**Study on Application of Constructability Principles in Addis Ababa's City Road Corridor Development Projects**


Name: - **Seifeddin Haji**


A Thesis Submitted to the Department of Civil Engineering

College of Civil Engineering & Architecture

Presented in Partial Fulfillment of the Requirement for the Degree of Master's in Civil Engineering (**Specialization in Construction Engineering and management**)

Office of Graduate Studies

Adama Science and Technology University

February 2025

Adama, Ethiopia

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Advisor: - Dr. Lemma Beressa

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# DECLARATION

I hereby declare that this Master Thesis entitled "**Study on Application of Constructability Principles in Addis Ababa's City Road Corridor Development Projects.**" is my own work. That is, it has not been submitted for the award of any academic degree, diploma or certificate in any other university. All sources of materials that are used for this thesis have been duly acknowledged through citation.

| **SEIFEDDIN HAJI** | ____________________ | ____________________ |
|---|---|---|
| Name | Signature | Date |

# RECOMMENDATION

I/we, the advisor(s) of this thesis, hereby certify that I/we have read the revised version of the thesis entitled “**Study on Application of Constructability Principles in Addis Ababa’s City Road Corridor Development Projects.**” prepared under my/our guidance by **Seifeddin Haji** submitted in partial fulfillment of the requirements for the degree of Mater’s of Science in Civil Engineering (Specialization in Construction Engineering and management). Therefore, I/we recommend the submission of revised version of the thesis to the department following the applicable procedures.

| **Dr. Lemma Beressa** | ____________________ | __________________ |
|---|---|---|
| Major Advisor | Signature | Date |
| ______________________ | ____________________ | __________________ |
| Co-advisor | Signature | Date |

# APPROVAL PAGE

I, the advisor of the thesis entitled " **Study on Application of Constructability Principles in Addis Ababa's City Road Corridor Development Projects."** and developed by **Seifeddin Haji** hereby certify that the recommendation and suggestions made by the board of examiners are appropriately incorporated into the final version of the thesis.

| Advisor | Signature | Date |
|---|---|---|

We, the undersigned, members of the Board of Examiners of the thesis by **Seifeddin Haji** have read and evaluated the thesis entitled "**Study on Application of Constructability Principles in Addis Ababa's City Road Corridor Development Projects.**" and examined the candidate during the open defense. This is, therefore, to certify that the thesis is accepted for partial fulfillment of the requirement of the degree of Master of Science in Construction Engineering and Management.

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# ABSTRACT

Enhancing the efficiency and quality of construction projects, while minimizing costs and timelines are critical issues in construction engineering and management. The concept of Constructability has re-emerged as a proactive approach that positively impact project quality, cost, and duration. The objective of the research is to study the Implementation Practice of constructability concepts in corridor development projects in Addis Ababa, Ethiopia. Evaluating the level of importance and application of constructability concepts, in local construction practices, with a particular focus on stakeholder perspectives and the importance of these principles. Utilizing a mixed-methods strategy, incorporates both quantitative and qualitative in data collection and analysis to respond to the research inquiries. A total of 40 constructability concepts were identified across the project life cycle, encompassing conceptual planning, design and procurement, and field operations. Data was collected through surveys and interviews with those stakeholders directly involved in corridor development projects, including contractors, consultants, clients, and regulatory authorities. The relative importance index (RII) method applied to prioritize the level of importance of constructability concepts. From the result it is found that the first three importance concept are "the use of advanced information technologies", "the integration of construction knowledge in the planning phase", and "the early identification of project team members", with RII values of 0.951, 0.930, and 0.910, respectively. The study shows that the integration of advanced information technologies, such as Building Information Modeling (BIM) and project management software, can significantly enhance the planning and execution phases of construction projects. The research highlights a notable commitment to examining political and legal factors prior to the design stage, which is crucial for understanding and applying constructability principles in government-led projects in Addis Ababa. To improve constructability in construction initiatives throughout the city, the study recommends fostering greater stakeholder engagement and collaboration, alongside a dedicated effort to educate and train pertinent individuals on the significance and application of constructability principles. Ultimately, the study proposes strategies for enhancing the implementation of a constructability program moving forward.

KEY WORDS: - Highway Construction, corridor development, Constructability concepts, Improvement Strategy

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| | |
|---|---|
| AEC; | Architecture, Engineering, and Construction |
| AISC; | American Institute of Steel Construction |
| BLIS; | Building Lifecycle Interoperable Software |
| CII; | Construction Industry Institute |
| CIIA; | Construction Industry Institute Australia |
| CIDA; | Construction Industry Development Agency |
| AACRA | Addis Ababa City Roads Authority |
| CIOB | Chartered Institute of Building |

# CHAPTER 1. INTRODUCTION

## 1.1. Background of the study

Improving productivity and quality in construction projects while reducing costs and time is a vital concern in construction engineering and management. A significant problem with traditional contracting methods is that design consultants work separately from construction contractors, who only commence their tasks once the design phase is entirely finished. This disconnect can create difficulties during construction, as unexpected environmental factors may require adjustments in resources, leading to increased costs and diminished quality. Constructability has re-emerged as a proactive program benefiting project quality, cost, and duration. The US construction industry saw a decline in value and quality during the 1940s and 1950s due to a separation of design and construction roles [1]. The historical master builder concept is being reestablished, with architects/engineers and constructors working together to ensure project success. Owners, architect/engineers, and constructors play crucial roles in a project's life cycle [2].

Highways are generally built in accordance with rigorous quality and safety standards; nonetheless, there are occasions when construction methods and specific details may be overlooked. Problems that arise during the construction phase can lead to considerable costs and complications, including traffic disruptions, necessary modifications, poor planning, disputes, budget overruns, safety hazards, and project delays. Insufficient constructability has been identified as a significant factor contributing to these issues. Improving constructability can lead to considerable savings in both time and expenses. By incorporating construction expertise in the design stage, many potential construction challenges can be addressed, thereby improving overall project efficiency. Professionals are actively involved in collecting best practices and developing innovative strategies to address the challenges posed by increasing costs and delays in road construction projects [3].

Designers have the ability to significantly reduce or even eliminate the risks associated with project delays, change orders, and additional expenses by addressing the completeness of a design and its construction requirements during the initial design phases. This proactive approach is preferable to depending on contractors to assess the design, identify errors, and confirm its completeness [4]. When designers neglect to incorporate construction requirements and limitations into their critical decision-making, they often encounter construction-related issues with their designs. Modifications made during the construction phase can be particularly challenging to implement and may incur considerable costs. Consequently, contractors frequently find themselves needing to redesign the project for easier construction, a process that can be both expensive and time-consuming [5].

Constructability is a refined methodology focused on integrating the design and construction phases of a project. It highlights the significance of incorporating construction knowledge and expertise during the initial stages of project development. This approach aims to optimize construction processes throughout all phases of the project life cycle, which encompasses initiating, planning, designing, executing, and closing. As an important project management technique, constructability—or buildability—serves as an alternative strategy to improve coordination among construction personnel and effectively address various challenges that may arise during the execution of the project. [6, 7].

The question arises regarding how designers, who often possess limited knowledge of construction, can more effectively integrate construction requirements and constraints to create designs that are easy to build. Constructability involves a systematic approach aimed at developing construction-oriented designs that align with the project objectives set by owners, focusing on critical areas such as safety, cost, schedule, and maintainability. In Ethiopia, there has been limited research on constructability in highway projects. This could be partly because constructability has not been understood by the stakeholders.

The primary aim of this study is to explore the application of constructability principles within road construction projects, specifically focusing on enhancing the overall effectiveness of highway construction initiatives in the Addis Ababa city road corridor development. This paper presents a comprehensive overview of various aspects related to the concept of constructability as articulated by numerous researchers. It further examines the necessity for implementing constructability principles, outlines their advantages and challenges, and assesses the level of awareness among project stakeholders. Additionally, this study advocates for more extensive research into constructability within the local context to deepen understanding of regional design and construction processes. Ultimately, these initiatives aim to make a positive impact on the overall development of Ethiopia's construction sector.

## 1.2. Statement of the problem

The conventional contracting model presents considerable difficulties in clearly defining the roles of design consultants and construction contractors, as contractors typically become involved only after the design phase is completed. This separation creates a-disconnect between design intentions and construction realities, often resulting in unexpected environmental challenges that necessitate resource reallocation, thereby increasing costs and compromising quality. Furthermore, the absence of early collaboration hinders designers from grasping construction constraints, leading to potentially impractical designs. Such fragmentation often leads to design modifications, a rise in requests for information (RFIs), conflicts, delays, and overall project cost increases. In Ethiopia, where the road sector is crucial for economic growth, these challenges adversely affect time, cost, and quality. This study investigate the application of Constructability Principles in the development of road corridors in Addis Ababa, highlighting the need for effective improvement strategies. However, the implementation of these principles in Ethiopian government projects remains poorly defined, making this research vital to address the costly and time-consuming issues that plague many construction projects. Despite constructability being recognized as a national concern, it has not received sufficient attention within the local construction industry, emphasizing the focus of this research.

## 1.3. Research Objectives

### 1.3.1. General Objective

The primary objective of this study is to examine the Application of Constructability Principles in Road construction Projects, specifically focusing on the Addis Ababa City Road Corridor Development Projects, with the goal of enhancing the overall efficiency of highway construction projects.

### 1.3.2. Specific Objective

1) To identify the fundamental concepts and principles of constructability in order to develop a comprehensive constructability assessment model.
2) To evaluate the significance and perception of constructability concepts, as well as the barriers encountered in implementing these principles within road corridor development projects in Addis Ababa.

3) To establish a constructability improvement strategies in Addis Ababa city construction industry.

## 1.4. Research Questions

To achieve the objectives specified in this thesis, the subsequent questions were formulated during this thesis work:

1) What are the constructability concepts, principles and improvement ideas useful for constructability assessment model?
2) How significant are constructability concepts perceived to be by stakeholders involved in road corridor development projects in Addis Ababa? And what barriers do stakeholders encounter when implementing constructability principles within these projects?
3) What could be done to learn from our best practices, close the gaps identified, and establish constructability improvement strategies to improve the general performance of Addis Ababa City construction industry?

## 1.5. Scope

The study focused exclusively on government initiatives in Addis Ababa, the capital of Ethiopia, constrained by time and budgetary factors. Furthermore, it specifically examined corridor development projects that have been implemented during the initial phase.

## 1.6. Significance of the Study

This research paper addresses deficiencies in Construction Project Management practices related to constructability in road corridor development projects in Addis Ababa. By identifying these challenges, the study aims to enhance constructability practices and maximize their benefits. The significance of this study includes enhancing knowledge by clarifying constructability's role in successful project delivery, addressing practical issues by deepening the understanding of design and construction factors, and promoting improved efficiency and collaboration among professionals. Additionally, it provides a foundation for future research as a valuable secondary data source and offers critical insights for policymakers on areas needing corrective action.

## 1.7. Structure of the Research Report

The research report is structured into five distinct chapters:

1. The first chapter serves as the introduction, outlining the general context of the study, articulating the problem statement, defining both the general and specific objectives, presenting the research question, and detailing the scope, significance, and limitations of the study.
2. The second chapter is dedicated to the literature review, which is divided into two sections. The first section provides a theoretical overview of international experiences and previous studies related to the topic. The second section focuses on empirical research concerning relevant issues.
3. The third chapter covers the research methodology, detailing the methodology and design employed in the study, the selection of the sample frame, the sources and types of data, as well as the methods for data collection and analysis.
4. The fourth chapter presents and analyzes the data, discussing how the collected information is organized and interpreted.
5. The fifth chapter concludes the report with a summary of the study's findings and offers recommendations to address the identified issues.

# CHAPTER 2. LITERATURE REVIEW

## 2.1 General Overview of Construction industry

The construction industry is acknowledged as a dynamic and risky sector where many projects fail to achieve their goals due to inherent risks and uncertainties. Construction project managers must ensure projects stay within budget and meet deadlines despite challenges. Concerns have been raised about the increasing number of difficult-to-bid projects in the industry, leading to more contract change orders and litigation. Constructability reviews have been shown to save time and costs throughout the project development process. Currently, designers and construction managers often work separately, leading to potential design flaws that result in increased costs and delays [8-9]. The traditional contract approach, where design is completed before construction begins, can lead to design requirements not being met during construction. In Ethiopia, constructability methods are not widely implemented, especially in government projects. This chapter provides an overview of existing theories and research on constructability in the construction industry.

## 2.2. The Project Life Cycle

A successful construction project begins with the owner defining requirements for the project team. Constructability should be integrated throughout the project life cycle, including feasibility studies, planning, procurement, construction, and post-construction. Stakeholder involvement is essential, with designers playing a critical role in applying constructability principles. During planning and design, planners and designers hold technical responsibility, as shown in Figure 2:1, which outlines the project life cycle under traditional contracts.

Project costs typically increase as implementation advances, highlighting that the planning phase is optimal for addressing constructability. Various Project Delivery Methods, such as Traditional (Design-Bid-Build), Management (Construction Management), Integrated (Design and Build, EPC), and partnering approaches, are available, with the choice depending on project owners' preferences. [10].

In Ethiopia, the construction sector primarily utilizes a conventional contract method known as design-bid-build, which is marked by minimal collaboration among stakeholders during the design stage. As a result, the construction process frequently faces considerable obstacles, especially regarding project delivery methods.

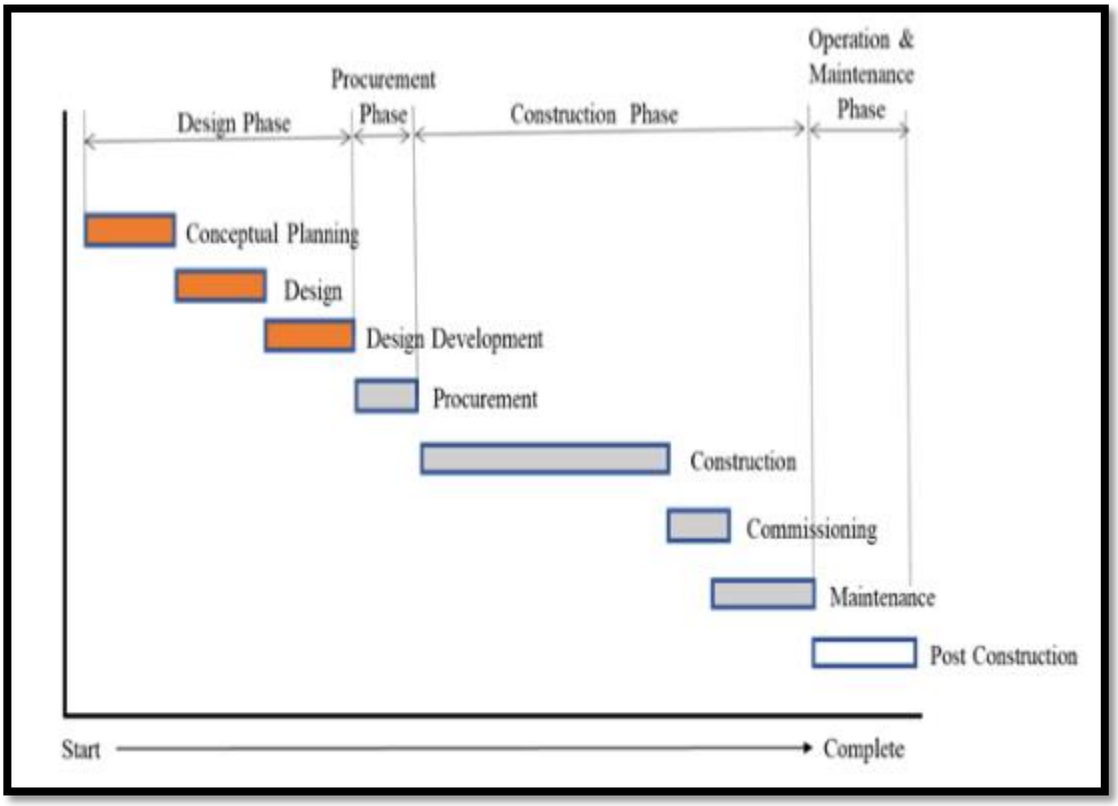


Figure 2-1; Project life cycle

Research has shown that many challenges related to insufficient design and production practices—regardless of whether traditional or non-traditional contracts are employed—arise from ambiguous or incomplete project information, poor quality of the data provided, and a general lack of coordination between the design and construction phases. Numerous studies have pointed out that the deficiency of integrated construction knowledge within the design process significantly hinders constructability. This lack of integration has been recognized as a key factor contributing to projects exceeding their budgets and failing to adhere to timelines. The gap between design aspirations and actual construction capabilities can result in inefficiencies and heightened costs, highlighting the urgent need for enhanced collaboration and communication among all stakeholders in the construction process [3].

- **Problems in the construction industry**

The construction sector is characterized by fragmentation and is beset by numerous challenges, including rising project costs, delays in completion, and issues with quality.

These time and cost overruns often lead to conflicts among stakeholders. Therefore, it is crucial to explore alternative strategies that can enhance project performance and mitigate these overruns. A discussion hosted by the Business Roundtable, in collaboration with the Construction Industry Institute, highlighted that project owners frequently overlook opportunities for reducing costs and timelines. To address this, the adoption of innovative construction methodologies and their integration into various project phases—such as planning, design, and engineering—can be beneficial. For instance, implementing "Constructability" principles has the potential to reduce total project costs by 10–20% [12, 13]

The intricate nature of construction systems contributes to a range of productivity and quality challenges within the industry, manifesting as frequent delays and budget overruns. Project owners' expectations are often unmet, while construction outputs may exhibit excessive quality, leading to waste. Numerous studies and reports have underscored these issues globally. For instance, a 2007 report by the American Institute of Architects revealed that the construction sector experiences approximately 30% waste due to over-quality, alongside a notable decline in productivity since 1964, in stark contrast to a 200% increase in other industries. Furthermore, interoperability issues within Architecture, Engineering, and Construction (AEC) software result in an annual cost of $15.8 billion to the U.S. construction sector. Some projects, such as the "Second Stage Expressway," have been abandoned mid-construction after significant financial investments, while the Berlin airport project faced 20,000 identified errors, leading to delays and escalating operational costs exceeding $16 million monthly for the municipality. Additionally, 77% of highway projects in the U.S. have experienced cost overruns, illustrating that these challenges are prevalent across both developing and developed nations, affecting various types of construction endeavors [14-15].

