREA.

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Regression	37.038	1	37.038	16.356	.000
Residual	58.878	26	2.265		
Total	95.916	27			

The independent variable is CONSTRUCTION AREA.

Coefficients

	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
CONSTRUCTION AREA	-.001	.000	-.621	-4.044	.000
(Constant)	6.210	.680		9.135	.000

Logarithmic

Model Summary

R	R Square	Adjusted R Square	Std. Error of the Estimate
.606	.367	.342	1.528

The independent variable is CONSTRUCTION AREA.

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Regression	35.184	1	35.184	15.063	.001
Residual	60.732	26	2.336		
Total	95.916	27			

The independent variable is CONSTRUCTION AREA.

Coefficients

	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
ln(CONSTRUCTION AREA)	-2.267	.584	-.606	-3.881	.001
(Constant)	20.277	4.278		4.740	.000

Quadratic

Model Summary

R	R Square	Adjusted R Square	Std. Error of the Estimate
.631	.398	.350	1.520

The independent variable is CONSTRUCTION AREA.

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Regression	38.178	2	19.089	8.265	.002
Residual	57.738	25	2.310		
Total	95.916	27			

The independent variable is CONSTRUCTION AREA.

Coefficients

	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
CONSTRUCTION AREA	-.002	.001	-1.013	-1.750	.092
CONSTRUCTION AREA ** 2	2.392E-7	.000	.407	.703	.489
(Constant)	6.978	1.291		5.405	.000

COST OF PPE USING DURATION

Linear

Model Summary

R	R Square	Adjusted R Square	Std. Error of the Estimate
.658	.433	.411	1.446

The independent variable is DURATION.

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Regression	41.559	1	41.559	19.879	.000
Residual	54.357	26	2.091		
Total	95.916	27			

The independent variable is DURATION.

Coefficients

	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
DURATION	-.012	.003	-.658	-4.459	.000
(Constant)	7.048	.796		8.850	.000

Logarithmic

Model Summary

R	R Square	Adjusted R Square	Std. Error of the Estimate
.671	.450	.429	1.424

The independent variable is DURATION.

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Regression	43.207	1	43.207	21.312	.000
Residual	52.710	26	2.027		
Total	95.916	27			

The independent variable is DURATION.

Coefficients

	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
ln(DURATION)	-3.443	.746	-.671	-4.617	.000
(Constant)	22.754	4.133		5.505	.000

Quadratic

Model Summary

R	R Square	Adjusted R Square	Std. Error of the Estimate
.698	.487	.446	1.403

The independent variable is DURATION.

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Regression	46.681	2	23.341	11.852	.000
Residual	49.235	25	1.969		
Total	95.916	27			

The independent variable is DURATION.

Coefficients

	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
DURATION	-.030	.011	-1.613	-2.648	.014
DURATION ** 2	2.771E-5	.000	.983	1.613	.119
(Constant)	9.617	1.771		5.431	.000

ELEMENTAL COST OF PPE USING CONSTRUCTION AREA EXCAVATION

Linear

Model Summary

R	R Square	Adjusted R Square	Std. Error of the Estimate
.435	.189	.158	.395

The independent variable is CONSTRUCTION AREA.

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Regression	.945	1	.945	6.068	.021
Residual	4.050	26	.156		
Total	4.996	27			

The independent variable is CONSTRUCTION AREA.

Coefficients

	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
CONSTRUCTION AREA	.000	.000	-.435	-2.463	.021
(Constant)	1.004	.178		5.632	.000

Logarithmic

Model Summary

R	R Square	Adjusted R Square	Std. Error of the Estimate
.414	.171	.139	.399

The independent variable is DURATION.

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Regression	.855	1	.855	5.371	.029
Residual	4.140	26	.159		
Total	4.996	27			

The independent variable is DURATION.

Coefficients

	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
ln(DURATION)	-.484	.209	-.414	-2.318	.029
(Constant)	3.284	1.158		2.835	.009

Quadratic

Model Summary

R	R Square	Adjusted R Square	Std. Error of the Estimate
.441	.195	.130	.401

The independent variable is DURATION.

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Regression	.973	2	.486	3.023	.067
Residual	4.023	25	.161		
Total	4.996	27			

The independent variable is DURATION.

Coefficients

	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
DURATION	-.005	.003	-1.122	-1.470	.154
DURATION ** 2	4.743E-6	.000	.737	.966	.344
(Constant)	1.514	.506		2.992	.006

MASONRY

Linear

Model Summary

R	R Square	Adjusted R Square	Std. Error of the Estimate
.539	.290	.263	.606

The independent variable is CONSTRUCTION AREA.

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Regression	3.897	1	3.897	10.625	.003
Residual	9.535	26	.367		
Total	13.432	27			

The independent variable is CONSTRUCTION AREA.

