INFLUENCE OF THE QUALITY OF STRUCTURAL ENGINEERING DESIGN ON COST CERTAINTY OF HIGH-RISE BUILDING PROJECTS IN NAIROBI CITY COUNTY, KENYA

BY

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DECLARATION

This research project is my original work and has not been presented in any other university for academic credit.

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This research project has been submitted for examination with my approval as the University of Nairobi supervisor.

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DEDICATION

To my late dad Joel and my late mum Helen for esteeming education, laying the foundation, sacrificing all and encouraging me to build on it to the furthest possible extent. My brother Fuchaka for spurring me on. Not forgetting Mildred my wife for keeping me focused on the goal when I sometimes wavered from the course. To my lovely daughters Nissi and Nirel for bearing with my periodic absence knowing that it was for the good. I hope this inspires you to go beyond where our footsteps have reached.

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God bless you all.

ABSTRACT

Clients are increasingly demanding a high degree of cost certainty from their project design teams to ensure that their building projects are completed within the budgeted resources. However this objective has been negated by various challenges that unfortunately cause budget overruns. Errors in design and documentation has been identified by previous studies as one of the major contributing factors to the problem of budget overruns and hence low cost certainty. The quality of structural engineering design in terms of accuracy, completeness, integration and build-ability in the multidisciplinary nature of projects plays a central role of defining and specifying the building blocks that account for a large proportion of the building cost. This study sought to investigate factors that bear on the quality of structural engineering design and subsequently influence the cost certainty of high-rise building projects in Nairobi County. A quantitative sample survey research methodology was used to assess the influence of structural engineering design coordination, level of engineering experience, the type of design software and amount of design fees on the quality of structural engineering design and subsequently the cost certainty of high-rise building projects. Respondents were consulting civil engineers drawn from the Engineers Board of Kenya's register using probability interval sampling technique. From this register 150 consulting engineers domiciled within Nairobi County were randomly selected and contacted using a web based structured questionnaire. Analysis of variance and Chi-square tests showed that design coordination, level of engineering experience, the type of design software and amount of design fees are correlated to cost certainty. Design coordination significantly helps to narrow gaps, uncertainties and risks as well enhance better understanding of the project scope. The level of experience is critical for problem solving, effective use of design software, quality control of design and documentation and integration. The amount of design fees directly influences the capacity of engineering firms to employ competent engineers. The design software influences accuracy and completeness of design output and consequently the accuracy of pre-tender cost estimates used for procurement. These four variable were found to be statistically significant and therefore the alternative hypotheses H_1: The quality of structural engineering design influences cost certainty of high-rise building projects was supported.

Key words: High-rise Building Projects, Quality, Structural Engineering Design, Cost Certainty, Budget Overruns.

LIST OF ABBREVIATIONS AND ACRONYMS

AAK	Architectural Association of Kenya
ANOVA	Analysis of Variance
API	Application Programming Interface
3D	Three Dimension
BIM	Building Information Modelling
BORAQS	Board of Registration of Architects and Quantity Surveyors of Kenya
CAD	Computer Aided Design
CAE	Computer Aided Engineering
CIOB	Chartered Institute of Building
COVID-19	Corona Virus Disease 2019
CTBUH	Council on Tall Buildings and Urban Habitat
EBK	Engineers Board of Kenya
FIDIC	Fédération Internationale des Ingénieurs-Conseils
ICT	Information Communication Technology
IEK	Institution of Engineers of Kenya
IQSK	Institute of Quantity Surveyors of Kenya
ISO	International Standards Organization
JBC	Joint Building Council
KPI	Key Performance Indicators
MOH	Ministry of Health
PMI	Project Management Institute
QMS	Quality Management System
RFI	Request for Information
SDGs	Sustainable Development Goals
SED	Structural Engineering Design
SPSS	Statistical Package of Social Sciences
UN	United Nations

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CHAPTER ONE: INTRODUCTION

1.1 Background

The Sustainable Development Summit of the UN held in New York in September 2015 identified sustainable cities and communities as one of the 17 Sustainable Development Goals (SDGs) to be achieved by 2030 through a balanced and integrated approach that takes into consideration economic, social and environmental aspects (UN,2015). This was informed by the projection that over 60% of the global population would live in urban areas and cities by 2050 thereby presenting huge challenges of housing, energy, water and transportation amongst others.

In response to this challenge, developers are opting for high rise building projects rather than building horizontally, thereby occupying lesser precious land area (Vijayasree, 2019). Many cities across the world including Nairobi are witnessing an increase of high rise building projects and this trend is expected to continue into the future (Construction Review, 2019).

Because of the nature of these projects, structural engineering design plays a pivotal role throughout the project cycle from conception to project closure. Design in it broad sense is the process of developing an answer to problem and mechanisms of implementing that solution (Designing Buildings Wiki, 2020). When it comes to high rise building projects, SED involves site investigations, technical and economic assessment of building alternatives, definition and specification of materials for construction, specification of construction methodologies geared to ensuring physical integrity of the building. The quality of SED in terms of its accuracy, completeness, integration with other disciplines and its build-ability becomes very important in the successful delivery of such projects.

Economic sustainability is an overarching objective for every stakeholder in a building projects. The aim is to ensure that the project will be executed to the required standards and completed within the approved budget. In their study Lopez, Craige and Gransberg (2016) wanted to find out whether maximizing cost certainty was the overarching objective of project implementation as opposed to minimizing costs. The research found out that in order to control the overall project costs, the project team had to guard against situations that compel them to seeking for more funding from clients. Ensuring that cost certainty of building projects is enhanced from concept to construction stage was found to be a workable strategy to achieving this objective. More so the research provided evidence on the need to invest in preconstruction activities that mitigate risk and lead to increased cost certainty as opposed to endeavouring to complete the project as cheaply as possible.

The preconstruction planning and design processes define and determine the overall quality of a project (Gransberg, Lopez and Humprey, 2007). From a project management perspective, it is vital to ensure that these processes are allocated sufficient resources to produce high quality designs and construction documents that can relied upon for bidding (Brown, 2002). The various professionals involved on the project such as the architect, project manager, structural engineer, services engineer, quantity surveyor and other specialists have the responsibility to planning, coordinating and managing the design and project formulation processes in a manner that adds value and enables achievement of project objectives that revolve around six important aspects, namely scope, time, cost, risk, benefits and quality (Axelos, 2017). Completing the project within the agreed budget is therefore one of the most critical objectives of any project.

In order to manage budget overruns on many projects, cost certainty becomes one of the key aspects to consider during project development. It is defined as the likelihood of completing a project within the budget agreed between clients and contractors before the commencement of construction (Xiao and Proverbs, 2003). The degree of cost certainty is therefore to a large extent dependent on quality of information used to develop the project and the control measures put in managing the implementation of the project. Accurate, complete, well-coordinated and easily build-able structural engineering design and documentation can be deemed as high quality project information that is likely to result in high cost certainty of the corresponding building project. A high cost certainty is desirable to ensure completion of the project within budget. In many cases however building project budgets go beyond the approved budgets for various reasons including errors in design and documentation. This phenomenon is referred to as budget overruns.

Budget overruns are undesirable for all the stakeholders in the construction industry. For the project owners, this interfere with financial planning and may over stretch available financial resources to a point where the project may not be finished to the required quality standards or abandoned altogether (Cunningham, 2017). Contractual disputes and litigations, loss of future jobs and income as well as negative perceptions are also consequences of budget overruns faced by project stakeholders (Gbahabo and Ajuwon, 2017). Understanding the dynamics of this phenomenon and its linkages with the various project phases and inputs of the various practitioners involved in the project is therefore important to minimize its adverse impacts. High construction cost certainty is desirable at all levels to manage the risks associated with budget overruns and optimize the allocation of resources.

1.2 Problem Statement

A number of studies such as Muhwezi, Kirenzi and Bangi (2020); Oyewobi *et al.* (2016); Peansupap and Ly (2015) and Kagiri (2005) have identified errors in design and documentation as a major contributing factor to the problem of budget overruns in construction projects. In this study a design error can be viewed a deficiency in a process or product which negatively affects its intended output or purpose. This is a measure of quality which is defined by Axelos (2017) as the extent to which inherent characteristics of a system, process or product fulfils its requirement. This means that the quality of design impacts on the fitness and overall outcome of a product such as a building project. Cunningham (2017) also identified design related issues as risks that cause budget overruns in building projects. Design is the basic foundation of every building project, and the success of such projects depends on how adequately the design was done. Projects comprise of many interrelated design issues and therefore non-performance in any one component can have significant influence on the entire project (Barton, 2019).

The ability to complete such projects within preconstruction estimates is influenced by the quality of structural engineering design (SED) of the building (Barber *et al.*, 2000). SED plays a central role of defining and specifying the building blocks of high-rise building projects that ensure its physical integrity. These systems include foundations upon which the entire building safely rests, columns, walls, floor systems, bracing systems, vertical movement systems and the roofs. Due to the complexity, size and nature of high rise building projects, the associated structural systems account for a significant proportion of the overall building project cost. An accurate preconstruction estimation of project cost requires that these components should be completely defined, accurately sized and specified, fully described in drawings without ambiguity, coordinated and integrated with other disciplines. This gives the level of cost certainty of a project which the likelihood of completing a project within the budget agreed between the client and contractor before the start of construction (Xiao and Proverbs, 2003). It therefore implies that if the quality of structural engineering design and documentation of these critical structural building components is poor during the preconstruction phase, such high-rise building projects are likely to incur budget overruns and in worst cases suffer structural integrity issues during the construction phase. The root causes of poor quality SED is the subject of investigation and the problem that this research attempts to answer.

Globally a number of researches have been done on the causes of budget overruns and most of the findings have identified design deficiencies as a major contributing factor. A case study by Patil and Bhangale (2016) on two projects in India found out that the cost escalated by 13.9% and 9.47% due to factors associated with owners, contractors and the design group. In addition, Shane *et al*. *(*2009), gives a classical example of the Holland Tunnel whose cost shot from an initial estimate of USD 12,000,000 to a staggering USD 48,400,000 in 1927. Design omissions and errors among other issues during preconstruction played a key role in this case.

In Kenya, public infrastructure projects have been adversely affected by massive budget overruns with hundreds of millions of additional taxpayers' money required to complete them. The Northern Collector Tunnel project signed on 1st September 2014 with an initial budget of Ksh. 6.8 billion and a 58 months' performance period continues to experience budget overruns due to design variations among other factors (The World Bank, 2013). The Outer Ring road project initial budget of Ksh 7.4 billion escalated by over 24% to Ksh. 9.2 billion due to design variations among other factors (Guguyu, 2015). The Thika superhighway whose initial budget was Ksh. 27 billion eventually consumed Ksh. 31billion (Kagai, 2012). The Nairobi Expressway whose initial budget of Ksh. 65.2 billion as provided by KeNHa was recently revised upwards by Ksh. 7.6

billion even before its completion (Marangu, 2021). These projects contained significant structural components such as tunnels, retaining walls, intake weirs, culverts, piles, piers, decks, pedestrian crossings and bridges just to name but a few which had a direct impact on cost escalation whenever the design was varied.

The negative impacts of budget overruns include low completion rate of projects, diversion of funds from other sectors, reduction of profit margins, contractual disputes, strained business relations among contractual parties, stalling of projects and failure to achieve project objectives which has wider ramifications on the economy in terms of loss of employment, income and general economic decline. (Chapellow, 2019).
Compared to public infrastructure projects, information on budget overruns on high rise building projects in Kenya is scanty partly due to the private nature of the projects and the confidentiality requirements. However proper management of the quality of design process and outputs remains critical in enhancing cost certainty and minimizing budget overruns that have characterized many projects. Deficiencies in preconstruction documents cause variations, delays and disputes all which contribute to budget overruns. (Patil and Bhangale, 2016).

These issues arising from deficiency in the quality of SED are a great concern to all stakeholders in the construction industry and the root causes need to be identified to mitigate the negative impacts. In light of the increasing number of high rise building projects in cities and the need for economic sustainability, the value of making determined efforts to exert tighter control over the quality of SED processes and outputs during the preconstruction phase cannot be overemphasized. Focus should be to identify and reduce wherever possible scenarios where the agreed pre-construction costs is altered as a result of design deficiencies. This study investigates the factors that have a bearing on the quality of SED and subsequent cost certainty of high-rise building projects. These factors include level of coordination, experience of the engineer, engineering design software used for design and the amount of fees paid for engineering design work. From a risk management perspective, high cost certainty in construction is a top priority for clients and contractors since it ensures prudent financial planning, cost management and optimal returns and competitiveness in the market (Xiao and Proverbs, 2003).

1.3 Hypotheses

This research was guided by the following hypotheses:

Null hypotheses H_0: The quality of structural engineering design has no influence on the cost certainty of high-rise building projects.

Alternative hypotheses H_1: The quality of structural engineering design has an influence on the cost certainty of high-rise building projects.

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1.4 Research Questions

The following questions formed the basis of this research:

i. How does planning and coordination of structural engineering design influence the cost certainty of building projects?

ii. Does the engineer's level of knowledge and experience in structural engineering design influence the cost certainty of high-rise building projects?

iii. In what ways does structural engineering design software affect the cost certainty of high-rise building projects?

iv. What influence does the amount of structural engineering design fees have on the cost certainty of building projects?

1.5 Specific Objectives

The overarching objective of this study was to find out how quality of structural engineering design influences the cost certainty of high-rise building projects in order to assist in the formulation of measures to mitigate the adverse effects of budget overruns. The specific objectives are:

i. To find out how planning and coordination of structural engineering design influences the cost certainty of high-rise building projects.

ii. To evaluate the influence of knowledge and experience in structural engineering design on the cost certainty of high-rise building projects.

iii. To explain how structural engineering design software contributes to cost certainty of high-rise building projects.

iv. To assess the influence of structural engineering design fees on cost certainty of high-rise building projects.

1.6 Significance of the Study

This study is important and will be beneficial to stakeholders in the construction industry as well as other sectors in the following ways:

i. For structural engineering practitioners, this research provides the basis of understanding the aspects that bear on the quality of SED and subsequently on cost certainty of high rise building projects. This should provide motivation to review and implement appropriate interventions such as quality management systems, internal workflow processes, benchmarking and adopting best design practices that promote cost certainty of the building projects in their portfolios. In addition, it will broaden their understanding of project cost management and the critical role they play thereby encouraging them to be more keenly involved in upstream project activities such as project formulation, cost planning and tendering as well as downstream project processes of construction and handover.
ii. In academia, the research provides an impetus for institutions offering engineering education to enrich their curriculum with appropriate knowledge that will equip the graduates to handle challenging building projects.
iii. It will equip clients, project managers, planners, government agencies, financiers and other agencies concerned with formulation and management of projects with knowledge of the critical linkages between preconstruction design, construction quality and cost management. This in turn is expected to assist them in strategic decision making throughout the project cycle. As a result, projects will be formulated and executed in a focused manner that derives value for the financial investment and achievement of project objectives.
iv. Regulatory bodies of the engineering profession such as the EBK will benefit from this research by better understanding the operating environment of their members. This will assist in reviewing and formulation of policies that promote the practice of engineering geared to providing quality services and growth of the industry.

v. It will provide reference to other professionals and regulatory bodies in the construction industry such as architects, quantity surveyors, interior designers and contractors on the importance of cost certainty. By investigating the factors that influence quality of SED and subsequently the cost certainty of high-rise building projects, this research can be taken as a case study that in turn can be replicated in the activities of the other professionals for better project integration and cost management.

vi. It will provide baseline information from which further research can be conducted to promote better understanding of the concept of cost certainty and how it interplays in diverse sectors of the economy.

1.7 Scope of the Study

This study focuses on factors that bear on the quality of structural engineering design and the subsequent cost certainty of high-rise building projects within Nairobi City County. The benchmark for defining high-rise buildings was guided by CTBUH (2020) an international body that develops international standards for measuring and defining tall buildings. This body provides a threshold of 14 stories as a typical measure of a tall building. In this study structured questionnaires were used to reach out to consulting structural engineers who had worked on high rise building projects in the last 10-year period within Nairobi City County because of the following reasons.

i. Nairobi is the capital and largest city in Kenya with the highest number of tall buildings in Kenya (Construction Review, 2020). A keen look at Nairobi's skyline shows that more of such tall buildings are coming up and therefore this research would be more relevant in this location.

ii. The bulk of the consulting structural engineers who are the primary respondents in this study have their firms in Nairobi. This is according to the register of consulting engineers available on the EBK website. It will therefore be easier to reach them within this geographical boundary.

iii. High-rise buildings are predominantly structural in nature and therefore the role and input of structural engineering design is inevitable and very significant. It is therefore more likely that such projects will bring out the real issues that affect the quality of structural design and cost certainty which is the main objective of this research.

iv. The capping of a 10-year period was to increase the probability of interrogating the engineer(s) that were actually involved in the design of those particular projects. Further, review of any secondary data from these projects was likely to be easier compared to older projects where records are difficult to find.

1.8 Limitations of the Study

The covid-19 pandemic characterized by lockdowns and restricted physical movement restricted data collection to mainly online questionnaires. Complementing the questionnaires with observations and interviews to get deeper insights would have enriched the study.

Access to project specific secondary information such as preconstruction bill of quantities, variation orders and final project costs was a challenge due to confidentiality restrictions. The research relied predominantly on the primary data and other sources of secondary data to draw its conclusions.