The construction industry is grappling not only with delays and budget overruns but also with significant quality challenges. The expectations of project leaders, future leaders, and operators are frequently unmet, leading to complications in verifying compliance with product requirements. A study from Carnegie Mellon University indicates that in the United States, defective components or modifications account for 6 to 15% of total construction costs, while an additional 5% is lost due to changes made during the operational phase. Similarly, French construction experts estimate that only 70% of the total costs associated with construction systems contribute to added value, with the remaining 30% attributed to inefficiencies stemming from quality issues [17, 20].

Design modifications pose a considerable challenge within the construction sector. They incur substantial administrative expenses, consuming 40-50% of a designer's overall work hours, and can lead to costs ranging from 5 to 15% of the total construction budget, even in projects that are effectively managed. These figures may underrepresent the true financial impact, as they exclude latent and indirect costs, disruptions from schedule delays, litigation expenses, and other intangible factors such as constructability issues. Notably, research indicates that approximately two-thirds of design changes, in terms of cost, are preventable, even in projects executed by leading industry professionals. This highlights a significant opportunity for enhancement in the management of design changes [21-27].

Managing change presents a significant challenge, as conventional design management methods often fall short in forecasting the repercussions of alterations on the design program. Consequently, identifying all potential change trajectories and selecting the most advantageous one becomes a complex task. If existing tools are inadequate in assessing the comprehensive effects of design modifications, and human judgment cannot adequately navigate the numerous interactions that influence outcomes, many design changes may occur without a complete understanding of their potential consequences. This limitation in predicting the impact of changes represents a substantial obstacle to the effective management of design modifications [28- 30].

## 2.3. Theory and Concepts on Buildability and Constructability

### 2.3.1. Definitions of Buildability

Buildability encompasses a broad area of study within construction technology, engaging numerous researchers and organizations. As a result, various definitions of buildability have emerged. The most widely accepted definition comes from the Construction Industry Research and Information Association (CIRIA), which states that buildability refers to the degree to which a building's design promotes ease of construction while adhering to the overall requirements for the finished structure [31].

Other definitions of buildability are listed below: Another researcher stated that buildability is "the ability to construct a building efficiently, economically and to agreed quality levels from its constituent materials, components and sub-assemblies" [32].

Another researcher also referred to buildability as "the extent to which decisions are made during the whole building procurement process, in response to factors influencing the project and other project goals, ultimately facilitating the ease of construction and the quality of the completed project" [8].

Numerous studies have identified three recurring themes across various definitions of buildability: the emphasis on facilitating construction, the importance of a comprehensive perspective on the building, and the notion that a building's performance over time is closely linked to the needs of users and the surrounding environment.

### 2.3.2. Definitions of constructability

Constructability is defined in multiple ways, with a prevalent definition established by the Constructability Task Force, which states that it involves the optimal application of construction knowledge and experience throughout planning, design, procurement, and field operations to meet overall project goals. The Construction Industry Institute (CII) has noted that, in accordance with the Pareto Principle, the capacity to impact costs diminishes as a project progresses. Therefore, it is essential to explore potential constructability savings at various phases of the project life cycle, specifically during conceptual planning, design and procurement, and field operations [9].

Another important definition was introduced by the Construction Industry Institute in Australia which described it as "the integration of construction knowledge in the project delivery process and balancing the various project and environmental constraints to achieve the project goals and building performance at an optimum level" [37].

This was, later modified as "a system for achieving optimum integration of construction knowledge in the building process, and balancing the various project and environmental constraints to achieve maximization of project goals and building performance" [3]. Another researcher referred to constructability as "programs aimed at integrating engineering, construction, operation knowledge, and experience to better achieve project objectives."[38]

### 2.3.3. The difference between buildability and constructability

Buildability refers to a design principle, whereas constructability encompasses the entire project lifecycle. While the terms constructability and buildability are often used interchangeably, many scholars argue that they are not synonymous. The distinction is particularly noted in regional usage, with buildability being more common in the UK and constructability in the USA. Nonetheless, we align with researchers who assert that constructability is fundamentally different from buildability due to its broader scope and implications [3].

**Buildability** refers to the extent to which a building design facilitates the ease of construction, whilst clients‟ requirements are met. It therefore focuses on the design of a building

**Constructability**, which embraces both design and management functions, is concerned with a wider scope than "buildability‟. It deals with the project management systems which optimally use construction knowledge and experience to enhance efficiency of project delivery.

We can express the difference in a simpler way: buildability is a design concept while constructability is a concept for the whole process of a project.

## 2.4. Constructability concepts and attributes

The Construction Industry Institute and [31-40] have developed 23 constructability concepts:

*Table 2-1; Constructability enhancement concepts during conceptual planning*

| Constructability enhancement concepts during conceptual planning phases of the project C1 to C7 | |
|---|---|
| Concept C1 | The project of the constructability program should be discussed and documented within the project execution plan, as well as the participation of all the project team members. |
| Concept C2 | A project team that includes a representation of the owner, the engineer, and the contractor should be formulated and maintained to consider the constructability issue from the outset of the project, and through its other phases. |
| Concept C3 | Individuals possessing knowledge and experience of modern construction should achieve the early project planning so that any interference between design and construction can be avoided. |

| | |
|---|---|
| Concept C4 | The construction methods should be taken into consideration when choosing the type and the number of contracts required for executing the project. |
| Concept C5 | The master project schedule and the construction completion date should be construction-sensitive and be assigned as early as possible. |
| Concept C6 | In order to accomplish the field operations easily and efficiently, major construction methods should be discussed and analyzed in-depth as early as possible to direct the design according to such methods. |
| Concept C7 | Site layout should be studied carefully to allow construction, operation and maintenance to be performed efficiently, and avoid interference between the activities performed during these phases |

*Table 2-2; Constructability enhancement concepts during design and procurement*

| ***Constructability enhancement concepts during design and procurement phases of the project C8 to C15:*** | |
|---|---|
| Concept C8 | Design and procurement schedules should be dictated through the construction sequence. Thus, the construction schedule must be discussed and developed prior to the design development and procurement schedule. |
| Concept C9 | Advanced information technologies are essential to any field, including the construction industry. Hence, the use of those technologies will overcome the problem of fragmentation into specialized roles in the field, and enhance constructability. |
| Concept C10 | Designing through design simplification, and design review by a qualified construction personnel must be configured to enable efficient construction |
| Concept C11 | Project elements should be standardized to an extent that prevents any costs from being negatively affected. |
| Concept C12 | The project's technical specifications should be simplified and configured to achieve efficient construction, without reducing the level or efficiency of the project performance. |

| | |
|---|---|
| Concept C13 | The implementation of modularization and preassembly of project elements should be taken into consideration and studied carefully. Modularization and preassembly design should be equipped to facilitate fabrication, transportation, and installations. |
| Concept C14 | Project design should consider the accessibility of construction personnel, materials, and equipment to the allocated position inside the site. |
| Concept C15 | Design should facilitate construction during adverse weather conditions. Efforts should also be made to plan for the construction of the project under suitable weather conditions. Otherwise, the designer must increase the project elements that could be fabricated in workshops. |

*Table 2-3; Constructability enhancement during field operation phases*

| ***Constructability enhancement during field operation phases of the project C16– C23*** | |
|---|---|
| Concept C16 | Field task sequencing should be configured in order to minimize damages or rework some project elements, while also minimizing scaffolding needs, formwork used or congestion of construction personnel, material, and equipment. |
| Concept C17 | Innovation in temporary construction materials/systems, or implementing innovative ways of using available temporary construction materials/systems that have not been defined or limited by the design drawings and technical specifications. Such actions will deliver a positive contribution to the enhancement of constructability. |
| Concept C18 | Incorporating new methods of innovation through the use of off-the-shelf hand tools or modifying available tools. Furthermore, the introduction of new hand tools can reduce labour intensity, increase mobility, safety or accessibility which will consequently enhance constructability at the construction phase. |
| Concept C19 | The introduction of innovative methods for using or modifying the available equipment to increase their productivity will lead to improved constructability. |

| | |
|---|---|
| Concept C20 | To increase productivity you must reduce the need for scaffolding, or improve the project constructability under adverse weather conditions, while constructors should be encouraged to use any optional preassembly. |
| Concept C21 | Constructability will be enhanced by encouraging the constructor to carry out the innovation of temporary facilities. |
| Concept C22 | Good contractors, based on quality and time of their work should be documented. Subsequently, future contracts for construction work would not solely be awarded based on low bids, but also by considering other attributes, i.e. quality and time. |
| Concept C23 | Evaluation, documentation and feedback of the issues of constructability concepts should be maintained throughout the project and used in later projects as learned lessons. |

## 2.5. The Major Issues of Constructability

Some of the major issues have been extracted from the research of various authors and organized under various heads for detailed discussion. The issues have been taken which were common to most of the papers and the viewpoints gathered thereof. These 16 issues can be listed as: Integration, Coordination, Bidding Process, Construction driven schedule, Simplification of Design, Standardization of element, Prefabrication, Accessibility to Site, Adverse weather conditions, Specifications, Encouragement to Innovations, Past Lessons Learned Exercise & Reviews, Availability of Resources, Appraise Recycling, Waste Management, Employment of Advance Information Technology.

### I. Integration:-

Integration, construction knowledge and team skills consider the importance of including the 'right' team members from the beginning of the project. Integration as an "invisible asset" [41]. The process of schedule development should involve an interdisciplinary team expert and well represented by construction personnel [42]. The experienced construction personnel should be available on a continuing or timely basis so that they can give their inputs to the design team. Construction expertise can also help in identifying potential areas where standardization can be applied in the design. Timely review of project by construction personnel can also minimize accessibility problems on site and hence improve the working.

Fragmentation of goals as one of the major issues that influenced the construction industry in recent days, which was a result of specialization of expertise [41]. As a result, the successful and timely completion of project may suffer. In this situation, the main objective were to develop integration framework. Nine managers were interviewed to derive at managerial techniques employed. The following benefits were identified:-
Improved project cost effectiveness and schedule. Increased safety, Prevention of claims and improved logistics management and cash flows
Integration during the design phase is crucial for two primary reasons: it helps avert issues in later stages and facilitates the selection of alternatives that can enhance project performance. It is essential for contractors and vendors to engage as equal partners in the design process, ensuring that joint decisions are made collaboratively. This integration process necessitates the sharing of information and expertise among independent subsystems, and it emphasizes the importance of collective decision-making [41]. Owners must make significant choices regarding the integration process, such as prioritizing a contractor's integration capabilities over merely selecting the lowest bid. Additionally, owners can provide training for personnel involved in integration and offer special incentives to those who contribute actively to the project's success. In the private sector, effective integration during the design stage can yield optimal cost-saving solutions and improve contract acquisition. The success of such projects can influence the ongoing relationship between contractors and corporate clients. In the public sector, a contractor's past performance and reputation play a vital role in their bidding strategy, although the lowest bid remains a critical factor.

Early involvement of contractor in design allows the contribution of construction knowledge and experience to design. Direct involvement of contractor gains better cooperation between contractor and other participants throughout the design and construction process [48]. In another paper, the inputs of contractor at early stage into four areas such as: (1) ability to develop creative solutions, (2) knowledge of construction space needs, (3) knowledge of fabrication and construction capabilities, (4) knowledge of supplier lead time and reliability[43]. Another paper has recommended for design firms to integrate construction knowledge and contractors experience in design process as approach to reduce construction waste and improve building performance [44].

## II. Coordination

Researcher had studied the building construction industry and identified three main functions of the building process: the design, the construction and the coordination. “Coordination is almost equivalent in meaning to control planning or management but is more descriptive of relating together of separate activities and their concerted direction towards a common purpose” [45] Coordination has also been defined as effective harmonization of planned efforts for accomplishing goals. It is the most important and sensitive issues of management. Coordination acts as a bridge in fills up the voids created in various departments by changing situations in system, procedures and policies [46].

A research performed in identifying what activities are performed to achieve coordination, which among those are most important and which among those are most time consuming coordination activities [47]. They identified 64 coordination activities and based on 33 responses received from practitioners in Hong Kong construction industry concluded the results. The six most important coordination activities have been identified as:

1. Identifying strategic activities and potential delays
2. Ensuring the timeliness of all work carried out
3. Maintaining records of all drawings
4. Information directives, verbal instructions and documents received from the consultants and client
5. Maintaining proper relationship with client, consultant and contractor
6. Liaison with the client and the consultant

The activities that consume most of the time are identified as:

a) Conducting regular meetings and project reviews
b) Gathering information on requirements of all parties and consolidating for use in planning, resolving differences etc.

The study also identified some important facts like; it is important to identify the activities which have greater impact than the other activities.

## III. Bidding Process

A researcher identified the need for the early involvement of contractor in design[46].The Chartered Institute of Building (CIOB) has given the definition of Design and Build method as, “the client deals directly with the contractor for the complete building and it is the contractor who is not only responsible for, but also coordinates the separate design and construction processes, including engagement of the design team who are, therefore, contractually linked with the contractor and the client. The construction process, whilst linked, is still separate from the design process, leaving the consultants free to concentrate on their own roles. The client may, however, directly appoint either in house staff or a separate consultant to check that the contractor is providing value for money and that content and quality are satisfying".

A researcher discussed one of the problems of Design bid Build contracting system [48]. The builder accepts the contract without asking for any kind of corrections in design and bidding time is short and the builder has little time to review. The builder later requests for extra time or extra compensation which appears to be an easy remedy but later on can result in serious impacts like delays of projects or affecting the financial feasibility of the project.

Design and Build contracting is the best and an effective mechanism to facilitate integration of design and construction. 3 main types of mechanism were identified to increase the project integration; (1) contractual, (2) organizational and (3) technological. Design Build contracts have been suggested, as the entire responsibility of engineering, procurement and construction process is under one organization. It is also appreciated because the contractors get an opportunity to participate in the design process right from the beginning of the project. The contractors give importance to corporate relationship and maintain long term relationship with the designers. This helps them understand the needs of the client and win the contract, even if the bid is not lowest. The construction firms which do not have in house design cells, insist on maintaining relationships with the designers. Such relations help them gain projects through joint proposals also, at times [41].

Another research have explained the philosophy of Design Build procurement method as "single point source" [49]. The Design Build methodology provides best combination of design, construction, buildability and economy. The design Build method has better scope of achieving synergy between the two phases of design and construction as compared to Design Bid Build because in the previous case a single body is responsible for all the major decisions and activities with fewer conflicts. The advantages of Design and Build can be listed as: - Shorter project execution time, Single point responsibility, Very less claims and disputes, Greater privacy certainty, Economy of project, Better communication in the project team and Collaborative work environment

The authors further added that Design and Build structures could be Designer led Design and build, Contractor led Design and build and Novated Design and Build. In the third category, the client hires the designer and gets the design prepared. The contractors bid on this design and the successful contractor enters into contract with the designer and develops the design details and executes the project.

**IV. Construction Driven Schedule**

Constructability of a project is increased when the design and procurement schedules are construction driven. The construction schedules should be prepared even before the design and procurement schedules are finalized. This leads to reduced project duration, fewer delays in field, effective prioritization of various activities, effective work package and goals of project are well known to the project personnel. Another paper explains that as the design process progresses the schedule must be updated on a regular basis. A Barr (Gantt) chart schedule should be prepared that identifies important activities. As the design progresses the schedule should evolve from initial bar chart to an informative network type chart schedule that shows activities and durations and their interrelationships. The design process is the time having much potential to correct the scheduling problems [40].

**V. Simplification of Design**

A research analyzed that constructability is increased when designs have considered efficient construction i.e. designs are configured to enable efficient construction. Some principles that can be adopted for simplifying designs are listed as:- Use of minimum number of components, elements or parts for assembly, Use of readily available materials in common sizes and configurations, Use of simple, easy to execute connections with minimum requirement of highly skilled labour and special environment controls, and Use of design which minimize construction task interdependencies. It is suggested that the design should be reviewed by qualified construction personnel [40].

**VI. Standardization of Element**

Constructability is enhanced when the design elements are standardized and repetition is followed [40]. This also leads to savings because variations are minimized. Various areas where standardization can be applied are building systems, materials types, construction details, dimensions and elevations. The extent to which standardization may be applied depends on the economic analysis also. The reduction in variety can lead to many benefits like discounts on more of same material, simplified procurement and materials management.

Another paper identifies some of the preliminary design variables as important for constructability like dimension of elements, distances between elements, their repetition and modularity of layout. It is also suggested that the constructability can be improved at preliminary design stage in three types of design decisions: the horizontal layouts, vertical layouts and the dimensioning of structural elements [50, 51]. "When a company sets up its own standards or the codification and own standardization of materials, it helps in the variety reduction as one can constantly monitor the amount of the materials used".

### VII. Prefabrication

Ease of construction enhances if preassembly work is thought of in advance and preassembly/module designs are incorporated in advance to facilitate the process of fabrication, transport and installation. It should be take care off at the conceptual planning stage. The items which can be prepared off site should be analyzed at early stage of design. This can lead to many benefits like improved task productivity, parallel sequencing of activity, increased safety, improved quality control and reduced need for scaffolding. It also studied that preassembly can increase constructability in case of elevated works because the need for scaffolding is reduced/eliminated. This issue also helpful in situations where site is congested and quality sensitive work is to be produced. Adverse weather conditions also promote the need for modular construction practices [40].

### VIII. Accessibility to Site

The constructability enhancement can be achieved when the design promotes accessibility of manpower, material and equipment. As study of accessibility becomes very important and crucial in cases where the sites are tight or roads capacity is limited, in case of renovation projects, working on high elevations, sites with steep grade changes, sites with extreme weather conditions or environmental conditions (like vegetation) or sites where multiple contractors are working. It is important to plan accessibility to site in terms of project elements, well defined and specified access lanes, clear spaces for placement of equipment. Proper communication is required with designers regarding transport, erection and sizes of equipment in terms of clearances etc. [40].

### IX. Adverse Weather Conditions

Constructability can be increased when design facilitates construction under adverse weather conditions, in case they exist. This is crucial in countries where climate is a challenge for construction activities smooth functioning. Both the designer and constructor have to be sensitive towards planning in such regions. Proper investigation is required to be done by the designer in advance to find out ways in which exposure to temperature extremes and effects of rain can be minimized. One of the major concerns in such cases is the quality control. Some of the important measures that can be incorporated are allowance for large enclosed spaces which can be used as fabricating shops and equipment storage, early paving of site to eliminate muddy operations, specifications such as admixtures for overcoming the effects of extreme weather and maximizing off site work [40].