Coefficients

	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
CONSTRUCTION AREA	.000	.000	-.539	-3.260	.003
(Constant)	2.036	.274		7.443	.000

Logarithmic

Model Summary

R	R Square	Adjusted R Square	Std. Error of the Estimate
.538	.289	.262	.606

The independent variable is CONSTRUCTION AREA.

ANOVA

	Sum of Squares	df	Mean square	f
Regression	3.885	1	3.885	10.580
Residual	9.547	26	.367	
Total	13.432	27		

The independent variable is CONSTRUCTION AREA.

Coefficients

	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
ln(CONSTRUCTION AREA)	-.753	.232	-.538	-3.253	.003
(Constant)	6.730	1.696		3.968	.001

Quadratic

Model Summary

R	R Square	Adjusted R Square	Std. Error of the Estimate
.547	.299	.243	.614

The independent variable is CONSTRUCTION AREA.

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Regression	4.018	2	2.009	5.335	.012
Residual	9.414	25	.377		
Total	13.432	27			

The independent variable is CONSTRUCTION AREA.

Coefficients

	Unstandardized Coefficients		Standardized Coefficients		
	B	Std. Error	Beta	t	Sig.
CONSTRUCTION AREA	-.001	.001	-.880	-1.409	.171
CONSTRUCTION AREA ** 2	7.802E-8	.000	.355	.568	.575
(Constant)	2.287	.521		4.387	.000

REINFORCED CONCRETE
LINEAR

Model Summary

R	R Square	Adjusted R Square	Std. Error of the Estimate
.547	.299	.272	.438

The independent variable is CONSTRUCTION AREA.

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Regression	2.127	1	2.127	11.095	.003
Residual	4.985	26	.192		
Total	7.112	27			

The independent variable is CONSTRUCTION AREA.

Coefficients

	Unstandardized Coefficients		Standardized Coefficients		
	B	Std. Error	Beta	t	Sig.
CONSTRUCTION AREA	.000	.000	-.547	-3.331	.003
(Constant)	1.054	.198		5.327	.000

Logarithmic

Model Summary

R	R Square	Adjusted R Square	Std. Error of the Estimate
.601	.362	.337	.418

The independent variable is CONSTRUCTION AREA.

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Regression	2.572	1	2.572	14.729	.001
Residual	4.540	26	.175		
Total	7.112	27			

The independent variable is CONSTRUCTION AREA.

Coefficients

	Unstandardized Coefficients		Standardized Coefficients		
	B	Std. Error	Beta	t	Sig.
ln(CONSTRUCTION AREA)	-.613	.160	-.601	-3.838	.001
(Constant)	4.934	1.170		4.218	.000

Quadratic

Model Summary

R	R Square	Adjusted R Square	Std. Error of the Estimate
.638	.407	.360	.411

The independent variable is CONSTRUCTION AREA.

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Regression	2.896	2	1.448	8.584	.001
Residual	4.217	25	.169		
Total	7.112	27			

The independent variable is CONSTRUCTION AREA.

Coefficients

	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
CONSTRUCTION AREA	-.001	.000	-1.729	-3.008	.006
CONSTRUCTION AREA ** 2	1.964E-7	.000	1.227	2.134	.043
(Constant)	1.684	.349		4.828	.000

ROOF WORK

Linear

Model Summary

R	R Square	Adjusted R Square	Std. Error of the Estimate
.221	.049	.012	.537

The independent variable is CONSTRUCTION AREA.

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Regression	.384	1	.384	1.331	.259
Residual	7.501	26	.288		
Total	7.885	27			

The independent variable is CONSTRUCTION AREA.

Coefficients

	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
CONSTRUCTION AREA	.000	.000	-.221	-1.154	.259
(Constant)	.816	.243		3.363	.002

Logarithmic

Model Summary

R	R Square	Adjusted R Square	Std. Error of the Estimate
.140	.020	-.018	.545

The independent variable is CONSTRUCTION AREA.

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Regression	.155	1	.155	.522	.476
Residual	7.730	26	.297		
Total	7.885	27			

The independent variable is CONSTRUCTION AREA.

Coefficients

	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
ln(CONSTRUCTION AREA)	-.151	.208	-.140	-.723	.476
(Constant)	1.662	1.526		1.089	.286

Quadratic

Model Summary

R	R Square	Adjusted R Square	Std. Error of the Estimate
.270	.073	-.001	.541

The independent variable is CONSTRUCTION AREA.

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Regression	.575	2	.287	.983	.388
Residual	7.310	25	.292		
Total	7.885	27			

The independent variable is CONSTRUCTION AREA.