CHAPTER TWO: LITERATURE REVIEW

2.1 Introduction

This section lays the foundation of the research by identifying and expounding the various variables that interplay in the subject of cost certainty. Firstly the issue of quality and it importance particularly in the context of high rise building projects is addressed. Secondly an overview of the place and role of structural engineering design in the whole project cycle is presented in order to give understanding of the cross functional nature of projects and the need to appreciate the unique contributions of each practitioner when addressing various challenges such as cost certainty in the construction industry.

Thirdly, the subject of cost certainty as the depended variable is presented and the relevant theoretical framework underpinning its applicability in the construction industry is presented to guide the research. Presentation of empirical results from previous researches on the subject of cost certainty, budget overruns and the main independent variables then follows. From the empirical review, this chapter concludes by identifying a knowledge gap that this research attempts to fill and provides a conceptual framework of how the variables interact in a typical high rise building project.

2.2 Quality and high- rise building projects

Quality, cost, time, scope, risk and benefits are the key performance targets that require planning monitoring and control in order to achieve the objectives of any project (Axelos, 2017). Gray (2020) opines that quality is an outcome that is dependent on inputs, endeavours, effort and time. It is a measure of the extent to which intrinsic attributes of a product, process or system satisfies the requirements. In the context building projects, quality is concerned with ensuring that the functional, legal, technical and business expectations are met throughout the project cycle (Axelos, 2017). According to PMI (2017), it is vital to address the quality of both the project processes and the products being produced to avoid detrimental impacts on project objectives and stakeholders. Structural engineering design is a process which results in various products such as drawings, methodologies, schedules and specifications and is therefore a subject of quality management. This is because quality on high-rise building projects has direct effects on costs. For example, quality reduces wastages, saves time, avoids re-workings, minimises injuries, defects, disputes and generally promotes better outcomes of the project that ensure achievement of stakeholder objectives. Since it is an outcome dependent on certain parameters, quality control must run throughout the project cycle if the project is to achieve any meaningful benefits.

High rise building projects are increasingly becoming the norm in major cities of the world in response to the steady increase in the number of urban inhabitants that is forecast to reach 60% of the global population by 2030 and a staggering 80% in 2050 (Kheir, 2018). Accommodating such huge numbers in cities will be extremely challenging hence the motivation to build upwards (Ali and Al-Kodmany, 2012).
Compared to other types of buildings, high-rise buildings require relatively complex engineering interventions, creative thinking and progressive structural systems (CGTN Africa, 2020). They are subjected to more significant forces of nature such as winds and earthquakes besides the massive gravity loads emanating from their multiple floors. They require complex foundation systems and stiffer structural systems to withstand these forces. Due to the complex nature of design and construction, high-rise buildings cost more to implement and are more likely to experience budget overruns. The quality of structural engineering design of these buildings therefore becomes very critical in order to manage the cost certainty of these projects.

2.3. Overview of Structural Engineering Design in High-rise Building Projects

In order to appreciate the linkage between cost certainty and quality of structural engineering design from a project management perspective, it is important to broadly review the place and role of structural engineering throughout the project cycle. The Project Management Institute (PMI) identifies five main phases for any project with specific deliverables that progressively and cumulatively add up to project outcome. These phases are conception and initiation, project definition and planning, implementation, performance and monitoring and project closure (Kate, 2018).

Initiation phase is concerned with broadly determining the feasibility of a project with respect to either a business case or other requirement. The role of structural engineering at this stage is largely to assess the technical feasibility of the project by interrogating various technical options that are responsive to the client's brief. In assessing these options, due diligence is taken of various parameters, applicable policies, constraints and requirements to arrive at a feasible solution. A preliminary or concept structural design would be produced at this stage. The objective is to enable key decision makers to determine if the project can be given a green light to proceed.

Once a project gets the nod to proceed based on the technical and economic feasibility emanating from phase one, the next stage is project definition and planning or detailed design. This is a very key phase that is concerned with the development of the blue print to guide all the subsequent project activities. One of the core deliverables is defining the scope of the project. Scope entails establishing the specifications, defining the features and functional requirements of a product and the resources or work required to achieve that particular quality of product (PMI, 2017). Detailed SED plays a key role with far reaching implications on the downstream phases. The success of the project is largely hinged on adequacy of the outputs from this stage. Detailed structural design crystallizes the concept design through a rigorous design process. It requires critical thinking, innovation, software, knowledge, skill and experience and collaboration. It involves simulation of behaviour of the building under the expected loading and ground conditions. It entails developing the most appropriate structural system, modelling, analysis, design and detailing using a combination of software and manual methods in order to comprehensively specify the entire structural system to meet requirements of the project and relevant codes of practice.

In addition, it entails coordinating with other disciplines notably the architects and services engineers so as to align the structural system to the architectural concept, synchronize structure and services concepts, and capture any salient issues and to resolve interface issues that would otherwise cause conflicts during construction.(Amanda, 2016). At the end of this stage detailed drawings and specifications are produced showing levels, sizes of elements, material type, quality specifications, schedules, construction methodology, workmanship requirements, connection details, test specifications and interface specifications. On the basis of the detailed design, Bill of Quantities which are a summation and description of the type, quality, quantity and cost of the work items forming the entire scope are produced by the Quantity Surveyor. The more detailed, complete, clear and buildable the structural design outputs are, the more accurate will the cost estimates be and the project will have a higher cost certainty. Tendering at this stage gives a lot more confidence on the cost certainty of the project. The costs of finding and correcting errors and omissions in the construction documents at this preconstruction stage would be lower than the costs of rectifying the same corrections after the award of the construction contract during project execution stage (Venters, 2004). In other words, the quality of design output at this stage should capture the requirements of the building project in its entirety and describe all the components without any errors, omissions or ambiguities.

The execution stage deals with practical implementation of the project plans on site. The key structural engineering role is the supervision of the construction works to ensure conformity with the detailed structural design, drawings and specifications. On the other hand, project management would be focused on managing, directing and controlling the project processes and activities, comparing actual progress against the established project plans to measure performance of the project against the objectives defined in the project charter (Arjun, 2018). Provided that the structural engineering design and documentation is adequate and that the contractor is competent and efficient, then *ceteris paribus*, the works should be carried out systematically without any significant variations. This also implies that the cost of construction is most likely to be within the preconstruction estimates used to tender. It can therefore be seen that structural engineering design is very central in determining the level of cost certainty of a high-rise building project and tight controls should be maintained over the processes involved.

Performance and monitoring essentially happens in tandem with the execution phase. It is related to measurement of progress, performance and tracking KPIs such as schedule, budget, quality and risks, among others. Structural engineering functions here are geared to further ensuring compliance whilst minimizing variations that can lead to deviations of KPIs from the project baseline. Project close out represents the completion of the project and handing over the project products to the client. Activities in this phase include evaluation of the project, preparation of final accounts, harmonizing and handing over project documentation, termination of supplier contracts, conducting lessons learnt on the successes and failures for future projects and releasing project resources (Axelos, 2017). From a structural engineering perspective preparation and handing over of As-built drawings and reports is the major deliverable in this stage.

From this broad overview of the project cycle, it can be deducted that structural engineering design exerts the greatest impact on cost certainty of a building project during the project definition and planning phase. It is at this stage that the structural components of the building project are wholly developed, described, documented and their cost estimates determined. These, together with other elements from other disciplines are integrated to form the overall preconstruction project documentation and cost estimates.

2.4 Cost Certainty

The cost of a building project can be influenced by many factors such as the specifications, location, form of procurement, site conditions, nature and complexity of the building, tax liabilities, time scale and inflation. Project cost control measures are meant to ensure that high levels of cost certainty run throughout the project cycle with the aim of completion within budget (Cunningham, 2015). However rarely have projects been completed within budget. A substantial number have suffered from budget overruns (Noorani, 2016). In the context of project financing, budget overrun is the amount by which the actual cost of a project exceeds its initial budget. Patil and Bhangale (2016) defines budget overruns as the excess amount incurred by comparing the final project cost at completion and the preconstruction cost agreed and signed by the client and the contractor. It therefore implies that when a project is completed at a cost higher than what was initially budgeted, it is said to experience a budget overrun (Sunjka and Jacob 2013).

Budget overruns is matter of concern to stakeholders in the public and private sectors of the construction industry. To the client and contractors, it has a direct impact on resources. Clients need to plan resources in terms of cash flow based on realistically firmed up figures. Indeed, the holy bible brings out this truth vividly in Luke 14:28-30 which says:

'Suppose one of you wants to build a tower. Will he not first sit down and estimate the cost to see if he has enough money to complete it? For if he lays the foundation and is not able to finish it, everyone who sees it will ridicule him, saying, 'This fellow began to build and was not able to finish' (Zondervan, 1991).

Two critical facts emerge from this passage. One, accurate estimation of cost is very important. This can only happen if the scope is fully understood, a proper design is done and all the components of the project accurately and completely described. Secondly there is grave risk to the client if he/she proceeds with project implementation on the basis of defective cost estimates. The risks include failure to complete the project, budget overruns, loss of investment funds and damage to reputation.

Majority of the previous studies focused mainly on finding the factors that cause budget overruns on different construction projects in a broad sense. Few researches have attempted to further investigate into these major factors to determine their underlying root causes particularly on a discipline by discipline basis. As such, this research focuses on the structural engineering discipline and specifically on the underlying factors that bear on the quality of structural engineering design which subsequently impacts the cost certainty of high-rise building projects.

2.5 Theoretical Framework

Jain and Singh (2012) in their theory of cost overruns developed a model which established that construction projects compared to other sectors experience higher cost overruns. In addition, cost overruns increase with project complexity. In this model, the authors postulate that typically a project starts with outlining the scope followed by detailed description of the work packages required to actualize it and finally costing the work items. Project scope planning helps to comprehensively define each projects product's purpose, composition, derivation, format and quality. It also assists to establish means for determining inputs required such as resources, labour, equipment and way of scheduling of activities (Axelos, 2017). Scope changes either result in new work items or vary the quantities of already estimated work items thereby increasing costs. The probability of scope changes depend on how much project designers endeavour to understand the project requirements and specify the scope comprehensively. Therefore scope changes reduce when more effort is put in the design and by employing more experienced designers.

Identifying the work packages and activities required to build the project at the preconstruction stage similarly depends on the complexity of the project; effort put in project specification as well as the experience of the planning and design team. It therefore follows that to capture the totality of a project scope of the project requires concerted effort and that the higher the effort the more complete the project scope can be specified in the initial design. Knowledge and experience of the designer is important when it comes to capturing the scope and consequently the completeness of design.

The final activity when preparing the project budget is the estimation of work activities and their unit costs. Generally, these costs are a function of material inputs, labour, transport, capital and the contractor's profits. In many countries established institutions have published standard construction rates of various work items that can be used to estimate the project budget. In Kenya, for example IQSK periodically publishes such per unit costs in the Building Construction Cost Handbook for use in preparing estimates for building projects. The initial estimate of the project would therefore be a summation of the quantities of the estimated work items and their respective per unit costs.

Usually at the commencement of any project, there are many unknowns regarding work packages, the quantities and the per unit price of the works. It may not be possible to capture the entire project scope. However the degree of scope that can be captured depends on the technical complexity of the project, experience of the designer and the level of effort to better understand and define the project. If therefore effort is increased to sufficient levels, then nearly all of project work packages can be defined in the initial design. The preconstruction cost estimates is then the summation of all the cost of the individual work items defined in the initial scope.

Budget overruns occur in the construction stage when the actual costs of project work end up being higher than the estimated values. This typically happens due to variations in either the actual quantities, unit costs or both. This theory therefore gives a proposition that *ceteris paribus* the variance in cost between the initial estimate and actual construction cost decreases as the effort and experience increases. Therefore, as effort levels approach infinity, the estimated cost approach/coincide with the actual cost. Cost overruns will thus decrease as completeness of design increases. The effort by the designer includes all such endeavours geared towards effectively and efficiently accomplishing a project. These include planning and organization of works, procurement of suitable design software, manpower, establishment of quality management systems, knowledge and skill up scaling, collaboration and coordination etc. It therefore follows that in order to minimize the probability of budget overruns on construction projects, experience and concerted effort from key stakeholders is required at the preconstruction design stage. Structural engineers are part of these key stakeholders on any high-rise building project. Their level and quality of input will therefore significantly impact on the cost certainty of such building projects.

2.6 Empirical Framework

2.6.1 Budget Overruns

A number of researcher such as Serdar (2020), Abdulaziz and Theo (2015) and Kagiri (2005) have identified deficiencies in engineering design as one of the significant factors causing budget overruns. In order to address the root cause of this challenge, this research attempted to find the underlying factors that influence the quality of structural engineering design and documentation. In this study, quality has been considered by the author in terms of the accuracy, completeness, integration and build-ability of structural engineering design outputs. Previous studies on the subject of budget overruns on construction projects mainly focused on identifying the factors that cause this undesirable phenomenon with little attention on the root causes.

Marisa and Yusof (2020) opined that the construction industry faces numerous challenges such as delays, design defects, cost overruns attributable to the professionals involved. In this study, they identified: (i) effective design process; (ii) working conditions; (iii) organization support and (iv) working relationships as key factors that affect architects' performance and hence the design quality outcomes of projects. Effective design process was found to have the greatest bearing on performance. This entails proper project definition, planning, establishing a competent design team and establishing good coordination within the project team. This should be given greater attention by stakeholders in the industry.

Oyewobi *et al*. (2016) in their study of education building projects found 13 variation causing factors that included: (i) poor understanding of the customers brief; (ii) poor application of technology; (iii) weak contractual procedures; (iv) omissions during construction; (v) changes by consultants; (vi) inaccurate project brief; (vii) insufficient project resources; (viii) inconsistencies from clients; (ix) poor coordination; (x) unclear work package separation; (xi) complex drawing information; (xii) handling multiple concurrent projects and (xiii) changes by the contractor. Omissions and changes by consultants can be related to design deficiencies. The findings showed that variations resulted in cost and time escalations amounting to 33.95% and 29.45% of the original project cost and time respectively. Oladapo (2007) found out consultants and clients were responsible for changing project specifications and scope. These variations accounted for 79% and 68% of cost overruns and time overruns respectively. The study however did not delve further to investigate the underlying issues behind the scope changes.

A study by Shane *et al*. (2009) found out that transportation projects such as roads, railways and bridges on a whole experienced average budget overrun of 27.6%. The researchers categorized 18 individual factors comprising of internal and external factors. Some of the critical internal factors causing budget overruns include poor assumption, engineering and construction complexities, scope changes and ambiguous contract documents. Notable external factors outside the control of the agency/owner included local government requirements, effects of inflation, and market condition. The internal factors such as poor assumptions, scope changes and ambiguities in contract documentation are indicators of quality and managing such factors can aid in cost control.

Muhammad *et al.* (2015) sought opinions from contractors, consultants and clients and identified fourteen factors responsible for the cost escalation of civil and building engineering projects in Nigeria. They include: (i) lack of coordination between contractors and consultants; (ii) variations; (iii) government policies; (iv) change of government and political instability; (v) wrong method of estimation; (vi) poor financial control on site; (vii) fluctuation of materials prices; (viii) extended period between design and tendering time; (ix) design errors; (x) poor supervision and liquidation damages; (xi) previous experience of contract; (xii) inadequate production of raw materials; (xiii) effect of weather and (xiv) absence of construction cost data. Ranking of these factors showed that fluctuation of materials prices and variation were the major causes of budget overruns with mean values of 3.9 and 3.73 respectively. Variations are indicative of scope changes which come as result deficiencies in the quality of design at the initial stage of the project.

A study by Jarkas and Haupt Theo (2015) ranked errors and omissions in design drawings, as the fourth most significant factor out of 10 critical risk factors in construction projects that were considered by major contractors in Qatar with a relative importance index of 0.827. Other factors included disruption and interference of planned work sequences due to unclear and incomplete drawings and technical specifications, errors and omissions in design drawings and uncoordinated design among the various disciplines working on the project such as mechanical, electrical, plumbing, architectural and structural. It was further established that excessive delays occur when contractors request clarifications, send RFIs or when there is a requirement to make substantial revisions to erroneous design documents. In worst case, scenarios like these cause reworks, loss of project time and increase in costs.

Kagiri (2005) while studying cost overruns in power project in Kenya identified thirty three variables contributing to time and cost overruns. These were consolidated into eight major factors that contribute significantly to time and cost overruns in public power projects. These are: (i) contractor's inabilities; (ii) improper project preparation; (iii) resource planning; (iv) interpretation of requirements; (v) work packages definitions; (vi) timeliness; (vii) government bureaucracy and (viii) risk allocation. Works definition was ranked as the third most significant factor with a relative importance index of 0.744 coming after resource planning and government bureaucracy. It included critical design related aspects such as inadequate expertise or experience, poor site investigations, incomplete and inadequate design and construction information, inadequate project analysis, Lack of proper project linkages and bad estimation. Whereas this research did not dig deep to find out why such deficiencies occurred, we can deduct for example that omission of project linkages points to lack of or insufficient design coordination between the cross functional members of the project team.

The CIOB (2002) underscores the importance of design by giving the proposition that upto 80% of any project cost can be determined from its designs. However in order to effectively manage and control project costs, design decisions should be made within the overall budgetary limitations established based on the established business base. Quality of design therefore plays a vital role in so far as cost certainty of projects is concerned. Based on this key contribution of design on cost, this research aims at investigating factors that affect the quality of structural design in terms of its accuracy, completeness, integration with other disciplines as well as its build-ability and how this level of quality affects cost certainty of high rise building projects.