### X. Specifications

Inputs should be invited from the construction personnel in finalizing of preferred specifications and methods but that should not be constraining design configuration. In case the views of construction personnel vary, specifications should allow for cost effective alternatives [45]. The specification of special or custom equipment or material should be avoided. Also the specification of obsolete materials, equipment and construction techniques should be avoided [53].

### XI. Encouragement to Innovations

Innovation defined as an attempt by, “right people” to the demands of their job [52]. It is defined as, “Innovation is a by-product” of people who are acting on their unique strengths and who are refining their gifts”. Individuals engaged in innovation are motivated by elevated project goals and possess a well-rounded view of change. These individuals adopt a proactive "attacker" mindset, focusing on addressing the shortcomings of existing technologies [53].

Effective management practices should encompass the reassessment of established methods and the encouragement of innovative ideas. The authors of the paper emphasize the importance of nurturing promising concepts and documenting successful outcomes. They identify several common innovation strategies that can improve the constructability of construction projects, categorized under various aspects such as the sequencing of field tasks, materials, and equipment. For instance, coordinating the use of cranes, scaffolding, and hoisting equipment among multiple subcontractors can minimize site confusion and congestion. Additionally, early installation of lighting systems can reduce reliance on temporary solutions, while the prompt erection of stairs and platforms can expedite project timelines [54].

Moreover, advancements in temporary construction systems, such as steam curing and ground freezing, represent significant innovations. The introduction of modern formwork techniques, including flying formwork and ship form systems, facilitates easier assembly. Enhancements in labor tools, such as cordless power tools and automatic nailing guns, contribute to improved mobility, safety, and reliability. The trend towards machine-driven processes, exemplified by fully automated concrete batch plants and remote-controlled welding systems, further accelerates construction efficiency. Additionally, the implementation of temporary facilities, such as weather-resistant enclosures and site pavements made from locally sourced materials, exemplifies innovative approaches to enhance project execution [54].

## XII. Past Lessons Learned Exercise & Reviews

When designers, owners, and construction personnel conduct a thorough review of the specifications, the project's constructability improves, leading to more streamlined field operations. Additionally, documenting the preferences and innovative ideas of constructors can further enhance future constructability, ultimately benefiting upcoming projects. Inadequate documentation can lead to delays when information is needed, negatively impacting constructability. Therefore, it is essential for both designers and constructors to implement effective information management systems [49, 54].

Furthermore, a separate study highlighted that corporate lessons learned are frequently neglected, with a lack of formal systems for capturing feedback. Establishing a structured approach to gather construction knowledge is crucial, as it allows this information to be effectively communicated to designers, benefiting both designers and contractors. Knowledge collected during and after the construction phase serves as a valuable reference for future projects, helping to prevent similar challenges and obstacles [50].

## XIII. Availability of Resources

It is always advisable to avoid materials which are difficult to obtain [40].  A paper discusses that the architects and engineers should consider the available local material, conditions as well as construction practices. The availability of labour, material and equipment should also be considered in design i.e. the type of labour skills and construction practices which are not locally available should be avoided, so that the project cost can be controlled and delays avoided [48].

### XIV. Appraise Recycling

Construction and demolition (C&D) waste constitutes approximately 10-20% of municipal solid waste. This type of waste is generated whenever construction or demolition activities occur. C&D waste is typically heavy, bulky, and requires significant storage space. According to a report from the Technology Information Forecasting and Assessment Council (TIFAC) in New Delhi, around 70% of the construction industry lacks awareness regarding recycling techniques for this type of waste. The management of construction and demolition waste can be divided into four key stages: (1) storage and segregation, (2) collection and transportation, (3) recycling and reuse, and (4) disposal [55].

### XV. Waste Management

Waste management is characterized as the systematic processes involved in the collection, transportation, processing, recycling, disposal, and monitoring of waste materials. This term is predominantly used in the context of materials generated through human activities. Effective waste management is essential for resource recovery and for mitigating adverse effects on public health, the environment, and aesthetic values [56].

Previous research indicates that waste is typically regarded as unwanted material, which can arise during construction activities or at the conclusion of a project. The authors emphasize that minimizing waste is crucial for enhancing profitability, as waste represents indirect costs. While management software can assist in tracking material usage throughout a project, many companies still rely on manual waste assessments on-site, resulting in inefficiencies and time loss. The significance of waste management has not been fully recognized within the Indian construction sector. Reducing waste is vital for economic sustainability. It is imperative for the government to establish regulations and standards regarding permissible waste percentages [49].

Various causes of waste have been categorized based on their severity. The most critical factors include: inadequate planning, poor management practices, insufficient quality control, lack of individual accountability, and general negligence. Moderately severe causes encompass: flawed designs, inappropriate specifications, and inadequate labor supervision leading to defective systems. Lastly, less severe causes include: insufficient technological expertise, resource scarcity, unsanitary working conditions, and a lack of standardization [49].

**XVI. Employment of Advance Information Technology**

Computer-aided design (CAD) overlay techniques have demonstrated their effectiveness in identifying accessibility issues during project execution ahead of time. In complex scenarios, computerized simulation models have been developed to optimize workflow and logistics. Research indicates that CAD and expert system technologies can enhance corporate knowledge by capturing lessons learned from previous projects, allowing these insights to be automatically applied during the design phase. This approach improves the constructability of projects, resulting in higher quality outcomes. A data system that integrates historical lessons learned can assist designers in saving time and resources, ultimately making projects more cost-effective. In India, companies frequently utilize “MS Project” for planning material quantities, while some also employ “PRIMAVERA” to verify the initial planning [50, 51].

## 2.6. Improvement in Constructability

### 2.4.1 Improvement of constructability during conceptual planning

In the United States, enhancing constructability has been recognized as a crucial element throughout the entire project life cycle. A research team from Stanford University was tasked by the CII Constructability Task Force to investigate ways to improve constructability during the conceptual planning stage. The research concentrated on three primary areas: project planning, site layout, and the selection of construction methods. The Task Force identified these areas as key opportunities for enhancing constructability during the early phases of project development. Findings from the report indicated that decisions made during conceptual planning significantly influence the subsequent phases of the project, particularly regarding construction feasibility. It emphasized that involving individuals with construction expertise during this phase could yield valuable insights for critical decisions in the following domains: Project planning can yield managerial benefits through the development of efficient work plans and schedules that align with construction needs, as well as technical benefits by facilitating design concepts that simplify the building process. Regarding site layout, assessing its impact on construction can help identify and mitigate potential issues with minimal alterations to the original design, thus fostering efficient construction practices. Lastly, considering construction methods during the conceptual phase presents substantial opportunities to enhance constructability, address significant technical challenges, and minimize high-risk operations, ultimately contributing to cost savings [55].

### 2.4.2 Improvement of constructability during design and procurement

The CIT Constructability Task Force partnered with a research team from the University of Texas at Austin to explore methods for improving constructability during the design and procurement phases. Their research confirmed the viability of seven out of eight proposed constructability concepts for these stages. The focus was on enhancing the design and procurement processes by examining their sequence, scope, and execution details, particularly in relation to electrical, instrumentation, piping, and structural works across five industrial construction projects and one building project. Findings revealed that constructability is enhanced when design and procurement timelines are aligned with construction requirements, rather than adhering to conventional design practices. Effective project planning should aim to optimize the overall schedule to yield maximum benefits throughout the project. Given the substantial costs associated with construction compared to design and procurement, construction should be central to schedule optimization. While procurement can adjust somewhat to construction timelines, design remains the most adaptable in fulfilling the needs of both procurement and construction [56]

### 2.4.3 Improvement of constructability during field operation

The CIT Constructability has engaged a Task Force, comprising a team from the University, to investigate potential enhancements in constructability during field operations. These operations can considerably influence the overall cost of a project. According to the CII, while decisions impacting constructability in relation to field operations may appear to be of low leverage individually, their cumulative effect can yield significant advantages. The advancement and application of innovative construction techniques can streamline construction processes and lower project expenses. In this context, innovative construction methods refer to the deployment of various construction resources that are not typically recognized as standard practices within the industry, representing creative solutions that address challenges encountered in the field [57].

The research findings suggest several innovative approaches that could enhance construction processes. Firstly, the strategic sequencing of field tasks is crucial for improving constructability throughout all project phases. Additionally, the application of temporary construction materials and systems can leverage new technologies, yielding significant advantages in various construction methods. Furthermore, the use of hand tools designed to reduce labor intensity, enhance mobility, improve accessibility, increase safety, and boost reliability is essential. The innovation extends to construction equipment, which includes both the upgrading of existing machinery by contractors and the introduction of automated and remotely operated tools. Moreover, constructor-optional preassembly can incentivize constructors by making elevated work more feasible at ground level, eliminating the need for scaffolding, and allowing for the transfer of tasks from congested to less congested areas, thereby improving productivity and safety. Innovative temporary facilities can also play a role in minimizing labor intensity, preventing utility-related delays, and enhancing the overall work environment. Lastly, post-bid constructor preferences concerning layout, design, and permanent material selection can be addressed through open 'or equal' specifications, value-engineering clauses, and the active solicitation of alternative project designs and materials [58].

## 2.7. Implementation of Constructability

The earlier sections covered the ideas related to enhancing the constructability of projects. This section provides a summary of how these improvements can be put into practice. It starts with an overview of constructability programs, followed by an examination of methods for advancing constructability improvements, the advantages and expenses associated with these enhancements, and the challenges faced in implementing such improvements.

### 2.7.1. Constructability Programs

Construction clients today have heightened expectations for their projects, insisting on timely completion, adherence to budget, and high-quality outcomes. They seek not only value for money but also a final product that is easy to use and maintain, emphasizing the need for efficiency and effectiveness throughout the building process. This context underscores the importance of constructability concepts and principles, which play a crucial role in meeting these demands. The CIIA Australia has introduced a systematic approach that encompasses four essential components: acceptance of the cost influence curve, implementation of a corporate program, establishment of a project-level program, and application of the Constructability Principles File figure2.2. Both the CII and CIIA assert that constructability is beneficial regardless of a company's or project's size [61].

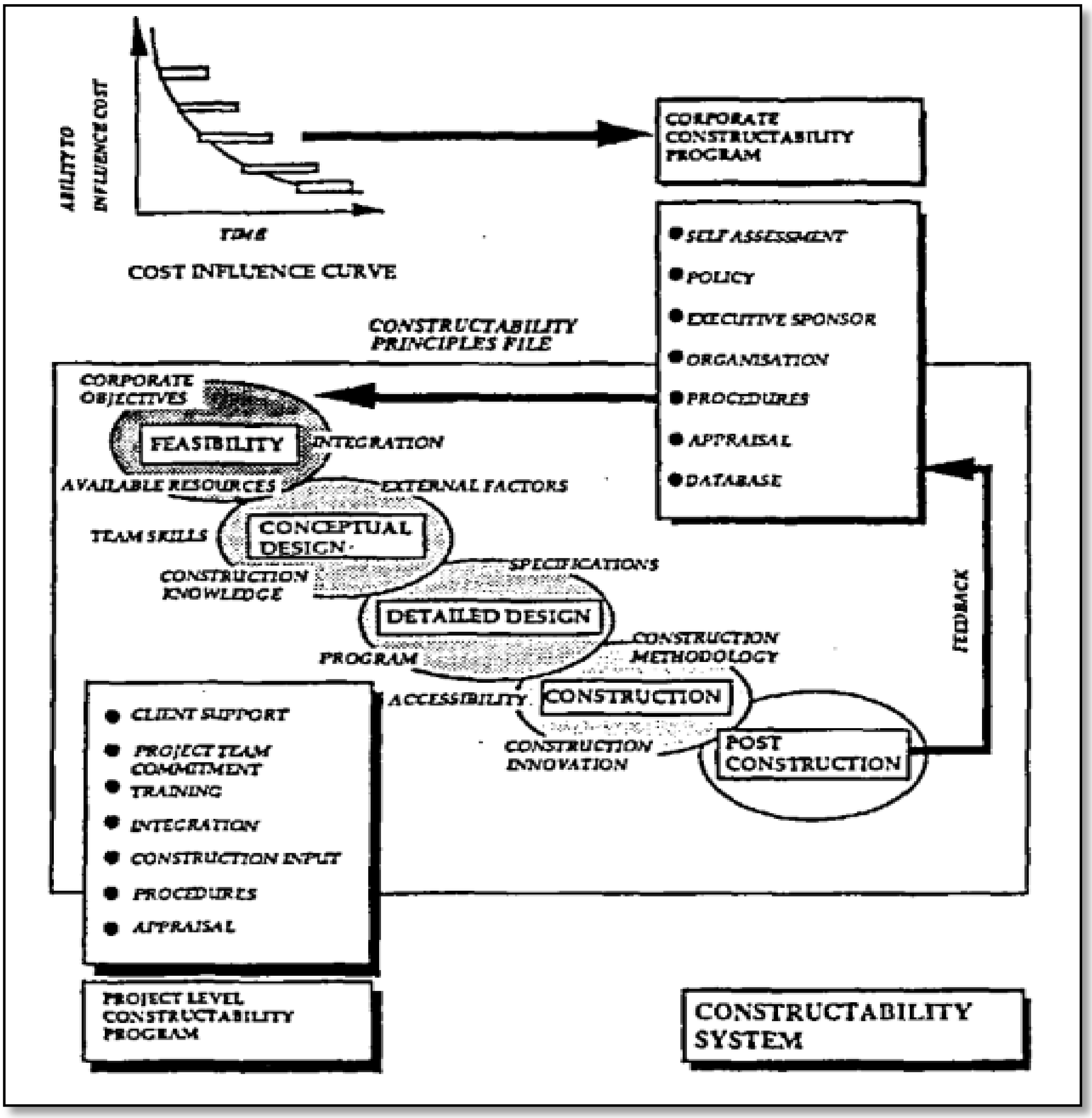


Figure 2-2. The Constructability System

Constructability programs can be effectively applied to projects of any scale, catering to the needs of both large and small organizations. While no single program can universally fit every company, successful constructability initiatives typically include several key elements. These include recognizing the impact of early project decisions on costs, ensuring clear communication of senior management's commitment to constructability, and establishing a single point of executive sponsorship. Additionally, a permanent corporate program alongside a customized implementation strategy for each project is essential. Clients should leverage constructability as a vital tool to meet their objectives related to cost, time, and quality, while design consultants must remain open to construction input. Early involvement of experienced construction personnel, user-friendly procedures, a lessons-learned database, necessary training, and straightforward appraisal and feedback mechanisms are also critical components of an effective constructability program [65, 66].

The Construction Management Committee of the ASCE Construction Division highlighted that a constructability program extends beyond merely reviewing plans and specifications post-design completion and providing feedback. It aims to enhance key project components throughout the entire project lifecycle. This includes developing a comprehensive project plan that integrates various elements such as objectives, timelines, budgets, contracting strategies, procurement plans, and construction methodologies. Additionally, the planning and design phases focus on recognizing and addressing the implications of design choices on construction processes. A construction-driven schedule is established by allocating time across all project phases—planning, permitting, design, construction, and start-up—ensuring optimization of the project as a whole rather than in isolation. The use of backward pass scheduling is employed to determine the duration of individual tasks. Furthermore, cost estimates are formulated with the involvement of a seasoned construction professional to ensure accuracy as the physical facilities are defined. Lastly, the early identification of key construction methods is crucial, as these decisions can significantly influence the project's design requirements. [14].

The CII suggested that a permanent corporate program is required for successfully implementing constructability. The CII suggested that a permanent corporate program is required for successfully implementing constructability. Whereas a permanent· corporate program is required for successfully implementing constructability, at the project level the constructability program is flexible and will vary with the contractual format selected for a specific project. Constructability should become simply a part of the project process, beginning with the earliest planning activities [59, 62].

### 2.7.2. Approach to Implementing Constructability

The CII Constructability Task Force engaged a team from the University of Wisconsin to investigate the implementation of constructability programs. Their literature review revealed three distinct types of constructability programs. First, corporate-level constructability programs align with the CII Guidelines for Implementing a Constructability Program. Second, project-level constructability programs show significant variation across different organizations within the construction sector, with a notable increase in U.S. organizations adopting formal project-level programs. Many of these have integrated procedures established by CII and The Houston Business Roundtable. Lastly, constructability review programs typically adopt a reactive stance, often confused with comprehensive constructability programs by some organizations. These reviews are characterized by their reliance on design checklists and are usually conducted at predetermined stages of design completion [59, 62].

The Construction Industry Institute (CII) has categorized constructability studies into two distinct groups: administrative solutions and implementation methods. The administrative solutions category encompasses studies that focus on guidelines for implementing constructability and enhancing collaboration among all stakeholders involved in a project. Conversely, the implementation methods category examines various cost-saving construction techniques, such as prefabrication and preassembly, as well as any approach that allows multiple activities to occur simultaneously [63].

The primary objective of studies in both categories is to enhance safety and quality while simultaneously minimizing costs and time associated with projects. To support these objectives, the Construction Industry Institute (CII) has developed various strategies for implementing constructability within construction projects. These strategies include: Historical Practices in Construction Management, Constructability Contract Documents, Constructability Services, Constructability Design Reviews, Quality Improvement Programs, Specialized Formal Constructability Programs, Standard Constructability Guidelines, and Comprehensive Tracking [64].

Based on the research findings, a structured set of procedures for a project-level formal constructability program has been proposed. This approach is believed to enhance constructability for several reasons: it allows for increased construction knowledge to be available earlier in the project timeline, which is crucial when there is the greatest potential to influence costs; it fosters unified objectives among project team members and enhances communication within the team; it incorporates tracking mechanisms that can aid in deriving insights from lessons learned; and it provides a framework for monitoring and evaluating improvements in constructability. Furthermore, it is suggested that the project owner should initiate the implementation of constructability by establishing clear project objectives, selecting an appropriate contract strategy, choosing suitable project participants, and allocating funding for constructability resources during the planning and design phases [65].

### 2.7.3. Barriers to Implementation of Constructability

Numerous barriers often hinder the integration of construction inputs with project planning and design. These obstacles include resistance from owners, a longstanding tradition among construction professionals to remain uninvolved in the early stages, opposition from engineers, a shortage of qualified personnel, insufficient training in construction integration, lack of incentives, and a low prioritization of constructability. Further investigation has revealed that one of the critical factors for successfully implementing constructability is addressing these barriers. It has been noted that these challenges are prevalent across three key organizations: owners, designers, and contractors. The identified barriers manifest at both corporate and project levels and can be categorized into four distinct types: cultural, procedural, awareness, and incentive barriers. Importantly, these categories are not mutually exclusive [68].

