JIMMA UNIVERSITY
JIMMA INSTITUTE OF TECHNOLOGY
SCHOOL OF GRADUATE STUDIES
FACULTY OF CIVIL AND ENVIRONMENTAL ENGINEERING
CONSTRUCTION ENGINEERING AND MANAGEMENT CHAIR

ASSESSMENT OF FREQUENT DESIGN-ERROR CAUSING CHANGE ORDER ON BUILDING CONSTRUCTION PROJECTS: IN CASE OF HAWASSA CITY

A Thesis submitted to School of Graduate Studies, Jimma University, Jimma Institute of Technology, Faculty of Civil and Environmental Engineering in Partial Fulfillment of the Requirements for the Degree Master of Science in Construction Engineering and Management

By

YISIHAK MATHEWOS DOGENO

April 2021
Jimma, Ethiopia

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Main -Advisor: Engr. Bien Maunahan (Assistant Prof.)

Co-Advisor: Engr. Abebe Eshetu (MSc.)

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DECLARATION

I declare that this research entitled **“**Assessment of Frequent Design-Error Causing Change Order on Building Construction Projects in Case of Hawassa City” is my original work and has not been submitted as a requirement for the award of any degree in Jimma University or elsewhere.

Yisihak Mathewos Dogeno ___________________ _________________

NAME SIGNATURE DATE

As research Adviser, I hereby certify that I have read and evaluated this thesis paper prepared under my guidance, by Yisihak Mathewos Dogeno entitled “ASSESSMENT OF FREQUENT DESIGN ERROR CAUSING CHANGE ORDER ON BUILDING CONSTRUCTION PROJECTS IN CASE OF HAWASSA CITY” and recommend and would be accepted as a fulfilling requirement for the Degree Master of Science in Construction Engineering and Management.

Main-Advisor: Engr. Bien Maunahan (Assistant Prof.) __________ ___________

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Co - Advisor: Engr. Abebe Eshetu (MSc.) ________________ ___________

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ABSTRACT

The building project phases are a set of complex processes involving many uncertainties. Since the nature of the industries and the uniqueness of projects, and the disintegration of the design and construction process increases the probability of changes. The design error that led change order is observed as one of the most frequently occurring issues in Ethiopia's building projects. Like other cities of the country, the building projects in Hawassa city are suffering from frequent design error. Thus, this study aims to assess the frequent design error that led change order on building projects in Hawassa city. This study's research design was descriptive analysis and relied on both qualitative and quantitative research approaches. As a sample population, 18 building projects were selected through the non-probability purposive sampling technique. A total of 45 questionnaries from contractors and 22 questionnaries from consultants were collected and interviews were conducted. The collected data were presented using the relevant tables and figures and, analyzed based on the Relative Importance Index (RII) by using Microsoft excel. The study revealed that the major types of frequent design error that led to change order was wrong/inadequate descriptions in specifications, discrepancies between drawing and site condition, errors in structural design calculations,and absence/omission of detail. The results indicated that the design phase's poor collaboration, owner changing design criteria late in the design process, designer rushes out drawings before a proper review, and lack of strong communication during design phases are the major causal factors. The cost and time-related claim, disputes among participants, additional work with a parallel increase in cost, and the completion time delay and disruption were the major impacts of frequent design error induced change order. Finally, the involvement of professionals at initial stages, comprehensive planning, thorough identification of client needs with detailed site-visitation before embarking on any design, and developing a quality control plan as a check and balance system was identified as the best antidote. Thus,effectively managing the frequent design error in building project phases is very important. It is recommended that all the design firms and the concerned bodies play their role, as per the expected disciplinary requirements, from the building project commencement to its execution. And also, they should establish quality control departments to verify all designs.

Keywords*: Building Construction, Change Order, Frequent Design-Error*

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ACRONYMS

BIM	Building Information Modeling
CI	Construction Industry
CO	Change Order
COM	Change Order Management
DCI	Design Construction Interface
DE	Design Error
Et.al	Et alia
FDE	Frequent Design Error
G.C.	Gregorian Calendar
JiT	Jimma Institute of Technology
NCM	New Construction Materials
PMI	Project Management Information
RII	Relative Importance Index
VE	Value Engineering
WA	Weighted Average

CHAPTER ONE

INTRODUCTION

1.1 Background

The CI is a dynamic part of any economy and unquestionably a national asset whose development must reflect the development and transformation of wider society. Additionally, the physical infrastructures delivered by the CI and its key allies affect the economic growth of a given country (Solomon S, 2015).

Cost, time, and quality constraints are used to measure construction project performance and achievement (Abera & Fekadu, 2016). Overall, a construction project's success is defined by accomplishing it within the specified cost, time, quality, and level of client's satisfaction (Bezawork & Bantayehu, 2020). Although the nature of construction projects is involved, where many factors and variables play significant roles (Staiti, et al., 2016). Unlike the other economic sectors, the design and construction activities of construction projects are usually separate functions. Moreover, the CI is complex and fragmented because it involves many stakeholders, including the public and private project owners, Engineers/Architects, building teams, project managers, affected parties, etc. (Abera & Fekadu, 2016). The product used for construction projects is usually "custom made," with almost every project a separate and unique entity, considered, funded, designed, constructed, and operated separately. Each of the firms that contribute directly or indirectly to construction is represented by individuals, companies with diverse and often fragmented interests.

According to (Choudhry, et al., 2017) mostly in building construction projects, discrepancies frequently occur between design and construction processes concerning architectural details, structural details, materials, and construction quality. Also, as stated by (Asamaoh & Nyako, 2013) the principal contracting parties (i.e., owners, contractors, and consultants) have different interests in building projects. For example, while the project owner wants value for money, the contractor wants to maximize profit. These adjustments are usually required through project construction because of the client's demand, design change, and unexpected situations. Typically, owners have major concerns about the change orders due to their significance on the project budget and program (Gunduz & Mohammad, 2020). Commonly, these interests lead to FDE as a significant source of the change order. Due to DE, the change order has become a serious and challenging issue in many building construction projects in developing countries. Even though construction works involve many buildings, railways, highways, waterworks, and specialist works. Building construction works include the construction of residential, commercial, and office buildings. And also, civil works contain the construction of highways and other infrastructural installations. Construction projects that involve extensive unforeseen conditions are likely to generate CO (Tewodros, 2015).

According to (Fuadie, et al., 2017), the design is an essential step in construction projects. Design error is a lack of instruction in the specification, and design omission is missing what is necessary to complete the design or comply with the design code. Consequently, this results change in design and costs the owner for its replacement (Matusala, et al., 2019). Moreover, a good design would enhance value generation, reduce disputes, and improve the workflow. But design defects typically result from the designer's failure to produce an exact and well-coordinated set of construction documents. Thus, design defects are usually considered as an error or omission, or both.

Furthermore, a design error is a mistake in a design component usually discovered by the build team during a building or structure and causes injury to a person or property. Therefore, errors in design cause failure in the construction stage and also the project development. Design errors also contribute to engineering failures, resulting in accidents and loss of life, generate change orders, contractual disputes, cost overrun, time delay, compromising on quality, and frustration (Fuadie, et al., 2017). However, this study's concern will be only to assess the design errors that led to the change order on building construction projects. CO on a construction project is an addition or deletion of work from the original scope of work of a contract which alters the original contract amount or completion date, design changes from the architect, cost and time changes caused by supplier problems, DE, material, and operational failures, or by unsatisfactory site conditions (Desai, et al., 2015).

The study in Ethiopia indicated that lack of early design review during the design process, design errors, and omission, plans change by the project proponent, inadequate contract and design documents, differing site conditions, lack of experience designers and other parties for design evaluation during design period and barrier in the prompt decision-making process were the main causes of design change, and their significant impact on completion schedule delay, increase in project cost, wastage of materials during rework, and productivity degradation (Matusala, et al., 2019). Also (Belay, 2016) stated that "Ethiopia is a country under a major and fast transformation on the subject of building projects and now building grand projects in areas like residential houses, higher education, health buildings, and many others. These fast-building projects in Ethiopia face many challenges. One of these challenges is the gap in building design process management caused by incomplete design and less integrated management of design.''

In general, change orders due to design errors play a significant role in the CI because they have a high impact on cost, schedule, quality, safety, and productivity. They are also significant causes of project failure (Desai, et al., 2015). They are also commonly required during construction projects' execution and affect construction jobs' performance; they disturb current jobs and affect their schedule, may increase, omit or adjust tasks in the project (Gunduz & Mohammad, 2020). However, this study was conducted to assess the frequent design error causing change order on building projects in Hawassa city.

1.2 Statement of the Problem

Construction processes are complex since they involve many human and nonhuman factors and uncertain conditions (Varghese & Xavier, 2018). Moreover, the nature of the industry and the uniqueness of projects, and the disintegration of the design and construction process, increase the probability of change (Mirshekarlou, 2012). (Han, et al., 2013) discovered that the design errors and discrepancies leading to change order are the primary contributor to schedule delays, cost overruns, poor quality, safety problems, and low productivity in construction projects, particularly in building projects.

Many previous investigators also agreed that the design error was the main cause of change in building projects in developing countries. The issue of design error induced change order was clearly observed in the Ethiopian building projects and significantly the reason for the unnecessary increase in cost, time extension claims, poor quality, low productivity, and sever adversarial relation between contracting parties (Tebeje & Teka, 2015). This indicates that design errors and change orders are innately part of many building projects and require careful attention to alleviate.

Nevertheless, there is a scarce study on the frequent design causing change order on building projects in Ethiopia, particularly in Hawassa city. Therefore, this study was attempted to assess the frequent design error causing change order on building projects in Hawassa city.

1.3 Research Questions

1. What are the frequently occurred types of design errors that led to change order in building projects?
2. What are the factors contributing to a frequent design error, causing change order in building projects?
3. What are the effect of frequent design error induced change order in building projects?
4. What are the possible solutions to reduce the frequent design-error causing change order in building projects?

1.4 The Objective of the Study

1.4.1 General Objective

This study's general objective was to assess the frequent design error causing change order in building construction projects in Hawassa city.

1.4.2 Specific Objectives

The specific objectives of this study were:

- ❖ To analyze the frequently occurred type of design error led to change order in building projects.
- ❖ To identify the factors contributing to a frequent design error, causing change order in building projects.
- ❖ To assess the Effects of frequent design error induced change order on the building projects.
- ❖ To identify the solutions to reduce the frequent design-error, causing change order in building projects.

1.5 Significance of the Study

This study gives a keen understanding of the various ways in which the public and private building construction sectors project owners, design firms, and contractors can increase their benefits, improve the quality, reduce the unnecessary increases in cost and time through better design with efficient and effective change order management. This study's findings would be guiding academic scholars who wish to conduct further research on titles related to this and draw definite conclusions and give recommendations for building construction professionals, interested and affected parties.

1.6 Scope and Limitation of the Study

Even though the construction industry includes numerous sectors and stakeholders, therefore, the scope of this study was only limited to purposively selected ongoing public and private building construction sectors, and the respondents were also limited to consultants and contractors who directly involved in public and private building construction projects in Hawassa city.

Due to the pandemic COVID-19 and other constraints, there were difficult situations to get enough valuation breakdown and change order documents to determine the specific FDE induced change order effects on the cost and project durations.

CHAPTER TWO
LITERATURE REVIEW

2.1 General Overview

CI plays a crucial role in many developing countries, including Ethiopia. This is primarily because developing countries are greatly dependent on the growth and development of their physical infrastructures. Unlike the manufacturing and other economic sectors, construction projects' design and production activities are usually separate functions. The design and construction of a building are two separate functions performed by different parties working independently (Dosumu & Aigbavboa, 2018). Besides, many problems are confronting the CI. One such problem is the lack of integration between the design and construction phases and the fragmented nature of the industry (Amade, 2016).

A process of creating the description of a new facility, usually represented by detailed plans and specifications, is said to design (Matusala, et al., 2019). Moreover, the design is defined as a strategic approach for a person to achieve unique expectations. It defines the specifications, plans, parameters, costs, activities, processes, legal, political, social, environmental, safety, and economic constraints in achieving those goals.

A good design will enhance value generation, reduce disputes, and improve the workflow. Different design drawings may have various DE levels due to many factors, such as an unclear overview of the designs, human mistakes, and lack of coordination (Peansupap & Ly, 2015). Thus, design errors generate CO and cause failure in the construction stage and project development (Fuadie, et al., 2017). Besides, according to (Choudhry, et al., 2017), errors and omissions in the design are a significant cause of project delays depending upon the timing of the project's errors, leading to delay and changes. CO in construction projects may include additional, substitution, or omission works (Staiti, et al., 2016).

The contractor's early involvement at the project design level and improved communication between the project team members could decrease change orders' adverse effects. Conflicts among the contracting parties (Gunduz & Mohammad, 2020), and also the design team should frequently educate themselves on the new construction techniques achieved by the contractors and incorporate that knowledge into the details of the project by integrating design quality to reduce the design error inducing change order in building construction projects (Shamsudeen & Biodun, 2016). Generally, this chapter presents the literature review on the FDE factors that led change order, the impacts of change order due to FDE, and the possible antidotes to reduce FDE that led change order in building construction projects.

2.2 Construction Project Phases and The Project Life Cycle

The construction companies performing projects will usually divide each project into several project phases to improve their management control and provide links to the performing organization's ongoing operations. Generally, the project phases are termed as the project life cycle. The project life cycle is a series of project stages, starting from initiation to closure (PMI,2013). Figure 2.1 below depicts each phase of the project life cycle in building construction projects.

Figure 2. 1 Project life cycle (PMI,2013).

2.3 Design and Building Construction Project

2.3.1 Design Phase

In the project life cycle, there is a phase in which the design process is performed as indicated in Figure 2.1 above; it can be seen that the design process consists of the planning phase, concept design phase, and detailed design phase (Fuadie, et al., 2017).

In the planning phase**,** the design process is called the design brief. The planning phase is more related to financial modeling and business plan.