2.6.2 Coordination of Structural Design

Projects can be viewed as temporary undertakings meant to generate unique products, services or results that bring about change (PMI, 2017). In order to accomplish this goal, projects are implemented by cross- functional professionals who harness their resources and skills to achieve the project objectives. Naturally these teams necessitate the formation of organizational structures which are frameworks that guide operations. Armstrong and Taylor (2014) defines organizing as the process of making plans that define responsibilities and relationships of groups of people to enable them work harmoniously and cooperatively. Project organization structures therefore provide mechanism of defining hierarchies, differentiating tasks and activities, allocating tasks and responsibilities to different members and establishing coordination mechanisms to integrate the different groups and hierarchies into a unitary whole (Kariuki, 2019).

The project team members or firms must individually and collectively organize themselves and their operations in a manner that efficiently and effectively delivers on the project objectives. An enterprise that is well organized is more likely to plan and coordinate its operations or projects effectively and efficiently. Planning as clearly defined and highlighted by Hugh (2013) is the extensive process of selecting a particular method as well as particular order of work to be adopted for a specific project from the many possible ways and sequences in which the project could be done. Planning basically involves looking at “What to do and also “How to do it”. Coordination on the other hand involves gathering all the works of various departments and sections in order to have good communication flow. It is the process of basically organizing people or groups so that they can work collaboratively in pursuit of the project objectives (Axelo, 2017). From a projects perspective, design coordination describes the process of sharing information, being on the same page, harmonizing the different designs prepared by the multidisciplinary members of the project team into a single, fully described project product. From these a unified set of design information can be produced which affords tendering and construction with minimal clashes within the components or variances in costs, time or quality.

According to Ali and Rahmat (2009), it is good practice for the team leader to coordinate and manage the design team once it has been assembled. The same principle applies at the individual firm’s level. In the case of a structural engineering firm, the planning and coordination of structural designs requires establishment of a system that drives and oversights the internal design processes as well as coordinate with external parties. In other words, a project organization structure should be established within the firm’s organization structure through which project tasks, responsibilities, and communication can be undertaken in a smooth and coordinated fashion. Further, this system should ensure that members be have a solid understanding of project scope, schedules and budgets constraints. In addition it should thoroughly review key submissions and deliverables in order to achieve project goals and design objectives, regularly verify stakeholder inputs for inclusion, verify construction phase functional, technical, business, statutory and other relevant code requirements.

Ali and Ramat (2009) found out that the risk of communication gaps owing to the fragmented nature of construction industry can lead to delays in decision making and effective completion of design. Chiu (2002) also supports this proposition that the interdisciplinary nature of the design process together with ineffective collaboration, uncertainty, limited understanding of scope and project complexity further compounds this problem. The danger of allowing this disjointed approach to creep into the design phase is that it will subsequently manifest in the quality of tender documentation and eventually fester in the construction phase as omissions, clashes, errors leading to variations with associated budget overruns.

Ali, Rahmat and Hassan (2008) underscore that the multidisciplinary nature of the design process of high-rise building projects involves several professionals. A typical building project will have an architect, civil and structural engineer, quantity surveyors, mechanical engineer, electrical engineer and the building contractor. The design process is dynamic and therefore, reducing uncertainty in design process requires proper coordination and integration between these diverse professions. However, lack of coordination among building designers has been and is still a major problem in the construction industry. Hegazy, Essam and Donald (2001) observed that this has significantly contributed to the lack of integration of design information, which in the end has led to design changes and variations during construction. In order to produce complete and accurate structural engineering drawings and specifications that can be used with a high degree of certainty for costing and construction, accurate design information must be shared during the planning stage. Coordination therefore affords exchange of information, thoughts, experiences between the parties to the project in order to minimize uncertainties, understand the scope and thereby increases the accuracy of initial cost estimation and reduces likelihood of scope changes during the construction phase.

Ali and Rahmat (2009) identified two coordination methods that can be helpful during the design process that is direct contact and meetings. He further expounded that direct contact can be formal or informal but involves direct approaches in gathering useful information. Direct formal contact involves documented information obtained through reports, memos, letters, and emails. In contrast, direct informal contact refers to using informal conversations such as telephone calls and discussions. This method is simple and helps to quickly resolve uncertainties. Typically, the building industry is fragmented with multiple participants and granted that the design process is iterative, direct contact is very critical in resolving uncertainties. The purpose of meetings is to keep participants informed, and to handle shared problems. They provide a platform for the design team to interact, providing feedback and comments and thereby providing better integration of the design. The structural design team should be in constant communication to share and exchange design information in order to increase accuracy and eventual completion of the project design. Appropriate use of coordination methods is very beneficial to the overall improvement of the project performance (Mitropoulus and Tatum, 2000).

Czmoch and Pekala (2014) have shown how design and coordination work has changed over the years from the use of ink and paper, then to CAD and CAE systems. Traditionally each design speciality on a project i.e architects and engineers would work separately on their drawings and then superimpose each other's drawings in a coordination meeting to check compatibility of their details. This system was prone to interdisciplinary conflicts and effecting changes was laborious. Technological advancement to BIM has enormously improved the design, coordination and collaboration on projects. This technological revolution is based on developing one 3D model and shared database of the project containing all the multidisciplinary information that allows for quick visualization and implementation of changes by all design team members during the coordination process. Structural engineers can for example use the same architectural model to form a structural model for analysis and production of drawings. This saves time, minimizes errors and prevents collisions.

Coordination is also closely intertwined with the quality of product being produced. Quality is the totality of characteristics of an entity that bear on its ability to satisfy stated or implied needs (PMI, 2017). Quality Assurance as defined by O'Brien (2013) are all planned systematic actions necessary to provide adequate confidence that a structure, system or component will perform satisfactorily and conform to project requirements. This works hand in hand with quality control which refers to the specific procedures involved in the quality assurance process. These procedures include; planning, coordinating, developing, checking, reviewing and scheduling work. Therefore, quality is achieved by individuals performing work functions carefully and in conformance with the given standards. Design entails progressively elaborating the product to such an extent that its characteristics can be fully described and documented. In the case of structural engineering design it also means achievement of an acceptable level of confidence that the structures being designed will perform satisfactorily during their intended life (BSI, 2002).

Schwinger (2010) opines that most RFIs from contractors to engineers are due to missing or conflicting information. Good quality assurance can help reduce them. Before the introduction of Quality Assurance programs in the 1990's, quality of design on projects was assured by relying on the designer's experience, skill, continual oversight and expertise of trained personnel. The author further emphasizes on the importance of both medium and large sized engineering firms to have comprehensive in-house systems that help to review design procedures, standards and methodologies in order to produce consistently high quality designs and documentation. These will so help minimize the risk of errors and omissions which cause variances during construction.

Taye (2008) emphasises that quality programs are very important in dealing with new challenges that continually occur in the field of structural engineering. These challenges include delays, defective designs, and challenges in building and structural failures. According to Abatemam and Dinku (2007), design related delays like variations, changes in design, incomplete documents and inadequate design team experience are the major contributors to overall project delays. In other cases, the design problems can easily go beyond the delay. This is supported by Assefa (2012) who further investigated and found that a large proportion of structural failures are due to human errors in the design stages of the structural engineering projects which could have been avoided with adequate design checking. One way of curing this challenge is the use of a QMS. This provides for mechanism of checking designs and documentations for quality before they are issued for use.

The ISO has developed the ISO 9001:2008 quality management systems which though generic, can be tailored and adopted by any organization including engineering design organizations to integrate their internal processes and provide mechanisms of quality control in project implementation. A quality management system that focuses of the processes helps the organization to identify, document, measure, control and improve the various core business processes by looking at the inputs and outputs. This will ultimately lead to improved business performance by consistently producing quality products or services (Standards-Stores, 2021). Whether or not structural engineering firm are ISO certified, it is important that they develop and maintain office design procedures and standards to keep everyone on the same page as well as providing a road map that ensures uniformity, completeness and accuracy of the design.

According to Chiu (2002), every project is distinct from another and is likely to have different challenges and opportunities that require considerable skills and creativity to overcome. This is therefore means having a good execution plan that can work in tandem with past experiences to deliver the project. Coordination becomes even more critical for complex projects such as high-rise buildings which are generally bigger, have more work items and complicated design and construction methodologies. With good planning and coordination, complex projects can therefore be broken down into smaller work packages that can be assigned and designed separately and later all the details integrated to form the whole project work package.

Olatunji (2010), notes that if the project details were not well understood, the works can be done erroneously and an attempt to correct the errors leads to project delay. This in most cases has led to serious consequences such as disputes, claims, litigations and in extreme cases project abandonment. Hussin and Omran (2011) emphasized the importance early identification of problems that are likely to occur during construction. Coordination of designers in the planning stage is therefore very crucial to mitigate these undesirable outcomes in the construction stage. If conceptual planning and preliminary design stages are not done properly, the successive project stages are likely to face major problems. This is well documented by Koushki, Al-Rashid and Kartam (2005) who illustrates that owners who carried out pre-planning phase prior to the commencement of the planning phase experienced shorter time delays than their counterparts who failed to pre-plan.

Sambasivan and Soon (2007) and Jagboro and Aibinu, (2002) in their separate studies identified the fact that designers and contractors improper planning are the major causes of project delay and eventual project failure. Failure to come up with an effective program of works at the early stages was found to affect the timely completion of the project. (Pourrostam and Ismail (2011) also found out that project delays invariably lead to budget overruns. These findings agree with McMinimee *et al*. (2009) and Mojahed (2005) who noted that investments in advance planning and coordinating project development, paid off in all subsequent project phases and in the overall project outcomes. From these researches good coordination is beneficial in reducing errors, re-works and overall delays in project completion.

Pakir, Omran and Abdalrahman (2012) found out the five most important factors that influence the performance of projects are: (i) leadership skills of the leader; (ii) the planning effort; (iii) experience of the team leader; (iv) adequacy of design and specifications and (v) cost progress monitoring. Planning efforts was ranked the second most significant factor with a relative importance of 0.91. Planning includes managing the all the aspects of coordination. Wideman (2001) agrees with this observations when he found that the success of the implementation stage of the project highly depends on the quality of planning in the prior initial stages. This sentiments were similarly echoed by Wambugu (2013) who observed that planning affected the timely completion of rural electrification projects in Kenya. He further reiterated that prioritizing project planning and coordination is an assurance for project success.

2.6.3 Experience in Structural Engineering Design

High-rise building projects present numerous technical and management challenges that require knowledge and experience to solve. The intricacies of modern structural engineering design for complex projects place a premium on sound knowledge and experience in this field (Designing Buildings, 2021). Cities worldwide are witnessing a steady increase of high-rise buildings characterized by complex geometries, innovative materials and iconic features. Whereas this is positive and indicative of growth and innovation, it has brought a lot of issues about the capacity of various professionals in the construction industry particularly structural engineers to effectively handle such building projects (Sheth and Rajendra, 2016).

Armstrong and Taylor (2014), describes the human capital of an organization as comprising of skills, abilities and the knowledge of the people employed in that firm. Bontis *et al*. (1999) further described human capital as mix of expertise, skills and intellectual capacity which distinguishes one organisation from another. These human attributes of an organization can provide the incentive for growth of the organization in an environment that allows for their development, innovation and adaptation to prevailing operating circumstances. Knowledge is the cognitive understanding of practices, concepts, suppositions and procedures. Armstrong and Taylor (2014) describes it as the “know-how” or “expertise” in cases where the knowledge is much specialised. In a competitive environment such as the construction industry, knowledge and experience becomes a vital resource and offers a clear competitive advantage in project delivery.

To illustrate the value of experience on projects, Barton (2019) presents a typical case where a client driven by desire to save on design fees employed an in-house Mechanical and Electrical design that was not experienced. Their work was design the electrical and mechanical services for the company’s new store. Sadly this resulted in doubling of the scope of electrical works and a budget overrun of four times the original estimates. The final cost of the project was found to be twice of what it would have costed the company had they engaged an experienced engineer to carry out the designs correctly in the first place. This is a common pitfall that bedevils a number of projects in Kenya. Catastrophic losses such as the collapse of a four storey building under construction in Utawala part of Nairobi was attributed to compounding factors including poor materials, workmanship and design deficiency to save costs (Nyakoe, 2022). Developers either out of ignorance or driven by misinformed desire to save costs circumvent knowledgeable and experienced structural engineers and opt for unqualified persons. In many cases, their projects have not only suffered defects but also incurred extra costs due to design related issues.

Schwinger and Meyer (2010) observe that employing the services of an unqualified structural engineer in most cases makes the building project more complex as many of the key elements of engineering design are overlooked or left out causing the contractor lots of challenges that usually have a financial implication leading to cost overruns. More so, it is important to appreciate that structural engineering is a high-liability profession where mistakes should not be tolerated since they can result not only in cost escalations but also loss of property and lives (SEI, 2013). It is therefore important that the lead structural engineer of any building project has the required qualification as a chartered or registered engineer accompanied with years of experience in the same field for him to handle the project with ease and also to assure the client and the users of the building of their safety.

Feng (2015) defines a structural engineer as professional with specialized knowledge, training and experience in all the scientific and mathematical domain that relate to analysing and designing force resisting systems for buildings and other structures. This basically mean that a person who fits the description should be able to superintend over the analysis, design and document preparation for any building structure and is equally knowledgeable of all that is required for the load carrying structural system. He should also be to satisfactorily perform structural engineering functions that are needed for the structure to be completed. For Feng (2015), a structural engineer should be able to create working designs that are safe and also provide a comprehensive list of the structural calculations that show the design meets the standard for approval by the Building Regulations. A knowledgeable and experienced structural engineer is a professional who knows how to do his design calculations right because correct calculations guarantee delivery of good structural engineering designs.

More so, Ahmed, Hacker and Wallace (2005) noted that competent structural engineers are very good at making complex projects easier to build within the time-frame given without major delays. Experienced engineers understand the construction intricacies and hence incorporate efficiency and constructability in the design process ensure practicality of implementation, that he can effectively oversee the project and more importantly that the costs will be managed (Barker Structural, 2017). In other words, they are able to foresee the challenges that may arise during construction and provide remedial measures to such risks at design stage. Additionally, it's important to note that when a competent structural engineer is engaged for engineering designs, operating costs as well as the main construction costs are usually lower than when an incompetent person is engaged. All this effect is because of the accuracy with which the design calculations are made in terms of materials needed. At the end of the day, the cost overruns are avoided and the client is able to get his project delivered within the cost estimates given.

Structural engineers are meant to provide crucial information about structural elements pertaining to the stability and durability of a building project (Chiu, 2002). This information is very crucial not only for the guaranteeing of the structural integrity of the building but for accurate cost estimation purposes. Poor, incomplete or inaccurate information emanating from designs produced by engineers lacking the requisite knowledge and experience have been known to cause variations and budget overruns on many projects. Colin and Hughes (2001) states that with required knowledge and experience in engineering designs, there is an assurance of quality products that have shorter lead times at very reduced costs. This is what every other client is looking for. Therefore, engaging a professional with adequate knowledge and experience in engineering designs helps a lot in prevention of cost overruns in the long run.

According to Ahmed *et al*. (2005), experience and expertise in engineering designs is built through long periods of exposure to lots of problem solving situations. It is very important as it enables a professional make decisions and choose particular measures required for the success of a given project. For Colin and Hughes (2001), structural engineering involves having a clear understanding of both static and dynamic loading and the different structural forms that are available to resist them. It also involves a great deal of creativity on the structural engineer's part for him to effectively handle complex modern structures with ease. Knowledge and experience play a significant role is enhancing creativity and capacity to use the available software such as design and coordination software to analyse, design, interpret, share and document structural components of building projects.

It is therefore not enough to solely look for an engineer with a degree certificate. The focus should be to engage an engineer with the right mix of skills and the capacity to apply them in a way that not only results in a structurally sound building, but also meets requirements of the design codes, supports the purpose and business case of the project, enhances build-ability and adds value to the overall project (Barker Structural, 2017). In conclusion therefore, it is important that a structural engineer must have both knowledge and experience of structural engineering designs acquired over a period of time for them to be able to deliver quality structures that are safe, durable and within budget.

2.6.4 Structural Engineering Design Software

Hunt (2013) opines that there is increasing requirement from stakeholders in the construction industry for higher productivity, higher quality but at reduced costs. With the increase in population, socio-economic development and demands, construction projects have steadily continued to increase in number, magnitude and complexity. In Kenya for instance, the construction industry grew by 7.2% in the second quarter of 2019 contributing significantly to the overall 5.6% growth of GDP (KNBS, 2019). This growth was spurred by two of Kenya's economic blue prints namely "Vision 2030" and the "Big Four Agenda". With this growth and development comes the challenge of planning, designing and constructing these facilities in a cost effective manner. Structural engineering software have significantly optimized the drafting, analysis, design, documentation and coordination of projects.

Michael (2006) views a structure is an assembly of parts that are configured to sustain applied loads without unacceptable deformations. Analysis of the behaviour of the structure is therefore a core concern to the structural engineer. It helps predict the properties and performance of the structure in real world. Before the emergence of computers and software design and construction of buildings was largely manual. This was tedious and very slow. Complex projects present huge challenges of timely completion, design errors and difficulty in coordination. But with the rapid technological revolution around the globe, design software have enabled most civil and structural engineers to speed up the design and construction processes whilst maintain quality and cost. BIM for example enables structural engineers to visualize, simulate, analyse, design and produce complete and well-coordinated construction documentation in a more efficiently manner (Autodesk, 2012). There is therefore need for greater investment of resources in progressive and versatile design software since these have multiplier benefits to the project.