A recent study has revealed that out of the 18 most common barriers to constructability, 14 are primarily linked to issues of awareness. The least common barrier identified is the incentive barrier. Companies that successfully implement constructability programs frequently encounter several key challenges, including complacency with the current situation, reluctance to invest additional resources and effort in the early stages of a project, limitations imposed by lump-sum competitive contracting, and a lack of construction experience within design teams. Additionally, designers often adhere to their established methods, reflected in the mindset of "we do it," while mutual respect between designers and constructors is often lacking. Furthermore, construction input is typically sought too late to be of substantial benefit [68].

### 2.7.4. Benefits and Costs of Constructability

In their investigation into project-level methodologies for the application of constructability, [65] executed four case studies aimed at gathering benefit/cost data related to the implementation of constructability principles. They categorized the advantages of constructability into two main types: quantitative and qualitative benefits. The quantitative benefits arise from strategic decision-making and functional analysis conducted during the preconstruction phases.

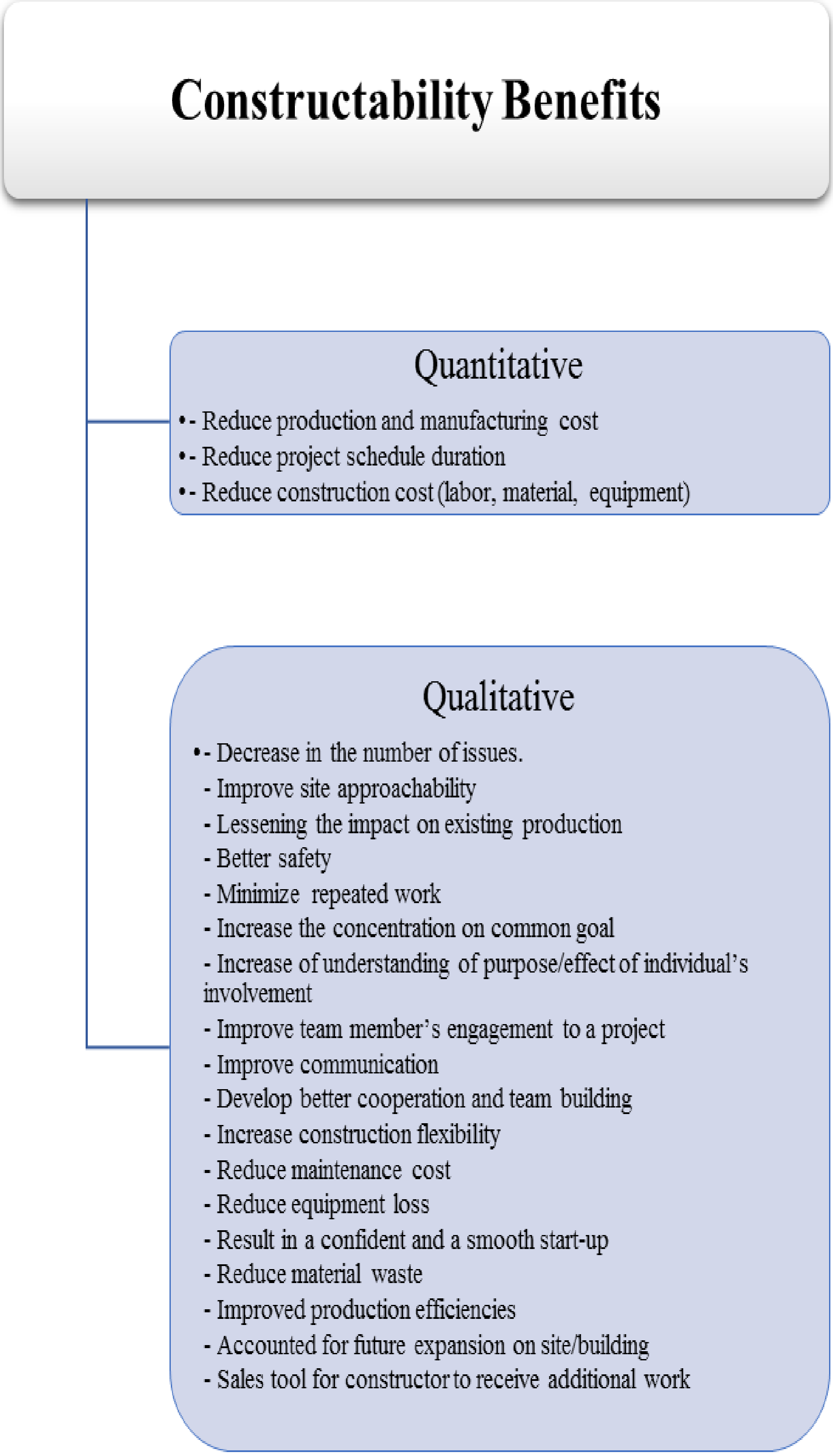


*Figure 2-3* Framework for determining constructability benefits [68]

## 2.8. Summary of the concepts and principles of constructability.

The constructability concept is a critical framework that enhances the efficiency and effectiveness of construction projects by integrating construction knowledge and expertise into the early stages of project development. A comprehensive review of the literature has identified 40 distinct constructability concepts that span the entire project life cycle as indicated in Table 2 4, Table 2 5 and Table 2 6. These concepts are categorized into three primary phases: Conceptual Planning, Design and Procurement, and Field Operations. Each phase presents unique challenges and opportunities for improving constructability, ultimately leading to better project outcomes.

### A. 14 constructability concepts During Conceptual Planning Phase

Constructability during conceptual planning refers to the process of considering the construction process during the early stages of project planning. This involves thinking about how to build a project even before it is designed, and it requires the integration of construction knowledge and experience into the planning and design phases. The optimal use of construction knowledge and experience in planning, design, procurement, and field operations to achieve overall project objectives is the key to constructability during conceptual planning. Constructability during conceptual planning is important because it can help identify potential construction issues early on, reduce costs, and improve project efficiency. By considering the construction process during the conceptual planning phase, project managers can make informed decisions about the project's design, materials, and construction methods, which can help minimize delays and cost overruns.

To apply constructability during conceptual planning, project managers should engage contractors and construction experts early in the design phase to identify potential challenges. They should also use collaborative platforms and shared workspaces to allow multiple stakeholders to contribute their insights and feedback in real time. Additionally, project managers should opt for simpler construction methods, use standardized components and processes, and leverage Building Information Modeling (BIM) tools to create detailed 3D models.

*Table 2-4 Summary of Concept during Conceptual Planning Phase*

| Concept | **A. During Conceptual Planning Phase** |
|---|---|
| C1.1 | Constructability programs are made an integral part of project execution plans. |

| | |
|---|---|
| C1.2 | A project team that includes a representation of the owner, the engineer, and the contractor should be formulated and maintained to consider the constructability issues in all phases. |
| C1.3 | Project planning actively involves construction knowledge and experience to avoid interference between design and construction. |
| C1.4 | Early construction involvement is considered in the development of contracting strategies. |
| C1.5 | Project schedules are construction-sensitive and assigned as early as possible. |
| C1.6 | Basic design approaches consider significant construction methods. |
| C1.7 | Site layouts promote efficient construction, operation and maintenance. |
| C1.8 | Advance information technologies are applied throughout the project. |
| C1.9 | To accomplish the field operations quickly and efficiently, primary construction methods should be analyzed in-depth as early as possible. |
| C1.10 | Operability and maintainability phases are integrated into project planning and design stages. |
| C1.11 | Political and legal factors are reviewed prior to the design stage. |
| C1.12 | Environmental factors are reviewed and addressed. |
| C1.13 | Construction methods are comprehensively reviewed to include the recovery and recycling methods along with sustainable and final disposal planning. |
| C1.14 | Simplify and separate building systems and components to facilitate maintenance and future renovations |

**B. 16 constructability concepts During Design and Procurement Phase**

The design and procurement phase is critical in the construction process, as it is where many of the decisions that will impact cost, schedule, and overall project success are made. Constructability concepts during this phase focus on ensuring that the designs created are practical, feasible, and aligned with the project's objectives.

*Table 2-5 Summary of Concept during Design and Procurement Phase*

| Concept | **B. During Design and Procurement Phase** |
|---|---|
| C2.1 | Design and procurement schedules are construction sensitive and considered in project sequencing |
| C2.2 | The use of Advanced information technologies will overcome the problem of fragmentation into specialized roles in the field, and enhance constructability. |

| | |
|---|---|
| C2.3 | Project Designs, through design simplification by designers and design review by qualified construction personnel, must be configured to enable efficient construction. |
| C2.4 | Project elements should be standardized. |
| C2.5 | The project technical specifications should be simplified and configured to achieve efficient construction. |
| C2.6 | Module/preassembly designs are prepared to facilitate fabrication, transportation, and installation |
| C2.7 | Designs considering construction accessibility of personnel, material, & equipment to the required position inside the site. |
| C2.8 | Design should facilitate construction during adverse weather conditions. |
| C2.9 | Design & construction sequencing must facilitate system turnover & start-up. |
| C2.10 | Safety and health reviews are considered comprehensively within the design specifications. |
| C2.11 | Project design considers operability and maintainability of the project. |
| C2.12 | Standardize repeatable components. |
| C2.13 | Ensure proper sizing and specification of equipment, products, and materials. |
| C2.14 | Optimize dimensions to utilize entire product/material |
| C2.15 | Use methods and materials that allow for ease of reconfiguration, renovation, or deconstruction |
| C2.16 | Designs are reviewed by construction personnel regarding minimizing material waste, recycling, and cost-effectiveness. |

### C. 10 constructability concepts During Field Operations Phase

The field operations phase of a construction project is critical for ensuring that the principles of constructability are effectively applied. This phase involves the actual execution of the construction work, where the plans and designs are transformed into physical structures. it is clear that effective implementation of constructability principles during this phase involves integrating construction knowledge, ensuring effective communication, adapting to site conditions, leveraging technology, prioritizing safety, establishing feedback mechanisms, managing resources efficiently, enforcing quality control measures, fostering collaboration among teams, and maintaining proper documentation practices.

*Table 2-6 Summary of Concept during Field Operations Phase*

| Concept | **C. During Field Operations Phase** |
|---|---|
| C3.1 | Constructability will be enhanced using innovative construction methods. |
| C3.2 | Tasks Sequencing is configured to minimize rework of project elements, scaffolding needs, formwork used, or congestion of labors & materials |
| C3.3 | Innovation in temporary construction materials/systems that have not been defined by the design drawings and technical specifications. |
| C3.4 | Incorporating new methods of innovation through the use of off-the-shelf hand tools or modifying available tools. |
| C3.5 | Innovative methods for using the available equipment or modification of the available equipment to increase their productivity. |
| C3.6 | Use preassembly to increase productivity, reduce the need for scaffolding, or improve the project constructability under adverse weather conditions. |
| C3.7 | Constructability will be enhanced by encouraging the constructor to carry out the innovation of temporary facilities. |
| C3.8 | Good contractors, based on quality and time of their work should be documented. Subsequently, future contracts for construction work would not solely be awarded based on low bids, but also by considering other attributes, i.e. quality and time. |
| C3.9 | Evaluation, documentation and feedback of the issues of constructability concepts should be maintained throughout the project and used in later projects as learned lessons. |
| C3.10 | As built documentation to facilitate any required reconfiguration or renovation. |

## **2.9.** Conceptual Framework of the Study

The conceptual framework of the research paper on constructability principles in road corridor development projects in Addis Ababa, outlines the relationships between various elements that influence the successful implementation of constructability concepts. Here are the key components collectively aim to enhance the effectiveness of constructability practices in road corridor development projects of the conceptual framework:

- **Constructability Principles**:

  The framework is based on the principles of constructability, which emphasizes the integration of constructability principles across different project phases.

- **Phases of Project Development:**

The study identifies three critical phases in project development: the conceptual planning phase, the design and procurement phase, and the field operation phase. Each phase has specific activities and considerations that impact constructability. For instance, the conceptual planning phase involves feasibility studies and design brief development, while the design and procurement phase focuses on detailed design and procurement of construction services.

- **Stakeholder Involvement:**

  A central aspect of the conceptual framework is the involvement of various stakeholders, including contractors, consultants, clients, and regulatory bodies. Engaging these stakeholders early in the project lifecycle is crucial for gathering diverse insights and ensuring that constructability principles are effectively applied throughout the project.

- **Critical Factors Influencing Constructability:**

  The framework highlights several critical factors that influence constructability, such as the integration of advanced information technologies, early identification of project team participants, and the inclusion of construction personnel in the planning process. These factors are essential for maximizing project objectives and mitigating common issues like cost overruns and delays.

- **Feedback Loop:**

  The conceptual framework also suggests a feedback loop where lessons learned from previous projects are integrated into future planning and design phases. This continuous improvement process is vital for enhancing constructability and overall project success.

# CHAPTER 3. RESEARCH METHODOLOGY

## 3.1. Introduction

This chapter describes the methodology of this thesis, the main topics included in this chapter are, Description of Project Target area, research strategy, research design, population, sample size determination, questionnaire design, questionnaire content, pilot study and tests of reliability and validity of questionnaire and the last thing is the process of data analysis.

## 3.2. Description of Project Target area

Addis Ababa, the capital of Ethiopia, ranks among the largest urban centers in sub-Saharan Africa, situated at coordinates 8°49'55.929"N and 9°5'53.853"N latitude, and between 38°38'16.555"E and 38°19'547"E longitude. The city's elevation varies from 2,054 to 3,023 meters above sea level, with average annual maximum and minimum temperatures recorded at 22.8°C and 10.6°C, respectively. Additionally, Addis Ababa experiences an average annual rainfall of 1,180.4 mm and encompasses approximately 51,948.85 hectares of land. The following figure provides the map of the city.

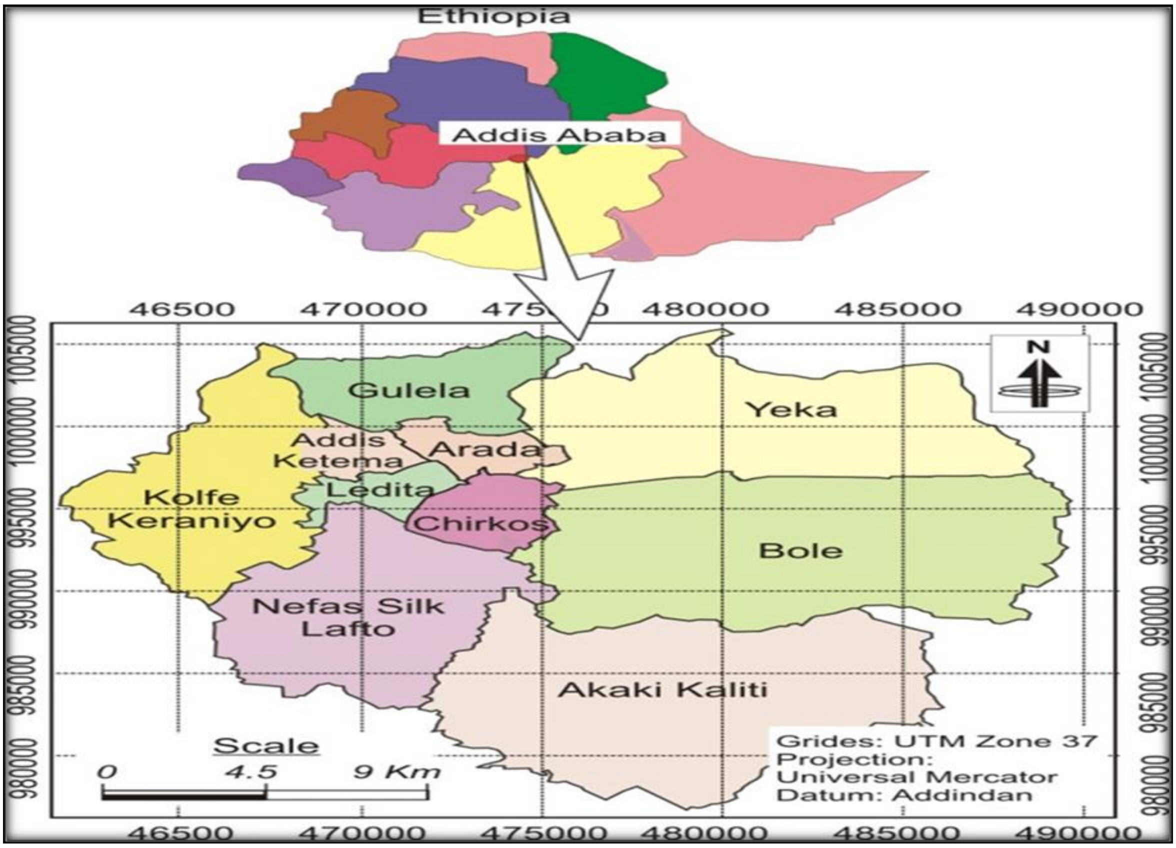


Figure 3-1; Map of study area

According to the 2007 population census, Addis Ababa has a population of 3,384,569, reflecting an annual growth rate of 3.8%. This figure has risen from the previously reported 2,738,248 and is likely still underestimated. As a chartered city, Addis Ababa functions as both a city and a state, serving as the headquarters for the African Union and its predecessor, the Organization of African Unity (OAU). Additionally, it is home to the United Nations Economic Commission for Africa and various other continental and international organizations, earning it the designation of "the political capital of Africa" due to its historical, diplomatic, and political importance on the continent. The city's population is diverse, comprising individuals from various regions of Ethiopia.

The city administration have a remarkable achievements in the road corridor developments. Addis Abeba Mayor Adanech Abiebie announced the completion and opening of some roads constructed under the city's road corridor development initiative launched three months ago. "Except for minor works," she disclosed, "roads covering routes from Mexico Square to Sar Bet, Tewodros Square to Adwa Victory Memorial Museum, and Arat Kilo to St. Mary Church have been completed and opened for residents." This announcement followed a field assessment conducted by Mayor Adanech and senior officials to evaluate the progress of the initiative over the weekend.