In the conceptual design phase, the design team is formed. The design team does the design process with design management principles. At this stage, the design has been described more broadly and intensely. Also, the dimension and capacity of a facility are determined.

In the detailed design phase, the design has been expressed in the form of images with a detailed description, and the drawings are used as a reference for the construction process. To better understand the design process in a construction project, the following stages of the construction design process are presented in Figure 2.2 below (Fuadie, et al., 2017).

Feasibility; -This is the first stage, and, in this stage, a small instruction is formed to investigate whether a location can accommodate the desired function or purpose. The result is usually a report that shows how to achieve the goal or modified in the presence of certain limitations. If the report points out that the project is feasible, the construction project can be implemented.

Tender; -In this phase, competitively, the design consultants will be selected.

Briefing; -Briefing is done between the client and the design consultant. The briefing is important to find relevant solutions in fulfilling the client's requirements and is approved by written form.

Concept; -The design concept stage is the creative process of making or personification of the owner's directions and designing the appropriate design responses. And also, analyses of design alternatives before the final design are determined. The design concept is usually less detailed for a plan but simply allows the client to determine whether the design is appropriate or not.

Scheme; -The design scheme is a final stage, and it is an approved design concept, including major decisions in layout, engineering, and material engineering. Moreover, functions, shapes, and economic aspects are determined to be made in more detail.

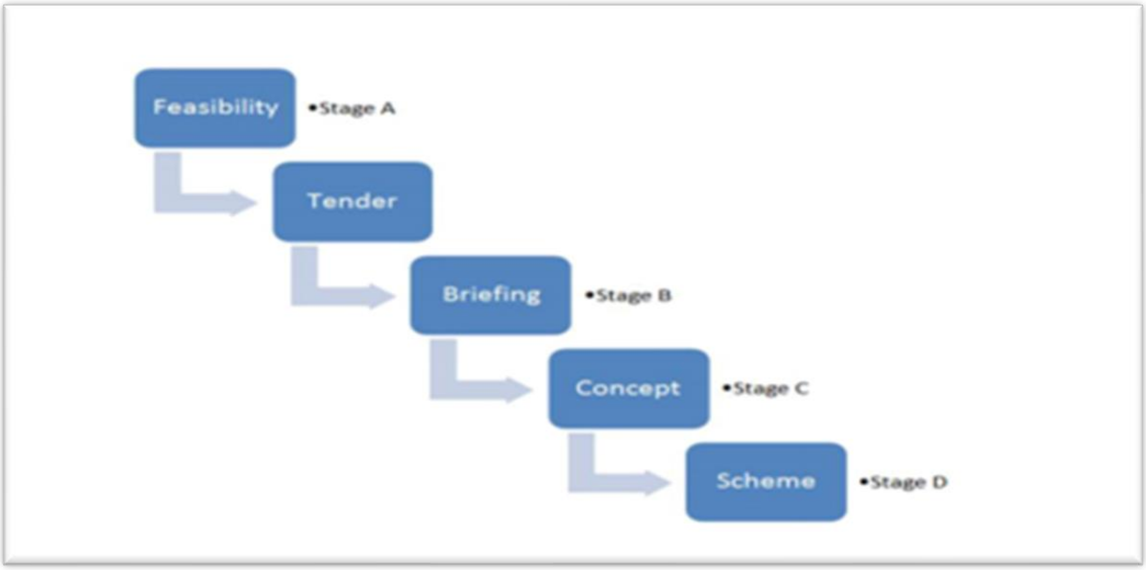

Figure 2. 2 Flowchart of the stage of the design process (Fuadie, et al., 2017) pp,285)

The quality of planning and design is a major success factor for any building construction project. The design also covers every aspect of the building construction process, including operational and maintenance phases. The design combines the specifications to guide the contractor in preparing the methods/techniques of construction.

2.4 Design Error in Building Construction Project

2.4.1 Definitions of Design Error

According to (Fuadie, et al., 2017), errors are deviations from actual values, lack of precision, measurement variations due to lack of human perfection and tools. Moreover, he also classified errors as neglect, imperfection, and incompatibility. Whereas according to (Peansupap & Ly, 2015), design mistakes, design omissions, design conflicts, deviation from actual values, inadequate precision, and inconsistencies in measurement are considered a design error. Simply design error can be understood as a deviation from planning and specification/description (Fuadie, et al., 2017).

Due to the required level of accuracy and time constraints, common human errors like design omission occur if any part of a system has been forgotten in the design can lead to DE. This problem can influence the quality of both the design and construction process of building projects. Also, the deviation from actual values, inadequate precision, and measurement inconsistencies are included under design errors (Peansupap & Ly, 2015).

2.4.2 Types of Design Error

According to (Dosumu, 2018) design errors in building construction projects can be classified as, the design errors can occur at the level of people, projects, and organizations. Hence, design error can be classified into skill/ based, violation/non-compliance, and rule/knowledge-based design error.

Slips, lapses, rule-based mistakes, and knowledge-based mistakes; for example, errors in design calculations can easily be placed under a mistake, slip, lapses, or violation. May be identified as errors of omission and commission. Thus, errors of omission and commission were further divided into intentional and unintentional omission and commission.

2.4.3 Factors Contributing to Frequent Design Error on Building Projects

According to (Shamsudeen & Biodun, 2016) and (Varghese & Xavier, 2018), the following identified factors play a critical role in causing design error in most construction projects. These are the insufficient fund to create quality documents (i.e., Low budgets for design acceptance of low design fee), unreliable and incompetent staff, lack of design management experience among others, lack of adequate time to prepare contract documents and insufficient time to create review quality documents, lack of coordination between principal players and other disciplines, unclear scope of work (description of required work), Human error (i.e., slips and lapses, mistakes and violations are the three classes of human errors (Dosumu, 2018), speed of work, frequent owner changing design criteria late in the design process, designer rushes out drawings before a proper review, designers lack construction knowledge and experience, lack of consistency, reusing of notes and details of similar projects, wrong assumptions of standard practice, and the poor project brief for design and construction (Dosumu, 2018).

Also (Peansupap & Ly, 2015) revealed that different design drawings might have various design errors due to many factors such as the unclear overview of the designs, human mistakes, and lack of coordination process.

2.4.4 Effects of Design Error

Design and construction are two different processes in the building construction sector; project stakeholders are active in handling the expected change throughout the building construction project lifecycle (Choudhry, et al., 2017). As shown in figure 2.3 below, most of the building projects have some minor and major changes at different stages of the project life cycle from design to the construction phase. All these changes bring a huge impact on the project, but consultants always undervalue the effects. Design error impose major negative effects on the time and cost performance of building projects.

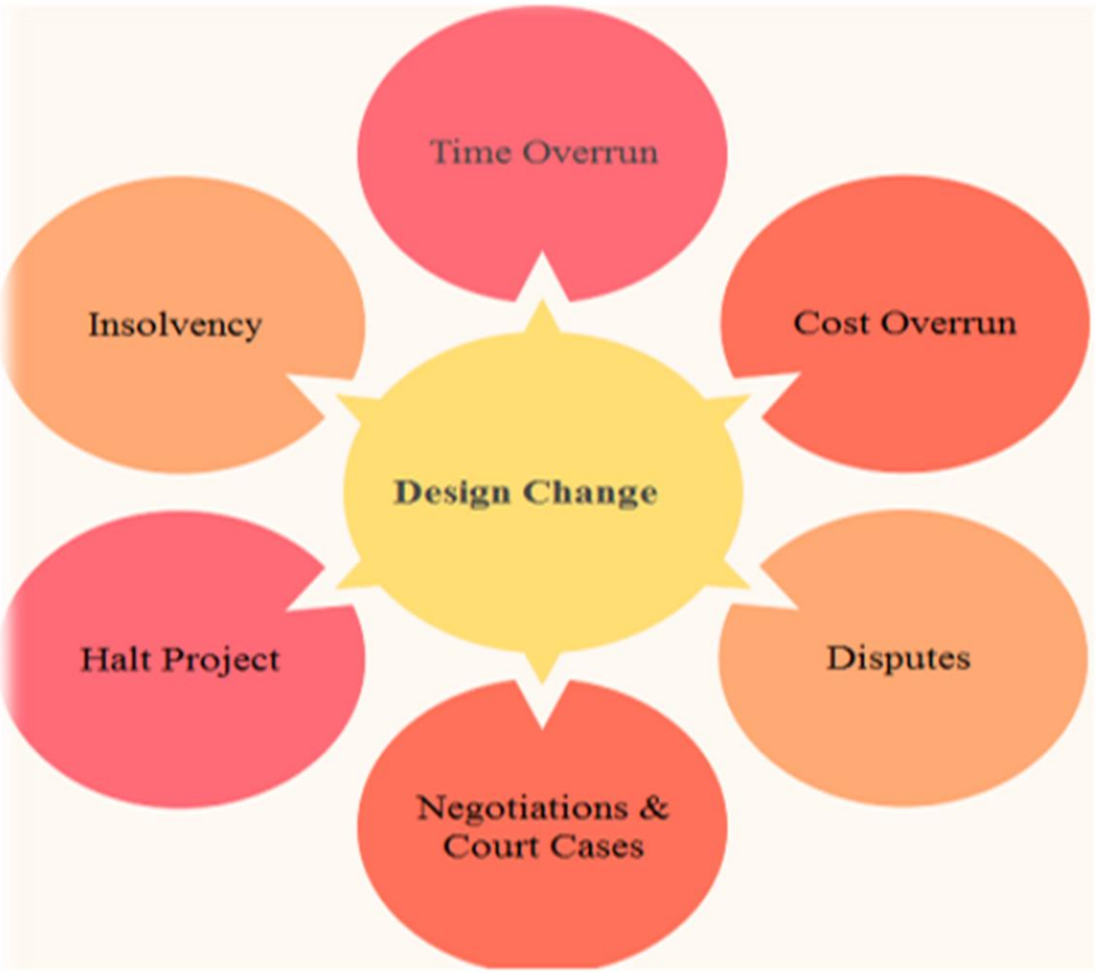

Figure 2. 3 Effects of Design Error

Moreover, according to (Juszczyk, et al., 2014), the most frequent and the most serious consequences of errors in design documentation at the stage of completion of the investment include the suspension of works until design changes are ready or disagreements in technical documentation are clarified, an increase in the contract value due to additional and complementary works when the scope and type of works have changed, and a hazard to workers' health and life.

According to (Fuadie, et al., 2017), design errors cause failure in the construction and project development stages. Design errors also contribute to engineering failures,resulting in accidents and loss of life, generate change orders, contractual disputes, cost overrun, time delay, compromising on quality, and frustration. Moreover, design errors have a negative impact on the design phase itself and the building construction phase. More importantly, these might negatively affect the post-construction/use phase of a building, with vast negative consequences for the project owners.

2.5 Overview of Change and Change Order in the Construction Industry

2.5.1 Definition of Change

In a broad engineering sense, a change refers to an event that affects the project scope, designs, contract requirements, or other assumptions, which have previously been considered final (Rita, et al., 2019). For further, change refers to any modification to the form, function of the product as a whole or part; moreover, it may lead to a variation in relations and dependencies of the product's constituent elements.

In a construction project sense, according to (Staiti, et al., 2016) change refers to the scope of projects; the size of construction processes may vary significantly; they tend to have one common element. Also, he argued that changes are pervasive and likely to occur at any construction phase. According to (Memon, et al., 2014) changes includes a change to plans, specifications, or any other contract documents that occur after the award of the initial contract or after work might have commenced; may be due to various reasons such as inadequate design, change in design, and misinterpretation of drawings leading to a construction error.

2.5.2 Definition of Change Order

A modification concerning the original plans, specification, or other contract documents and other vibrant factors in construction project management is referred to as a change (Richard, et al., 2016), while; a change order is a written and signed instruction from the owner to the contractor, and issued after the implementation of the contract, approving a change in the work or an adjustment in the contract amount or the contract period (Gokulkarthi & Gowrishankar, 2015). Additionally, any occasion that results in an adjustment of the original scope, execution time, or cost of work happens on most construction projects due to its uniqueness. The limited resources of time and budget available for planning are referred to as change. While change orders are necessary to address unanticipated conditions and other inevitable occurrences, they negatively affect any construction project (Mekonnen, 2015).

Change order on a construction project is an addition or deletion of any of work from the original scope of work of a contract which alters the original contract amount or completion date; inevitably, a change order represents a problem on the project in terms of additional cost and time (Desai, et al., 2015). CO in building construction projects may include additional, substitution, or omission works as described by (Staiti, et al., 2016).

2.5.3 Types of Construction Change and Change Order

2.5.3.1. Types of Construction Changes

Based on their basis, purposes, and effects of the changes, changes can be classified as formal/directed, constructive, cardinal, additive, deductive, reworks, and force majeure changes.

2.5.3.1.1. Directed Change Versus Constructive Change

A change arises when the owner or the owner's representatives instruct the contractor to perform tasks that are not stated in the contract document or make additions to the original scope of work (Dosumu & Aigbavboa, 2018). Besides, subject always to the specific requirements of the contract and examples of the directed type of changes include the addition or deletion of work, a revision to material specifications, a revision to project phasing, change to site access, and change to contract duration((Mekonnen, 2015).

Whereas, the constructive changes are informal acts or modifications to a contract due to any act or failure to act (Dosumu & Aigbavboa, 2018) or constructive change is the type of change which arises in the circumstances when the owner by his action and/or inaction changes the scope of work but does not recognize a change. Therefore, this type includes changes resulting from design problems, interface with the contractor's responsibilities, clarifications, and failure to provide owner furnished work items (Sadrija, 2016).

Moreover, a constrictive type of change is not originally documented as a change and becomes a potential source of dispute among the parties. The failure of the owner or owner's representative may take the form of error in design or drawings, wrong Engineer's interpretation of contract documents, change in construction sequence imposed by a construction requirement, etc. also, depending on the specific requirements of the contract types, constructive changes include the following: Failure to disclose material information, impracticality of executing the work as designed, use of the project before completion date, the slow turnaround of submittals and requests for information, untimely inspections. Finally, constructive changes are usually more difficult to recognize than directed changes and, therefore, often become the basis for a dispute, or in the worst case, a formal claim (Mekonnen, 2015).