Otero (2012) noted that the increasing use of computers in the structural engineering companies has given greater impetus to further development of computer integrated design systems. These systems are valuable to the designer because of the many benefits they come with. For instance, with these systems in place, designers are able to organize, process, manage and communicate design information effectively. Additionally, the systems free designers into conceiving creative solutions to the project problem as well as manage the entire process making the decision making process very easy. Traditionally, and most often due to time constraints, structural design of projects runs hand in hand with production of tender or construction documents. Various structural engineering software are used for design and on the other hand separate software are used for production of documentation. This disjointed approach requires a lot of manual effort to keep the design and documents synchronized. Efficiency and flexibility is compromised as well as quality of outputs. This has led to the need to adopt solutions that integrate workflow processes of design and documentation.

According to Mwero and Bukachi (2019), digitalization is progressively replacing manual processes in lieu of using computers. The construction industry has equally embraced these paradigm. The industry has witnessed a tremendous shift from manual design to CAD then to 3D. From the rudimentary use of pencil and paper to BIM with dimensions that additionally allow manage costs, materials, time, safety, sustainability and life cycle maintenance of projects. CAD and now BIM significantly transforms how design and documentation of projects are done and more improvements will continue in the future (Constructible, 2018). This is supported by Chi, Wang and Jiao (2015) who opined that the development of computer aided software has focused on assisting designers to finish their work efficiently, increase flexible modification capacities, and eliminate design errors.

Mumbua (2016) found out that contractors, engineers and architects are the key players in the construction industry that are affected by BIM. The research also found out that most firms that adopted the BIM in design and construction stages were more effective than those that did not adopt its usage. This findings are supported by Chi *et al*. (2015) who found that BIM affords automatic code checking, seamless data exchange, sustainability evaluation, powerful communication interfaces through virtual reality technology, 3D visualization and navigation tools and an integrated data base that can be shared by all designers. Nyaga (2016) noted however that effective use of Information Communication Technology was key to successful adoption of BIM by contractors. Gitee (2018) discovered that when BIM is implemented in project design and project estimation it had a positive and significant effect on the project implementation success. However, other dimensions of BIM such as material estimation and project scheduling have not been fully exploited.

Hunt (2013) in his study of benefits of BIM in structural engineering identified four major benefits of this tool in enhancing structural engineering design workflow. BIM increases productivity by automatically generating construction documents such as drawings and schedules. Secondly BIM significantly enhances coordination particularly for complex projects by providing data exchange between team members. Its allows all the project team members to work on the same model and thereby enables consistency, detection of clashes or interferences thereby reducing errors in design. Thirdly unlike manual methods, BIM provides tools for visualization. Powerful 3D graphical modelling and navigation technology provides deep project insight, enhances understanding, and evaluates structure performance digitally before construction. Fourthly the ability to simulate and review different structural options significantly assists in making informed decisions as well as promoting problem solving. Design clashes, workflow management and construction sequences can also be simulated before actual works commence. These benefits of BIM as a design tool have a positive impact on cost certainty of a project. Minimization of design and documentation errors, promotion of consistency, coordination and simulation are positive efforts that significantly increase the quality of design and consequently the cost certainty.

Olga and Andy (2003) viewed buildings as being very complex and contain large number of distinct parts interconnected in several assemblies. These require different analysis, design and production approaches. Modelling of such buildings in fully parametric 3D CAD systems offers a number of benefits to the structural engineer in terms of improved productivity. The CAD system also enables the designer to rapidly generate design alternatives faster and easily at different levels while eliminating errors that might have resulted from the disparities associated with the traditional approaches. Otero (2012), agrees that 3D integrated structural design and analysis software are efficient, more user friendly, improve productivity and reduce time.

Omtoriogun (2022) opines projects present challenges that require the right software to solve. Previously there were three distinct categories of structural engineering software i.e those for structural analysis, design and CAD for producing drawings. Software developers have merged these three functions to produce integrated software but still most available software in the market are capable of only one of two of the three core functions. The author further notes that technical and general factors are the two main considerations engineers should make when choosing the right software for their projects. Technical considerations include the capability and limitations of the software.

The general considerations include cost, functionality, future potential, BIM integration and interoperability.

Autodesk (2007) supports this view by appreciating that whereas there are quite a number of structural engineering design software in the market for designing different kinds of structures, cost, ease of use, technical support, knowledge, experience, quality of outputs and interoperability are critical factors that engineering firms consider when procuring such software. The type of analysis required nonetheless remains one of the most critical factors to bear in mind. High rise building projects may require static, dynamic, linear, non-linear, seismic, wind analysis or combinations for various reasons. Due to this multiplicity of project requirements many engineers prefer to procure an all- in-one solution capable of providing the entire scope of analysis options. The use of an Application Programming Interphase (API) enables the process of developing different and adaptable analysis solutions for different types of structures. APIs are the core components that allows the transfer of data between the BIM software and the conventional structural analysis and design software (Hunt 2013).

2.6.5 Fees for Structural Engineering Designs

Ayodeji (2015) defines fees as all payments that are made by the client to consultants for services rendered under the terms of an agreement. Fees is a payment made to a professional or professional body in exchange for advice or services. According to. There are alternative methods for charging professional fees for rendering engineering works. These include time basis, lump sum (fixed Contract) or Ad-valorem (percentage fees) (EBK, 2013). In either case, the fee is usually paid in proportions based on mutually agreed dates or at predefined stages of completed work. This basically means that full payment for a given project can be distributed throughout the project cycle depending on the nature of the project. Fees can also be adjusted following changes in the design of the project.

IESL (2010) proposed that in order to provide competent professional services in compliance with the Code of Ethics of the Industry, regulations should develop scales of fees to ensure uniformity in pricing professional services. The consultant’s fee should be able to cover all his costs including salary costs, statutory costs, overheads, reimbursable costs among others upon the completion of the scope of works as well as leave him with a reasonable margin for profit. According to Riba (2010), the scales for fees are meant to act as an aid in selecting a professional for the works, defining the services being contracted and also as the basis for fair remuneration of the services procured. The scope of services to be provided are usually determined by the client in consultation with the consultant. This helps to understand the project requirements as well as form the basis of agreeing on the ultimate fee that will be charged.

Kariuki (2019) showed that the amount of compensation influences the success of an organization. The various professionals on a project usually agree to work in exchange for monetary consideration from the client or the employer. Research has shown that reward system can influence an organizations success in three ways. One, it motivates, energizes and directs behaviour. Secondly compensation attracts and retains qualified, high performing workers. Thirdly compensation influences the success of the organization. In order for any organization to perform at highest level, investment in the people of the organization is paramount. Motivation, commitment and engagement are vital ingredients that influence behaviour and performance. Motivation looks at what makes people to behave in certain ways and directing behaviour in line with the strategic objectives of the organization. Commitment is the degree of an individual's energy when it comes to identifying and being involved in the affairs of an organization or a project. Engagement encompasses both commitment and motivation of workers to achieve high levels of performance (Armstrong and Taylor, 2014). The amount of compensation for structural engineering design services therefore can influence performance quality of design and consequently the cost certainty of the project.

According to Riba (2010), fees depend on the nature of the project and also on the circumstances under which an appointment was made. For instance, the percentage of fees charged for large new building projects may be lower than that of small works to existing buildings. Additionally, commercial works may be charged lower fees than private residential works. On the type or nature of the appointment, the Asian Development Bank (2013) found out that this is was contingent on the nature and scope of the assignment. Therefore, the amount of fees charged for structural engineering design service will vary depending on the type, size, location and complexity of design as well as the scope of additional services such as supervision of works (Ayodeji, 2015).

For Henry and David (2004), fees is negotiated between the consultant and the client taking into account the nature of work, the degree of special expertise that the consultant has to offer and the “the going rate” in the market for that type of work. Fees although mostly charged hourly or daily may also be charged as a lump sum against an agreed scope of work.

Ayojedi (2015) argues that adopting scales of fees enable professional designers to offer competent, reliable and quality services to their clients. However, according to CPA (2011), the scales of fees and the rates are only guidelines and not mandatory for every project. They may be adjusted to take into account the complexity of the design as well as the extent of the services to be provided. Consequently, a highly competitive market has emerged whereby bidding for engineering design work has become free for all. This has in one way or the other driven down the fees, the quality and standards of the design leading to the eventual transfer of the design work to specialist contractors who include design costs in the lump sum building agreements. Ashworth (2004) highlights that professional institutes used to publish recommended fee scales that were expressed as a percentage of the total construction costs for different building types. This was meant prevent anti-competitive behaviour such as price undercutting among the members. However these professional institutes were forced to abolish these scales, leaving negotiation to market forces.

Salim (2006) however noted although consulting engineers were familiar with the different ways of pricing their design services at the tender stage, they incapable of effectively pricing whenever changes were introduced to the designs at later stages. They thus resorted to using estimates depending on the extra man hours needed to effect the change. In most cases the new rate are usually rejected by the clients who feel they are exorbitant. Such a situation if not handled accordingly may increase contractual disputes affecting the relationship further leading to dissatisfaction from both the client and the consulting engineer. Other previous studies by Anderson and Tucker (1994), Chang (2002) and Burati, Farrington and Ledbetter (1992) have revealed and shown that engineering projects faced increased construction costs as well as engineering consultancy fee as a result of the design changes at the different stages of development.

Tilley, Fallan and Tucker (1999) in their conference paper on Design and Documentation Quality and Its Impact on the Construction Process noted that according to designers, the level of design fees that's required in order to provide proper service and offer quality work have been on the decline over the past twelve to fifteen years. This has impacted negatively on fees required for simple projects which have declined up to 5%. Furthermore, they noted that reduced fee levels were seen to have high detrimental effect on design quality. This position is supported by Jarkas and Haupt (2015) who opines that slashing down design fees is counterproductive since it may encourage designers to compromise quality in an attempt to rationalise their business case.

Barton (2019) found that the construction industry incurs losses of 21% on error and that four of the top ten root causes of error have their genesis in the design. The report recommended investing sufficient time and resources into the design process as a fundamental step in reducing design-related errors which are known to cause budget overruns on construction projects. This entails allocating more money to the design process and allowing sufficient time to get the design right before construction. To illustrate this issue, GIR assumed a logical project whose typical design fees was charged at 15% of the project cost, and having design related errors contributing to 21% of the cost of error. If the design fees were marginally increased by 10% to 16.5%, and if this increase resulted in a reduction of the error cost by a similar margin of 10%, then the investment would have more than paid for itself. In reality however such improvements have multiplier effects that result in greater savings.

Mani (2011) found a negative correlation between the design fees and cost growth of public projects in the United States. This means that that higher design fees resulted in decreased budget overruns. In Kenya, professional design fees for building projects are provided for in various statutes and regulations such as the Scale of Fees and Conditions of Engagement for Consulting Engineering Services in Kenya, scale of fees for professional engineering services 2020 and the Architects and Quantity Surveyors Act (CAP 525). Based on these guidelines, consultancy fees in Kenya would be expected to be in the range of 12% to 15% of the cost of the project for the whole consultancy team on a building project. The reality however is that on many projects clients set aside these guidelines and negotiate or even prescribe for much lower fees to consultants. On the other hand, due to increased competition and undercutting practices, consultants including structural engineers have agreed to work for much lower fees than prescribed by the regulatory bodies.

Lopez, Craigie and Gransberg (2016) studied 1267 projects in four states of Oklahoma, Texas, Massachusetts and Washington in the USA and compared the relationship between the design fee expressed as a percentage of estimated construction cost and the eventual budget overrun relative to the initial cost estimation. The findings pointed to existence of a relationship between design fees and budget overrun from early estimates made during the pre-construction stage. Secondly it seemed that up to some point as the design fee increased, the cost growth from early estimates (budget overruns) decreased. Their hypothesis that up to some particular break-even point, construction budget overruns were inversely related to the percentage of project design fee was therefore supported. Therefore saving money in design fees is a futile exercise as it will negate achievement of high quality design and documentation. The design fee can therefore be viewed as an investment by owners to improve quality of design and manage costs throughout the project life-cycle.

Ansah (2011) opines that delayed payments is still a persistent problem in the construction industry notwithstanding clear provisions in many standard forms of construction contracts. For consultants this could be as a result many factors such as poor financial management by the employer, withholding of payments by the employer for a variety of reasons such as defective work or dispute or a failure by the consultant to comply with a material provision of the contract. In addition delayed payments have been found to be as a result of an entrenched culture, attitude of employers and the use of "pay when paid" clauses in the contracts. Such clauses tie payment of consultant's fees to receipt of monies from third parties such as financial institutions funding the project. Whatever the reason, delayed payments are counterproductive and delay works, are a source of conflicts, negative social impacts, abandonment of projects and in worse cases bankruptcy.

Harris and McCaffer (2003) defines late payment as failure of a paymaster to honour payment within the period as provided in the contract. This is a behaviour risk that impairs that capacity of the affected party to meet its contractual obligations (Zhang, 2006). The JBC standard form of contract which is commonly used for building projects in Kenya clearly obligates the Employer to make adequate financial arrangements to ensure that all payments to the Contractor are made within the stipulated periods (JBC 1999). The EBK (2020) regulations that operationalize section 58 of the Engineers Act, 2011 also made clear provisions for professional fees to be charged for engineering services. The obligation for the employer is to pay timely. Delayed payments have adverse implications for both the client and the engineer. It negatively affects the morale of the engineer and reduces the level of productivity in the design process. This in turn can result in defective designs, errors and incomplete documentation that eventually cause cost overruns. According to Construction Industry Working Group on Payment (2007), most problems in payment of consultants at the higher end will always lead to serious problems with the implementation of the contract requirements.

Research by El-Razek, Basioni and Mobarak (2008) found out that factors like delayed payments, coordination difficulty and poor communication were the major causes of construction delay in most building projects in Egypt. Additionally, Sambasivan and Soon (2007) established that delayed payments of fees, poor planning, poor management of the site, inadequate supervision of the works by the engineer and the contractor, poor communication among others were the key drivers of delayed projects in Malaysia. This was equally supported by Kaliba, Muya and Mumba (2009). Moreover delayed payment was ranked as the fourth most critical factor out of twenty one factors affecting construction productivities in Oman with a relative importance of 0.8185 (Alawi, 2021).

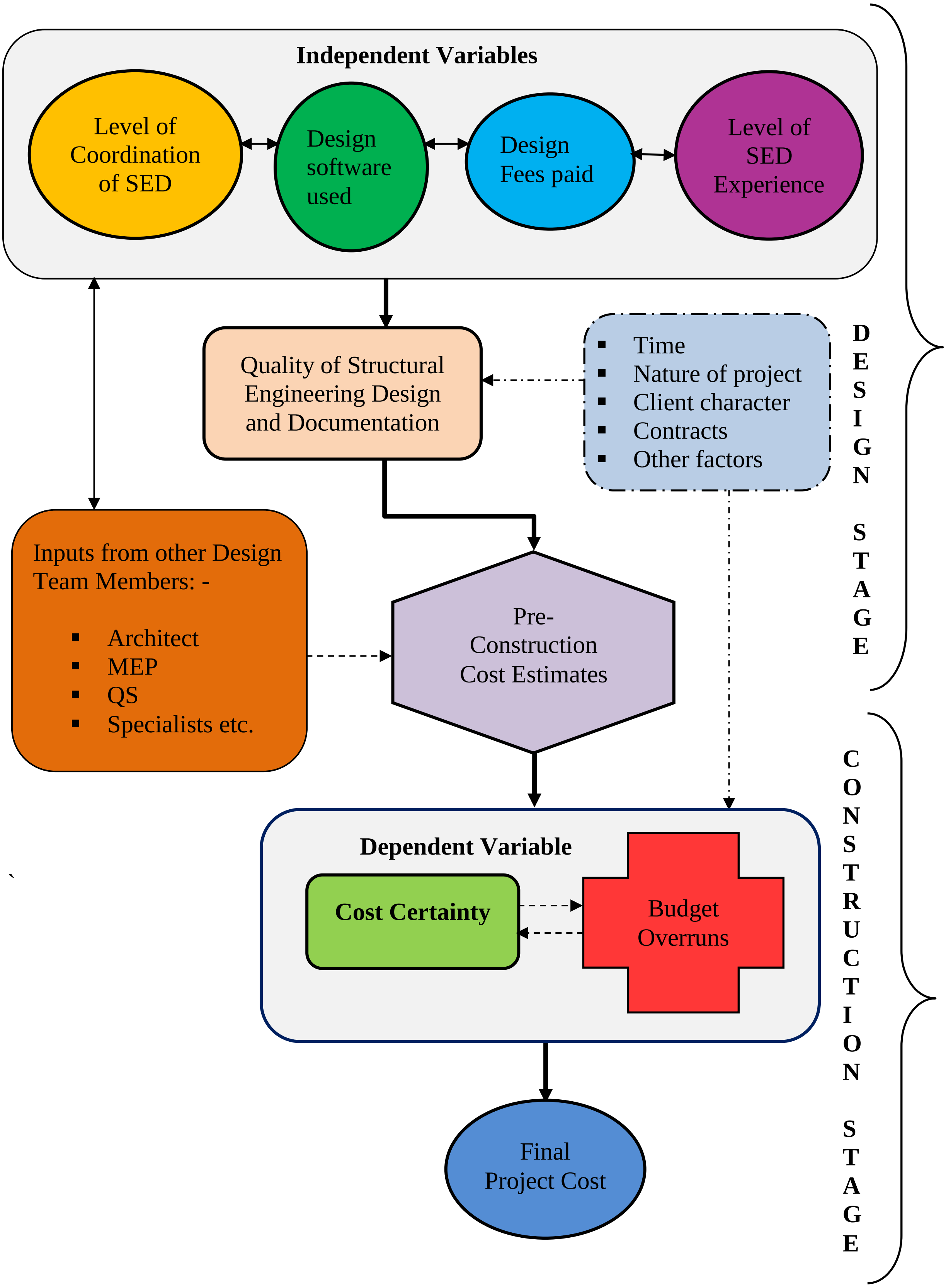
2.7 Conceptual Framework

Structural engineering design is a process that produces outputs such as drawings, schedules, specifications and methodologies. These are important documentation used for preparation of pre-construction cost estimates, tendering, bidding and project implementation. Further these estimates are used for development of a cost baseline that is useful in measuring and monitoring cost performance of the project. The quality of structural engineering design in terms of accuracy, completeness, integration and build-ability of its outputs is influenced by a number of factors. These factors include the level of coordination of the design, level of experience in structural engineering design, the kind of structural engineering software used in design and the amount of fees for the design. These factors do not work in isolation but are closely intertwined and contribute collectively to the cost certainty of the building project.