Figure 3-2; photo of the corridor development project. [Internet Cherchel Street]

To expedite the modernization of the Capital City within the designated timeframe, Mayor Adanech Abiebie of the Addis Ababa City Administration has announced that she, along with other senior officials, has conducted an inspection of the extensive corridor development reform underway in the city. In a post on her social media platform, Mayor Adanech highlighted that several roads have been completed (aside from minor repairs) and are now accessible to the public, fulfilling her commitment to the capital's residents. "Work will proceed throughout the week to finalize the remaining tasks by the deadline, which includes the routes from Tewodros Square to Adwa Victory Memorial, from Degole to Keye Bahir Condominium, from Arat Kilo to St. Mary’s Crossing Roads, and from Mexico Square to Sarbet. I would like to express my sincere gratitude to all project workers, engineers, experts, consultants, managers at all levels, security personnel, and city residents for their support and collaboration. So far, the City Administration has successfully completed the following infrastructure as part of the first phase of the corridor development; -

**Highway Engineering**

The "Complete streets" concept was implemented, where streets are designed and operated to enable

- safe, attractive and comfortable access and travel for all users,
- Including pedestrians, bicyclists, motorists and public transport users of all ages and abilities.

**The city administration so far achieve in Road infrastructure**

Road infrastructure

- Over 48 km of vehicle road development,
- 96 km of broad pedestrian and
- 100 km of bicycle paths

Road infrastructure

, 5 km of running track,

- 4 underground pedestrian walkways,
- 9 bus and taxi terminals, and loading and unloading zones

Road infrastructure

Two vehicle bridge

Three modern pedestrian bridge

Over 240 km of roads and associated infrastructure.

Figure 3:3; the achievements of city Administration in road infrastructure

## Urban Engineering

"Urban design" is the art of making places for people.

- Character – a place with its own identity.
- Continuity and enclosure –spaces are clearly distinguished.
- Quality of the public realm – attractive outdoor areas.
- Ease of movement –is easy to get to and move through.
- Legibility –has a clear image and is easy to understand.
- Adaptability – a place that can change easily.
- Diversity – a place with variety and choice.

**The city administration so far achieve in making places for people**

### Green Spaces, Recreation And Parks, Children's Playgrounds And Public Plazas

| |
|---|
| 70 public parks including, fast food service selling places |
| 120 modern road side public toilets, |
| 32 water fountains |
| 20 hectares coverage river side Revitalization |
| More than 50 hectares green spaces development works |
| 8 rivers integrated development |
| Renovating more than 400 buildings and fitting the city's standards. |

Figure 3:4; the achievements of city Administration in Recreation and Parks

**The city administration so far achieve in security, safety…**

Electric infrastructure works

- 430 smart pols having screen and security cameras
- 48 km cable installed for the security cameras
- 1582 normal street lights
- 96 km deteriorated electric pols and cable changed and installed underground

To modernize the transport service

- 32 modern parks serving 6,369 cars at a time from G+0 to G-3
- 50 km ITS
- 85 road side bus and taxi bay
- 9 bus and taxi terminal

Figure 3:5; the achievements of city Administration in security & safety

Mayor Adanech Abiebie of the Addis Ababa City Administration stated that upon the completion of construction, Addis Ababa will play a significant role in achieving its ambition of becoming a renowned tourist destination, truly embodying its identity as A Beautiful, Blossoming City that serves its residents well and evolves into a prominent international hub. The city administration has recently set a goal to finish the majority of the projects associated with this initiative before the forthcoming winter season.

## 3.3. Research Approach

Research is defined as a systematic process of gathering, analyzing, and interpreting information to address specific questions [66]. In the context of this thesis, it pertains to a practical investigation that seeks to discover new information or compile existing knowledge through scientific methodologies, aiming to refine current theories or apply them to real-world challenges. Research can be classified as theory-driven (deductive), problem-oriented for theoretical advancement (inductive), or a blend of both methodologies.

This study utilizes a descriptive research design, employing opinion surveys and interviews for data collection. It adopts a mixed-method analytical framework, which entails the concurrent or sequential gathering and analysis of both qualitative and quantitative data within a single investigation. This methodology allows for the integration of data at various stages throughout the research process [67].

The research employed a combination of a questionnaire survey and interviews as its primary methodologies. Key literature on constructability, particularly from the Construction Industry Institute (CII) in both the USA and Australia, as well as the Construction Industry Research and Information Association (CIRIA), were utilized as essential sources of information. Through a comprehensive literature review, 40 distinct constructability concepts identified, alongside an evaluation of existing methods aimed at improving constructability. The findings derived from the questionnaire survey provide a solid foundation for developing a constructability assessment model. Additionally, the results from the interviews, in conjunction with the questionnaire survey, highlight the concepts that contribute to enhancing constructability.

## 3.4. Research design

Research design is the structured approach or blueprint for conducting scientific studies. It encompasses the formulation of a strategy that directs the gathering and examination of data. The methodology specifies the particular techniques and processes employed in the study to address the research question. Initially, the constructability concepts were gathered from the literature across different phases of the project life cycle to create an assessment model and develop a questionnaire. Data collection was conducted through a combination of questionnaire surveys and interviews, systematically organized into distinct phases. The data analysis utilized a relative importance index to rank the concepts across the various phases, ultimately leading to the formulation of an implementation strategy, as illustrated in Figure 3.6.

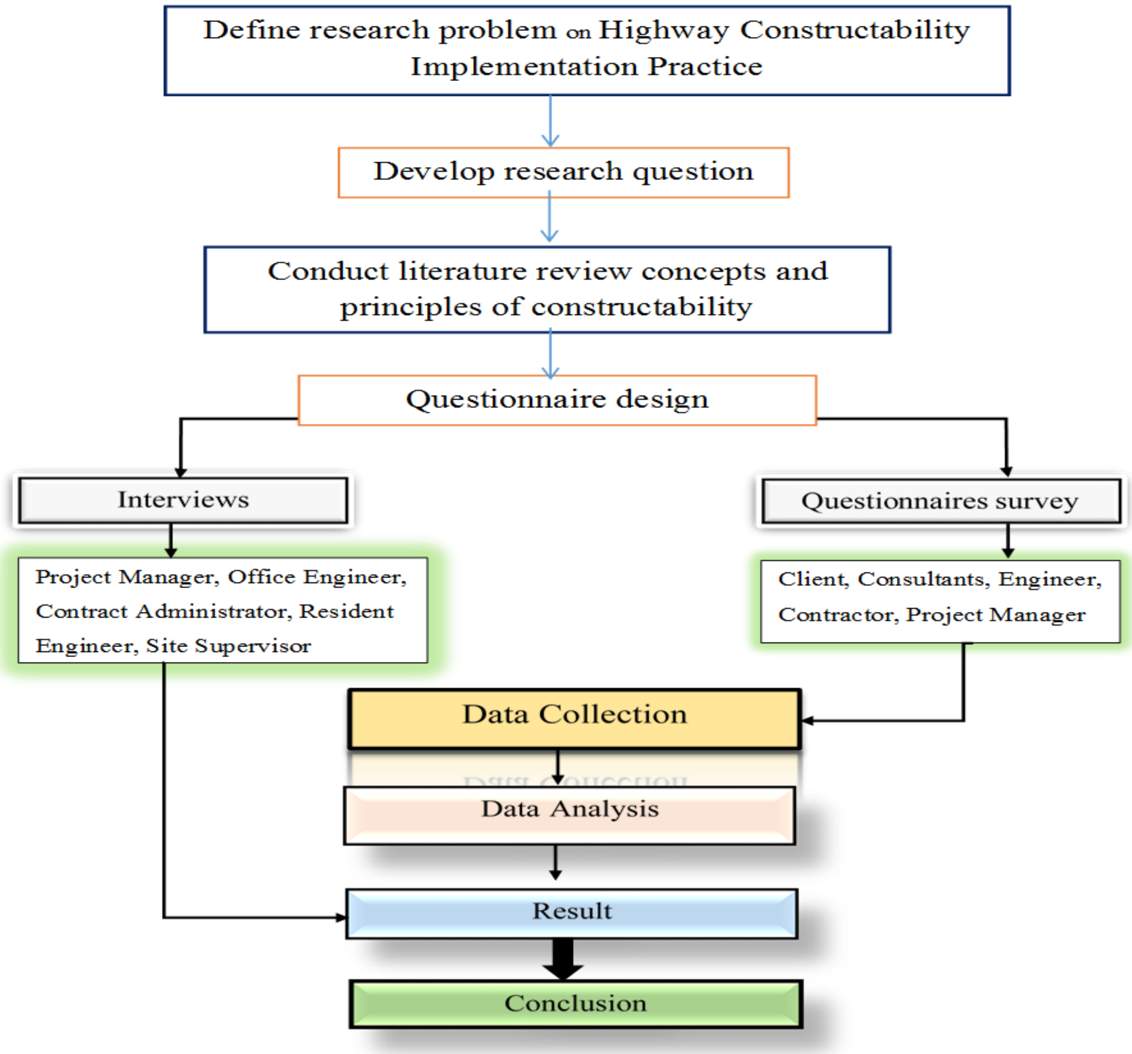


*Figure 3:6;* Methodology Flowchart

## 3.5. Research Population

This research focuses on the road corridor development projects in Addis Ababa city. This is a significant area of study as urban infrastructure plays a crucial role in economic development and quality of life. The stakeholders involved in these projects include contractors, consultants, clients, and regulatory bodies. Each of these groups contributes uniquely to the planning, execution, and oversight of construction projects.

### 3.5.1. Target Population

The target population comprises organizations engaged in road corridor development projects in Addis Ababa, which can be categorized into four primary groups:

**Contractors**: These are the firms or individuals responsible for the actual construction work. They play a critical role in project delivery and have insights into operational challenges.

**Consultants**: This group includes professionals who provide expertise in various aspects such as engineering, design, and project management. Their input is vital for ensuring that projects meet technical standards and regulations.

**Clients**: Clients are typically government agencies or private entities that commission the construction projects. Their perspectives can shed light on project objectives, funding issues, and stakeholder expectations.

**Regulatory Bodies**: These organizations ensure compliance with local laws and regulations governing construction practices. Their involvement is essential for maintaining safety standards and environmental considerations.

### 3.5.2. Sampling Methodology

The researcher has opted for purposive sampling as the chosen method for selecting participants. Purposive sampling is a non-probability technique where individuals are selected based on specific characteristics or criteria that are pertinent to the research question. This approach is particularly advantageous when the goal is to gather insights from particular segments of a population that possess significant knowledge about the subject matter. Consequently, purposive sampling enables the researcher to concentrate on individuals from each identified stakeholder group who have direct experience or expertise related to corridor development projects in Addis Ababa.

### 3.5.3. Sample Size Determination

In research, the sample size is a critical factor that influences the validity and reliability of the study's findings. A well-chosen sample size can help ensure that the results are representative of the larger population from which it is drawn. The number 30 is often cited as a rule of thumb for achieving statistical significance in many fields, particularly in quantitative research.

- **Central Limit Theorem**

One fundamental reason why a sample size of 30 is often considered sufficient is due to the Central Limit Theorem (CLT). The CLT states that as the sample size increases, the distribution of the sample means will tend to be normally distributed, regardless of the shape of the population distribution, provided that the sample size is sufficiently large. This approximation to normality becomes reasonable when $n \geq 30$. Therefore, with a sample size of 30 or more, researchers can apply various statistical tests (like t-tests and ANOVA) that assume normality in their calculations for confidence intervals and p-values [74].

- **Statistical Significance and Type I Error Control**

When conducting hypothesis testing, researchers aim to control for Type I errors (false positives), which occur when they incorrectly reject a true null hypothesis. With a typical significance level set at 0.05 (5%), having a sample size of 30 allows researchers to maintain this level effectively across most statistical tests [74]. This means that with this sample size, there is a reasonable balance between detecting true effects while minimizing false claims.

- **Power Analysis and Type II Error**

Power analysis is another important aspect when determining an adequate sample size. Power refers to the probability that a test will correctly reject a false null hypothesis (avoiding Type II errors). A larger sample size generally increases power; however, even with a sample size of 30, researchers can achieve an acceptable level of power (often set at 80%) for detecting medium effect sizes in many studies [75]. This means that with 30 participants, there's still a good chance to identify significant differences or relationships if they exist.

- **Variability and Population Characteristics**

While 30 participants may be sufficient for many studies, it's crucial to consider variability within the population being studied. If there is high variability among participants regarding key characteristics relevant to the research question, then larger samples may be necessary to capture this diversity adequately [76]. Conversely, if studying a homogeneous group where responses are expected to be similar, then 30 might suffice.

- **Practical Considerations**

From a practical standpoint, collecting data from more than 30 participants can be resource-intensive in terms of time and cost. Researchers must weigh these factors against their need for precision and confidence in their results. In many cases, especially in exploratory studies or pilot projects where resources are limited or time constraints exist, establishing a sample size around 30 can provide meaningful insights without overwhelming logistical demands [77].

## 3.6. Data Collection and Instruments

This section describes various data collection methods, including interviews, questionnaires, observation, and documentation. The study adopts a mixed-methods approach, utilizing both questionnaires and interviews to gather data from contractors, consultants, clients, and regulatory bodies involved in the Addis Ababa City road corridor development project. To acquire relevant information from primary sources, and survey questionnaires format (see **Appendices part 1 & 2**) a semi-structured interview (see **Appendices part 3 & 4**) employed. The survey questionnaire method was chosen for its efficiency in terms of cost and time, while interviews were conducted to clarify any ambiguities present in the questionnaires and related concepts.

### 3.6.1. Questionnaire approach

A questionnaire was created to gauge perceptions of constructability concept importance in Addis Ababa's construction industry. This initiative was informed by a comprehensive review of existing literature and insights gathered from seasoned professionals in the field.

## 3.7. Questionnaire design

The literature review identifies a compilation of 45 Constructability concepts that span various phases of engineering projects across different countries and historical contexts. Following discussions with the thesis supervisor, the draft questionnaire was sent to a statistical expert and three construction specialists for their feedback and recommendations. The finalized version of the questionnaire now includes 40 Constructability concepts. Respondents were assured that their information would remain confidential and used solely for research purposes. The questionnaire is structured into four sections: general information, opinions, constructability application, and specific experiences related to constructability. Its primary objective is to evaluate constructability issues in road corridor development projects within Addis Ababa city.

## 3.8. Methods Data Analysis

The Relative Importance Index (RII) method is utilized to determine the relative significance of specific causes and effects based on their likelihood of occurrence and their impact on a project, using a 5-point Likert scale system [66]. This approach is applied to quantify the rate and importance of each Constructability concept. Respondents are asked to evaluate the Constructability concepts using the Likert scale, which assigns scores ranging from 5 for "Very Important" to 1 for "Not Important." The scale includes five levels: (5) "Very Important," (4) "Important," (3) "Moderately Important," (2) "Little Important," and (1) "Not Important." These ratings are then used to calculate the RII based on Equations (1) and (2), as shown below:

Equation (1): $$\mathbf{RII = \Sigma W / A \times N}$$

Equation (2): $$\mathbf{\Sigma W = 5n_5 + 4n_4 + 3n_3 + 2n_2 + 1n_1}$$

Where:

- RII stands for Relative Importance Index.,
- ΣW represents the total of the weights assigned to each factor, multiplied by the frequency of responses;
- n1, n2, n3, n4, n5 denote the number of respondents who answered each factor.
- The values 1, 2, 3, 4, and 5 indicate the weights assigned to each factor, on a scale from 1 to 5.
- A signifies the highest score for the criteria, which in this instance is 5.
- N refers to the total number of respondents.

## 3.9. Pilot study

The development of structured questionnaires necessitates a meticulously crafted set of questions that undergoes piloting and refinement until the researcher is confident in their validity. Consequently, pre-testing emerges as a crucial phase in the questionnaire design process, occurring before the finalization of the instrument. This stage involves administering the questionnaire to a select group of potential respondents, along with knowledgeable individuals, to pinpoint and rectify any design flaws. In this instance, ten drafts of the questionnaire were distributed: two to contractors, three to consultants, three to owners, and two to regulatory bodies. Overall, after receiving feedback and making necessary modifications, there was a consensus that the questionnaire is appropriate for achieving the study's objectives.

# CHAPTER 4. RESULTS AND DISCUSSIONS

## 4.1. The result of evaluation basic information

### 4.1.1. Basic Information about the Respondents

The questionnaire utilized a nominal scale to assess the actual values of the independent variables. For the dependent variables, a five-point scale was employed, where a score of '1' indicated no effect, '3' represented a neutral position, and '5' denoted maximum effect. Respondents were instructed to select a number on the scale that best represented their evaluation of various factors related to constructability concepts. A comprehensive list of contractor, consultant, and client organizations involved in highway construction was compiled from corridor development projects. Out of 30 questionnaires distributed, 20 were returned, resulting in a sample size of n = 20. In total, 30 respondents were approached, with 20 (67%) questionnaires successfully evaluated. The sampling framework and response outcomes of the survey are detailed in the accompanying Table 4-1. This outcome provides a random and equitable representation of the surveyed population, regardless of the number of observations. The collective findings can be regarded as a prototype of a project team that reflects the broader construction industry in Addis Ababa City construction industry.

*Table 4-1 Survey Sampling Structure and Return Result*

| Description | Client | Consultants | Engineer | Contractor | Project Manager | Total |
|---|---|---|---|---|---|---|
| Number of Questionnaire Sent | 6 | 6 | 6 | 6 | 6 | 30 |
| Number of Questionnaire Returned | 4 | 4 | 4 | 4 | 4 | 20 |
| Response Rate | 67% | 67% | 67% | 67% | 67% | 67% |

Note: * one Project Managers is the same one of Contractor, therefore the effective total number of response is 20 instead of 21.

### 4.1.2. General Understanding of Constructability by Professionals

In light of the awareness surrounding the terms constructability and buildability, eleven out of seventeen respondents expressed a positive recognition of these concepts. This suggests that such terminology is not unfamiliar within the local industry. The findings from the questionnaire survey indicate a varied level of awareness among participants regarding constructability. As illustrated in Figure 4:1, 65% of respondents demonstrated familiarity with constructability, while 35% reported a lack of knowledge on the subject.