2.5.3.1.2 Cardinal Changes

"Cardinal changes are changes that arise as a result of the long-time recognition in the federal sector of contracting and changes that are beyond the scope of work; in other words, scope change that can be caused by differing site conditions (Sadrija, 2016)". Furthermore, the cardinal type of change makes the work performed fundamentally different from the work the parties agreed to when the contract was bid and awarded. It is also executed only after the complete redefinition of the scope and re-negotiation of the contract agreement. It may not necessarily be a single change. Still, it can result from several changes that have the net effect of modifying the original scope of works, and it is typically viewed as a breach of contract by the owner. A contractor is not obligated to continue with a cardinal change if directed to do so by the owner. The unanticipated requirements imposed by third parties such as permitting agencies, utility companies, and unforeseen environmental issues are included under cardinal types of changes (Mekonnen, 2015).

Depending on the effect of the change orders, the changes are classified as additive changes are changes that are added to the original scope of work, deductive changes are changes that are deleted from the original scope of work, reworks are changes done due to quality deficiencies, and force majeure changes are changes done due to the weather conditions that can impact the project's schedule and cost (Sadrija, 2016).

2.5.3.2 Types of Construction Change Orders

Change orders in construction projects may be classified as formal change orders and informal change orders (Mekonnen, 2015).

Formal types of a change order - This is a change order type issued in writing by an authorized representative of the owner or by the contractor to a sub-contractor. Formal change order rarely causes problems, because they are generally identified before they are incorporated. They are based on a planned and deliberate choice of the contracting parties. Most often, formal change orders include unilateral and bilateral types of change orders. A unilateral change order is issued when an agreement is reached in negotiations or when a contractor fails to submit his proposals in time. It is based on the owner's estimate of cost and time for work. Such a change order is not considered desirable because it requires the owner's decision, generating appeals. Hence, a unilateral change order should only be issued when reasonable efforts have been exhausted to reach an agreement. Whereas bilateral types of change orders are a supplementary agreement whereby the owner's directives are issued to the contractor with a bilateral agreement as to contract price or contract duration. The supplemental agreements are understood as mutual agreements for the parties to increase or decrease the work agreed upon.

The informal type of the change order- Results from constructive changes, as discussed above, which arise from the client or his representatives' informal acts and conduct. It may increase the contractor's cost of performance. But Informal change order has the same effects as that of the formal change order.

2.6 The Root Cause of Change Order in Building Construction Projects

A building construction project is an assignment undertaken to create a unique facility, product, or service within the specified scope, cost, time, and quality. The one thing certain on any building project is that there will be changes occurring along the way, sometimes even before signing the contract (Yadeta, 2017). According to (Senouci, et al., 2019), project changes are inevitable even if all project documents are complete without mistakes. Furthermore, he classified the leading causes of change orders as owner directed changes, unforeseen conditions, design errors/omissions, value engineering(VE), and code requirements. Also, the most five common causes of change orders identified by (Alaryan, et al., 2014) based on their RII rank are; change of plans by the owner, change of project scope by owner (i.e., additional-enhancement), problems on-site, errors and omission in design (main element), poor design and poor working drawing details (secondary element). Furthermore, according to (Khahro, et al., 2017), the Owner, Contractor, and Consultant related key factors causing change orders that lead to project delays (time overrun) are identified clearly.

The owners related factors are financial problems and scope change during the execution of the project. Wereas, inadequate drawings, inadequate details, change in project specification, conflicts in contract documents, and inadequate design and design errors/omissions are consultant related factors. The lack of strategic planning, a possible shortage of equipment's and contracts unfamiliarity of local conditions classified as the contractor related factors.

Moreover, in Ethiopia, (Mekonnen, 2015) confirmed that the significant causes of change orders were originated from the principal contracting parties such as the client, consultant, and contractor. Then, according to his findings from all the causes, the design errors and omissions account for the greatest portion by causing change order, followed by the design error change of scope by the owner, unforeseen conditions, value engineering, and force majeure were identified as the root causes of the change order.

As indicated in Table 2.1 below, the other study showed that the different DE factors influence change order in infrastructural projects (Sadrija, 2016).

Table 2. 1 Factors Influencing Change Order in Infrastructural Projects

Groups	Factors	Groups	Factors
Design errors	Inadequate Design	Changes in Market conditions	Specified Item Became Unavailable
	Inadequate Shop Drawing Details		New products became available cheaper, more efficient
	Inadequate Working Drawing Details		The required tools and equipment are not available
	Consultant Lack of Required data		Substitution of Materials or Procedures
	Change in Specification by Consultant	Scope and Quantities of Work	Significant changes in the quantities of the work
	Design Criteria Changes		Construction method
	Changes in Design by Consultant		Plan Errors
	Non-compliance of Design with Owner's Requirements		Material Plan Errors
	Change in Design		Change of Plans by Owner
	Errors and Omissions in Design		Change of Scope by Owner
External Conditions	Uncovering Disclosed Existing Conditions		Changes in Specification by Owner
	Extreme Weather Conditions		Contractor financial difficulties
	Material Non-Availability		Change of schedule by owner
	Unforeseen Site Conditions		Inadequate project objectives
	Poor Investigation		Owner Financial Difficulties
Differing Site conditions	Differing Site Conditions		Contractor Desire to Improve his Financial Conditions
	Safety Considerations		Inadequate Planning
	Differing Subsurface conditions		Poor Estimation
Suggestion to Initiate Better	Suggestion to Initiate Better	Final Coordination	Scope
	Suggestion to Initiate more Economical Construction		Mechanical and Electrical Provision
	Value Engineering		Lack of Coordination Technology Changes

Finally, most of the reviewed studies confirmed that design errors were the primary source of change orders on construction projects in many developing countries, including Ethiopia, particularly in building projects. For further, (Mekonnen, 2015) revealed that from the total change orders encountered, the highest percent of the change orders were caused by design errors and omissions, followed by design error the change of scope by owner, unforeseen conditions, value engineering, and force majeure account for the 2nd, 3rd, 4th, and 5th respectively.

2.7 Frequent Design Errors that Led to Change Order in Building Projects

According to (Shamsudeen & Biodun, 2016) the structural and architectural defects in design, defects in maintenance practicality design, defects due to consultant and contractor firm administration, defects due to construction drawings, defects due to construction inspections, defects due to construction equipment, defects due to construction materials and specifications are identified types of design and construction errors. Out of the identified total errors in building construction projects, the narrow stairs, passages, and doors ranked first under architectural defects as a common design error in building construction projects. In most building projects, an inadequate concrete cover on reinforcement in structural design and under defects due to consultant firm administration, designer's ignorance of material properties, and misjudgment of user's intended use respectively was another common construction error. Additionally, specifying an inadequate concrete mix design and poor communication with the design team and the project owner are defects due to specification and defects due to contractor's administration respectively was the ranked least among the design errors identified.

Correspondingly, design errors, and omissions type change orders are due to errors or omissions in the contract documents or design descriptions. The design omission results from an incorrect design item or a work scope missed by the designers in their construction documents. It may be added to the contractor's work scope due to change orders in building construction projects. Therefore, the change orders resulting from improper design are due to the failure of the designer to adequately specify all building project elements to an acceptable level so that the contractor can proceed with construction works (Stone et al. 2011 and Gunhan et al. (2007) as cited in (Senouci, et al., 2019). Also, according to (Dosumu, 2018), the findings of the past study show that the design-error induced change/variation are the wrong/inadequate description in specifications, errors in design calculations, the omission of details in the specification, dimensional errors in architectural drawings, absence of specification, the discrepancy between technical description with the drawing, no detailed information about technology or materials, and incorrect dimensions in drawings.

Besides, in building construction, discrepancies frequently occur between design and construction concerning architectural details, structural details, materials, and quality of construction, as stated by (Choudhry, et al., 2017). In structural and architectural drawings, errors constitute approximately 70% of the total design errors that led to change/variation in the building construction projects. This shows that, if structural engineers and architects can do something radical about their designs, roughly 70% of design-induced change could be avoided (Dosumu, 2018).

Moreover, according to (Shamsudeen & Biodun, 2016), the designer's ignorance of materials properties, misinterpretation of drawings, replacement of materials or procedures, ambiguous design details, change in design, and violation of regulations drawings are frequent reasons for a change order in building construction projects.

2.8 Effects of Frequent Design Error Induced Change Order on Building Projects

2.8.1 Cost Overrun and An Increase in Project Duration

As stated by (Choudhry, et al., 2017), errors and omissions in the design are a significant cause of project delays depending upon the timing of the project's errors, which may lead to delay and variations/changes. Accordingly, design errors are not easily avoided, and essential issues in any construction project and can negatively affect the cost, schedule, and safety performance as claimed by (Peansupap & Ly, 2015).

According to (Matusala, et al., 2019), lack of design review during the design process, errors and omission in design plans change by the client, incomplete contract documents, differing site conditions, lack of experience for design evaluation during the design period, an impediment in the quick decision-making process was the most causes of design change in construction projects. Thus, design errors can significantly degrade the project performance by generating reworks, demanding resource expenditure, and requiring additional project duration (Han, et al., 2013).

Cost overrun and increased project duration are the two main effects of change orders, as stated by (Staiti, et al., 2016). The disputes between parties to the contract and labor productivity degradation are a significant concern (Varghese & Xavier, 2018). According to (Khahro, et al., 2017), change orders play a significant role in the CI as the significant impact the cost of the project, schedule, quality, safety, and performance.

In Ethiopia, a study conducted by Nega (2008) as cited in (Tebeje & Teka, 2015) on predominant factors for cost overrun in public building projects in Ethiopia identified the inflation or increase in the cost of construction materials, CO due to enhancement required by clients, and excess quantity during construction as the high cost overrun factors. The other study conducted by (WerkuKoshe, 2016) identified that inadequate drawings and specifications cause the most common form of time delay in construction projects, owner's changes in design or materials, and infective project planning, scheduling, or resource management, delay in progress payments for completed activities.

2.8.2 Claim and Disputes in Building Construction Projects Participants

As a result of changes, change orders are issued to modify the original scope or design. Most of the change order issued during construction has a significant impact on cost and time of the project and in the worst case could lead to delay, abandonment of project and disputes which are common in developing countries (Alnuaimi, et al., 2010).

According to (Abdulnabi & Agarwal, 2016), claims caused by the design engineer when Conducting a study of the project including documents and drawings, and specifications, where the engineer may commit unintended errors due to lack of awareness or weakness of experience in the design work as a result of insufficient time, which, these errors can cause disagreements between the parties of the project resulting in financial and time claims of both the contractor and the owner. An increase in these errors' quantity and volume increases the project's volume, termed a design error. Additionally, the other effects of change order identified by (Varghese & Xavier, 2018) are delay in payment to the contractor, increase in contractors overhead, a decrease in the quality of work, contract termination, and demolition and rework.

2.9 The Solutions to Avoid Frequent Design-Error-Causing CO in Building Projects

2.9.1 Effective Change Order Management

CO is a widespread problem all over the world's construction industry. Changes are the necessity for modifying the contract as a result of the construction conditions. The change orders are included in every stage of the project, causing different impacts on cost, time, productivity. For this reason, change order management is very important in the construction industry to avoid those problems (Sadrija, 2016). Implementing change management on construction projects is very important to control the negative impact of change orders (Richard, et al., 2016). Similarly, according to (Alsuliman , et al., 2012), change orders are managed more quickly at the earlier phases of a project; for example, during the design phase, these changes do not require any rework or demolition.

The change orders' control must be based on three different stages with their elements, as shown in figure 2.4 and table 2.2 below: (Sadrija, 2016).

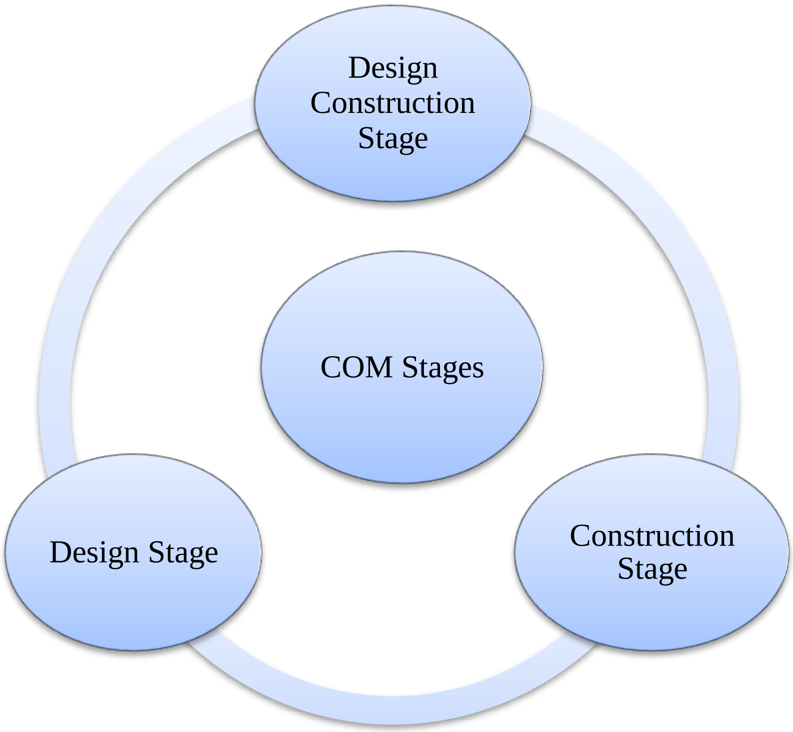

Figure 2. 4 Change Order Management Stages (Sadrija, 2016)

Table 2. 2 Change Order Management Stages

COM at Design Stage
○ Review of Contract Documents ○ Freezing Design ○ VE at the conceptual phase ○ Involvement of professionals at initial stages of the project ○ Owners involvement in the planning and design phase ○ Contractor's involvement in the planning and scheduling process ○ Thorough detailing of design ○ Clear and thorough project brief ○ Reducing contingency sum

COM at Construction Stage	COM at DCI Stage
• Clarity of change order procedures • Written approvals • Change order scope • Change logic and justification • Project manager from an independent firm to manage the project • Restricted pre-qualification system for awarding projects • Owners involvement during the construction phase • Avoidance of use of open tendering • Use of project scheduling/management techniques • Comprehensive documentation of change order	▪ Prompt approval procedures ▪ Ability to negotiate change ▪ Valuation of indirect effects ▪ Team effort to control change orders and coordination ▪ Utilize work breakdown structure ▪ Control the potential for change orders arising through ▪ contractual clauses ▪ Comprehensive site investigation ▪ Use of collected and data compiled by the owner, consultant and contractor ▪ Knowledge-base of previous similar projects

The design team should frequently educate themselves on the contractors' new construction techniques and incorporate them into the project's details by integrating design quality. They will be required to deal with communication between the main parties, coordination of the other disciplines, and professionally review the plans and specifications before the issue as studied by (Shamsudeen & Biodun, 2016).