The final project cost compared with the pre-construction cost estimate gives an indication of the level of cost certainty of the project at the point of procurement. For this research project, the independent variables were the level of coordination of the design, level of experience in structural engineering design, the kind of structural engineering software used in design and the amount of fees for the design. The dependent variable is cost certainty which is measured by budget overruns. Other intervening variables that can affect the quality of structural design include time allocated for design, the nature of the project, client characteristics and the nature of contracts. Design requires adequate time to understand the scope, generate working concepts and crystalize the outputs into quality working documents. Size and complexity of building projects also bears on the quality of structural design. Large and complex projects present many challenges of scope, design and integration. Projects are unique undertakings and so are the clients. How clients formulate and direct projects impacts on the quality of the design. Contracts provide for establishing obligations and liabilities to the parties involved in a project. Contractual provisions places certain demands on the parties and this influences how they execute their responsibilities on a project.

Figure 2.1 below presents the relationship between these variables and how they interact in a typical building project during the design and construction stages.

Figure 2.1 Conceptual model: Influence of SED Quality on Cost certainty



Source: Researcher (2022)

2.8 Summary of literature review

The theory of cost escalations by Jain and Singh (2012) provided the insight and basis of investigating how various factors influence cost certainty. Factors that touch on the capacity to understanding the nature and scope of the project such as experience and the level of effort put in by the designers have a proportionate influence on the cost certainty of building projects.

Empirical review of literature from various researches has brought out the influence of such factors on project outcomes. Hassan (2008) appreciates that the construction industry is cross functional and uncertainties in the design process require proper coordination and integration between the multidisciplinary professionals involved. The complexities of high rise building projects places a premium on the designer's level experience in structural engineering design. Barton (2019) presents a strong case how employing the services of inexperienced engineers lead to errors and deficiencies in design and ultimately huge cost escalations.

Design software enable effective and efficient generation of design. When integrated software with BIM technology are used, they enhance the design flow process, increase productivity, enhance coordination, provides creative solutions for visualization, simulations and enable effect changes quickly (Gitee,2018). Deign fees is a compensation that motivates, energizes and directs behaviour of the designer (Kariuki, 2019). The research of Lopez, Craigie and Gransberg (2016) established an inverse relationship between the design fees and the amount of cost growth. When design fees is increased, the budget overruns decreased. This was also supported by Barton (2019) who opines that additional investment in the design cost results in reduction in the cost of errors in building projects.

CHAPTER THREE: RESEARCH METHODOLOGY

3.1 Introduction

This section presents the research methodology used in the study. It explains the research design adopted and the instruments used for data collection. The study population, sampling technique and how the sample size was obtained are outlined. Lastly the chapter highlights the tools used for data analysis and the kind of statistics that the research presented to make meaningful conclusions.

3.2 Research Design

This research adopted a quantitative sample survey approach to gain greater understanding of how the independent variables influence the quality of structural engineering design and consequently the cost certainty of building projects. It is correlational and cross-sectional in nature since it was aimed at finding out the relationship between the variables at a specific point in time. This gives a basis for conducting future and more detailed research on the subject matter.

3.3 Research Instruments

The study used structured questionnaires to collect primary data from the respondents. According to Burns and Grove (2009), questionnaires are regarded as being rich for both quantitative and qualitative research. Structured questionnaires enable the collection standardized information and are relatively inexpensive to administer and analyse thus suitable for this study (Creswell, 2009). In addition, this method was more practical considering the prevailing Covid-19 pandemic characterized by restricted movements, working from home and maintaining social distancing. A number of previous studies on related subjects also used this method with appreciable success. For example, Ikechukwu, Emoh and Okoracha (2017) used structured questionnaires in to study of the causes and effects of cost overruns in public building constructions projects delivery in Imo state of Nigeria.

3.4 The research population

The research targeted registered consulting civil engineers with experience in structural engineering design of high-rise buildings as the primary respondents. Structural engineering is one of the core speciality fields in the broader civil engineering profession. The sample frame was drawn from the EBKs register of consulting engineers. This is the apex category for engineers based on the EBK classification system and can be deemed to contain the most experienced engineers who understand the dynamics of the construction industry. EBK is a statutory body established under section 3(1) of the Engineers Act No. 43 of 2011 with the primary object of registration of engineers and firms, regulation of engineering professional services, setting of standards, development and general practice of engineering. At the time of conducting data collection, there were 337 registered consulting civil engineers in the EBK register obtained on 7th May 2021. This formed the initial research population for the study.

3.5 Sample Sizing and Sampling

The scope of research was restricted to respondents and high rise projects within Nairobi County. On this account 299 out of the 337 consulting civil engineers were selected. Further only 243 of the 299 within Nairobi County, had their emails addresses and telephone contacts included in the register. In the light of the Covid-19 pandemic and the need to comply with MOH protocols of limiting physical meetings, this research settled for this population of 243 consulting civil engineers since they could be reached by mail and phone. In quantitative research it is important to select a sample that is representative in order to apply the results to the general population (Omair, 2014). Hogg and Tannis (2009) provide the following formula for determining a statistically representative sample.

$$n = \frac{m}{1+\left(\frac{m-1}{N}\right)}$$

Where:

n, m and *N* represent the sample size of the limited, unlimited and available population respectively

m is estimated by the formula

$$m = \frac{z^2 \times p \times (1-q)}{\varepsilon^2}$$

Where

z is the statistic value for the confidence level used, i.e., 2.575, 1.96, and 1.645, for 99%, 95%, and 90% confidence levels, respectively;

p is the value of the population proportion which is being estimated; and *ε* is the sampling error.

Since the value of *p* is unknown, Sincich, Levine and Stephan (2002) suggest a conservative value of 0.50 be used so that a sample size that is at least as large as required can be obtained. Most researchers use a 95% confidence level, i.e., 5% significance level and a sampling error *ε* of 0.05. Therefore, the unlimited sample size of the population, *m* is computed as:

$$m = \frac{1.96^2 \times 0.5 \times (1-0.5)}{0.05^2} = 385$$

And therefore given that *N*=243, then the representative sample, *n* is given by

$$n = \frac{385}{1+\left(\frac{385-1}{243}\right)} = 149.2, \text{ say } 150$$

This formula is suitable when the sample frame is known and takes account of the two critical measures that affect the accurateness of data i.e.

i. Margin of error (confidence interval). This is the negative and positive deviation that is allowed on survey results for the sample. An error of 5% is commonly used.
ii. Confidence level tells how sure you can be that the % of population who pick the answer lies within the confidence interval.

This formula was also used by Jarkas and Haupt (2015). Therefore, a total of 150 consulting civil engineers were randomly selected using the probability interval sampling technique from the 243 consulting civil engineers domiciled in Nairobi County to participate in the survey.

3.6 Data Collection Methods

Primary data was collected through structured questionnaires which were administered to respondents by the researcher. Due to the current Covid-19 pandemic that limited in-person interactions, web based questionnaires were e-mailed to the respondents using the online google forms platform. Phone calls were used as a follow up or to get clarity on feedback where necessary. There were challenges of obtaining secondary data from project documents such as contracts, drawings, instructions, reports, correspondence, work programs, minutes of meetings and schedules due to the Covid-19 restrictions and logistics. To mitigate this research explored journals, textbooks, and the internet. This limitation provides an opportunity for further research on this topic.

3.7 Pilot Study

Before the main survey, a pilot study using an online survey programme was carried out on 12 respondents out of which 9 (representing 75%) returned their dully filled questionnaires. The aim of this pilot was to gauge the response rate, assess the adequacy of the research instrument and thereafter make any necessary adjustments to make the questionnaire more efficient for the main survey. Feedback from the respondents suggested that the questionnaire needed to be structured in sections not continuous. Some questions were ambiguous and needed clarity. Based on this the final questionnaire was divided into five sections. The first section focused on capturing the respondent’s general particulars. The remaining four sections focused on addressing constructs inn each the four independent variables and how they influence cost certainty. The number of questions in each section was limited to a maximum of nine to mitigate chances of respondent’s fatigue. Additional guidance was given to help answer particular questions and the order of questions was adjusted to give a systematic flow across the variables.

3.8 Data Analysis and Presentation of Results

The web based google forms questionnaire provides a mechanism of automatically saving the responses from each respondent in excel format. This is then imported into the SPPS program for both descriptive and inferential statistical analysis. Descriptive statistics were used to analyse general respondent's characteristics. These are analysed in terms of frequencies, proportions and percentages and presented using tables, charts and graphs to summarize the data and give a quick glimpse of the distribution of output. Further for each of the variables, the analysis illustrates the distribution of responses (frequency distributions), measures of central tendency (mean, median and mode) as well as measures of dispersion such as variance and standard deviations. Means indicate the average response of the entire sample while dispersion measures give an indication of spread of results from the mean value. This gives an indication of reliability of data. Inferential statistics such as ANOVA, correlation and non-parametric analysis such as Chi-square have been used to test hypotheses and association between the dependent variable and independent variables. It is from these descriptive and inferential statistics that important conclusions and recommendations are made as presented in chapter five.

3.9 Research ethics

This research has adhered to generally accepted research practices. Informed consent to conduct the research was obtained from the university department. Further consent to contact the respondents was sought from the EBK who allowed access to the engineer's database. Anonymity and confidentiality of the respondents was strictly adhered to. The questionnaire did provide any section where personal data of the respondents was required. The web based questionnaire also did not allow the researcher to know from which respondent the feedback was received. The identity and details of the researcher and the purpose of the research was clearly presented and explained to the respondents and they had the right to choose to participate in the research or otherwise.

CHAPTER FOUR: DATA PRESENTATION AND FINDINGS

4.1 Introduction

This chapter presents the research findings. They are analysed and summarized from data obtained from the questionnaires sent to the respondents. Both descriptive and interferential statistics are presented and conclusions made at the end of this chapter.

4.2 Response Rate

A total of 150 questionnaires were e-mailed to respondents that were randomly selected for this study. Out of these 106 questionnaires duly completed were received, representing a return rate of 70.7% (Table 4.1). The minimum established response rate according to Mugenda and Mugenda (2003) is 60%. On this account this response rate was deemed acceptable as it exceeds the minimum threshold.

Table 4.1: Response rate

Respondents	Frequency	Percentage Frequency
Who Responded	106	70.7
Did not respond	44	29.3
Total	106	100

Source: Researcher (2022)

4.3 Data Reliability

Analysis of the data was done to check the true measure and consistency of responses. Conbach's Alpha coefficient of reliability was computed to measure of internal consistency of the questionnare. The higher the alpha coefficient score, the more reliable the generated scale is. Nunnaly (1978) indicated that a value of 0.700 is an acceptable reliability coefficient. In this study SPSS was used to measure internal consistency of each variable using a number constructs. The results are shown in Table 4.2 below. From this table it can be seen that Cronbach's Alpha coefficient for all the variables is above the minimum recommended of 0.7. It can therefore be concluded that the questionnaire used in this survey produced valid and reliable measurements.

Table 4.2: Data Reliability Test

Variable	Cronbach's Alpha	No. of Constructs
Planning and Coordination	0.97	11
Knowledge and Experience	0.984	15
Structural Engineering Design Software	0.863	9
Structural Engineering Design Fees	0.951	5

Source: Researcher (2022)

4.4 Respondents Characteristics

In the first sections of the questionnaire respondents were requested to give general information about themselves which was deemed necessary for this study. This included highest levels of academic qualification, years of experience in structural engineering design and the number of high-rise buildings (preferably 14 storeys and above) they had designed in the last 10 years. Table 4.3 gives a summary of this information.

Table 4.3: Respondents Academic Qualifications

Academic qualification	Frequency	Percentage Frequency
Bachelors	56	52.8
Masters	46	43.4
PhD	4	3.8
Total	106	100

Source; Researcher (2022)

From this table, the bulk of the civil engineers (52.8%) were still at the Bachelors level. A sizeable proportion of 43.4% had proceeded to attain Master's degrees and only a paltry 3.8% of the engineers had attained PhD qualification. When it came to years of experience the distribution is as shown in Table 4.4.

Table 4.4: Years of Structural Engineering Design Experience

Years of Experience	Frequency	Percentage
Less than 10	27	25.5
10 to 15	35	33.0
16 to 20	20	18.9
Over 20	24	22.6
Total	106	100

Source: Researcher (2022)

The majority of the engineers cumulatively accounting for 74.5% had at least 10 years of experience in structural engineering design. EBK (2013) defines a senior engineer as a professional engineer registered as such by the EBK and having a minimum experience of ten years from the date of registration. We can therefore infer that the respondents in this survey are of such calibre and capacity to satisfactorily handle structural engineering design matters on building projects and whose feedback is reliable. Table 4.5 below shows the frequency distribution of the number of high-rise buildings designed by the respondents.

Table 4.5: Number of high-rise building projects Designed

No. of High rise Buildings	Frequency	Percentage Frequency
None	30	28.3
1 to 10	62	58.5
11 to 20	8	7.5
Over 20	6	5.7
Total	106	100

Source: Researcher (2022)

On the basis of the threshold proposed by CTBUH, 71.7% of the respondents have designed at least one high rise building project of at least 14 storeys in the last 10 years. The proportion diminishes drastically to only 5.7% of the respondents who have designed over 20 buildings within the same period. Whereas a sizable proportion of 28.3% have not designed any high rise building that meet this threshold, they have nonetheless designed high rise buildings of fewer numbers of storeys. The bulk of the respondents at 58.5% had designed up to 10 high rise buildings within the period. Table 4.6 below gives an overview of the size of firms the respondents work in terms of number of employees.

Table 4.6: Number of employees in respondent's organization

No. of employees	Frequency	Percentage Frequency
1 to 5	34	32.9
6 to 10	20	18.1
11 to 20	12	11.3
21 to 50	10	9.4
Over 50	30	28.3
Total	106	100

Source: Researcher (2022)

A majority of the respondents 32.9% work in organizations with up to 5 employees. A cumulative 38.8% work in organizations with number of employees ranging between 6 and 50. Another 28.3% work in organizations with over 50 employees. These may represent small, medium and large engineering firms respectively. This gives a reasonable blend that covers the spectrum of the operating environment in the industry.

4.5 Descriptive statistics

In this section the research presents findings in terms of frequencies, proportions, means, modes and dispersion of data. These help to describe the outcomes.

4.5.1 Influence of Coordination of SED on Cost Certainty

In trying to answer the question of how planning and coordination of structural engineering design impacts the cost certainty of building projects, the research first, sought to find out the various methods used by engineers in coordinating their design both within their firms and with other related disciplines constituting the project team. Further the study sought to find out how their respective systems of coordination have helped in enhancing the quality of SED. Finally, some of the adverse impacts of poor or lack of coordination was investigated.

When it comes to external coordination of SED with other project team members, majority of the engineers at 50.9% relied on direct and formal contact as a way of sharing information for coordination purposes. Another 32.1% used meetings either physical or virtual to coordinate their designs. This agrees with Rahmat (2009) who found out that direct contact and meetings were the main methods of design coordination. The research however noted that only 9.4% employed the use of modern integrated design and coordination technology such as BIM while a paltry 3.8% rarely coordinated their work. This low uptake is a matter of concern given the benefits of employing such technology as shown in the studies by Nyaga (2016), Mumbua (2016) and Gitee (2018). These results are shown in table 4.7 below.

Table 4.7: Methods of SED Coordination

Methods for SED coordination	**Count**	**Total N %**
Direct formal contact e.g. through letters, emails, reports and drawings	54	50.9
Informal contact e.g. telephone, discussions and social media platforms	4	3.8
Meetings- physical or virtual	34	32.1
Integrated design and coordination technology e.g. BIM	10	9.4
Rarely done. Each professional works independently	4	3.8
Total	106	100

Source: Researcher (2022)

When it comes to quality checks of SED within their firms, 54.7% had their design process and outputs checked by an experienced engineer within or without the organization. 26.4% had established office procedures for quality checks while only 11.3% used established QMS system such as ISO 9001:2008. Interestingly 5.7% solely relied on the level of knowledge and experience of the engineer and a further 1.9% relied on the output from the design software as adequate. This is shown in table 4.8 below. The premium placed on the experience of the engineer in assuring quality of SED agrees with findings of Barton (2019) and Barker Structural (2017) as way of mitigating undesirable project outcomes such as defects and budget overruns. This is summarized in table 4.8 below.