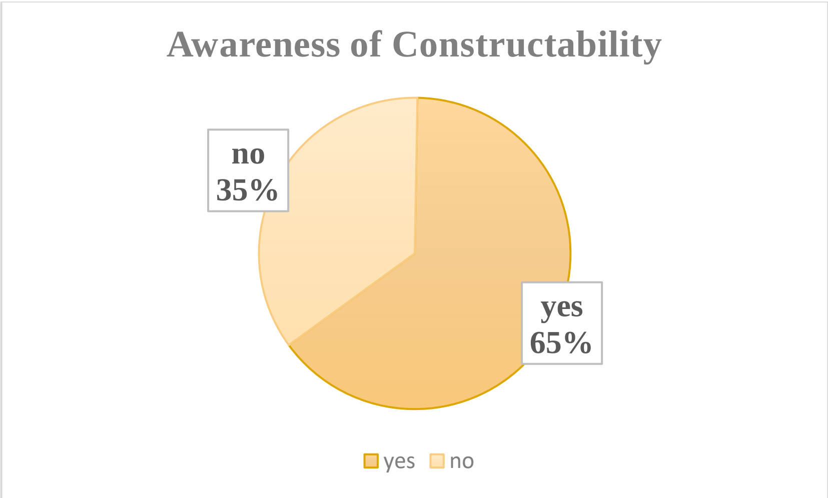


*Figure 4-1;* Understanding of Constructability by Professionals

The application of the Constructability principle in Highway Construction projects was examined and analyzed, as illustrated in Figure 4:2. The findings revealed that 41% of respondents implemented the Constructability principle, while 59% did not apply it in their projects. This indicates that a majority of participants reported a lack of adherence to Constructability Principles in their ongoing Highway construction endeavors.

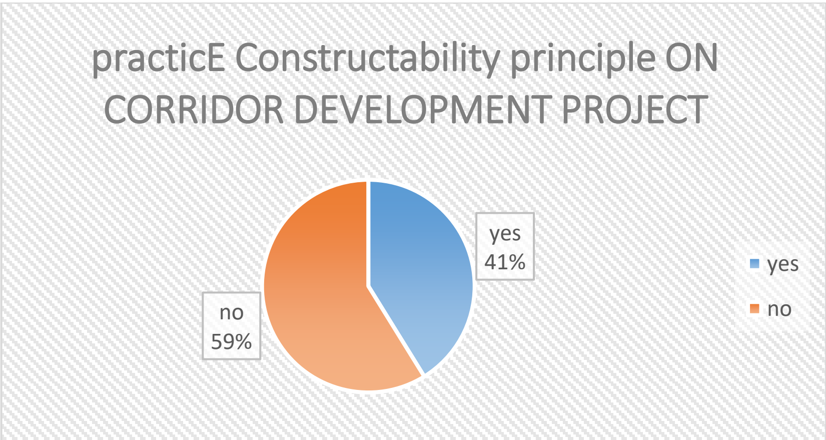


*Figure 4-2;* Practice constructability principle on corridor development project

### 4.1.3. Organizational More Concerned Ensuring Constructability

In this research, data was gathered according to the Organization category, which includes Clients, Consultant firms, Construction firms, and Regulatory bodies, all of which demonstrate significant concern for ensuring constructability in highway construction projects within Addis Ababa city. As illustrated in Figure 4:3, the survey results indicate that the organizations most focused on constructability in these projects are Clients (26.3%), Consultant firms (36.8%), Construction firms (15.8%), and Regulatory bodies (21.1%).

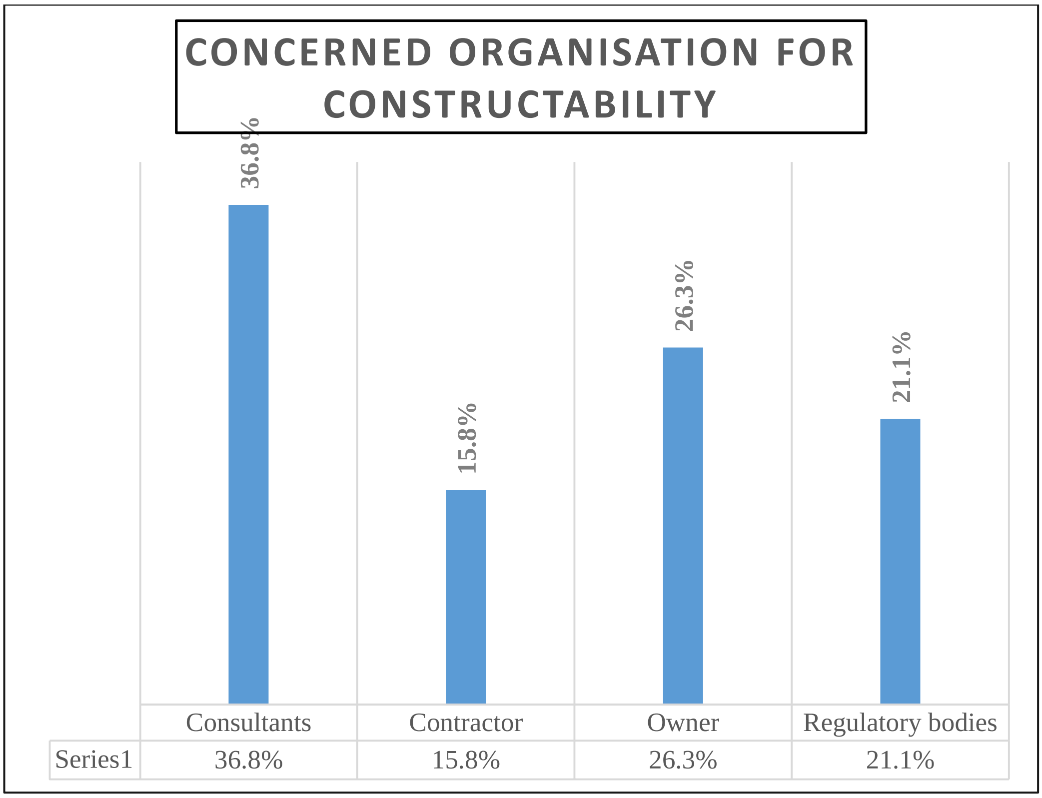


*Figure 4-3;* Organization category more concerned to ensure constructability

According to the results, the percentage of concern regarding constructability in highway construction projects in Addis Ababa is highest among Consultant Firms at 36.8%, followed by Clients at 26.3%, Regulatory Bodies at 21.1%, and Construction Firms at 15.8%. This indicates that Consultant Firms are the most focused on ensuring constructability.

Table 4-2 presents the types of organizations that participated in the survey, which included a total of 30 respondents: clients, consultants, contractors, and regulatory bodies. Figure 4:6 illustrates that clients comprised the largest group in the survey with 9 out of 30 respondents, followed closely by consultants and contractors, each with 8 respondents, while regulatory bodies contributed 5 respondents.

*Table 4-2 Survey Sampling Structure and Return Result*

| Type of Organizations | | | | | |
|---|---|---|---|---|---|
| Type of Organization | **Consultants** | **Contractor** | **Client** | **Regulatory bodies** | Total |
| **Frequency** | 8 | 8 | 9 | 5 | 30 |
| percent | 26.7% | 26.7% | 30.0% | 16.7% | 100.0% |

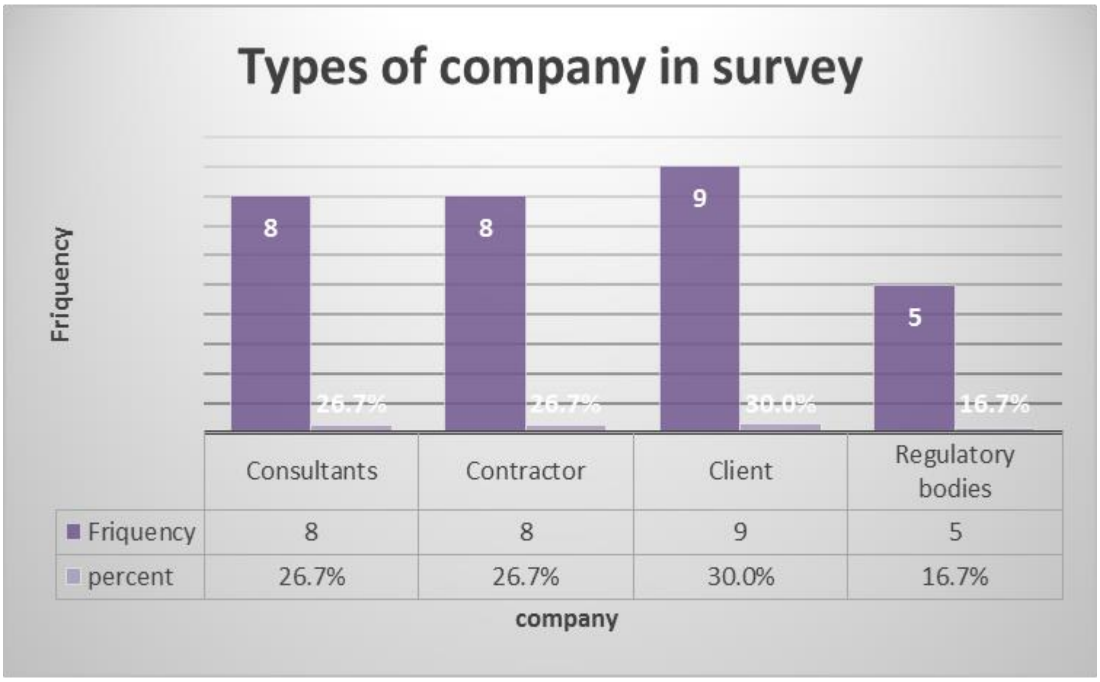


*Figure 4-4;* The type of company or organization involved in the survey

Table 4-3 presents the roles of respondents within their respective companies or organizations, which include Office Engineer, Contract Administrator, Project Manager, Resident Engineer, and Site Supervisor. As illustrated in Figure 4-5, the data reveals that the majority of participation comes from Project Managers, accounting for 23% of the responses. Following closely are the Office Engineers and Contract Administrators, each representing 20%, while both Resident Engineers and Site Supervisors contribute 17% to the overall involvement.

*Table 4-3 the type of professional involved in the survey*

| The role of respondent in their Engineering & Construction Industry | | | | | | |
|---|---|---|---|---|---|---|
| **Professional** | **Project Manager** | **Office Engineer** | **Contract Administrator** | **Resident Engineer** | **Site Supervisor** | **Total** |
| **Frequency** | 7 | 6 | 6 | 6 | 5 | 30 |
| **Percent** | 23% | 20% | 20% | 20% | 17% | 100% |

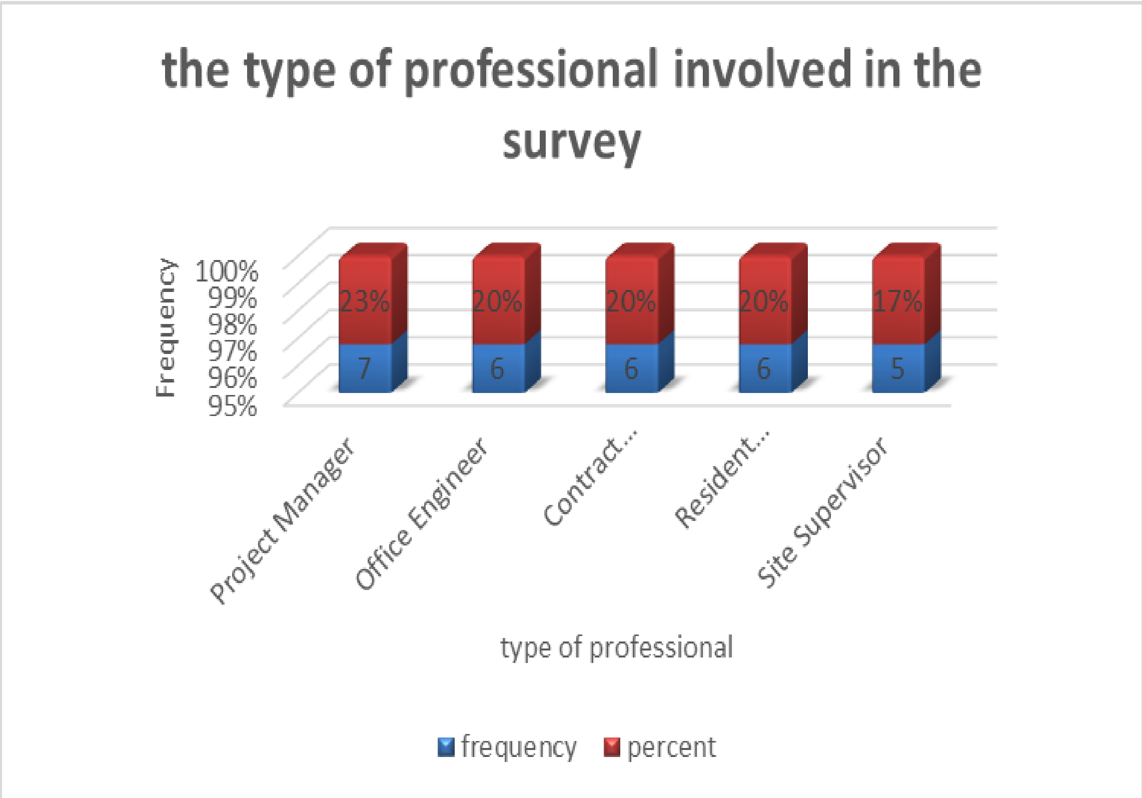


*Figure 4-5;* The type of professional involved in the survey

The data regarding the years of experience in construction and design work for the respondents is summarized in Table 4-4 and illustrated in Figure 4:6. A significant portion of the respondents, accounting for 33%, possess less than four years of experience in this field.

*Table 4-4 The Experience of those professionals involved in the survey*

| **Experience of these professionals in engineering & construction industry** | | | | | | |
|---|---|---|---|---|---|---|
| **Years of Experience** | **1-5 years** | **6-10 years** | **10-15 years** | **16-20 years** | **20+ years** | **Total** |
| **Frequency** | 10 | 6 | 6 | 5 | 3 | 30 |
| **Percent** | 33% | 20% | 20% | 17% | 10% | 100% |

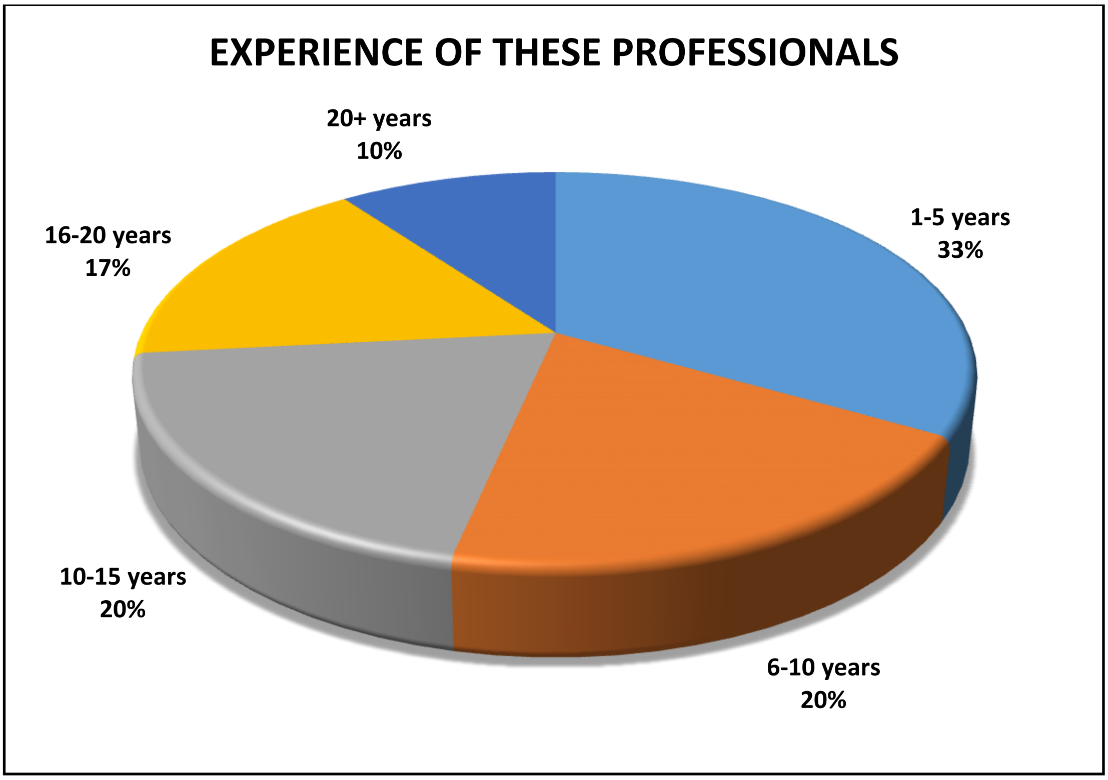


*Figure 4-6;* The Experience of those professionals involved in the survey

Table 4-5 and Figure 4:7 demonstrate the distribution of respondent’s Qualification. BSc (57%) the first, MSc (37%) are the second, and PhD (7%) the third. So, based on the data, BSc holders are the most involved in the survey.