Also, improved communication between the project team member should decrease the adverse effects of CO and decrease conflicts among the contracting parties (Gunduz & Mohammad, 2020). The contractor’s early involvement at the project design level would minimize changes and lead to better project achievements. Improved coordination within the different discipline is also recommended by (Shamsudeen & Biodun, 2016)

Develop a quality control plan as a check and balance system (Shamsudeen & Biodun, 2016); For all building construction project participants, implementing a quality assurance/quality control program is important as it will minimize defective tasks. Implementing the quality control plan allows the contractor to repair defective work prior to completing the project, reducing financial damage to the contractor, and keeping the contractor from a future adversarial relationship with other parties.

During design phases establishing effective communication between the project owner and the consulting firm to manage design error related change orders.

2.9.2 Controlling Design Error Causing Change Order at Design Stage

The building design stage consists primarily of design works and the generating of contract documents. The design administrators and the owner share the responsibility in which the designers prepare the design works, while the owner reviews and approve the design. The proposed control system indicates the next action to control change orders caused by design errors in this phase (Sadrija, 2016).

According to (Sadrija, 2016), the following points are necessary to eliminate and reduce the errors in the design phase:

A good collaboration between all the involved specialties and beneficiaries of the work is needed (improve collaboration). Moreover, as stated by (Bezawork & Bantayehu, 2020), for any construction project's timely delivery all involved, stakeholders must collaborate implicitly, check all the calculations and drawings by an authorized person who did not participate in the design team, and the designer must assure the technical consultancy during the entire phase of erection to avoid misinterpretation of the project or inappropriate modifications.

Moreover, a clearly defined and well-managed design process will mitigate the error. It requires the team to adopt the early defined roles and responsibilities, a greed milestones, strong leadership, well prepared brief, Robust cost advice, change control, sufficient time for design evolution, continual client review and approval, peer reviews. Additionally, will implement building information modeling (BIM), buildability reviews, and design interface management, duildability reviews, and design interface management.

In general, a clearly defined and well-managed design process should be established at the start of a project and involve all key members of the project team.

2.9.3 Implementing and Practicing of BIM Technologies

As suggested by (Khahro, et al., 2017), using Building Information Modeling (BIM) to plan, design, and manage the project's execution is an effective system for the project management system. Nevertheless, changes that arise in all projects are unique. Still, by instituting standard actions for documentation, pricing, and taking benefit of digital technology (i.e., BIM), owners will be capable of efficiently managing the change order's occurrence. The benefits of implementing BIM have been studied and proved in many fields, such as reducing design and drafting errors, increasing productivity, flexible design, reducing design and change order costs, increasing communication between different construction teams, etc. as stated by (Chi , et al., 2015) and also according to (Ganbat, et al., 2020) effectively facilitate communication management, mitigating risks engendered by language barriers among stakeholders, for instance, design errors) are the main application of the BIM in building projects.

The BIM results manage iterative change through a building's design, construction, and operation. A change to any part of the database is coordinated in all other parts. The process of building design and documentation is iterative. Then, the understanding of a design problem starts with the design process. Moreover, the modifications typical to any design process, a new intuition into the design problem may go to the design team to determine that the solution could be quite different, and possibly better. At that point, another iteration occurs that may reconsider earlier assumptions. Managing this iterative change is an inherent part of the design process. The new technology tools and work processes that do not allow the design to be refined and reconsidered iteratively as the project develops discourage the design problem's best possible solutions. Using building information modeling tools results in the highest quality project for the owner and the team's best possible work; maintaining an internally consistent representation of the building as a database improves drawing coordination and reduces errors in the documents to benefit all building team members. The time that would otherwise be spent in manual document checking and coordination can be invested instead in the real work of making the building project better. The resulting documents are of higher quality, and thus the costs of changes and coordination are reduced (Belay, 2016).

Building information modeling (BIM) tools allow the design, construction, and occupancy of the building to continue with low friction and fewer problems than the conventional systems. Estimating, procurement, and construction are also iterative processes of definition and elaboration.

Ambiguities in the design documents are resolved between the design and construction teams before the construction process begins. The construction and design teams consider changes to improve constructability and value for the project owners. Each of these decisions requires evaluation and that new information be captured to support later evaluations and operation and management of the building construction. Building information modeling solutions capture and manage this information and make it available to support the collaborative process (Belay, 2016).

After completion, buildings' operation is also an iterative process supported by building information modeling resolutions. At the end of the conventional design and construction cycle, the first occupancy of a building is just the beginning of the structure's life and use. The Building information modeling supports the building life cycle with solutions for the design and documentation of the continuing maintenance, renovation, and renewal of the building itself within the building information model (Belay, 2016).

The better solution to achieve sustainable infrastructure in Ethiopia and its implementation in Ethiopia is still in infancy. Among all the factors, fragmentation was identified as one of the biggest causal variables. In the traditional design preparation and delivery approach, sustainability issues are not adequately addressed, resulting in infrastructure becoming fragmented and highly unsustainable and vulnerable. Due to the huge input and complex process in sustainable infrastructure design and delivery, the need for Building Information Modeling (BIM) is predictable (Denamo, 2016).

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 Study Setting/Area

This study was done in Hawassa city in Ethiopia. Hawassa city is located 275 km south of Addis Ababa via Debre Zeit, 130 km east of Wollita Sodo, and 75 km north of Dilla, as shown in figure 3.1 below. It is also situated in the Sidama region, the southern part of Ethiopia. It lies on the Trans-African highway for Cairo-Cape Town and geographical coordinates between 7° 3' 0" North latitude and 38° 28' 0" East longitude and an elevation of 1708 meters above sea level (Google Earth,2020).

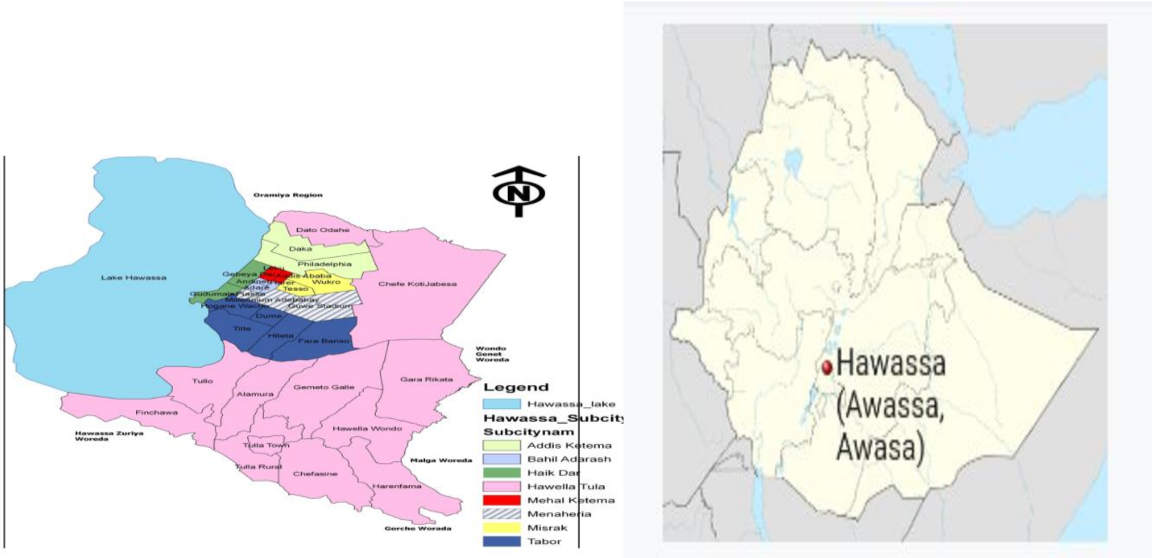

Figure 3. 1 (Source; google earth map) Map of the study area.

3.2 Research Design

The research design adopted for this study was a descriptive analysis. It relied on qualitative and quantitative research approaches to understand construction professionals' perception of a design error, causing the change in building construction projects in case of Hawassa City.

3.3 Target Population of the Study

The targeted population in this study was ongoing/active high rise building project which was found n Hawassa City.

3.4 Sampling Procedures and Sample size determination

A non-probability purposive sampling technique was adopted for selecting the sample population of the study because it allows a researcher to get information from a sample of the population that one thinks or knows most about the subject matter.

Therefore, 18 ongoing high rise building projects were selected purposively based on their physical progress, complexity of the projects, financial capacity, organized data recording and involving experienced professionals.

As well, the respondent from the population were consultants and contractors. Therefore, 45 contractors (project manager, architect, site engineer, office engineer, construction engineer, and quantity surveyor) and 22 consultants (office engineer, architects, site engineer, and resident engineer) were selected for the questionnaire survey. Three project managers, three senior office engineers from the contractor side, and four senior architects from the consultant side were selected for the interview due to their positions and experiences in the building sector.

3.5 Study Variables

3.6.1 Dependent Variable

- The Frequent Design-Error-Causing Change Order

3.6.2 Independent Variables

- In this study based on the specific objectives and literature review the frequent design error causal factors were considered as a major independent variables. Because they cause a critical change on dependent variable.

3.6 Data Collection Process

3.7.1 Primary Data Collection Process

This study was started with problem identification. For an in-depth understanding, the researcher has used both the primary and secondary sources of data collection. The primary data was collected directly from the information source, such as a questionnaire survey and personal interviews.

The questionnaires and interviews were designed to elicit information on the respondent's role in building construction projects. They were pre-tested to check their appropriateness for gathering all the required information. Finally, the researcher distributed and collected from the stakeholders in the building construction industry involved in consulting and building teams (contractors) in Hawassa City.

❖ Questionnaire Design and Content

The pretested questionnaire survey was developed to assess causes, effects, and antidotes of a design error, causing change order. Preliminary questionnaires were sent to the four experts rather than the main and co-advisors for their comment and adjustment. Their comments and inputs were combined in the organization of the final questionnaire that was distributed and collected.

The questionnaire's respondents consist of all private and public building project contractors and consultants found in Hawassa City. The five-point Likert scale was used for the questionnaire structures, as shown in Table 3.1 below.

The questionnaire distributed for both contractors and consultants had six sections, as follows:

- ✓ Section one(I)indicates a general introduction to the survey.
- ✓ The second section (II) contained basic background information about the company's specific company and respondents. It includes five questions aiming at providing general information about the contracting companies and respondents such as type of organization, specialized company sector, respondents position, and respondent’s year of experience.
- ✓ Section Three (III) lists the frequently occurred type of design error that causes the change order on building construction projects.
- ✓ The fourth section (IV) consists of the contributing factors to the frequent design error that led to change order whereby respondents are expected to rate based on their importance.
- ✓ The fifth section (V) contained lists of impacts of design error induced change order on building construction projects.
- ✓ Section six (VI) contained the identified antidotes to reduce the frequent design error, causing change order in building construction projects.

Finally, the questionnaires, along with the cover letter, were distributed to the concerned public and private building construction company consultants and contractors either in hard or soft copies, whichever were suitable. Physical visits and intensive telephone conversations were made with some respondents. The purpose of the communication was to clarify some of the points found vague to the respondents in the questionnaires, follow up the responses, and collect filled ones. Respondents were assured that their responses would be kept confidential. The sample of questionnaire survey used in this study is attached in (appendix A).

Table 3. 1 The Ranking Scale Designation

Section	**Five-point Likert Scale**				
	Rating scale 1 to 5 in ascending order 1 2 3 4 5 Increasing Degree of Importance				
	5	**4**	**3**	**2**	**1**
Section (III&V)	Strongly Agree Very	Agree	Fairly Agree	Never	Undecided
Section (IV)	Very High Contribution	High Contribution	Medium Contribution	low Contribution	Very Low Contribution
Section (VI)	Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree

❖ **Interview Design**

A separate unstructured interview was prepared for both contractors and consultants to understand the causes, impacts, and antidotes of a design error, causing change order in building construction projects. Since three project managers, and three senior team leaders from the contractor side, and four senior consultants were interviewed to gather relevant data regarding the design error causing change order in building construction projects in Hawassa city. The interview prepared for both consultants and contractors can be found in (Appendix A).

3.7.2 Secondary Sources

For the secondary sources, the researcher has used a variety of books, published and unpublished documents, the internet, previous researches are reviewed to make the study fruitful.

3.7 Data Processing and Analysis

The research was relying on both qualitative and quantitative types of data. Qualitative data were gathered from key respondents through interviews and change order document reviews. Then those qualitative data were organized and categorized thematically and written up into descriptions. The descriptions followed by analysis and interpretation. On the other hand, the data gathered informally was analyzed through concepts of explanation and elaborate descriptions of respondents' ideas and opinions. Whereas the questionnaire's quantitative data were analyzed based on descriptive statistics analysis method, descriptive survey methods (frequencies and percentages) were used, and rating and Likert scale.