Table 4.8: Methods of SED Quality Management

Methods of SED quality check	Count	Table N %
Review by an experienced engineer within or without the firm	58	54.7
Output from the design software is generally satisfactory	2	1.9
Rely on the designers level of knowledge and experience	6	5.7
Use of established QMS system such as ISO 9001:2008	12	11.3
Review through established office procedures	28	26.4

Source: Researcher (2022)

In terms of how the various methods of planning and coordination enhance the quality of SED, the respondents were asked to rank five statements of quality enhancement with 1 being the most significantly enhanced. The outcome is as shown in table 4.9. The most notable quality of SED enhanced by planning and coordination was narrowing of gaps, uncertainties and risks on the project which was ranked as number one by a majority of the respondents. This also had the lowest mean of 2. Better understanding of the scope of the project ranked second while fostering the establishment of roles of roles and responsibilities for the design team ranked third. Optimization of design and better monitoring and evaluation ranked fourth and fifth respectively.

The findings in table 4.9 support Jain and Singh (2012) theory of cost overruns which postulates that effort helps understand the nature and scope of the project and with sufficient effort from the designers the entire scope of the project can be captured. Gaps and errors in design and documentation can thus be reduced.

Table 4.9: Benefits of SED Coordination

Benefits of SED coordination	Mean	Max.	Min.	Std. Dev.	Mode
Helped in narrowing gaps, uncertainties and risks	2	5	1	1	1
Enhanced better understanding of the project scope	3	5	1	1	2
Fosters establishment of roles and responsibilities for the design team	3	5	1	1	3
Enables optimization and integration of design	3	5	1	1	4
Promoted monitoring and evaluation of progress and quality of design	4	5	1	1	5

Source: Researcher (2022)

Looking at the adverse effects of poor or lack of coordination on the building projects, respondents acknowledged that all the listed adverse effects were significant. Frequency of occurrence of these defects was measured using a Likert scale of 1 to 5 where 1 represented never, 2 represented rarely, 3 represented sometimes, 4 represented often and 5 represented always. The results are summarized in table 4.10. A cumulative 60.4% noted that interface conflicts with other disciplines often and always occurred. 33.9% often and always noted errors and omissions in designs and documentation, 51% often and always experienced design changes during construction, 41.5% often and always experienced schedule overruns and 28.3% eventually experienced budget overruns during construction. This information agrees with the rankings of table 4.9 where narrowing gaps, uncertainties and risks ranked as number one. These findings also corroborate Hegazy et al. (2001) and (Chiu 2002) who noted that the interdisciplinary nature of the design process lends itself to risks of having gaps and errors which if unresolved creep into the construction stage and manifest as budget overruns. The more the engineer can narrow the gaps through proper coordination, the less likely it is for the project to experience the adverse effects in table 4.10.

Table 4.10: Adverse effects of lack of coordination on SED quality

	Never %	Rarely %	Sometimes %	Often %	Always %	Total		
						Count	Mean	Std. Dev
Interface conflicts with other disciplines	1.9%	3.8%	34.0%	39.6%	20.8%	106	4	1
Omissions and errors in design and documentation	0.0%	17.0%	49.1%	24.5%	9.4%	106	3	1
Design changes during construction	0.0%	5.7%	43.4%	32.1%	18.9%	106	4	1
Schedule overruns	3.8%	20.8%	34.0%	26.4%	15.1%	106	3	1
Budget overruns during construction	11.3%	15.1%	45.3%	15.1%	13.2%	106	3	1

Source: Researcher (2022)

4.5.2 Influence of Experience of SED on Cost Certainty

As a second objective this research sought to find out the influence of knowledge and experience on cost certainty of high rise building projects. The respondents were asked to indicate their level of agreement based on 5 statements on how knowledge and years of experience impacts the quality of structural engineering design. The level of agreement was measured on a scale of 1 to 5 where 1 represented Strongly Disagree, 2 represented Disagree, 3 represented Neutral, 4 represented Agree and 5 represented Strongly Agree. What evidently come out is that the level of knowledge and experience of the engineer in charge of the project has a huge bearing on design parameters that ultimately affect cost certainty of building projects. From the table 4.11 below it can be seen that a significant proportion of respondents with a mean of 4 either agreed or strongly agreed that the level of knowledge and experience improved problem solving capabilities, improved effectiveness in use of design software, enhanced constructability of design, enhanced quality of design and documentation and improved coordination and integration of design. This corresponds to 98.1%, 96.2%, 81.1%, 81.1% and 79.2% for each of the above parameters respectively. This is in agreement with Schwinger and Meyer (2010), Feng (2015) and Ahmed, Hacker and Wallace (2005) who acknowledged the place of experience in effective project delivery. High rise building projects are complex and present unique challenges that have a bearing all facets of project delivery such as technical, financial, safety, logistical, operation and so forth. Knowledge and experience is valuable in addressing these issues.

In terms of adverse effects on the quality of SED, attributable to the level of knowledge and experience, the respondents responded as shown in table 4.12 based on the frequency of occurrence on a scale of 1 to 5 where 1 represented Never, 2 represented Rarely, 3 represented Sometimes, 4 represented Often and 5 represented Always. With an exception of structural integrity issues which the respondents said that they rarely occur with a mean of 2, all the other adverse effects had a mean of 3 indicating that they sometimes occur.

Table 4.11: Benefits of Knowledge and Experience

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree	Total		
	Row N %	Row N %	Row N %	Row N %	Row N %	Count	Mean	Std. Dev.
Improved problem solving capability	1.9	0.0	0.0	26.4	71.7	106	5	1
Improved effectiveness in use of design software	0.0	1.9	1.9	52.8	43.4	106	4	1
Enhanced design and constructability	0.0	3.8	15.1	35.8	45.3	106	4	1
Enhanced quality control of design and documentation output	3.8	5.7	9.4	35.8	45.3	106	4	1
Improved the coordination and integration of design	7.5	7.5	5.7	41.5	37.7	106	4	1

Source: Researcher (2022)

A closer study of the data from table 4.12 below indicates that errors and omissions in design and documentation can be tied to the level of knowledge and experience of the engineer in charge of the project. 41.6% acknowledged that error and omissions were often and always found in their design and documentation. Only 11.3% of the respondents claimed that their projects rarely or had never been adversely affected.

Table 4. 12: Adverse effects attributable to Knowledge and experience

	Never	Rarely	Sometimes	Often	Always	Total		
	Row N %	Row N %	Row N %	Row N %	Row N %	Count	Mean	Std. Dev.
Errors and omissions found in designs and documentation	1.9	9.4	47.2	20.8	20.8	106	3	1
Coordination gaps with other disciplines	1.9	11.3	43.4	34.0	9.4	106	3	1
Contractual disputes	13.2	37.7	35.8	9.4	3.8	106	3	1
Cost escalations due to variations/reworks	1.9	26.4	34.0	20.8	17.0	106	3	1
Delays in project works	7.5	18.9	35.8	26.4	11.3	106	3	1
Structural integrity issues	28.3	32.1	24.5	3.8	11.3	106	2	1

Source: Researcher (2022)

Another 43.4% of the respondents acknowledged that their building projects had often and always been adversely affected in terms of having coordination gaps with other disciplines. These gaps eventually had to be addressed in the course of construction with varying degrees of implications to the project. Variations during construction with resultant cost escalations and delays in project works were similarly noted as significant outcomes related to the level of knowledge and experience of the engineer. Respectively, a total of 37.8% and 37.7% of the respondents acknowledged these adverse effects on their projects as occurring often and always. Contractual disputes and adverse effects on the structural integrity of the building projects were noted to be the least prevalent affects related to knowledge and experience of the engineer with 50.9% and 60.4% of the respondents reporting that this never or rarely occurred. These research findings agree with Jain and Singh (2012) that knowledge and experience plays a vital role in capturing the scope and consequently the completeness of design.

4.5.3 Influence Structural Engineering Design Software on Cost Certainty

To find out more about the contribution of structural engineering software on cost certainty of building projects, this research sought to find out the kind of software engineers used in design, factors that influenced their choice of those software, challenges when using them and how these challenges have affected their building projects. In table 4.13 below 67.9% of the engineers used a combination of software and manual methods for design and documentation purposes. None of them used manual methods solely as the design tool. This indicates that the practitioners have embraced the technology in their design work process. For coordination purposes, 77.4% used software while a sizeable 22.6% still used manual methods. When compared with table 4.7 there is a disparity since only 9.4% used BIM software when it comes to coordination. This could imply that although they use software, the majority do not use the appropriate software with BIM capability for coordination. The distribution is shown in table 4.13 below.

Table 4.13: Level of Design Software Usage

		Count	**Total N %**
Tools for structural design and documentation of high rise building projects	Manual	0	0.0
	Software	34	32.1
	Both	72	67.9
	Total	**106**	**100.0**
Tools for design integration, coordination and collaboration	Manual	24	22.6
	Software	82	77.4
	Total	**106**	**100.0%**

Source: Researcher (2022)

The cost of purchase of design software and licences was ranked as the number one consideration that influenced the respondent's choice of design software. This was closely followed by the versatility and ease of use. Quality of output from the software came in third position. The least consideration was given to interoperability and the information sharing capability of the software. This is however very key for coordination purposes particularly in the current dispensation where the focus of design is towards collaboration and integration. The summary is shown in table 4.14 below.

Table 4.14: Factors influencing choice of design software

Choice of software	Mean	Max	Min	Std Dev	Mode
Cost of purchase and licenses	2	4	1	1	1
Versatility and ease of use	2	4	1	1	2
Quality of output	2	4	1	1	3
Interoperability/information sharing capability	3	4	1	1	4

Source: Researcher (2022)

Cost being a major consideration in the choice of design software the engineers resorted to use in their design, the research sought to find out the some of the challenges of the current software. On a scale of 1 to 5 with 1 representing Never, 2 representing Rarely, 3 representing Sometimes, 4 representing Often and 5 representing Always, respondents were asked to select the frequency of occurrence of four common challenges associated with design software. On average all the respondents agreed that all the four challenges sometimes occur in their design with a mean of 3. A Closer analysis shows some interesting outcomes. 47.1% reported that they often and always experienced the challenges of limitations in modelling, visualization and simulation of complex buildings. It would then imply that a likelihood of omissions, errors and gaps to occur in the design output. 37.7% often and always had difficulty in coordination, collaboration and integration with designs of other team members. 24.5% often and always lacked flexibility in effecting design changes and synchronizing documentation while 20.7% often and always had flaws and gaps in design and documentation.

Table 4.15: Challenges of current SED software

	Never	Rarely	Sometimes	Often	Always	Total		
	Row N %	Row N %	Row N %	Row N %	Row N %	Count	Mean	Std Dev
Limitations in modelling, visualization and simulation of complex building projects	0.0	20.8	32.1	39.6	7.5	106	3	1
Flaws and gaps in designs and documentation	11.3	13.2	54.7	11.3	9.4	106	3	1
Lack of flexibility in effecting design changes, updating and synchronizing documentation	5.7	24.5	45.3	17.0	7.5	106	3	1
Difficulty in coordination, collaboration and integration with designs of other team members	3.8	11.3	47.2	26.4	11.3	106	3	1

Source: Researcher (2022)

On average about 23.5% of all respondents often experienced these challenges and about 9% always experienced all these challenges. This is summarised in table 4.15 above.

Table 4.16 below presents the adverse effects of the current software used by the respondents on the quality of SED. The greatest adverse impact on quality attributable to the kind of design software used by engineers is the effect on the accuracy of the pre-tender cost estimates used for procurement. Inaccurate pre-tender estimates usually manifest later on in the construction phase when variations occur. They are indicative of gaps and flaws in the designs. This is a precursor to cost overruns during construction. Delays in issuing information and resolving interfaces as well as cost escalations due to variations during construction came in at second and third position respectively. Contractual disputes were the least adverse impacts attributable to SED software. This results agree with Olga and Andy (2003) and Otero (2012) who recognized the importance of integrated CAD software in not only solving complex building projects but also eliminating errors.

Table 4.16: Adverse effects of current SED software

	Mean	**Mode**	**Max**	**Min**	**Std. Dev**
Affected the accuracy of pre-tender cost estimates used for procurement	2	1	4	1	1
Caused delays in issuing information and resolving interfaces	2	2	4	1	1
Resulted in cost escalations due to variations during construction	3	3	4	1	1
Contributed to contractual disputes with other parties	3	4	4	1	1

Source: Researcher (2022)

In terms of uptake and use of BIM software for coordination and integration of SED with other disciplines on building projects 70 respondents representing 66% of the population did not use it. 34% of the respondents reported use the technology. However compared with table 4.7 where only 9.4% reported to be using BIM for coordination, it shows the level of inconsistency in use of this technology. The 66% cited various reasons for not using the technology. The largest proportion (38.6%) stated that the BIM was not yet embraced in the industry. Another 30% cited the high cost of the technology as a hindrance. 18.6% considered their current software to be just sufficient for the job while 12.8% confirmed not having knowledge or capacity to use BIM. The low uptake of BIM in spite of the immense benefits highlighted by Hunt (2013) and other researchers and practitioners is a matter requiring further review. This is summarized in table 4.17 below.

Table 4. 17: Reasons for not using BIM

	Count	**Total N %**
High cost of the BIM technology	21	30.0
Satisfied with current software	13	18.6
Lack of knowledge and capacity to use BIM technology	9	12.8
BIM not yet embraced in most of projects that I undertake	27	38.6
TOTAL	70	100

Source: Researcher (2022)

4.5.4 Influence of SED Fees on Cost Certainty

On the issue of fees and its impact on cost certainty on high rise building projects, the research sought to find out how much fees structural engineers charge for their services, how the fees is determined, whether or not the amount of fees affects the quality of SED and more importantly what aspects of SED that have a bearing on cost certainty are adversely affected by issues related to fees. Out of 106 respondents, 76 out of the 106 representing 71.7% reported that the amount of fees payable affects the quality of SED. When it comes to methods of charging fees and how the fees is determined, the respondents' feedback is summarize in table 4.18 below.

Table 4.18: Methods of charging SED fees

		Count	Total N %
Methods of charging SED fees on high rise building projects	Time Based	14	13.2
	Percentage	56	52.8
	Lump sum	36	34.0
	Total	**106**	**100.0%**
How fees is determined	Directly negotiated with Architect/P.M	38	35.8
	As prescribed by relevant statutes	8	7.5
	Decided by the Architect/P.M	58	54.7
	Decided by the Client	2	1.9
	Total	**106**	**100.0%**

Source: Researcher (2022)

A majority of the engineers at 52.8% charge their SED fees mostly as a percentage of the total building project cost. Those who mostly charged fees as Lump sum or on time basis accounted for 34.0% and 13.2% respectively. In seeking to understand how the fees was determined, 54.7% of the respondents interestingly confirmed that whichever the method of billing that was adopted for the high rise building projects, the amount of fees was decided by the Architect or project Manager. Those who negotiated their own fees stood at 35.8% while those whose fee was as prescribed by relevant statues came a distant third at 7.5%. A paltry 1.9% of the engineers had their fees decided by the client. Ashworth (2004) noted that whereas professional bodies set scales of fees for their members the reality on the ground is that market forces prevail thus opening up the space for negotiations. This appears to be the case from these results.

For the majority of respondents (52.8%) when using the percentage method of billing, charged SED fees of between 1.5% and 2.5% of the project cost. A sizeable proportion of 35.8% charged less than 1.5% and only 11.3% charged fees of between 2.6% and 4.0% of the project cost. The distribution is summarized in table 4.19. The two most critical issues related with fees, and having adverse effect on the quality of SED in order of priority according to the respondents was low amounts of fees and delays in payment. From this summary cumulatively 88.6% of the respondents charged not more than 2.5% of the project cost.

Table 4.19: SED fees charging distribution

		Count	Total N %
Amount of fees as a percentage of project cost.	Less than 1.5	38	35.8
	1.5 - 2.5	56	52.8
	to 2.6 4.0	12	11.3
	Total	106	100.0

Source: Researcher (2022)

The research then sought to find out how the amount of fees impacts on the operations of the engineers. The feedback is as shown in table 4.20.

Table 4.20: Impacts of low SED fees on the firm

	Mean	Mode	Max	Min	Std. Dev
Capacity to employ competent engineers for the project	2	1	3	1	1
Ability to procure, train and use of appropriate design software	2	2	3	1	1
Ability enhance motivation and commitment of the design team	2	3	3	1	1

Source: Researcher (2022)

In terms of actual impacts on the quality of SED, the respondents ranked capacity to employ competent engineers for the project as number one followed by the ability to procure and use appropriate design software. In third place the amount of fess affected the ability to enhance motivation and commitment of the design team.

On a scale of 1 to 5 with 1 representing Never, 2 representing Rarely, 3 representing Sometimes, 4 representing Often and 5 representing Always, the respondents were asked to the select the frequency of occurrence of four adverse effects associated with low amount of fees on their high-rise building projects. All the four returned a mean of 3 indicating that these effects sometimes occur. This is summarized in table 4.21 below

Table 4. 21: Adverse effects of low fees payment on the project

	1	**2**	**3**	**4**	**5**	**Total**		
	Row N %	Row N %	Row N %	Row N %	Row N %	Count	Mean	Std. Dev
Flaws and gaps in design and documentation	5.7	15.1	47.2	20.8	11.3	106	3	1
Design related variations during construction	1.9	13.2	32.1	39.6	13.2	106	3	1
Delays and stoppages of Works	9.4	18.9	43.4	17.0	11.3	106	3	1
Inadequate resources for supervision of Works	9.4	17.0	22.6	35.8	15.1	106	3	1

Source: Researcher (2022)

Notably table 4.21 above indicates that 32.1% noted that flaws and gaps in design and documentation often and always occurred. Only 20.8% reported that such effects never or rarely occurred. In addition, 52.8% noted that design related variations often and always occurred during construction due to fees related issues. 43.4% noted that low fees and or delayed payments sometimes resulted in work stoppages while 50.9% reported that it often and always resulted in inadequate provision of resources for supervision of works. This agree with Kariuki (2019) who reckons that compensation system influences organization success by motivating, energizing and directs behaviour in addition to attracting and retaining qualified, high performing workers. Well compensated engineers are likely to be more committed and keen with their work.