*Table 4-5 The Qualification of those professionals involved in the survey*

**Qualification of these professionals in engineering & construction industry**

| Qualification | BSc | MSc | PhD | Total |
|---|---|---|---|---|
| Number participant | 17 | 11 | 2 | 30 |
| percent | 57% | 37% | 7% | 100% |

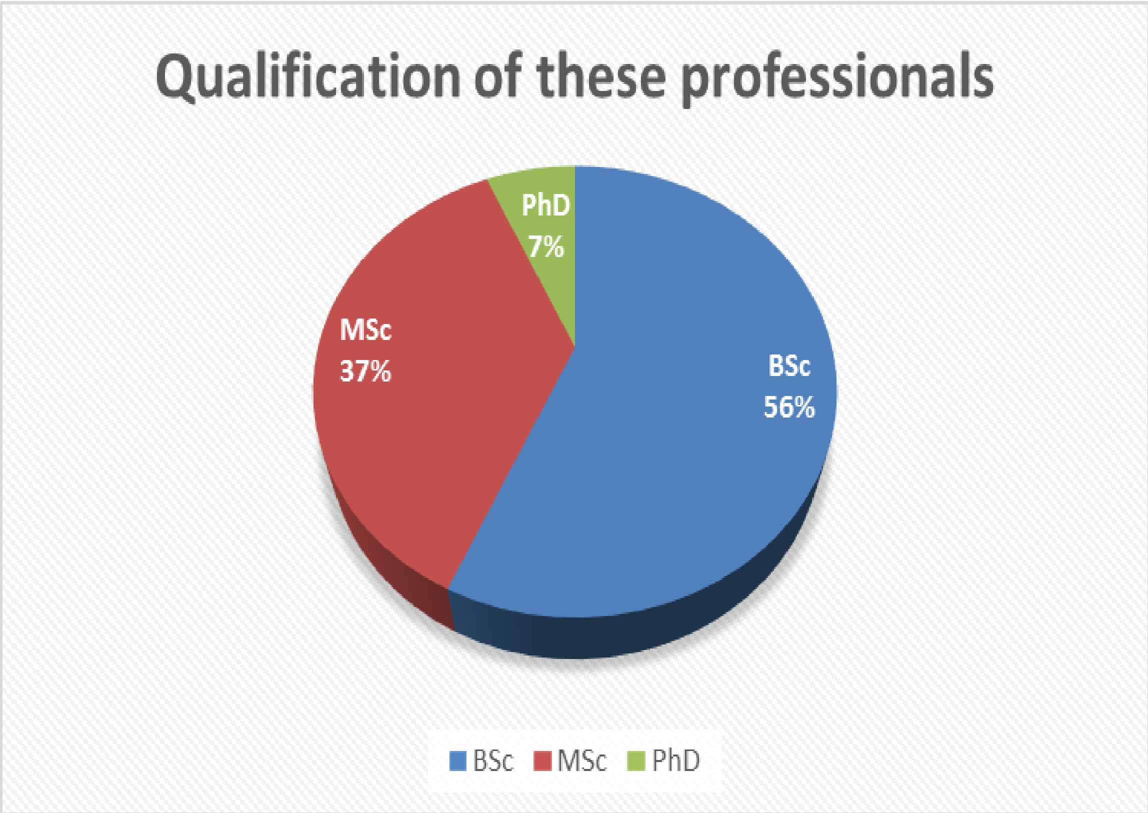


*Figure 4-7;* The Qualification of those professionals involved in the survey

## 4.2. Level of importance of Constructability Concept

The study used expert interviews and questionnaire surveys to establish design phase constructability concepts for highway projects. Three project managers were interviewed to confirm the list of concepts identified. The research focused on highway projects under construction by corridor development projects. Professionals closely involved in highway project construction were targeted for the questionnaire and interviews. Data analysis was done using frequency and average index methods.

### 4.2.1. Relative Importance Index (RII)

The evaluation of various factors concerning their degree of significance was conducted using the Relative Importance Index (RII) [59]. The interpretation of RII values is categorized as follows: items with an RII value less than 0.60 are considered to have low significance; those with an RII ranging from 0.6 to less than 0.80 are deemed to have high significance; and items with an RII of 0.80 or greater are classified as having very high significance.

### 4.2.2. Constructability Concept during Conceptual Planning Phase.

In the conceptual planning phase, the constructability concept plays a crucial role, as highlighted in Table 4-6 and Figure 4:8. The three concepts deemed most significant include: the application of advanced information technologies throughout the project, the integration of construction knowledge and experience into project planning, and the early identification of project team participants responsible for constructability. Concepts that achieve a Relative Importance Index (RII) of 0.8 or higher are considered to have very high significance due to their substantial impact on project outcomes.

Table 4-6; Result of RII during Conceptual Planning Phase

| | Constructability Principles during pre-construction phase<br>**C1. During Conceptual Planning Phase** | **Relative Importance Index (RII)** | **Rank** |
|---|---|---|---|
| C1.1 | Advanced information technologies are applied to facilitate efficient construction | 0.950 | 1 |
| C1.2 | Constructability programs are made an integral part of project execution plans. | 0.930 | 2 |
| C1.3 | A project team that includes a representation of the owner, the engineer, and the contractor should be formulated and maintained to consider the constructability issues in all phases. | 0.910 | 3 |
| C1.4 | Development of the project contracting strategy involves construction knowledge and experience | 0.900 | 4 |
| C1.5 | Basic design approaches consider significant construction methods. | 0.890 | 5 |
| C1.6 | Site layouts promote efficient construction, operation and maintenance. | 0.880 | 6 |
| C1.7 | Project schedules are construction-sensitive and assigned as early as possible. | 0.870 | 7 |

The concept that "**#1 Advanced Information Technologies are integrated throughout the project**" is of utmost importance, particularly influencing the "Conceptual Planning Phase" with a relative importance index of 0.951. This highlights the critical need for the effective utilization of Information Technology tools to manage historical data, which is stored in computerized databases. These databases should include insights derived from the constructability program, acting as an essential element of the project control system (e.g., budget amounts, change orders, and purchase orders).

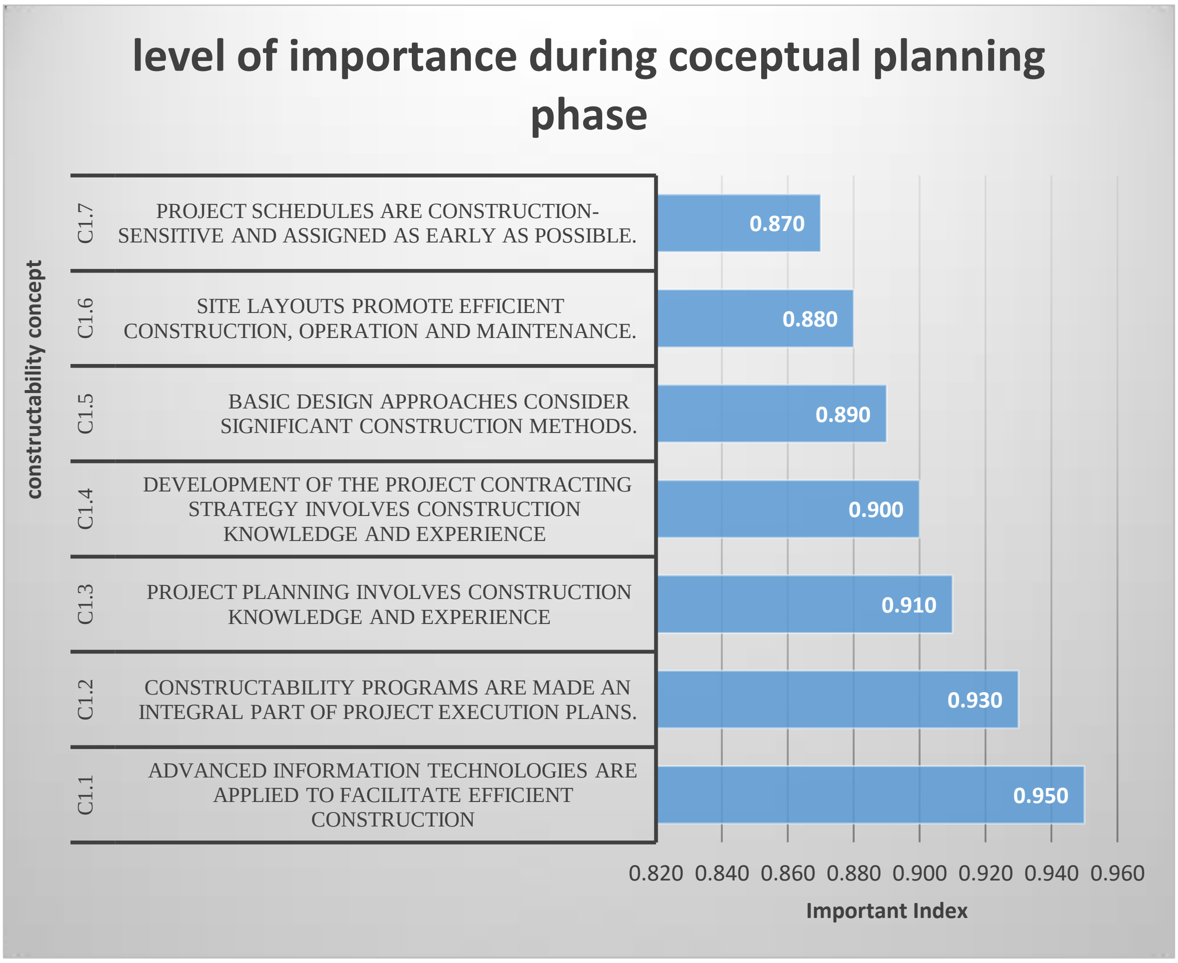


Figure 4-8; Result of RII during Conceptual Planning Phase

The integration of advanced information technologies (AIT) into project management is increasingly recognized as a critical factor that influences various phases of project development, particularly during the conceptual planning phase. This phase is essential for laying the groundwork for successful project execution and involves strategic decision-making based on historical data and insights.

The statement highlights that AIT holds a top position in influencing the conceptual planning phase with a relative importance index of 0.951. This high index indicates that effective use of information technology tools is paramount for managing historical data, which plays a vital role in informing decisions throughout the project lifecycle.

Historical data encompasses past records that offer valuable insights into earlier projects, highlighting both their achievements and shortcomings. In the realm of construction and project management, this data can encompass various aspects, such as budget figures, which aid in accurately estimating costs for upcoming projects. Additionally, examining change orders reveals the frequency and reasons behind modifications in previous projects, thereby enhancing change management strategies. Furthermore, reviewing past purchasing decisions can streamline procurement processes. Collectively, these components are essential for gaining a thorough understanding of potential risks and opportunities in new projects.

To efficiently handle historical data, it is essential to store and manage it within computerized databases. These databases fulfill several critical roles: They provide centralized access, enabling team members to swiftly retrieve pertinent information, which supports informed decision-making. Additionally, computerized systems enhance data integrity by ensuring that information remains accurate and current, thereby minimizing errors linked to manual record-keeping. Furthermore, many contemporary databases are equipped with analytical tools that allow users to efficiently derive insights from extensive datasets.

The constructability program focuses on evaluating how easily a project can be constructed based on its design. Insights gained from this program should be integrated into the database as they provide valuable lessons learned regarding: Design feasibility, Construction methods, Resource allocation. Incorporating these insights into the project control system enhances overall project performance by allowing teams to anticipate challenges before they arise.

A comprehensive project control system encompasses all facets of project management, such as budgeting, scheduling, and resource distribution. By incorporating historical data and insights on constructability, organizations can realize several benefits. Firstly, they can enhance forecasting capabilities, leading to more accurate predictions of timelines and costs grounded in previous performance. Secondly, improved risk management is achieved by enabling teams to identify potential challenges early, allowing for the proactive development of mitigation strategies. Lastly, streamlined communication is facilitated through centralized information, promoting collaboration among stakeholders by ensuring that all parties have access to consistent data.

**#2** ***Constructability programs are made an integral part of project execution plans*** holding the second highest ranking with a RII value of 0.930. This underscores the importance of leveraging knowledge from past experiences for the success of any constructability initiative. Typically, lessons learned are shared through various channels such as project kick-off meetings, informal discussions, meeting notes, and post-project review sessions.

**Understanding Constructability Programs**

Constructability programs are essential components of project execution plans in the construction industry. They focus on ensuring that projects are designed and planned in a way that facilitates efficient construction, ultimately leading to successful project outcomes.

**Importance of Constructability Programs**

The high ranking of constructability programs, with a RII (Relative Importance Index) value of 0.930, indicates their critical role in project success. This value suggests that stakeholders recognize the significant impact that effective constructability practices can have on overall project performance.

**Leveraging Past Experiences**

One of the key aspects of constructability initiatives is the utilization of knowledge gained from past projects. By analyzing previous experiences, teams can identify potential challenges and develop strategies to mitigate risks associated with construction processes. This proactive approach helps in avoiding common pitfalls and enhances the likelihood of project success.

To effectively utilize past experiences, it is essential to have established mechanisms for sharing lessons learned. These mechanisms promote communication among team members and ensure that important insights are shared across the organization. Common approaches include project kick-off meetings, which set the project's direction and allow for discussions on relevant lessons from previous projects. Informal discussions among team members can also yield valuable exchanges about past experiences and best practices. Additionally, documenting meeting notes provides a structured way to capture insights and decisions related to constructability issues. Finally, post-project review sessions enable teams to reflect on successes and areas for improvement, thereby nurturing a culture of continuous learning.

***#3 The establishment and maintenance of a project team that includes representatives from the owner, engineer, and contractor is crucial for addressing constructability issues throughout all project phases.*** This concept is ranked third in importance, with a Relative Importance Index (RII) value of 0.910. It emphasizes the necessity of drafting an organizational chart during the design phase to identify participants in the constructability team and clarify their roles. Additionally, developing the project contracting strategy requires construction knowledge and experience, while basic design approaches must take into account significant construction methods; these are ranked third, fourth, and fifth in importance respectively, each with RII values exceeding 0.8, indicating very high significance. Furthermore, advanced information technologies should be utilized to enhance construction efficiency. Project schedules need to be sensitive to construction requirements and assigned as early as possible. Lastly, site layouts should be designed to promote efficient construction, operation, and maintenance; these factors rank sixth, seventh, and eighth respectively, also reflecting very high significance with RII values above 0.8.

Constructability refers to the ease with which a project can be constructed, taking into account factors such as design, materials, and methods. The involvement of key stakeholders—namely the owner, engineer, and contractor—throughout all phases of a project is crucial for addressing constructability issues effectively.

**Importance of a Collaborative Team**

Involving representatives from the owner, engineer, and contractor in a project team guarantees that a variety of viewpoints are taken into account. Each stakeholder contributes distinct perspectives: the owner emphasizes project requirements, budget limitations, and the overarching vision; the engineer brings technical knowledge and ensures compliance with safety and regulatory standards; while the contractor shares practical insights regarding construction methods and potential obstacles.

Frequent communication among these stakeholders promotes transparency and collaboration, allowing for the early identification of possible constructability issues during the design stage. By proactively addressing these concerns, the team can effectively reduce risks related to delays, budget overruns, and safety incidents throughout the construction process.

**Drafting an Organizational Chart**

To create an effective organizational chart, begin by identifying the key participants involved in the constructability team, ensuring representation from each stakeholder group, including the owner, engineer, and contractor. Next, define the roles and responsibilities of each team member, specifying tasks such as the owner's representative overseeing budget compliance, the engineer focusing on design feasibility, and the contractor providing insights on construction methods. Establish clear reporting lines to facilitate information flow and streamline decision-making processes among team members. Additionally, schedule regular meetings to monitor progress and address any constructability issues that may arise during the design phase. Finally, maintain thorough documentation of discussions and decisions made in these meetings to ensure accountability and traceability.

### 4.2.3. Constructability concepts During Design and Procurement Phase

Table 4:7 and Figure 4:9 presents the essential concepts associated with highway construction in the context of corridor development projects during the Design and Procurement Phase. The timelines for design and procurement are closely linked to construction schedules, with project sequencing being the top priority, assigned a relative importance index (RII) of 0.890. Following this, the simplification and configuration of technical specifications for the project to enhance construction efficiency is ranked second, with an RII of 0.860. It is imperative that project designs are streamlined by designers and thoroughly reviewed by qualified construction professionals to ensure effective execution. Furthermore, the standardization of project components and the incorporation of construction efficiency considerations during the development of specifications are vital. The designs for modular and preassembly components are also critical, ranking third, fourth, fifth, and sixth, respectively, each with a relative importance index (RII) of 0.8 or higher, underscoring their significant role in the overall construction process.

Table 4-7; Result of RII during Conceptual Planning Phase

| | Constructability Principles during pre-construction phase<br>**C2. During Design and Procurement Phase** | Relative Importance Index (RII) | Rank |
|---|---|---|---|
| C2.1 | Design and procurement schedules are construction sensitive and considered in project sequencing | 0.890 | 1 |
| C2.2 | The project technical specifications should be simplified and configured to achieve efficient construction. | 0.860 | 2 |
| C2.3 | designers and design review by qualified construction personnel, must be configured to enable efficient construction. | 0.840 | 3 |
| C2.4 | Project elements should be standardized. | 0.820 | 4 |
| C2.5 | Design should facilitate construction during adverse weather conditions. | 0.810 | 5 |
| C2.6 | Module/preassembly designs are prepared to facilitate fabrication, transportation, and installation | 0.780 | 6 |
| C2.7 | Designs considering construction accessibility of personnel, material, & equipment to the required position inside the site. | 0.760 | 7 |

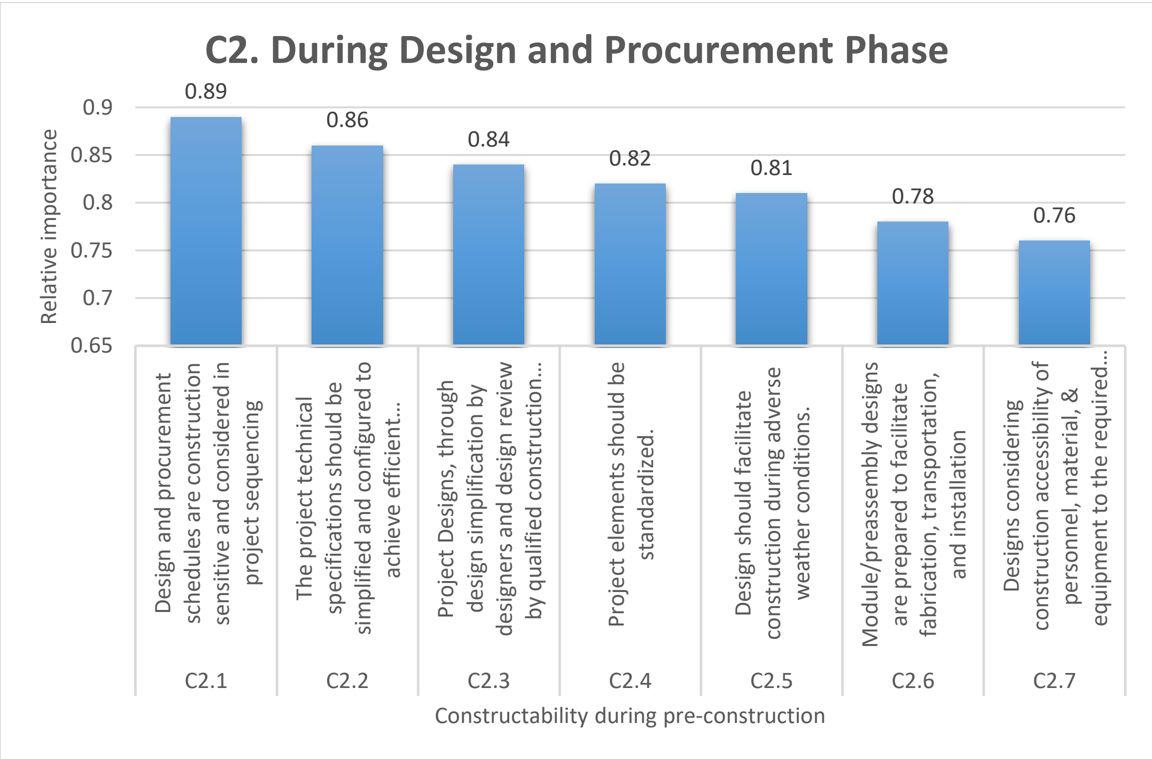


Figure 4-9; Result of RII during Design and Procurement Phase.