Furthermore, to present the data, the researcher was tried to demonstrate the findings using relevant tables and figures (graphs, histograms, diagrams, and illustrations). Finally, the researcher analyzed the data using excel, carefully completed the variable view, and imputed the extracted data appropriately on the data view based on the Relative Importance Index (RII) to determine the significance of the findings.

The five-point Likert scale was converted to a Relative Importance Index (RII) for each respondent factor using the following formula (Tebeje & Teka, 2015). Relative importance index

$$(RII) = \Sigma W_A \div (H * N), (0 \leq RII \leq 1) \quad \text{…… Eqn. (1)}$$

$$WA = \sum (D_i N_i)/N \Rightarrow WA = (1n_1 + 2n_2 + 3n_3 + 4n_4 + 5n_5)/N$$

$$RII = \sum (D_i N_i)/H*N \Rightarrow$$

$$RII = (1n_1 + 2n_2 + 3n_3 + 4n_4 + 5n_5)/5N \Rightarrow RII = 1/H*(WA) \quad \text{…… Eqn. (2)}$$

Where,

WA…................Weighted Average

Ni………..….Number of Respondents for that Particular Ith Degree

RII…………...Relative Importance Index

∑……………. Summation Sign

Di...................ith Degree of Importance

Ni……………Number of Respondents for that Particular ith Degree

N…………….…Total Number of Respondents for the Questionnaire

H………….….....The Higher Degree of Contribution

n_1…... ………Number of Respondents for 1 Degree of Importance

n_2…... ………Number of Respondents for 2 Degree of Importance

n_3…... ………Number of Respondents for 3 Degree of Importance

n_4…............... Number of Respondents for 4 Degree of Importance

n_5…................ Number of Respondents for 5 Degree of Importance

The Spearman (Rho) rank correlation coefficient is used for measuring the differences in ranking between two groups of respondents (consultants versus contractors) scoring for various factors. The Spearman (rho) rank correlation coefficient for any two ranking groups is given by the following formula.

$$Rho = 1 - \frac{(6*(\sum d_i^2)}{N(N2-1)} \quad \text{...Eqn. (3)}$$

Where:

Rho (ρcal) – Spearman rank correlation coefficient

di– The difference in ranking between each pair of factors

N– Number of variables

The value of the Spearman (rho) rank correlation coefficient ranges between -1 and +1. The higher positive values show a high degree of agreement between the two respondents (contractors v/s consultants). The negative value implies that the two respondents' correlation (contractors v/s consultants) strongly disagreed. Whereas a spearman rank correlation coefficient of =+1 indicates a perfect positive correlation, 0 implies no correlation, and -1 implies a perfect negative correlation. i.e., they have the exact reverse ranking to each other.

CHAPTER FOUR

RESULTS AND DISCUSSION

This chapter describes the results and discussion of a questionnaire survey and interview regarding design error, causing CO in building Hawassa city projects from contractors' and consultants' viewpoints. These help to know the contributing factors for FDE and the impacts of a DE, causing change order on building construction projects in Hawassa city.

4.1 Results and Discussion of the Questionnaire Survey

4.1.1 Population Characteristics

This section mainly intended to provide general information about the respondents in terms of the organization's name, company type, job position, and respondents' experience.

4.1.1.1 Type of Respondent's Organization

For this thesis's successful achievement, the representative respondents from public and private building project participants are categorized into two, specifically contractors' and consultants' groups. Figure 4.1 below illustrates an average response rate in terms of the number of questionnaires distributed and collected returns from the representative participants. Entirely, 75% (45 out of 60 respondents) contractors and 88% (22 out of 25 respondents) consultants participated in the questionnaire survey. While the general response rate for contractors and consultants was 78.83%, and the total number of respondents for the two parties is 67 out of 85 respondents. However, both the consultants and contractors included in this study were legally licensed and had sufficient knowledge of the title and the addressed problems.

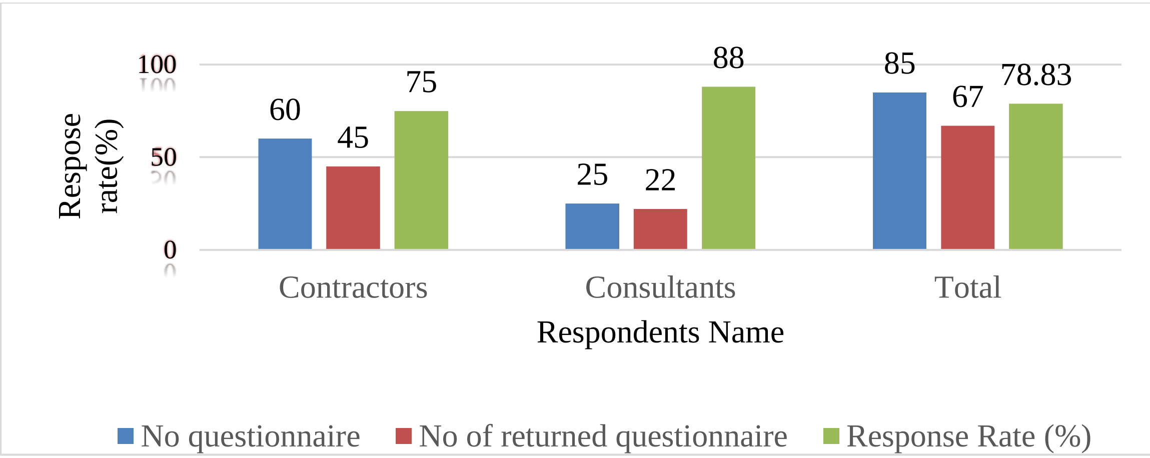

Figure 4. 1 Response Rate of Respondent

4.1.1.2 Respondents Designation

Table 4.1 below depicts that among the 45 respondents from the contractor's side, 11.11 % (five out of 45) were site engineers, 31.11% (14 out of 45) were office engineers, 24.44 % (11 out of 45) were architects, 15.56% (seven out of 45) were project managers, 11.11% (five out of 45)were construction engineers, and 6.67% (three out of 45) were quantity surveyors. Whereas, from the total of 22 respondents from the consultants' group, it has been founded that 36.36 % (eight out of 22) resident engineers,18.18% (four out of 22) site engineers, 27.27(six out of 22) office engineers, and 18.18% (four out of 22) architects. The respondents were selected because of their closeness with the problem and sufficient knowledge on the subject matter based on the researchers' judgments.

Table 4. 1 The Designation of Respondents

Respondents Designation	Contractors	Consultant	Percentage (%)	
			Contractors	Consultants
Resident Engineer	0	8	0	36.36
Site Engineer	5	4	11.11	18.18
Office Engineer	14	6	31.11	27.27
Architect	11	4	24.44	18.18
Project Manager	7	0	15.56	
Construction Engineer	5	0	11.11	
Quantity surveyor	3	0	6.67	
Total	45	22	100	100

4.1.1.3 The Types of Building Projects

Figure 4.2 shows that among the total sample of 18 building projects in Hawassa City, 56 % (10 out of 18) were owned by private owners, and projects owned by government bodies were 44% (8 out of 18).

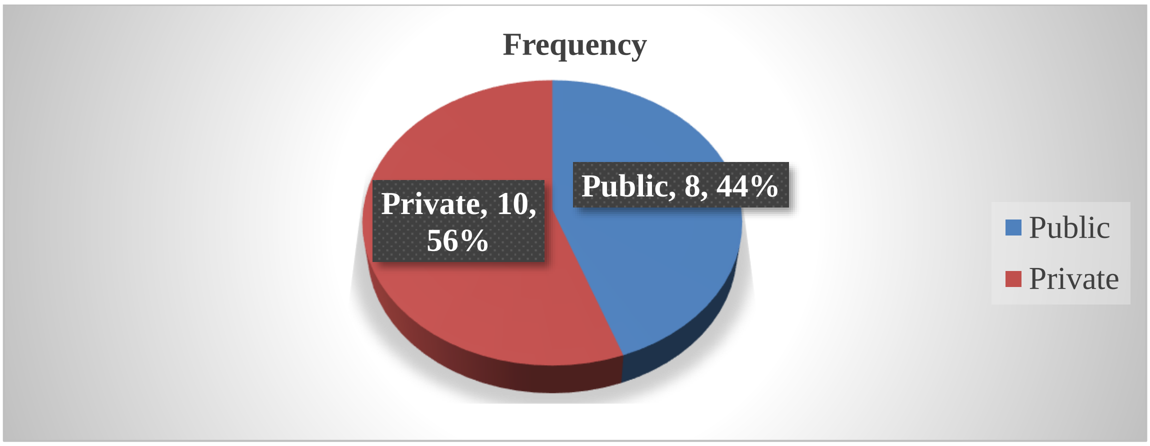

Figure 4. 2 Sector to which Building Projects Respondents Belong

4.1.1.4 Experience of Respondents

Table 4.2 and Figure 4.4 below indicates that 76.11 % (51 out of 67) of the respondents from both firms have experienced between 1 to 4 years, 5 to 8 years, and 9 to 12 years at building and related construction projects, and the rest 23.88 % (16 out of 67) of respondents have to experience more than 12 years. Thus, the result indicated that most of the participants from both consultants and contractors side had a working experience greater than four years. Moreover, those who had nine to 12 and above 12 years of experience takes for about 49.58 % combined. In general, these ranges of respondents' experience are comparatively well enough to provide reliable data.

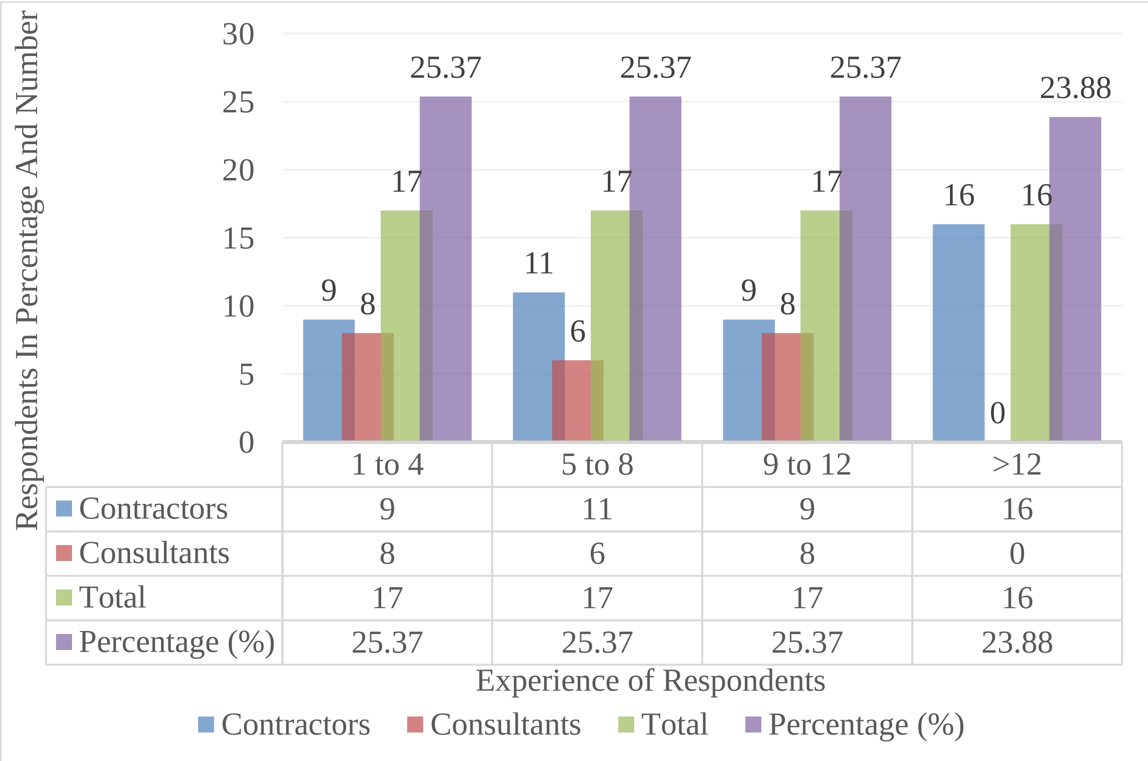

Figure 4. 3 Experience of the Respondents

4.1.2 Frequent Design Error Types That Led Change Order on Building Projects

Table 4.2 below indicates the result of the questionnaire survey collected from both contractors and consultants on the frequently occurred type of DE that led CO in building construction projects. Once the contents of the questionnaires' results were analyzed, 12 frequently occurred type of DE that led CO were identified and tabulated as shown.

Table 4. 2 The FDE Type Causing Change Order on Building Projects

SN	Frequent Design Error Type That Led to Change Order	Contractors	Consultants	Overall Rank	
		RII	RII	RII	Rank
1	Wrong/inadequate descriptions in specifications	0.85	0.82	0.84	1st
2	Errors in structural design calculations	0.76	0.80	0.78	4th
3	The absence/omission of details in specification.	0.71	0.87	0.79	3rd
4	The dimensional errors in architectural drawings	0.64	0.69	0.67	7th
5	Replacement of materials or procedures	0.61	0.53	0.57	10th
6	Ambiguous design details	0.76	0.78	0.77	5th
7	Change in design	0.70	0.80	0.75	6th
8	Violation of codes, laws, and regulations in drawings	0.72	0.53	0.62	8th
9	Discrepancies between drawing and site condition	0.81	0.80	0.80	2nd
10	Noncompliance of design with client's requirement	0.61	0.47	0.54	11th
11	Inadequate working drawing details	0.66	0.55	0.60	9th
12	Inadequate shop drawing details	0.62	0.45	0.53	12th

It was found that the wrong/inadequate descriptions in specifications, discrepancies between drawing and site condition, and errors in structural design calculations and the absence/omission of details in specification with RII of (0.84),(0.80), and (0.79) respectively, were the top three frequently occurred type of design error that led CO in building projects. All the drawing details and specifications are the systems of communication among the design firms, build teams and other concerned bodies. Accordingly, to bear a complete concept of the building project design, all the drawing details and specifications must be clear and brief. This study also revealed that the insufficiency in drawing details was the main type by causing change order. Therefore, a detailed reviewing of design details can reduce changes caused by the inadequacy of drawing details in building projects. The study also showed that the specifiation-related errors accounts the greatest porton in relaton to the total design errors leading to change order in building construction projects. This implies that many problems are yet to be solved in the specifiations of building construction drawings. These problems include provision of clear and detailed specifiations for materials, and correct and adequate description of specification.