Coefficients

	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
CONSTRUCTION AREA	.000	.000	.339	.471	.642
CONSTRUCTION AREA ** 2	-9.782E-8	.000	-.580	-.808	.427
(Constant)	.502	.459		1.093	.285

FLOOR

Linear

Model Summary

R	R Square	Adjusted R Square	Std. Error of the Estimate
.023	.001	-.038	.253

The independent variable is CONSTRUCTION AREA.

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Regression	.001	1	.001	.014	.906
Residual	1.669	26	.064		
Total	1.670	27			

The independent variable is CONSTRUCTION AREA.

Coefficients

	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
CONSTRUCTION AREA	-7.398E-6	.000	-.023	-.119	.906
(Constant)	.391	.114		3.416	.002

Logarithmic

Model Summary

R	R Square	Adjusted R Square	Std. Error of the Estimate
.117	.014	-.024	.252

The independent variable is CONSTRUCTION AREA.

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Regression	.023	1	.023	.363	.552
Residual	1.647	26	.063		
Total	1.670	27			

The independent variable is CONSTRUCTION AREA.

Coefficients

	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
ln(CONSTRUCTION AREA)	.058	.096	.117	.603	.552
(Constant)	-.045	.705		-.064	.949

Quadratic

Model Summary

R	R Square	Adjusted R Square	Std. Error of the Estimate
.384	.147	.079	.239

The independent variable is CONSTRUCTION AREA.

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Regression	.246	2	.123	2.161	.136
Residual	1.424	25	.057		
Total	1.670	27			

The independent variable is CONSTRUCTION AREA.

Coefficients

	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
CONSTRUCTION AREA	.000	.000	1.355	1.965	.061
CONSTRUCTION AREA ** 2	-1.109E-7	.000	-1.430	-2.075	.048
(Constant)	.035	.203		.171	.865

PLASTERING

Linear

Model Summary

R	R Square	Adjusted R Square	Std. Error of the Estimate
.623	.388	.364	.218

The independent variable is CONSTRUCTION AREA.

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Regression	.781	1	.781	16.482	.000
Residual	1.232	26	.047		
Total	2.013	27			

The independent variable is CONSTRUCTION AREA.

Coefficients

	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
CONSTRUCTION AREA	.000	.000	-.623	-4.060	.000
(Constant)	.780	.098		7.934	.000

Logarithmic

Model Summary

R	R Square	Adjusted R Square	Std. Error of the Estimate
.709	.503	.484	.196

The independent variable is CONSTRUCTION AREA.

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Regression	1.013	1	1.013	26.332	.000
Residual	1.000	26	.038		
Total	2.013	27			

The independent variable is CONSTRUCTION AREA.

Coefficients

	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
ln(CONSTRUCTION AREA)	-.385	.075	-.709	-5.131	.000
(Constant)	3.228	.549		5.880	.000

Quadratic

Model Summary

R	R Square	Adjusted R Square	Std. Error of the Estimate
.684	.467	.425	.207

The independent variable is CONSTRUCTION AREA.

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Regression	.941	2	.470	10.973	.000
Residual	1.072	25	.043		
Total	2.013	27			

The independent variable is CONSTRUCTION AREA.

Coefficients

	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
CONSTRUCTION AREA	-.001	.000	-1.637	-3.005	.006
CONSTRUCTION AREA ** 2	8.961E-8	.000	1.052	1.932	.065
(Constant)	1.068	.176		6.071	.000

PAINTING

Linear

Model Summary

R	R Square	Adjusted R Square	Std. Error of the Estimate
.627	.393	.369	.036

The independent variable is CONSTRUCTION AREA.

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Regression	.022	1	.022	16.805	.000
Residual	.034	26	.001		
Total	.055	27			

The independent variable is CONSTRUCTION AREA.

Coefficients

	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
CONSTRUCTION AREA	-3.629E-5	.000	-.627	-4.099	.000
(Constant)	.129	.016		7.912	.000

Logarithmic

Model Summary

R	R Square	Adjusted R Square	Std. Error of the Estimate
.664	.441	.419	.035

The independent variable is CONSTRUCTION AREA.

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Regression	.024	1	.024	20.484	.000
Residual	.031	26	.001		
Total	.055	27			

The independent variable is CONSTRUCTION AREA.

Coefficients

	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
ln(CONSTRUCTION AREA)	-.060	.013	-.664	-4.526	.000
(Constant)	.505	.097		5.220	.000

Quadratic

Model Summary

R	R Square	Adjusted R Square	Std. Error of the Estimate
.665	.442	.397	.035

The independent variable is CONSTRUCTION AREA.

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Regression	.025	2	.012	9.890	.001
Residual	.031	25	.001		
Total	.055	27			

The independent variable is CONSTRUCTION AREA.

Coefficients

	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
CONSTRUCTION AREA	-8.244E-5	.000	-1.424	-2.552	.017
CONSTRUCTION AREA ** 2	1.169E-8	.000	.827	.	.
(Constant)	.166	.030		5.559	.000