4.6 Inferential statistics

In line with the main objective of this study which was to find out how the quality of SED affects the cost certainty of high-rise building projects, this section draws inferences from the data obtained by assessing the relationship between the answers to different questions. According to Syagga (2019), the underpinning objective of research is to enable generalization of results obtained from samples to populations. It seeks to determine how likely it is for the results obtained from a sample to be similar to results expected from the entire population. This is accomplished by hypothesis testing and testing for significance using parametric and non-parametric approaches. In this section the bearing of the four independent variables i.e. Coordination of SED, Experience, Structural Engineering Design Software and SED Fees on the cost certainty of high rise building projects is tested for statistical significance by cross table analysis

4.6.1 Significance of SED Coordination

In order to accomplish this cross table analysis between methods of SED coordination and enhancement of the quality of SED. This was followed by analysis of variance (ANOVA) to establish the level of significance between the constructs. Results are summarized in table 4.22.

Table 4.22: Significance testing of Coordination

ANOVA Table							
			Sum of Squares	df	Mean Square	F	Sig.
Enhances and better understanding of the project scope * Methods used to coordinate SED issues with project team	Between Groups	(Combined)	14.171	4	3.543	2.792	.030
		Linearity	3.431	1	3.431	2.704	.103
		Deviation from Linearity	10.740	3	3.580	2.821	.043
	Within Groups		128.169	101	1.269		
	Total		142.340	105			
Enables optimization and integration of design * Methods used to coordinate SED issues with project team	Between Groups	(Combined)	17.164	4	4.291	2.920	.025
		Linearity	8.967	1	8.967	6.102	.015
		Deviation from Linearity	8.197	3	2.732	1.859	.141
	Within Groups		148.421	101	1.470		
	Total		165.585	105			
Promotes monitoring and evaluation of progress and quality of design * Methods used to coordinate SED issues with project team	Between Groups	(Combined)	69.875	4	17.469	14.573	.000
		Linearity	12.989	1	12.989	10.836	.001
		Deviation from Linearity	56.886	3	18.962	15.819	.000
	Within Groups		121.068	101	1.199		
	Total		190.943	105			

Source: Researcher (2022)

The various methods of coordination were statistically significant in so far as enhancing better understanding of the project, enabling optimization and integration of design and promotion of evaluation, monitoring and quality of design with P- values of 0.03, 0.025 and 0.000 respectively.

In addition, analysis of the various quality management systems employed by engineers versus the frequency of occurrence of adverse effects on projects also showed statistical significance for constructs such as errors and omissions in design and documentation and budget overruns. This ANOVA is shown in table 4.23 below.

Table 4.23: ANOVA: Adverse impacts due to Coordination challenges

ANOVA Table							
			Sum of Squares	df	Mean Square	F	Sig.
Omissions and errors in design and documentation * Quality management systems used in the organisation	Between Groups	(Combined)	7.344	4	1.836	2.678	.036
		Linearity	2.479	1	2.479	3.615	.060
		Deviation from Linearity	4.865	3	1.622	2.365	.075
	Within Groups		69.259	101	.686		
	Total		76.604	105			
Budget overruns during construction * Quality management systems used in the organization	Between Groups	(Combined)	21.435	4	5.359	4.731	.002
		Linearity	9.416	1	9.416	8.312	.005
		Deviation from Linearity	12.020	3	4.007	3.537	.017
	Within Groups		114.414	101	1.133		
	Total		135.849	105			

Source: Researcher (2022)

Analysis of variance shows significance between the methods of quality assurance and omissions and errors in design and documentation as well as budget overruns during construction. Table 4.24 presents the measures of association and direction of relationships.

Table 4.24: Measures of association of Coordination constructs

Measures of Association				
	R	R^2	Eta	Eta Squared
Omissions and errors in design and documentation * Quality management systems used in the organization	-.180	.032	.310	.096
Budget overruns during construction * Quality management systems used in the organization	-.263	.069	.397	.158

Source: Researcher (2022)

From this table it can be inferred that the negative R value reveals that budget overruns and errors in design and documentation decrease when coordination effort geared to enhancing quality of SED is increased. Since the P values from the ANAOVA are less than the level of significance α=0.05, it implies that a correlation exists between the constructs.

4.6.2 Significance of SED Experience

In order to make meaningful inferences on the influence of experience on cost certainty, cross table analysis of number of years of experience of the engineer versus their influence on the quality of SED was done. This was followed by Chi-Square analysis to measure significance between the constructs involved. The summary in table 4.25 below shows that years of SED experience was correlated to quality since it improved problem solving capability as well as coordination and integration of design. The two constructs have a P-value of 0.031 and 0.02 respectively which is less than level of significance α=0.05

Table 4.25: Chi-Square: Years of experience vs. benefits to SED Quality

Pearson Chi-Square Tests		
		Years of SED experience
Improves problem-solving capability	Chi-square	13.881
	df	6
	Sig.	0.031*
Improves the coordination and integration of design	Chi-square	30.357
	df	12
	Sig.	0.002*
*. The Chi-square statistic is significant at the .05 level.		

Source: Researcher (2022)

This statistical significance implies that these factors have a bearing on cost certainty of high-rise building projects. In addition, cross table analysis of years of experience versus the adverse effects on building projects attributable to the level of experience produced significant results. These are shown in the table 4.26 below.

From the Chi-Square test able in table 4.26 it can be inferred that years of SED experience is statistically significant with respect to errors and omissions in designs and documentation, coordination gaps with other disciplines, cost escalations due to variations and reworks, delays in project works and structural integrity issues. The P-values in all these constructs is less than the significance level $\alpha=0.05$.

The strength and directional relationships is shown by the R and R^2 values (Table 4.27). R is negative indicating an inverse relationship between experience and the various constructs that influence cost certainty.

Table 4.26: Chi-Square: Years of experience vs. adverse effects on SED Quality

Pearson Chi-Square Tests		
		Years of SED experience
Errors and omissions found in designs and documentation	Chi-square	46.931
	df	12
	Sig.	.000*,
Coordination gaps with other disciplines	Chi-square	36.419
	df	12
	Sig.	.000*
Cost escalations due to variations and reworks	Chi-square	42.220
	df	12
	Sig.	.000*
Delays in project works	Chi-square	31.747
	df	12
	Sig.	.002*
Structural integrity issues	Chi-square	35.826
	df	12
	Sig.	.000*,
*. The Chi-square statistic is significant at the .05 level.		

Source: Researcher (2022)

So it can be said that increasing experience results in reduction in errors and omissions, coordination gaps, cost escalations due to variations, delays in projects works and well as structural integrity issues. Consequently, the cost certainty is increased. On the basis of this Chi-Square analysis it can be inferred that there is a correlation between the experience in SED and the constructs that affect quality of SED.

Table 4.27: Measure of Association of experience constructs

Measures of Association				
	R	R^2	Eta	Eta Squared
Errors and omissions found in designs and documentation * Years of experience in SED	-.323	.104	.327	.107
Coordination gaps with other disciplines * Years of experience in SED	-.058	.003	.253	.064
Contractual disputes * Years of experience in SED	-.146	.021	.282	.079
Cost escalations due to variations/reworks * Years of experience in SED	-.468	.219	.505	.255
Delays in project works * Years of experience in SED	-.401	.161	.464	.215
Structural integrity issues * Years of experience in SED	-.305	.093	.361	.130

Source: Researcher (2022)

4.6.3 Significance of SED Software

Cross table analysis between various constructs related with design software and budget overruns was used to make determine correlation. In the first instance the type of design software used and adverse effects experienced on building projects was analysed. The influence of design software in terms of affecting accuracy of pretender estimates used for procurement and delays in issuing information and resolving interfaces were found to be statistically significant with P-Values of 0.001. This analysis of variance is summarised in table 4.28.

Table 4.28: ANOVA: Design software vs. project challenges

ANOVA Table							
			Sum of Squares	df	Mean Square	F	Sig.
Affects accuracy of pre-tender cost estimates * Type of SED software used	Btw Groups	(Combined	10.315	1	10.315	11.050	0.001
	Within Groups		97.082	104	0.933		
	Total		107.396	105			
Delays in issuing information and resolving interfaces * Type of SED software used	Btw Groups	(Combined)	7.727	1	7.727	11.442	0.001
	Within Groups		70.235	104	0.675		
	Total		77.962	105			

Source: Researcher (2022)

Another cross table analysis between the challenges of the respondents current design software and the resultant budget overrun beyond the pre-construction estimates in their projects portfolios also showed significance. Chi-Square test results are presented in table 4.29 below. The P-Values of all the constructs that measure efficacy of design software and their impacts on budget overruns on high-rise building projects were found to be less than the significance level α=0.05.

Table 4.29: Chi-Square: Budget overruns vs. Design software challenges

Pearson Chi-Square Tests		
		Average project budget overrun beyond the pre-construction budget
Limitations in modelling, visualization and simulation of complex building projects	Chi-square	29.260
	df	12
	Sig.	.004*
Flaws and gaps in designs and documentation	Chi-square	39.033
	df	16
	Sig.	.001*
Lack of flexibility in effecting design changes, updating and synchronizing documentation	Chi-square	48.204
	df	16
	Sig.	.000*
Difficulty in coordination, collaboration and integration with designs of other team members	Chi-square	62.972
	df	16
	Sig.	.000*
*. The Chi-square statistic is significant at the .05 level.		

Source: Researcher (2022)

This statistical significance implies that the variables are correlated.

4.6.4 Significance of SED Fees

Cross table analysis of amount of fees charged by engineers as a percentage of the building project cost versus related adverse effects on high-rise building projects showed statistical significance for all the constructs as shown in the Chi-Square summary shown in table 4.30. All the constructs returned a P-value of less than the level of significance α=0.05. These constructs are therefore correlated with the amount of SED fees charged.

Table 4. 30: Chi-Square: SED fees vs. adverse effects on high-rise building projects

Pearson Chi-Square Tests		
		SED Fees as percentage of the building project cost
Flaws and gaps in design and documentation	Chi-square	35.992
	df	8
	Sig.	.000*
Design related variations during construction	Chi-square	15.887
	df	8
	Sig.	.044*
Delays and stoppages of Works	Chi-square	20.884
	df	8
	Sig.	.007*
Inadequate resources for supervision of Works	Chi-square	21.462
	df	8
	Sig.	.006*
*. The Chi-square statistic is significant at the .05 level.		

Source: Researcher (2022)

R which is a measure of direction shows an inverse relationship between the amount of fees and all the constructs which affect cost certainty. This is shown in Table 4.31. It follows that increasing fees has an effect of reducing flaws and gaps in designs and documentation, building related variations, delays and stoppages of works as well as tendencies to have inadequate resources for supervision.

Table 4.31: Measure of association SED fees vs. adverse effects on building projects

Measures of Association				
	R	R Squared	Eta	Eta Squared
Flaws and gaps in design and documentation * SED Fees as percentage of the building project cost	-.065	.004	.194	.038
Design related variations during construction * SED Fees as percentage of the building project cost	-.051	.003	.234	.055
Delays and stoppages of Works * SED Fees as percentage of the building project cost	-.169	.028	.178	.032
Inadequate resources for supervision of Works * SED Fees as percentage of the building project cost	-.196	.038	.221	.049

4.6.5 Hypotheses testing

Null hypotheses H_0: The quality of structural engineering design has no influence on the cost certainty of high-rise building projects. Evidence from the research was used to test the Alternative Hypothesis H_1: The quality of structural engineering design has an influence on the cost certainty of high-rise building projects. To accomplish this goal cross table analysis was done between the four independent variables namely design coordination of SED, level of experience in SED, the kind of software used in SED and the amount of SED fees paid and the resulting budget overruns on building projects. This was followed by ANOVA. From the analysis all the four variables were found to be statistically significant with P- values less than the level of significance α=0.05. On this basis the null hypotheses H_0 is rejected and the alternative hypotheses H_1: The quality of structural engineering design has an influence on the cost certainty of high-rise building projects is supported. The summary of these results are shown in table below 4.32 below.

Table 4.32: ANOVA: All independent variables vs. Budget overruns

		Sum of Squares	df	Mean Square	F	Sig.
The kind of structural design software/tools used	Between Groups	12.535	3	4.178	3.456	.019
	Within Groups	123.314	102	1.209		
	Total	135.849	105			
Experience of the structural engineer	Between Groups	17.040	3	5.680	4.876	.003
	Within Groups	118.810	102	1.165		
	Total	135.849	105			
The amount of structural design fees for the project	Between Groups	11.430	3	3.810	3.123	.029
	Within Groups	124.419	102	1.220		
	Total	135.849	105			
Coordination of the structural design	Between Groups	10.480	3	3.493	2.842	.042
	Within Groups	125.369	102	1.229		
	Total	135.849	105			

Source: Researcher (2022)

CHAPTER FIVE: SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction

This research sought to find how the quality of structural engineering design influences cost certainty of high-rise building projects. In order to do this, the research investigated the underlying issues that bear on the quality of structural engineering design. The factors that were considered in this study were coordination of SED, experience in SED, SED design software and SED fees. This chapter presents a summary of critical findings of how each of these variable influences the cost certainty of building projects. This summary is derived from the output of data analysis which is presented and discussed in chapter four. Out of these, recommendations are given and finally suggestions of areas for further research are outlined.

5.2 Summary of Research Findings

The descriptive and inferential statistics in chapter four have shown how the four independent variables influence cost certainty. ANOVA and Chi-Square tests show that the independent variables are statistically significant with respect to the influence they have on structural engineering design quality aspects that ultimately bear on cost certainty of high-rise building projects. This implies a correlation between the independent variables and the dependent variable. Measures of association showed an inverse linear relationship between the independent variables and constructs that have adversarial effects on quality of SED design of high-rise building projects. Specific findings are summarized for each variable in the subsequent sections.

Coordination in projects aims at capturing the entirety of scope integrating all the work packages from different consultants into one whole. Interface conflicts with other disciplines and design changes that creep into the construction stage were noted as the most adverse effects associated with lack of or poor coordination. These two constructs has the highest mean of four as shown in table 4.10. The two major benefits of planning and coordination identified by this research were helping in narrowing gaps, uncertainties and risks as well as enhancing better understanding of the project scope. This is shown in table 4.9. It was however noted that although majority of engineers have some form of coordination measures in their workflow processes such as office procedures, review by experienced engineers, only 9.4% have embraced modern use of BIM technology which is touted to be more efficient according to Mumbua (2016).

Experience in SED significantly influences the capacity of engineers to solve project problems as well as coordinate and integrate SED with other disciplines. Results in table 4.11 show that these two constructs had the highest means of five and four respectively. Experience also contributes to effective use of design software, enhanced linkages of design and constructability as well as quality control of design and documentation. These constructs had an equally high mean of four. In addition a premium is placed on experienced engineers to coordinate quality management of SED within engineering firms. The largest proportion of respondents at 54.7% used experienced engineers for this work as shown in table 4.8. Importantly table 4.12 reveals that at least 37.7% of respondents reported that errors in designs and documentation, coordination gaps with other disciplines, variations and reworks and delays in projects works often and always occurred in their projects due to SED experience related issues.

From table 4.20, the amount of fees payable for SED was found to have the greatest influence on the capacity of engineering firms to employ competent engineers for their high-rise building projects. In addition it influences the ability to procure, train and use appropriate design software. Interestingly, a majority of engineers at 54.7% had no control in the determination of their own fees. For this proportion, their fees was determined by the project manager or architect as shown in table 4.18. With a majority of engineers at 52.8% of the respondents charging their fees at between 1.5% and 2.5% of the projects cost as shown in table 4.19, this research has shown that low fees is associated with adverse effects such as flaws and gaps in designs and documentations, design related variations during construction, delays and stoppages of works and inadequate provision of resources for supervision of works.

The greatest influence design software have on a cost certainty of building projects is the accuracy of the pre-tender cost estimates used for procurement as shown in table 4.16.Whereas all engineers reported to be using software for design and documentation, only 9.4% used software with integrated design and coordination capability such as BIM as shown in table 4.7. This disjointed approach to design and documentation could be contributing factor to the inaccuracies in pre-tender documents. A strong linkage was also established between fees charged and the kind of software used. Low uptake of modern integrated design software was attributed to high cost of purchase and licences as shown in table 4.14. Left with their current software present a number of challenges such as limitations in modelling complex buildings, inflexibility in effecting design changes, updating and synchronizing project documentation and flaws and gaps in design and documentation with a mean of three as shown in table 4.15

Thus increasing levels SED coordination, being more knowledgeable and experienced, increasing the amount of SED fees and using more efficient design software have an effect of reducing adversarial effect on the quality of structural engineering design .The quality of SED in terms of completeness, accuracy, integration and build-ability is therefore enhanced and the cost certainty of the building projects subsequently increases.

5.3 Conclusion

This research has shown that any adversarial influence on the quality of structural engineering design in terms of its level of completeness, accuracy, integration and build-ability has the effect of reducing the cost certainty of building projects and vice versa. In this study four factors that affect quality of SED were investigated. From data analysis this research has shown that the level of SED Coordination, SED experience, the amount of SED fees and the kind of SED software used in design and documentation have an influence the quality of SED and consequently on the cost certainty of high-rise building projects. Therefore high cost certainty can be achieved by exerting tighter control on the factors that have an adverse effect on the quality of structural engineering design and thereby avoid the problem of seeking more funding as describe by Lopez, Craige and Gransberg (2016).