Conclusively creating an effective communication platform and coordination is important in a principal participants environment in most building projects in Ethiopia. Strong and continuous communication is essential for creating optimum coordination among parties. Although the changes in the project owners' idea of either of the material types and specifications late in the design or construction phase may ultimately affect the project completion, project cost may cause conflict among the parties. Therefore, through better communication and strong coordination, all the concerned bodies, including the main constructor and design firms, can overcome the identified frequent design error problems at the initial phases of building projects.

4.1.2.1 Spearman Correlation Test for Agreements on The Frequently Occurred Type of Design Error That Led Change Order on Building Projects

As indicated in Table 4.3 below, with a significance level of 95% (P = 0.05), the calculated value of Rho (ρcal) is greater than the critical values of ρ, so there is significant agreement between the contractors and consultants.

Table 4. 3 Correlation Test on The Design Error Causal Factors

Respondents	Rho (ρcal)	Critical value of ρ, N=12 (Annex c)	Significance for P<0.05
Contractors versus consultants	0.7727	0.5035	Significant

From Table 4.3 above, it can be concluded that there is a strong correlation between the attitudes of the respondents (contractors and consultants). It means that most of the contractors and consultants who participated in this survey have the same perception about the frequently occurred type of design error that led to change order in building projects.

4.1.3 Factors That Contribute to Frequent Design Error, Causing Change Order on Building Projects

Table 4.4 below indicates the result of the questionnaire survey collected from both contractors and consultants on the causal factors of a design error that led to change the order in building construction projects. Once the contents of the questionnaires' results were analyzed, 12 causal factors of a design error that led to change order were identified and tabulated as shown.

Table 4. 4 Factors Contributing to Frequent Design Error that led Change Order on Building Projects.

SN	Frequent Design Error Causal Factors	Contractors	Consultants	Overall RII	
		RII	RII	RII	Rank
1	Insufficient fund to create quality documents (i.e. Low budgets for design)	0.64	0.80	0.72	6th
2	Insufficient time to create review quality design documents	0.71	0.72	0.71	7th
3	Lack of coordination and communication between stakeholders during design phases	0.72	0.85	0.79	4th
4	Poor collaboration in the design phase	0.79	0.85	0.82	1st
5	Unclear scope of work	0.63	0.67	0.65	9th
6	Increase of current workload of the designer	0.56	0.55	0.55	12th
7	Speed of work	0.54	0.62	0.58	11th
8	Owner changing design criteria late in the design process	0.78	0.82	0.81	2nd
9	Lack of familiarity with advanced engineering design software	0.75	0.65	0.70	8th
10	Poor project brief for design and construction	0.70	0.84	0.77	5th
11	Designer rushes out drawings before proper review	0.76	0.84	0.80	3rd
12	Designers lack of updated construction knowledge and experience	0.55	0.64	0.59	10th

The study results revealed the top three contributing factors to FDE that led to CO in the building projects. The first identified contributing factor is the poor collaboration in the design phase, with the RII value of (0.82); in contrast, the second factor is the owner changing design criteria late in the design process, and the designer rushes out drawings before the proper review having an RII value of (0.80). However, the third one is the lack of coordination and communication between stakeholders during design phases with an RII value of (0.79).

In general, this result depicts that all the listed factors, especially the top three identified above, are the main reason for FDE in building projects. So, all the concerned bodies, including the interested and affected parties, should have improved collaboration and communications. Strong and continuous communication is essential for creating optimum coordination among parties. Although the changes in the project owners' idea of either of the material types and specifications late in the design phases may ultimately affect the project completion, project cost, and may cause conflict.

The design firms should also have professional experience and capabilities because professional capability and judgment are important for completing a building project. However, the lack of professional experience raises the risk of errors in any building project's design phases and construction phases.

4.1.3.1 Spearman Correlation Test for Agreements on the Factors Contributing to Frequent Design Error That Led Change Order on Building Projects.

Spearman's rank correlation coefficient (Rho) is a reliable and fairly simple method of testing both the strength and direction (positive or negative) of any correlation between the two variables. In order to decide whether to accept or reject the agreement between contractor and consultant, the level of significance 95% (P = 0.05) is used. It allows to state whether or not there is an "agreement" between the respondent's response. If the calculated value of ρ exceeds the critical value, the agreement is significant, i.e., there is evidence of a statistically significant agreement between them. Suppose the calculated value of ρ is lower than the critical value. In that case, the agreement is not significant, i.e., there is no evidence of a statistically significant agreement between the two respondents. In this case, as indicated in Table 4.4 below, assuming a significance level of 95% (P = 0.05, then the critical value of ρ=0.5035, the calculated value of Rho (ρcal) is greater than the critical values of ρ, so there is significant agreement between the contractors and consultants.

Table 4. 5 Correlation Test on The Design Error Causal Factors

Respondents	Rho (ρcal)	Critical value of ρ, N=12 (Annex c)	Significance for P<0.05
Contractors versus Consultants	0.76923	0.5035	Significant

From Table 4.5 above, it can be concluded that there is a strong correlation between the attitudes of the respondents (contractors and consultants). It means that most of the contractors and consultants who participated in this survey have the same perception about the frequent design error causal factors causing change order in building projects.

4.1.4 Effects of Frequent Design Error Induced Change Order on Building Projects

Figure 4.4 below, indicates the result of the questionnaire survey collected from both contractors and consultants to assess the effects of frequent design error induced change order in building projects in Hawassa city. Once the contents of the questionnaires' results were analyzed, eight major effects of FDE induced CO were identified and tabulated as shown.

According to the overall rank, the top three effects of FDE induced CO in building projects are frequent design error causing change order led to cost and time-related claim and disputes among the contracting parties in building construction projects (RII=0.90), additional work due to design error can increase the cost of a change order in building construction projects (RII=0.88). Consequently, the frequent design error induced change orders can cause a completion time delay and disruption on building projects (RII=0.87).

Finally, a lack of effective communication, the owner’s idea changes late in the design phases, and lack of the strong coordination among the main parties was the main reason of the major impacts that could eventually affect the building project badly depending on the timing of the presence of the errors. It shows any design errors that are not corrected during the early design phase will eventually appear in building projects' development and construction. The impact can be more severe than in the design phase of a project. Therefore, the frequent design errors that led to the change order can usually be resolved in the project's early stages with due thoroughness in coordination between the principal parties.

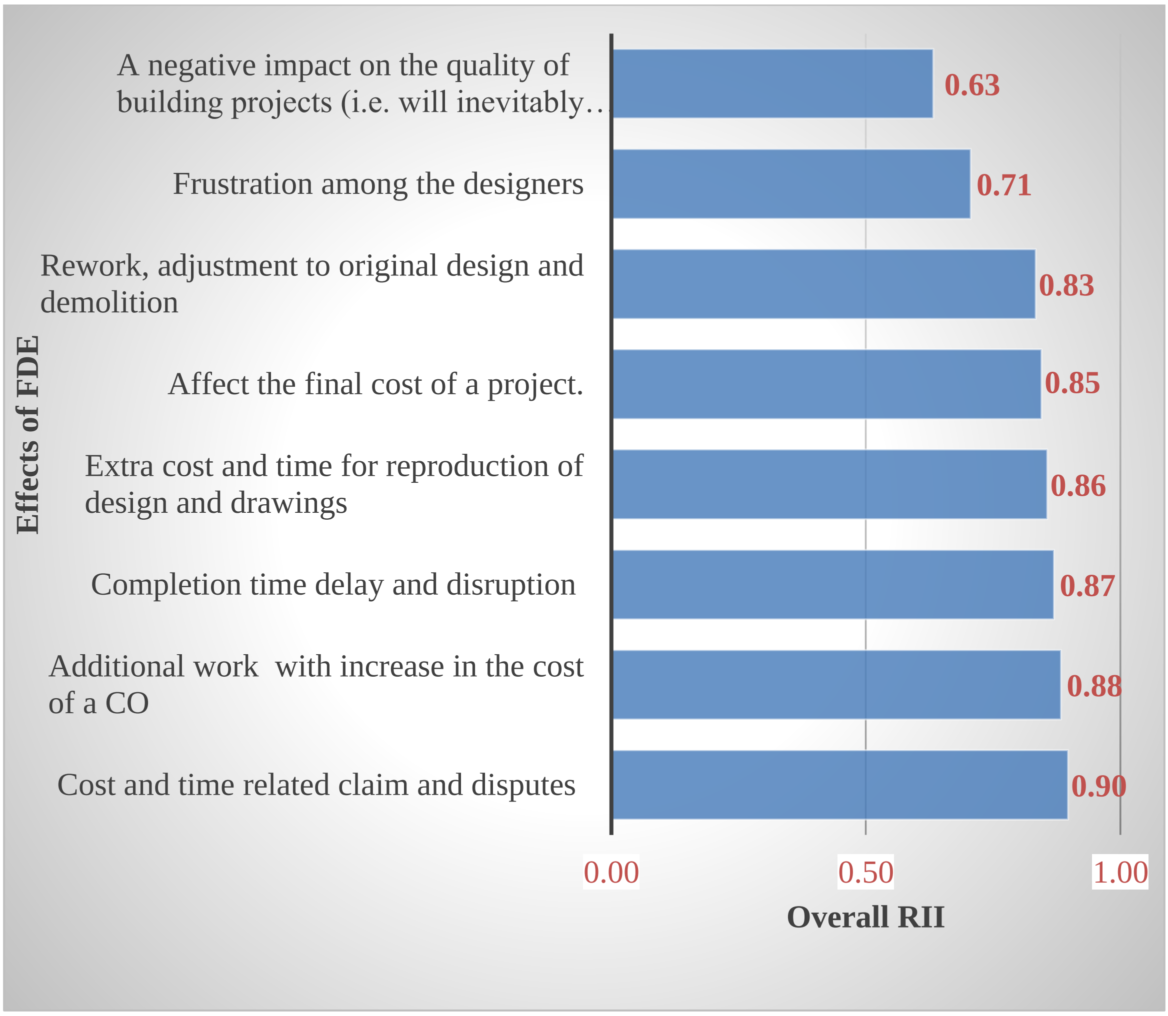

Figure 4. 4 Effects of FDE Induced Change Order in Building Projects

4.1.4.1 Spearman Correlation Test for Agreements on The Impacts of Frequent Design Error Induced Change Order on Building Projects

As indicated in Table 4.6 below, with a significance level of 95% (P = 0.05), the calculated value of Rho (ρcal) is more than the critical values of ρ, so there is a significant agreement between the respondents (contractors and consultants).

Table 4. 6 Correlation Test on The Design Error Causal Factors

Respondents	Rho (ρcal)	Critical value of ρ, N=8 (Annex c)	Significance for P<0.05
Contractors Versus Consultants	0.7381	0.6429	Significant

From Table 4.6 above, it can be concluded that there is a strong correlation between the attitudes of the respondents (contractors and consultants). It means that most of the contractors and consultants who participated in this survey have approximately the same perception about the frequently occurred type of design error that led to change order in building projects.

4.1.5 Solutions to avoid FDE Causing Change Order in Building Projects

Table 4.7 below, indicates the result of the questionnaire survey collected from both contractors and consultants on the antidotes to reduce the frequent design error, causing change order in building projects. Once the contents of the questionnaires' results were analyzed, 23 antidotes were identified and tabulated as shown.

Hence, according to the overall rank, the involvement of professionals at initial stages, comprehensive planning, thorough identification of client needs and site visitation before embarking on any design of building projects, and develop quality control plan as a check and balance a system were the top three identified antidotes used to reduce the FDE that led CO in building construction projects. Therefore, all the consulting firms, contractors, and project owners should give thorough attention to the identified antidotes to implement in their project progress to reduce the probability of frequent design error that led to change order. All the identified antidotes are derived from the intensive literature review and the purposively selected consultants and contractors directly affected by the addressed problems.

Table 4. 7 Antidotes to Reduce the Frequent Design Error Causing Change Order in Building Projects

SN	Antidotes to reduce FDE causing CO in building projects	Contractors	Consultants	Overall RII	
		RII	RII	RII	Rank
1	Comprehensive planning, thorough identification of client needs, and Site visitation before embarking on any design	0.95	0.95	0.90	2nd
2	Allocation of enough resources	0.78	0.75	0.76	18th
3	Clearly define role and responsibilities among the stakeholder's	0.68	0.89	0.79	16th

SN	Antidotes to reduce FDE causing CO in building projects	Contractors	Consultants	Overall RII	
		RII	RII	RII	Rank
4	Agreeing and putting in place change management procedures before the commencement of projects (incorporating this into the contract if possible)	0.65	0.76	0.71	20th
5	Develop a strong leadership	0.69	0.71	0.70	21th
6	Freezing design at the appropriate stage of a project or implementing intermediate design freezes at various stage	0.61	0.73	0.67	22th
7	Rechecking design documents before presenting them for use	0.79	0.84	0.81	14th
8	An adequate review of specifications and contract documents	0.84	0.82	0.83	12th
9	Adequate and continual client review plan and written approval	0.84	0.79	0.82	13th
10	Ensuring Prompt approval procedures	0.83	0.71	0.77	17th
11	Better designs and visualization by Implementing (BIM)	0.90	0.85	0.88	7th
12	Knowledge-base of previous similar building projects and Knowledge sharing among designers	0.89	0.85	0.87	8th
13	Involvement of professionals at initial stages of building project	0.1	0.95	0.97	1st
14	Owners involvement at planning, design phase	0.82	0.78	0.80	15th
15	Representation of contractor in the planning, design phase	0.60	0.65	0.63	23th
16	Provide clear and thorough clients detail project briefs to design teams to assist designers in arriving at conclusive designs	0.91	0.82	0.86	9th
17	Use of competent designers	0.87	0.84	0.85	10th
18	Sufficient time to complete the design documents, including reviews, field investigations, and greater involvement in the inspection process.	0.92	0.94	0.93	4th
19	Paying adequate and thorough attention to detail design	0.86	0.82	0.84	11th

SN	Antidotes to reduce FDE causing CO in building projects	Contractors	Consultants	Overall RII	
		RII	RII	RII	Rank
20	Improved coordination within the different discipline	0.92	0.89	0.90	5th
21	Develop quality control plan as a check and balance a system	0.93	0.95	0.94	3rd
22	During design phases establishing effective communication between the project owner and the consulting firm to manage design error related CO	0.87	0.91	0.89	6th
23	Empower better COM with more information and data available	0.86	0.62	0.74	19th

4.1.5.1 Spearman Correlation Test for Agreements on The Antidotes to Reduce the Frequent Design Error Causing Change Order in Building Projects

As indicated in Table 4.8 below, it shows that with a significance level of 95% (P = 0.05), the calculated value of Rho (ρcal) is greater than the critical values of ρ, so there is significant agreement between the contractors and consultants.

Table 4. 8 Correlation Test on The Design Error Causal Factors

Respondents	Rho (ρcal)	Critical value of ρ, N=23 (Annex c)	Significance for P<0.05
Contractors Versus Consultants	0.82164	0.3528	Significant

From Table 4.8 above, it can be concluded that there is a strong correlation between the attitudes of the respondents (contractors and consultants). It means that most of the contractors and consultants who participated in this survey have the same perception of the identified antidotes used to reduce the FDE that led to change order in building projects.

4.2 Interview Results and Discussion

Unstructured interview was conducted between selected building construction project professionals who were currently involved in public and private building projects. In total, three interviews were conducted, namely with a senior team leader (A) from the contractor's group, a senior architect (B) from the consultants, and a senior project manager (C) from the contractor's group as shown in (Appendix C). Therefore, the interview aims to identify the causal factors, the impacts, and the antidotes of FDE, causing CO on building projects in Hawassa city. Then, from the interview, (16) causal variables and (12) impacts, and (15) antidotes from all interviewees were found. All the factors were merged, and the researcher checked if they were out of the literature to include them in the questionnaire. But most of them with the same meaning were the domain of the factors analyzed from the literature.

Thus, the interviewees' average results revealed that a lack of knowledge in building laws/codes. This means the unfamiliarity of the contracting parties with building codes would reduce the project and perform the tasks effectively. Followed by the lack of knowledge in building law/codes, the poor of information flow among the principal parties during design phases, the introduction of NCM with new technology which were not introduced/known during design phase, lack of training on the concept of constructability, availability, appropriateness of materials and engineering design methods, problem in the description of required type work during design phases (frequent scope change by the employer), no early involvement of contractor during design phase, scarce resources in quality or quantity (For instance. tools, equipment, staff, or financial), not giving attention for each detail during generation of the design, (poor information about governmental regulations, municipality requirements, statutes and their adjustments), (no design checking or 2^{nd} or 3^{rd} party reviews, no system of design checking), and delay in the approvals of design process were the FDE causal factors that led change orders in building construction projects.

The finding from the interviewees' average responses, unexpected increase cost, impact on the progress and final project duration, disputes among the contracting parties, and payment delay to the contractor were the major impacts. Finally, implementation of advanced engineering software, creating smooth collaboration with the designers, value engineering, rechecking the design and different approvals, producing a concluding design and contract documents, give attention to each detail, updating the construction knowledge were the identified antidotes based on the average responses of the interviewees. In general, all the plans, each detail, and specifications are the only means for the contractor to understand the job wants. Henceforth, the information from each detail should be made clear and concise before the commencement of any building projects. Otherwise, the build team and other involved parties' lack of knowledge of each design detail and provisions may cause an error in the projects' execution.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

This chapter includes the conclusions and recommendations that would help solve the frequent design error, causing change orders on building construction projects in Hawassa city in Ethiopia. The specific objectives are identifying and analyzing the causal factors and assessing their effects in general to identify the antidotes. Questionnaire surveys, interviews, and change order document reviews were used to collect the relevant data to achieve each specific objective. Accordingly, based on the study's research objectives, the following conclusions and recommendations were drawn.

5.1 Conclusion

It is well known that design error is one of the major causes of a change order in most building construction projects. Based on the findings of this study, it was concluded that the poor collaboration in the design phase, owner changing design criteria late in the design process and/or designer rushes out drawings before the proper review, and lack of communication between principal parties during design phases were the common causal factors that contribute to a frequent design error.

It was concluded that the change orders in building construction projects occurred more frequently due to the absence/omission of detail on structural drawing, and wrong description of specification on a structural drawing, error in structural design calculation, the wrong description of specification on electrical drawing.Therefore, in building construction projects, the plans, drawings, and specifications must be clear and unmistakable to understand the required type or description of work. So, well-detailed drawing designs and specifications are believed to reduce the occurrence of change orders. Most professionals also argue that a detailed drawing design should be prepared before any building project's tender stage.

Inadequate design details and the other frequently occurred type of design error can generate a major change order that may eventually affect project progress. A change in the plans, drawings, and descriptions during the project design phases requires changes in building project planning, costing, procurement, and other tasks. The study also revealed that the most important effects of frequent design error induced change order on the projects were the time-related claim, cost-related claim and disputes among the contracting parties, additional work with an increased change order cost and total project cost, completion time delay, disruption on projects, additional work with additional payments for the contractor, negative effect on project progress, increase in overhead expenses. Moreover, regarding their consequential cost impacts, the design calculation error, missing items in drawing and specifications, design change, the introduction of the new design, and design modification were the most implicated factors.

The frequent design error that led change order on building projects can be minimized if the complete designs and contract documents at the tender stage were prepared, the professionals at initial stages of the building project involved, comprehensive planning, thorough identification of client needs, and site visitation took place before embarking on any design, and quality control plan as a check and balance a system were developed.

In general the design error inducing change order in building projects are very common and likely to occur from diverse sources, by various causes at any phases of a project, and they have a significant negative impacts on project final cost, schedule, and quality. Consequently,effectively managing the frequent design error causing change orders in building project phases is very important.

5.2 Recommendation

5.2.1 Recommendation Drawn from The Conclusion

- All the drawings, including the design calculations, should be confirmed by dedicated government authorities before building construction projects. Hence, legislation towards achieving this accomplishment is recommended.
- All the concerned bodies, should become involved in the design preparation at an early step to make sure whether it meets all requirements or not.
- The study's result and the conclusion declare that developing a quality control plan as a check and balance system reduces the frequent design error that led to change the order in building projects. It indicates that all the design organizations or the consulting firms should establish quality control departments to verify all designs. Appropriate sanctions should be prescribed for defaulters.
- As per the expected disciplinary requirements, consulting firms should play their role from the building project's inception to its implementation on the ground. It is so because it is the consultant's responsibility to coordinate all types of information to satisfy the project owners and any interested and affected parties. Moreover, the designers or the consulting firms should do the following before the beginning of the building construction project:
  - ✓ Gather reliable field information during detailed site investigation phases
  - ✓ Organize the appropriate and complete feasibility study to accommodate the clients' needs and different stakeholders' interests and should also prepare a peer review on the feasibility study and collect professional opinion as input during design activities. For sure, this would minimize change orders due to frequent design errors and any other situations.
  - ✓ Should be aware and use updated lists of building materials to avoid wrong material specifications or descriptions.

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APPENDIX(A); -

I. Questionnaire and Interview

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FACULTY OF CIVIL AND ENVIRONMENTAL ENGINEERING

CONSTRUCTON ENGINEERING AND MANAGEMENT CHAIR

ASSESSMENT OF FREQUENT DESIGN ERROR CAUSING CHANGE ORDER ON BUILDING CONSTRUCTION PROJECTS IN CASE OF HAWASSA CITY

BY;YISIHAK MATHEWOS

Section (1); - Introduction

Dear Sir/ Madam

I am Yisihak Mathewos, a postgraduate student from Jimma University, Department of Construction Engineering and Management. This is a questionnaire designed for a research purpose, and the main aim of this survey is to assess the design error causing change order on building construction projects in Awassa City.

Please, I respectfully ask you to complete the questionnaire and be assured that your responses to the questions will be kept confidential, and no firm, organization, or individual will be identified in the report or publication based on this research. I would also like to assure you that the collected data will be used in the survey is only for academic purposes and perhaps for further recommendations to improve similar works in the future time.

Thanks in advance for your co-operation.

Yours sincerely;

Yisihak Mathewos

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Email; -yisu143mat@gmail.com

Section (II): General Information:

1. Respondents profile; -
   - Your Work Organization ☐ Contractors ☐ Consultant Firms
   - The Current position in your organization
     ☐ Project manager ☐ Office Engineer ☐ Site Engineer ☐ Architect ☐ Construction Engineer ☐ Other……………
   - Project Ownership which you are involved in ☐ public sector ☐ private sector
   - Work experiences (in years) ☐ 1-4 yrs. ☐ 5-8 yrs. ☐ 19-12 yrs. ☐ > 12 yrs.

Section (III); -The Frequently Occurred Type of Design Error That Led to a Change Order in Building Construction Projects.

According to your experience, to what extent do you agree with the following statements on the types of a frequent design error that led change order? Please indicate your response throughout the questionnaire by ticking the appropriate box where (5 = strongly agree, 4 = agree, 3 = fairly agree, 2 = never, 1 = Undecided)

Table 2; -Frequent Design Error Type That Led to Change Order	Please tick (√) on the box				
	5	**4**	**3**	**2**	**1**
Wrong/inadequate descriptions in specifications					
Errors in structural design calculations					
The absence/omission of details in specification.					
The dimensional errors in architectural drawings					
The replacement of materials or procedures					
Ambiguous design details					
Change in design					
Violation of codes, laws, and regulations in drawings					
The discrepancies between drawing and site condition					
Noncompliance of design with the client's requirement					
Inadequate working drawing details					
Inadequate shop drawing details					
If any other frequently occurred type of design-error that led change order on Building construction project, please specify….	**Please tick (√) on the box**				
	5	**4**	**3**	**2**	**1**

Section (IV); -Factors Conntributing to the Frequent Design Error, Causing Change Order in Building Construction Projects.

In (Table 1) Listed below are the common identified factors that contribute to frequent design errors that led to change order on the building construction projects. Based on your experience, please specify to what extent do you think the following factors contribute to design error, causing change order? Please tick (√) your rating on a scale of 1 to 5; where (5= very high Contribution, 4= high contribution, 3=medium contribution, 2= low contribution, 1=very low contribution)

Table 1**; - **Factors Contributing to Frequent Design Error, causing change order on Building Construction Projects.	Please tick (√) on the box				
	5	**4**	**3**	**2**	**1**
Insufficient fund to create quality documents (i.e. Low budgets for design)					
Insufficient time to create review quality documents					
Lack of coordination and communication between stakeholders throughout construction process					
Poor collaboration in the design phase					
Unclear scope of work					
Increase of current workload of the designer					
Speed of work					
The Employer changing design criteria late in the design process					
Designer rushes out drawings before proper review					
Designers lack of construction knowledge and experience					
Lack of familiarity with advanced engineering design software					
Poor project brief for design and construction					
If any other factors which contribute the frequent design-error that led change order on Building construction project, please specify….	**5**	**4**	**3**	**2**	**1**

Section (V); -Impacts of Frequent Design Error Induced Change Order on Building Construction Projects.

To what extent do you agree with the following statements of effects about frequent design error induced change order? Please indicate your response all over the questionnaire by ticking the appropriate box where; (5 = strongly agree, 4 = agree, 3 = fairly agree, 2 = never, 1 = Undecided)

Table 3; -Effects of Frequent Design Error Induced Change Order on project cost, time and quality	**5**	**4**	**3**	**2**	**1**
Additional work due to design error can increase the cost of a change order in building construction projects.					
Change order induced due to design error affects the final cost of a building construction project.					
Design error induced change orders can cause a completion time delay and disruption on building construction projects.					
Frequent design error related change orders have a negative impact on the quality of building construction projects (i.e. will inevitably degrade project performance)					
Frequent design error causing change order may leads to rework, adjustment to the original design, and demolition of a given part in building construction projects.					
Frequent design error causing change order led to cost and time- related claims and disputes among the contracting parties in building construction projects.					
The frequent design error induced change order is the reason for extra cost and time for reproduction of design and drawings					
Design error induced change order cause frustration among the designers					
If any other effects of Frequent design error induced change order, please specify…….	**5**	**4**	**3**	**2**	**1**

Section (VI); -To analyze the Antidotes to Reduce the Frequent Design Error Causing Change Order on Building Construction Projects.