5.4 Recommendations

Structural engineering practitioners as well as other professionals in the construction industry should endeavour not only to establish functional quality management procedure within their operations but also to shift from disjointed working and adopt design solutions that allow project teams to work collaboratively on the same model. Such solutions include using BIM platform. Whereas these solutions may require higher initial investment and training, the benefits of consistent use would outweigh the initial investment in the long term.

Experience in SED is a premium asset for both the practitioners and clients who employ their services. Developers, project managers and any procurement entities of engineering services should be sensitised on the pitfalls of employing inexperienced engineers on their high-rise building projects. Public awareness should be enhanced and sustained by government institutions, media and professional bodies through different forums to educate the stakeholders. Stakeholders such as government institutions, procurement entities, financiers, sponsors, private developers, corporate institutions and project managers should make it a policy to only engage engineers with requisite knowledge and experience in their building projects.

Solid engineering knowledge is foundation for practice and experience. University engineering education should be reviewed and aligned to the current industry needs. Practitioners should broaden their knowledge by pursuing graduate studies and other forms of professional certifications. Professional regulatory bodies such as EBK should reach out more and continue revamping their policies to equip their members with relevant skills to address the various challenges in the sector.

Professional engineering fees should be reviewed and engineers allowed to negotiate their own fees at the earliest opportunity during the project formulation process on the basis of the nature of projects, associated risks, scope but also within a legal framework that sets guiding parameters to avoid exploitation and price undercutting. To this effect, the draft Scale of Fees for professional Engineering Services, 2020 by EBK should be prioritized and fast-tracked. It may also be necessary to harmonize all legislation touching on matters fees for the various professionals in the built environment. EBK, AAK, BORAQS, IQSK, IEK and other regulatory bodies in the built environment should come together and deliberate on this matter.

The importance of using appropriate design software for practitioners in the construction industry cannot be overlooked. To meet the expectations of the modern world characterised by increasing numbers of high-rise and complex building particularly in cities, engineers must embrace cutting edge design solutions that are efficient and minimize errors. Stand-alone engineering design software that handle design, documentation and coordination separately should be discarded in favour of more integrated and collaborative solutions that integrate workflow processes of design and documentation. This calls for investment in terms of capital as well as human resource development in the use of the available technological solutions such as BIM

5.5 Suggested Areas for Further Research

For further research the following areas are suggested:

i. Deeper experimental investigation of this subject for better understanding of impact of variables, their relative importance and relationship. The prevailing covid-19 pandemic, time and resource constraints limited this scope of study.
ii. Investigation of specific skill sets and expertise that are critical for each cadre of professional in the construction industry in order to address challenges of quality, cost, schedule and risk among others. Experience was noted to be very critical in managing cost certainty and therefore it would be helpful to find out sets of knowledge and skills that can be pursued by practitioners in order to bolster their capacity to holistically handle projects from both technical and non-technical perspectives.
iii. Best practices that can be adopted when it comes to planning and design coordination and integration. The research found out that majority of engineers use formal contacts and meetings to coordinate, while in terms of quality control most rely on individual office procedures and experienced engineers to check output. Few use BIM and QMS such as ISO. There is opportunity to find out how effective these methods are and how they can be improved or adoption of best practices known to improve quality.

iv. Investigation of specific SED software used by construction industry members and how these compare with software used in more progressive and advanced economies or sectors known for better project quality control.
v. In Kenya scales of professional fees is yet to be firmly established. Given the bearing fees has on quality it would be important to look at this in more detail using case studies in other sectors of the economy and professional bodies both within and without the country to getter more insight on best practices in the management of professional engineers' fees.

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APPENDIX I: AUTHORIZATION LETTER

UNIVERSITY OF NAIROBI

DEPARTMENT OF REAL ESTATE & CONSTRUCTION MANAGEMENT

P.O. Box 30197, 00100 Nairobi, KENYA, ***Tel: No. +254-020-491 3532***

E-mail: *dept-cmqs@uonbi.ac.ke*

Ref: B53/11833/2018 **Date:** 10th February, 2021

To Whom It May Concern

Dear Sir/Madam,

RE: RESEARCH LETTER – WASWA SIMIYU GAMMALIEL

This is to confirm that the above named is a student in the Department of Real Estate & Construction Management pursuing a course leading to the degree of M.A. Construction Management.

He is carrying out a research entitled '***Impact of Structural Engineering Design Quality Determinants on Cost Certainty of High Rise Building Projects in Nairobi County***' in partial fulfillment of the requirements for the degree programme.

The purpose of this letter is to request you to allow him access to any kind of material he may require to complete his research. The information will be used for research purposes only.

CHAIRMAN
DEPARTMENT OF CONSTRUCTION MANAGEMENT AND QUANTITY SURVEYING
UNIVERSITY OF NAIROBI

Arch. Peter Njeru
Ag. Chairman & Lecturer,
Department of Real Estate & Construction Management

APPENDIX II: REQUEST TO EBK FOR DATA

Waswa Simiyu Gammaliel,
Reg. No.: B53/11833/2018,
P.O Box 4267-00100,
Nairobi.
Tel: 0722285710.
E-mail: waswasg.@students.uonbi.ac.ke.

8TH April, 2021.

The Registrar,
Engineers Board of Kenya,
P.O BOX 30324-00100.
Nairobi.

Dear Sir,

RE: REQUEST FOR DATA FOR MASTERS DEGREE RESEARCH PROJECT.

I am finalist student pursuing a Master of Arts degree in Construction Management at the University of Nairobi. I am also a professional engineer registered with the Engineers Board of Kenya (Reg No. A-2668) and a Corporate member of the Institution of Engineers of Kenya (Reg. No. M-3293).

My research is entitled ***"Impact of Structural Engineering Quality Determinants on Cost Certainty of High- Rise Building Projects in Nairobi County".*** The objective is to find out how various factors bear on quality of design and subsequently on cost of the building projects. The ever ballooning urban population presents huge challenges of accommodation among other issues such as transport, waste management, water, security, food security, health e.t.c. The situation is exacerbated by limited and prohibitive cost of land. Consequently the trend in most cities worldwide is to build upwards rather than horizontally hence the upsurge of high rise buildings. Nairobi, Kenya's capital city is not an exception. This research focuses on high rise buildings of 14 storeys and above, a threshold for tall buildings as defined by Council on Tall Buildings and Urban Habitat.

Structural engineers play a pivotal role in designing these towers owing to their complexity and stringent requirements to adequately sustain the fierce loads they are subjected to. The make-up of such buildings is therefore predominantly structural in nature and therefore accounts for a significant proportion of the cost of the project. Anything that has a bearing on the quality of structural design will in turn affect the cost certainty of the project.

Understanding the factors that affect the quality of structural design in terms of its adequacy, completeness, level of integration with other disciplines and its build-ability will go a long way in addressing the root challenges of cost certainty and related cost escalations. Further, the findings will benefit all stakeholders in the construction industry in formulating policies that promote best practices geared towards provision of quality services.

This research will immensely benefit from The Engineers Board of Kenya (EBK) pursuant to its objectives in section 7 (1) (a) to (x) of the engineers act 2011. The respondents of this research are consulting structural engineers within Nairobi as contained in the database of your registered consulting engineers. The research hopes to gain insights on how knowledge and experience, design fees, collaboration and design tools bear on the quality of structural design and subsequently on the final cost of the project. The quantity surveyors will be helpful in giving tangible cost variation associated with any structural design aspects.

In this regard I am kindly requesting for your assistance in getting names, mobile and e-mail address of consulting structural engineers within Nairobi. This will form the sample frame for the research. This data will strictly be used for this research and treated with utmost confidentiality. Attached is an introductory letter from the university department for your further review.

I thank you and look forward to your favourable response.

Yours faithfully,

Waswa Simiyu Gammaliel

APPENDIX III: QUESTIONNAIRE

Influence of the Quality of Structural Engineering Design on Cost Certainty of High Rise Building Projects in Nairobi County.

Structural engineering design is central in the successful delivery of high rise building projects. It does not only ensure integrity of the building and thereby safeguard public safety but also significantly bears on the cost and hence the investment dynamics of the project. High rise building projects are predominantly structural in nature and its building blocks constitute the largest proportion of the overall project cost. Factors that bear on the quality of structural design in terms of completeness, accuracy, integration and build-ability inevitably affect the cost certainty of these projects (i.e the probability that the project will be completed within the agreed pre-construction budget). This research investigates these factors in order to appreciate their impact and provides opportunity for intervention measures to be instituted by practitioners, regulators, policy makers, developers, financiers and other stakeholders for the benefit of the building industry. Your participation in this survey as a practitioner is very key and will go along way in attaining this overarching objective. There is no requirement for identification and this information will be treated with utmost care and confidentiality. Thank you.

* Required

1. What is your highest academic qualification? *

Mark only one oval.

- ⬭ Bachelors
- ⬭ Masters
- ⬭ PhD

2. How many years of structural engineering design experience do you have? *

Mark only one oval.

- ⬭ Less than 10
- ⬭ 10 to 15
- ⬭ 16 to 20
- ⬭ Over 20

3. How many high rise building projects within Nairobi County of minimum 14 storeys have you designed in the last 10 years? *

Mark only one oval.

- None
- 1 to 10
- 11 to 20
- Over 20

4. How many employees does your organization have? *

Mark only one oval.

- 1 to 5
- 6 to 10
- 11 to 20
- 21 to 50
- Over 50

5. Which method of charging structural engineering design fees do you mostly use on your high rise building projects? *

Mark only one oval.

- Lump Sum
- Percentage
- Time Based

6. How is the amount of fees mostly determined? *

Mark only one oval.

- Decided by the Client
- Decided by the Architect/P.M
- Directly negotiated with Client
- Directly negotiated with Architect/P.M
- As prescribed by relevant statutes

7. As a percentage of the project cost, what amount of fees do you commonly charge for structural engineering design? *

Mark only one oval.

- Less than 1.5%
- Between 1.5% and 2.5%
- Between 2.6% and 4.0%
- Over 4.0%

8. From your experience does the amount of fees affect the quality of structural engineering design? *

Mark only one oval.

- Yes
- No

9. The following fees related issues impact the quality of structural engineering design. From your experience rank these factors in order of magnitude of impact. (1 being greatest impact) *

Mark only one oval per row.

	1	2
Low amount of fees	⬭	⬭
Delayed fees payment	⬭	⬭

10. The aspects below can affect the quality of structural engineering design. How severely are these aspects affected by your response above? (Rank in order of severity with 1 being the most severely affected) *

Mark only one oval per row.

	1	2	3
Capacity to employ competent engineers for the project	⬭	⬭	⬭
Ability to procure, train and use of appropriate design tools	⬭	⬭	⬭
Ability to enhance motivation and commitment of the design team to the project	⬭	⬭	⬭

11. In what ways have your building projects been adversely affected as a consequence of your response above? *

Mark only one oval per row.

	Always	Often	Sometimes	Rarely	Never
Flaws and gaps in design and documentation	⬭	⬭	⬭	⬭	⬭
Design related variations during construction	⬭	⬭	⬭	⬭	⬭
Delays and stoppages of Works	⬭	⬭	⬭	⬭	⬭
Inadequate resources for supervision of Works	⬭	⬭	⬭	⬭	⬭

12. What design tools do you use for structural design and documentation of high rise building projects? *

Mark only one oval.

- Manual
- Software
- Both

13. What tools do you use for design integration, coordination and collaboration? *

Mark only one oval.

- Manual
- Software

14. Of what significance did the following factors play in the choice of your current design software? (Rank with 1 being the most significant factor) *

Mark only one oval per row.

	1	2	3	4
Cost of purchase and licenses	⬭	⬭	⬭	⬭
Versatility and ease of use	⬭	⬭	⬭	⬭
Quality of output	⬭	⬭	⬭	⬭
Interoperability/ information sharing capability	⬭	⬭	⬭	⬭

15. What kind of challenges do you experience with your current set of tools? *

Mark only one oval per row.

	Always	Often	Sometimes	Rarely	Never
Limitations in Modeling, visualization and simulation of complex building projects	⬭	⬭	⬭	⬭	⬭
Flaws and gaps in designs and documentation	⬭	⬭	⬭	⬭	⬭
Lack of Flexibility in effecting design changes, updating and synchronizing documentation	⬭	⬭	⬭	⬭	⬭
Difficulty in coordination, collaboration and integration with designs of other team members	⬭	⬭	⬭	⬭	⬭

16. How have these challenges affected your recent high rise building projects? Rank with 1 being most prevalent *

Mark only one oval per row.

	1	2	3	4
Affected the accuracy of pre tender cost estimates used for procurement	⬭	⬭	⬭	⬭
Caused delays in issuing information and resolving interfaces	⬭	⬭	⬭	⬭
Resulted in Cost escalations due to variations during construction	⬭	⬭	⬭	⬭
Contributed to contractual disputes with other parties	⬭	⬭	⬭	⬭

17. Do you employ the use of integrated design tools such as Building Information Modeling (BIM)? *

Mark only one oval.

- ⬭ Yes
- ⬭ No

18. If No, why? (Choose one answer that most accurately applies to you)

Mark only one oval.

- ⬭ Current tools just work fine
- ⬭ High cost of the BIM technology
- ⬭ Lack of knowledge and capacity to use BIM technology
- ⬭ BIM not yet embraced in most of projects that i undertake

19. High rise buildings present complexities in design. How has your knowledge and years of experience helped you in enhancing the quality of structural design of building projects? *

Mark only one oval per row.

	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
Improved problem solving capability	⬭	⬭	⬭	⬭	⬭
Improved effectiveness in use of design tools	⬭	⬭	⬭	⬭	⬭
Enhancing design and constructability linkage	⬭	⬭	⬭	⬭	⬭
Enhanced quality control of design and documentation outputs	⬭	⬭	⬭	⬭	⬭
Improved the coordination and integration of design	⬭	⬭	⬭	⬭	⬭

20. Holding project timelines constant, the aspects below may influence the way you deploy or assign resources for the design of high rise building projects. How would you rank these factors in order of importance to your practice?. *

Mark only one oval per row.

	1	2	3
Nature and complexity of the project	⬭	⬭	⬭
Expected remuneration from the project	⬭	⬭	⬭
Current workload at the firm	⬭	⬭	⬭

21. Have any of your high rise projects been adversely affected due to the level of knowledge and experience of the engineer(s) in charge? *

Mark only one oval.

- Yes
- No

22. In what ways have your projects been adversely affected due to the level of knowledge and/or experience of the engineer (s) in charge? *

Mark only one oval per row.

	Always	Often	Sometimes	Rarely	Never
Errors and omissions found in designs and documentation					
Coordination gaps with other disciplines					
Contractual disputes					
Cost escalations due to variations/reworks					
Delays in project works					
Structural Integrity issues					

23. Which of the methods below best describes how you collaborate and coordinate structural design related issues with other members of the project design team? *

Mark only one oval.

- Direct formal contact e.g through letters, emails, reports and drawings
- Informal contact e.g telephone, discussions and social media platforms
- Meetings- physical or virtual
- Integrated design and coordination technology e.g BIM
- Rarely done. Each professional works independently

24. How do you ensure quality of design process and outputs within your organization? *

Mark only one oval.

- Review by an experienced engineer within or without the firm
- Output from the design software is generally satisfactory
- Rely on the designers level of knowledge and experience
- Use of established QMS system such as ISO 9001:2008
- Review through established office procedures

25. Based on your system of planning, coordination and quality control, how has the quality of structural design been enhanced in your building projects? (Rank with 1 being the most significantly enhanced) *

Mark only one oval per row.

	1	2	3	4	5
Helped in narrowing gaps, uncertainties and risks	⬭	⬭	⬭	⬭	⬭
Enhanced better understanding of the project scope	⬭	⬭	⬭	⬭	⬭
Fosters establishment of roles and responsibilities for the design team	⬭	⬭	⬭	⬭	⬭
Enables optimization and Integration of design	⬭	⬭	⬭	⬭	⬭
Promoted monitoring and evaluation of progress and quality of design	⬭	⬭	⬭	⬭	⬭

26. In what ways have your building projects been adversely affected by challenging issues of planning and coordination? *

Mark only one oval per row.

	Always	Often	Sometimes	Rarely	Never
Interface conflicts with other disciplines	◯	◯	◯	◯	◯
Omissions and errors in design and documentation	◯	◯	◯	◯	◯
Design changes during construction	◯	◯	◯	◯	◯
Schedule overruns	◯	◯	◯	◯	◯
Budget overruns during construction	◯	◯	◯	◯	◯

27. The following factors affect quality of design and can impact the cost certainty of building projects.(i.e. the probability of finishing the project within the agreed pre-construction budget) and subsequently cause budget overruns. From your experience rank them in order of greatest to least impact on cost certainty. (1 being greatest impact) *

Mark only one oval per row.

	1	2	3	4
The kind of structural design software/tools used	◯	◯	◯	◯
Knowledge and experience of the structural engineer	◯	◯	◯	◯
The amount of structural design fees for the project	◯	◯	◯	◯
Planning and coordination of the structural design	◯	◯	◯	◯

28. From your high rise building projects portfolio, what proportion has experienced budget overruns due to the critical factor above or in combination of the other factors? *

Mark only one oval.

- Less than 20%
- 21% to 40%
- 41% to 60%
- 61% to 80%
- Over 80%

29. Of these projects above what is your average estimation of the resultant budget overrun beyond the pre-construction budget? *

Mark only one oval.

- Less than 10%
- 11% to 20%
- 21% to 40%
- 41% to 50%
- over 50%