1. *Is the frequent design error causing change order is preventable in building construction projects? Yes ☐ No ☐*
2. *If your answer is "yes'' for question one, based on your best practices, to what extent do you agree with the following antidotes to reduce frequent design error that led to change order on building construction projects? Please specify your level of agreement by ticking (√) on the provided box following the measurement scales of 1 to 5 where (5 = "Strongly agree",4 = "Agree", 3 = "Neither agree nor disagree", 2 = "Disagree", 1 = "Strongly disagree")*

Table 5; Antidotes to reduce frequent design error causing change order in building construction projects	***Please tick (√) on the box***				
	5	***4***	***3***	***2***	***1***
Comprehensive planning, thorough identification of client needs, and Site visitation before embarking on any design of building projects					
Allocation of enough resources to manage with a design error					
Clearly define role and responsibilities among the stakeholder's					
Agreeing and putting in place change management procedures before the commencement of projects (incorporating this into the contract if possible)					
Develop a strong leadership					
Freezing design at the appropriate stage of a project or implementing intermediate design freezes at various project stages depending on the type of contract					
Rechecking design documents before presenting them for use					
An Adequate review of specifications and contract documents					
Adequate and continual client review plan and written approval					
Ensuring Prompt approval procedures					
Better designs and visualization by Implementing Building information modeling (BIM)					
Knowledge-base of previous similar building projects and Knowledge sharing among designers					
Involvement of professionals at initial stages of building project					
Owners involvement at planning, design phase, and construction phase					
Representation of contractor in the planning, design phase, and scheduling process of building projects.					
Provide clear and thorough clients detail project briefs to design teams to assist designers to arrive at conclusive designs					
Use of competent designers					
Sufficient time to complete the design documents including reviews, field investigations and greater involvement in the inspection process.					
Paying adequate and thorough attention to detail design					
Improved coordination within the different discipline					
Develop quality control plan as a check and balance a system					
During design phases establishing effective communication between the project owner and the consulting firm to manage design error related change orders					
Empower better change order management with more information and data available					
If any other antidotes to reduce the frequent design-error that led change order on Building construction project, please specify….	***Please tick (√) on the box***				
	5	***4***	***3***	***2***	***1***

II. Interview Questions

1. Is design error the main cause for change order in your building construction project?
…………………………………………………………………………………………
…………
2. If your answer is yes, based on your experience, what are the factors which contribute to frequently occurred type of design error that led change order in building projects?
……
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……
……
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……………………………………………………………………………
3. How do you manage design error causing change orders in the design stage?
……
……
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…………………………………………………
4. What are the negative impacts of FDE induced Change order in building construction projects?
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……
……
……
……
…………………

APPENDIX B

Questionnaire Results and Analysis

Frequent Design Error Causal Factors	Frequency											Contractors			Consultants			Weighted, Average	
	5	4	3	2	1		5	4	3	2	1	WA	RII	Rank	WA	RII	Rank	RII	Rank
Insufficient fund to create quality documents (i.e. Low budgets for design)	6	21	3	6	9		8	6	8			3.20	0.64	7th	4.00	0.80	4th	0.72	5th
Insufficient time to create review quality documents	10	21	3	5	6		7	6	4	3	2	3.53	0.71	6th	3.59	0.72	5th	0.71	6th
Lack of coordination and communication between stakeholders between stakeholders	5	25	8	5	2		6	16				3.58	0.72	5th	4.27	1st	3.58	0.79	4th
poor collaboration in the design phase	15	22		6	2		6	16				3.93	0.79	1st	4.27	0.85	1st	0.82	1st
Unclear scope of work	5	10	20	7	3			14	4	2	2	3.16	0.63	8th	3.36	0.67	6th	0.65	8th
Increase of current workload of the designer		20	10	2	13		6	8	4	4		2.82	0.56	9th	2.73	0.55	10th	0.55	11th
Speed of work			34	9	2		4	6	6		6	2.71	0.54	11th	3.09	0.62	9th	0.58	10th
Owner changing design criteria late in the design process	12	21	7	5			6	12	4			3.89	0.78	2nd	4.09	0.82	3rd	0.80	2nd
Lack of familiarity with advanced	15	16	3	9	2			12	4	6		3.73	0.75	4th	3.27	0.65	7th	0.70	7th

engineering design software																			
Poor project brief for design and construction	5	23	12		5		8	10	4			3.51	0.70	6th	4.18	0.84	2nd	0.77	4th
Designer rushes out drawings before proper review	14	17	8	4	2		12	4	4	2		3.82	0.76	3rd	4.18	0.84	2nd	0.80	2nd
Designers lack of construction knowledge and experience		17	8	12	8			8	10	4		2.76	0.55	10th	3.18	0.64	8th	0.59	9th

Frequent Design Error Type That Led to Change Order												Contractors			Consultants				
	5	4	3	2	1		5	4	3	2	1	W_A	RII	Rank	WA	RII	Rank	RII	Rank
Wrong/inadequate descriptions in specifications are frequent	23	14	5	3			12		10			4.27	0.85	1st	4.09	0.82	2nd	0.84	1st
Errors in structural design calculations	12	15	15	3			4	14	4			3.80	0.76	3rd	4.00	0.80	3rd	0.78	3rd
The absence/omission of details in specification.	12	7	20	6			10	8	4			3.56	0.71	5th	4.27	0.85	1st	0.78	3rd
dimensional errors in architectural drawings	5	15	11	12	2		6	8	2	2	4	3.20	0.64	8th	3.45	0.69	5th	0.67	6th
Frequently replacement of materials or procedures	6	14	9	9	7		4	12		6		3.07	0.61	10th	2.64	0.53	7th	0.57	9th
Ambiguous design details are frequent	11	20	8	6			6	10	4	2		3.80	0.76	3rd	3.91	0.78	4th	0.77	4th
Change in design	5	20	15	3	2		8	10		4		3.51	0.70	6th	4.00	0.80	3rd	0.75	5th

Violation of codes, laws, and regulations in drawings	12	15	10	3	5			6	6	6	4	3.58	0.72	4th	2.64	0.53	7th	0.62	7th
Frequently discrepancies between drawing and site condition	17	15	11	2			12	2	4	4		4.04	0.81	2nd	4.00	0.80	3rd	0.80	2nd
Noncompliance of design with client's requirement	5	11	17	5	7		3	7	7	5		3.04	0.61	10th	2.36	0.47	8th	0.54	10th
Inadequate working drawing details	3	20	11	9	2		4	10	6	2		3.29	0.66	7th	2.73	0.55	6th	0.60	8th
inadequate shop drawing details	4	15	14	6	6			2	10	3	7	3.11	0.62	9th	2.32	0.46	9th	0.54	10th

Effects of Frequent Design Error Induced Change order												Contractors			Consultants			Weighted average	
	5	4	3	2	1		5	4	3	2	1	W_A	RII	Rank	WA	RII	Rank	RII	Rank
Additional work due to design error can increase the cost of a change order in building construction projects.	26	6	13				12	10				4.29	0.86	2nd	4.55	0.91	2nd	0.88	2nd
Change order induced due to design error affect the final cost of a building construction project.	17	15	13				10	10	2			4.09	0.82	4th	4.36	0.87	4th	0.85	5th
Design error induced change orders can cause completion time delay and disruption on	27	9	6	3			10	10	2			4.33	0.87	1st	4.36	0.87	4th	0.87	3rd

building construction projects.																			
Frequent design error related change orders have a negative impact on the quality of building construction projects	10	12	18	5			2	6	4	4	6	3.60	0.72	5th	2.73	0.55	6th	0.65	8th
Frequent design error causing change order may leads to rework, adjustment to original design and demolition of a given part in building construction projects.	19	15	10	1			8	10	4			4.16	0.83	3rd	4.18	0.84	5th	0.84	6th
Frequent design error causing change order led to cost and time related claim and disputes among the contracting parties in building construction projects.	25	4	14	2			18	4				4.16	0.83	3rd	4.82	0.96	1st	0.90	1st
The frequent design error induced change order is the reason for extra cost and time for reproduction of design and drawings	22	10	9	4			14	4	4			4.11	0.82	4th	4.45	0.89	3rd	0.86	4th
Design error induced change order cause frustration among the designers	7	5	25	8			4	12	4	2		3.24	0.65	6th	4.18	0.84	5th	0.79	7th

Antidotes to reduce frequent design error causing change order in building construction projects												**Contractors**			Consultants	Overall RII	
	5	4	3	2	1		5	4	3	2	1	W_A	RII	WA	RII	RII	Ranks
Involvement of professionals at initial stages of building project	36	9	3				18	2	2			5.00	1.00	4.73	0.95	0.97	1
Comprehensive planning, thorough identification of client needs, and Site visitation before embarking on any design of building projects	34	11					17	5				4.76	0.95	4.77	0.95	0.95	2
Develop quality control plan as a check and balance a system	30	15					16	6				4.67	0.93	4.73	0.95	0.94	3
Sufficient time to complete the design documents including reviews, field investigations and greater involvement in the inspection process.	28	16	1				15	7				4.60	0.92	4.68	0.94	0.93	4
Improved coordination within the different discipline	26	19					10	12				4.58	0.92	4.45	0.89	0.90	5
During design phases establishing effective communication b/n the project owner and the consulting firm to manage DE related CO	29	3	13				12	10				4.36	0.87	4.55	0.91	0.89	6
Better designs and visualization by Implementing(BIM)	34		11				10	8	4			4.51	0.90	4.27	0.85	0.88	7
Knowledge-base of previous similar building projects and Knowledge sharing among designers	22	21	2				7	14	1			4.44	0.89	4.27	0.85	0.87	8

Provide clear and thorough clients detail project briefs to design teams to assist designers to arrive at conclusive designs	26	17	2				8	8	6			4.53	0.91	4.09	0.82	0.86	9
Use of competent designers	29	8	3	5			12	2	8			4.36	0.87	4.18	0.84	0.85	10
Paying adequate and thorough attention to detail design	21	16	8				4	16	2			4.29	0.86	4.09	0.82	0.84	11
An Adequate review of specifications and contract documents	21	11	13				2	20				4.18	0.84	4.09	0.82	0.83	12
Adequate and continual client review plan and written approval	25	7	11	2			5	12	4	1		4.22	0.84	3.95	0.79	0.82	13
Rechecking design documents before presenting them for use	13	19	11	2			6	14	2			3.96	0.79	4.18	0.84	0.81	14
Owners involvement at planning, design phase, and construction phase	14	22	9				6	8	8			4.11	0.82	3.91	0.78	0.80	15
Clearly define role and responsibilities among the stakeholder's	8	22		10	5		12	8	2			3.40	0.68	4.45	0.89	0.79	16
Ensuring Prompt approval procedures	22	7	16					16	2	4		4.13	0.83	3.55	0.71	0.77	17
Allocation of enough resources to manage with a design error	15	15	10	5			4	8	10			3.89	0.78	3.73	0.75	0.76	18
Empower better change order management with more information and data available	24	10	11					8	8	6		4.29	0.86	3.09	0.62	0.74	19
Agreeing and putting in place change management procedures before the commencement of projects (incorporating this into the contract if possible)	3	15	20	5	2		2	14	6			3.27	0.65	3.82	0.76	0.71	20
Develop a strong leadership	8	13	17	5	2			12	10			3.44	0.69	3.55	0.71	0.70	21

Freezing design at the appropriate stage of a project or implementing intermediate design freezes at various project stages depending on the type of contract		15	20	8	2			14	8			3.07	0.61	3.64	0.73	0.67	22
Representation of contractor in the planning, design phase, and scheduling process of building projects.		18	18		9		2	6	10	4		3.00	0.60	3.27	0.65	0.63	23

APPENDIX(C)

Interview Results

1. Is design error the main cause for change order in your building construction project?		
Interviewee (A)	Interviewee (B)	Interviewee (C)
Yes	Yes, of course	Yes
2 If your answer is yes, based on your experience, what are the FDE causal factors, that led change order in building projects?		
Interviewee (A)	Interviewee (B)	Interviewee (C)
Giving of less time to produce and review the contract documents.	Insufficient information provided to designer	The introduction of NCM with new technology which were not introduced /known during design phase
Poor of information flow among the principal parties	Problem in the description of required type work during design phases	Unstructured design process
May be lack of communication and collaboration of the principal parties during design phases	Scarce resources in quality or quantity (For instance. tools, equipment, staff, or financial)	No design checking or 2nd or 3rd party reviews, No system of design checking
The absenteeism of early involvement of contractor during design phase	Not giving attention for each detail during generation of the design.	Frequent scope change by the employer
Ignorance during preparation of detail drawing	Lack of training, lack of knowledge in (building laws/codes, on the concept of constructability, availability and appropriateness of materials, engineering design methods.	Poor collaboration in the design phases
Poor information about governmental regulations, municipality requirements, statutes and their adjustments	Delay in the approvals of design	No early involvement of contractor during design phase

3 How do you manage the Frequent design error causing change orders?			
	Creating effective communication plat form	Producing quality design documents	By implementing and practicing advanced engineering software
	By updating the construction knowledge	Allocation of enough budget for design production	Smooth collaboration with the designers
	Carry out detail site investigation including detail soil investigations and consider it during tendering stage of building projects	Rechecking the design and different approvals	Value engineering
	By improve collaboration	Creating clear information platform for all involved parties	Enhance communication between principal stakeholders
	By producing a concluding design and contract documents	Give attention to each detail	Complete the drawings and specifications at tender stage
4 What are the impacts of FDE induced change order?			
	Unexpected increase in building project cost	Dispute between contracting firms	Cost overrun
	Affect the progress and final project duration	Completion time delay	Dispute
	Disputes among the contracting parties	Incur additional cost	Time overrun
	Payment delay to the contractor	Affect the relationship of the parties	Contract termination

APPENDIEX(D)

Spearman's rank table

Sample size (n)	p = 0.05	p = 0.025	p = 0.01
4	1.0000	-	-
5	0.9000	1.0000	1.0000
6	0.2860	0.8857	0.9429
7	0.7143	0.7857	0.8929
8	0.6429	0.7381	0.8333
9	0.6000	0.7000	0.7833
10	0.5636	0.6485	0.7455
11	0.5364	0.6182	0.7091
12	0.5035	0.5874	0.6783
13	0.4825	0.5604	0.6484
14	0.4637	0.5385	0.6264
15	0.4464	0.5214	0.6036
16	0.4294	0.5029	0.5824
17	0.4142	0.4877	0.5662
18	0.4014	0.4716	0.5501
19	0.3912	0.4596	0.5351
20	0.3805	0.4466	0.5218
21	0.3701	0.4364	0.5091
22	0.3608	0.4252	0.4975
23	0.3528	0.4160	0.4862
24	0.3443	0.4070	0.4757
25	0.3369	0.3977	0.4662
26	0.3306	0.3901	0.4571
27	0.3242	0.3828	0.4487
28	0.3180	0.3755	0.4401
29	0.3118	0.3685	0.4325
30	0.3063	0.3624	0.4251
40	0.2640	0.3128	0.3681
50	0.2353	0.2791	0.3293
60	0.2144	0.2545	0.3005
70	0.1982	0.2354	0.2782
80	0.1852	0.2201	0.2602
90	0.1745	0.2074	0.2453
100	0.1654	0.1967	0.2327