Designs that account for the accessibility of personnel, materials, and equipment to necessary locations on-site are ranked seventh, while designs that facilitate construction during adverse weather conditions are ranked eighth, both receiving a high relative importance index (RII). The results indicate that design and procurement schedules are sensitive to construction needs and should be integrated into project sequencing. Additionally, project technical specifications must be streamlined and tailored to enhance construction efficiency, emphasizing the importance of constructability concepts in corridor development projects.

### 4.2.4. Constructability concepts During field operations phase

Table 4:8 and Figure 4:10 illustrates the concepts of constructability during the field operations phase of project works. Among these concepts, the use of innovative construction methods emerged as the most significant factor, achieving a relative importance index (RII) of 0.840. This indicates a strong enhancement in constructability through innovation. Following closely, tasks sequencing—designed to minimize rework of project elements, reduce scaffolding requirements, optimize formwork usage, and alleviate congestion among labor and materials—ranked second with an RII of 0.810. Both indices reflect very high significance values.

Table 4-8; Result of RII during Conceptual Planning Phase

| | Constructability Principles during pre-construction phase | Relative Importance Index (RII) | Rank |
|---|---|---|---|
| | **C3. During Field Operations Phase** | | |
| C3.1 | Constructability will be enhanced using innovative construction methods. | 0.840 | 1 |
| C3.2 | Tasks Sequencing is configured to minimize rework of project elements, scaffolding needs, formwork used, or congestion of labors & materials | 0.810 | 2 |
| C3.3 | Innovative methods for using the available equipment or modification of the available equipment to increase their productivity. | 0.780 | 3 |
| C3.4 | Incorporating new methods of innovation through the use of off-the-shelf hand tools or modifying available tools. | 0.750 | 4 |
| C3.5 | Innovative methods for using the available equipment or modification of the available equipment to increase their productivity. | 0.740 | 5 |
| C3.6 | Use preassembly to increase productivity, reduce the need for scaffolding, or improve the project constructability under adverse weather conditions. | 0.730 | 6 |
| C3.7 | Good contractors, based on quality and time of their work should be documented. Subsequently, future contracts for construction work would not solely be awarded based on low bids, but also by considering other attributes, i.e. quality and time. | 0.700 | 7 |

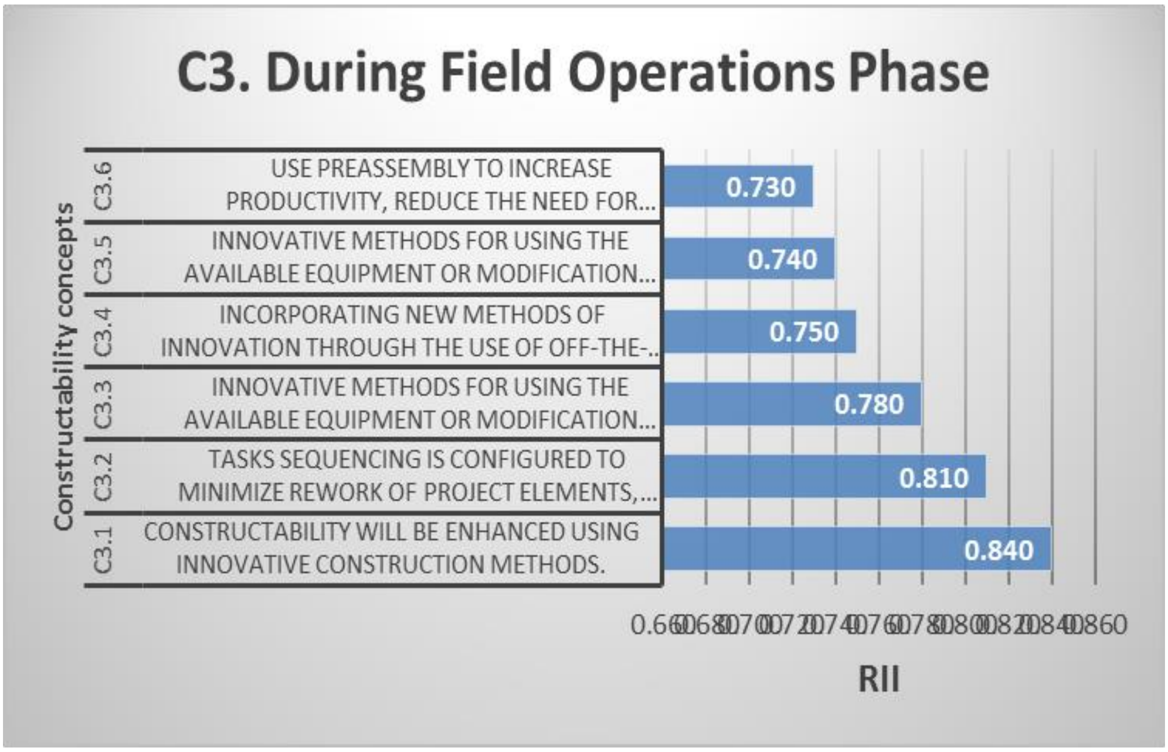


Figure 4-10; Result of RII during Field Operations Phase.

Innovation in temporary construction materials and systems that are not explicitly outlined in design drawings and technical specifications is essential. This includes the integration of new innovative methods through the use of readily available hand tools or the adaptation of existing tools. Additionally, there are innovative approaches to utilizing or modifying available equipment to boost productivity. It is crucial to document the performance of competent contractors based on the quality and timeliness of their work. Consequently, future construction contracts should not be awarded solely on the basis of the lowest bids; rather, they should also take into account factors such as quality, time, and constructability. Encouraging contractors to innovate in the development of temporary facilities is of significant importance, as indicated by their ranking in relative importance. The results demonstrate that constructability can be improved through innovative construction methods that are vital for the successful execution of corridor development projects during the operational phase.

## 4.3. Perception of Application of Constructability Concept in Industry

The responses to Part 3 of the Questionnaire were notably varied, with numerous participants providing additional comments alongside their answers. This diversity posed a challenge for analysis. To gain deeper insights into the responses, including the supplementary comments, follow-up telephone interviews were conducted with respondents whose names and organizations were identifiable from the Questionnaire. These interviews facilitated clarifications and discussions about the details of the answers and comments, significantly improving the accuracy of understanding the responses.

In this section of the survey, the 40 constructability concepts developed by CII USA were rephrased into more practical terms, resulting in 24 applications of constructability. Each concept, as outlined by CII USA, corresponds to a specific stage in the project life cycle, excluding the operation and decommissioning phases. This includes eight concepts for the conceptual planning phase, eight for the design and procurement phase, and eight for the field operation phase. The conceptual planning phase involves feasibility studies, design brief development, and conceptual design, while the design and procurement phase encompasses basic design development, detailed design, and the procurement of construction services, commonly referred to as the tender stage in the City construction industry. The field operation phase pertains to the actual construction stage of a project.

### 4.3.1. Conceptual Planning Phase

In this stage the client selects the consultants, the site and tests the feasibility of the project by doing elementary work in estimate, plans etc. Thereafter he makes a decision of whether to proceed with the project or not.

***Concept 1.1: Advanced information technologies are applied to facilitate efficient construction***

The effective utilization of Information Technology tools is essential for the storage of historical data, which is organized within computerized databases. These databases should integrate insights derived from the constructability program as a vital element of the project control system, encompassing budget figures, change orders, and purchase orders. Learning from past experiences is crucial for the success of any constructability initiative. Typically, lessons learned are disseminated through project kick-off meetings, informal discussions, documentation from project meetings, and post-project review sessions.

***Concept 1.2; The project execution plan outlines and addresses the programming for constructability.***

To maximize the benefits of constructability, it is crucial to incorporate it early in the project lifecycle. The project owner should integrate constructability considerations into the execution plan. It is essential to treat constructability with the same importance as other standard functional areas of contracting and procurement to fully realize its advantages. It should not be regarded as an additional task or an afterthought during the design phase. By including constructability in the execution plan, a conducive environment is created to evaluate how all project decisions impact the construction process. This approach advocates for the establishment of a dedicated constructability program during the project's conceptual planning phase, making it a fundamental component of the project execution plans. In response to this approach, most respondents indicated that while it is relevant, they find it challenging to implement. Below is a summary of the comments and clarifications from those who selected this option:

The constructability program appears promising in theory; however, its practical implementation is often not prioritized. Such a program tends to complicate the conceptual planning process and is typically only integrated into large-scale projects where constructability is factored into the initial design phase. One participant noted that the concept was deemed inapplicable, as he had never encountered its implementation and did not believe it was necessary to allocate additional resources for a dedicated program within the conceptual planning framework.

The feedback regarding this concept indicates that the successful establishment of a constructability program necessitates a commitment from the Client, who must justify the resources needed to implement it while balancing other project goals and priorities. While there are certainly advantages to adopting this approach, it is not without associated costs. The challenge lies in determining the optimal balance, which is the most complex aspect of the process.

***Concept 1.3: To include construction personnel early in the project team so as to make full use of construction knowledge and experience during conceptual stage.***

Both formal and informal planning efforts must incorporate individuals or sources of expertise in the construction field. This principle emphasizes that involving construction professionals early in the project team can significantly enhance the project’s outcomes by leveraging their specialized knowledge and experience. Figure 4-12 indicates some of the area where construction professionals can bring their specialized knowledge and experience as input. Furthermore, the Concept File indicates that during the conceptual phase, input from construction experts can provide valuable insights that contribute to more effective project development.

.a. To establish realistic project objectives.
- b. To select major construction methods.
- c. To select site.
- d. To ensure feasibility of Programme.
- e. To prepare estimate and budget.
- f. To develop the contracting strategy.
- g. To source materials and equipment.


*Figure 4-11; Some of the input needed from construction knowledge and experience.*

Respondents who selected "applicable but difficult to implement" regarding this concept provided several insights and explanations:

The approach is relevant primarily in specific scenarios where the Client recognizes its value and actively seeks input from construction personnel at the project's inception.

It is predominantly suitable for large-scale projects, particularly when the Client possesses the financial resources necessary to engage contractors for their expertise.

Implementation poses challenges as many individuals do not fully appreciate its significance.

***Concept 1.4: To use alternative contracting strategy e.g. design-build, project management etc. as a way to have construction knowledge input early in a project***

Owners exhibit diverse contracting philosophies regarding the allocation of responsibilities and the payment structures for design and construction services. The selected approach significantly influences who is accountable for managing and coordinating constructability efforts. When design and construction responsibilities are merged and outsourced, the owner's role in ensuring constructability diminishes. Conversely, under the traditional design-bid-build model, the owner is tasked with coordinating or facilitating the constructability process. This notion implies that clients can optimize construction expertise by embracing alternative contracting arrangements, such as engaging a Design-Build Contractor, hiring a third-party consultant as Project Manager, or implementing Build-Operate-Transfer models. Respondents indicated that these practices are already prevalent within the industry, with a notable consensus among those who believe such approaches have become standard.

Respondents highlighted numerous current and past instances in Addis Ababa where alternative contract strategies, such as design and build, have been employed by clients to facilitate the integration of construction knowledge early in project development. Notable examples include the CBE Bank and the ADWA 00 Projects. However, those who indicated that these strategies are "applicable but difficult to implement" pointed out several challenges that hinder their application. Key issues include concerns regarding design liability and the limited number of organizations in the market possessing comprehensive capabilities in both design and construction. Despite these challenges, there is a growing trend within the industry to merge construction expertise with design from the outset of projects through the adoption of alternative contracting strategies.

***Concept 1. 5: To consider major construction methods during basic design approaches of a project.***

The methods employed in construction significantly influence the overall cost of a project. These methods are frequently determined by the initial conceptual design and planning stages. By correlating the design alternatives under consideration with their respective construction methods during the conceptual phase, substantial cost savings can be achieved. As the design evolves, it is crucial to evaluate any potential changes in construction that may be necessary, along with the corresponding adjustments in costs. This principle underscores the importance of integrating major construction methods into the fundamental design process of a project to enhance its constructability. The Concept File provides several examples of key construction factors that should be taken into account [61]:

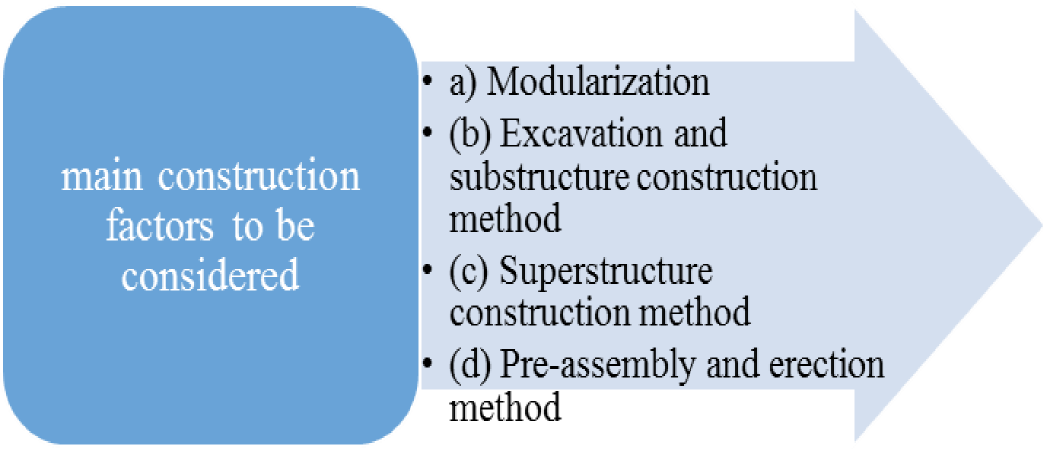

Figure 4-12; Factors to consider major construction methods during basic design.

The majority of responses indicated that while the concept is deemed “applicable,” its implementation poses significant challenges. Many respondents expressed the view that fundamental design considerations typically fall within the purview of design consultants, with contractors often lacking the requisite expertise. Additionally, one respondent noted that designers are generally reluctant to allow contractors to influence their foundational designs. The approach to basic design varies significantly from project to project and among different consultants. Consequently, opinions diverge regarding the necessity and significance of construction methodology and its impact on basic design strategies, particularly in the context of design and build approaches in both public and private sectors.

***Concept 1.6: To Overall project schedules are construction sensitive.***

The planning process typically involves establishing an end date, followed by the execution of planning and design activities, which then leads to a requirement for construction to be completed within the remaining timeframe. While this method may enhance the effectiveness of design and planning efforts, it often results in inefficiencies during the construction phase. Therefore, it is essential to optimize the overall schedule, necessitating compromises across all phases of the project.

One respondent expressed that while the concept is applicable, its implementation poses significant challenges. They noted that liability issues arise unless the designer and contractor are part of a unified group sharing risks; otherwise, the potential for delays creates complications in applying the concept effectively. Another respondent echoed this sentiment, stating that project duration is frequently dictated by the client’s desired completion date rather than the actual time required for completion. Consequently, projects often experience delays during the initial stages, placing considerable pressure on clients regarding increased financing costs. To mitigate these challenges, clients frequently resort to shortening construction durations without adequate justification.

***Concept 1.7: Design of general layout takes into account construction efficiency through considering both permanent and temporary facilities.***

The principle of construction efficiency plays a crucial role in the layout of both permanent and temporary facilities. An effective site layout can significantly enhance construction activities, ultimately leading to reduced project costs. However, a majority of respondents indicated that while they recognize the importance of this concept, they find it "applicable but difficult to implement." This sentiment arises from several challenges:

I. Many design consultants often overlook construction efficiency when planning the general layout of a project.

II. It proves challenging to balance the considerations for both permanent and temporary facilities during the design phase, especially at the conceptual stage.

Respondents noted that the concept of integrating both temporary and permanent structures into the design of large civil engineering and infrastructure projects is already a common practice. They emphasized that due to the substantial physical size of these structures, it is essential to consider both types in the design process. The feedback provided by industry professionals highlights a significant challenge: achieving a balance between the requirements for temporary and permanent facilities during layout design can often be difficult, if not impossible. Typically, permanent structures take precedence over temporary ones.

In Addis Ababa, this issue is particularly pronounced in densely populated commercial areas where space is at a premium. Developers frequently find themselves unable to allocate any additional land for temporary facilities, as doing so would compromise their construction efficiency and financial viability.

On the other hand, the nature of a project can significantly influence the feasibility of its layout design, particularly when temporary facilities are involved. Numerous examples exist in local civil engineering projects where designers must take into account temporary structures in their layout designs. These temporary facilities can be substantial and may impact the construction of permanent structures, as well as necessitate diversions and modifications to adjacent facilities..

### 4.3.2. Design and Procurement Phase

In this stage the design team does analysis about the alternate solutions and materials. The detailed drawing is finalized together with the major systems, materials, components etc. All technical documents, specifications, schedules and budgets are developed in this stage.

**Concept 2.1: To adjust design and procurement programme as much as possible to suit construction programme.**

The underlying principle of this concept is that, given the relatively higher costs associated with construction compared to design and procurement, construction should be prioritized when developing and optimizing the project program. An examination of Concept File [54] reveals that this concept largely mirrors Concept 1.4, with the primary distinction being the specific Project Phases to which each concept pertains. Feedback regarding this concept was akin to that received for Concept 1.4; however, one respondent raised a valid concern regarding the assertion made in this concept, arguing that design should not be entirely compromised to accommodate the construction schedule. This perspective highlights the importance of considering various critical factors in the optimization of the program.

**Concept 2.2 in writing specification, consider construction efficiency simultaneously with other factors like quality, aesthetics operation, maintenance, reliability' and expandability**

The returned questionnaires revealed that the statement regarding this concept caused some confusion among respondents, as evidenced by unanswered questions and responses that were not directly related to the topic. Follow-up telephone interviews helped clarify some of these ambiguities. In simpler terms, this concept emphasizes the importance of construction input in the development of specifications, asserting that a clear and comprehensive specification can significantly improve constructability. Respondents who affirmed that this concept was "already a common practice" noted that construction efficiency in this context primarily pertains to traditional methods rather than newer techniques. This indicates that since the efficiency levels of traditional construction methods are well understood, they can be effectively incorporated into specification writing.

Respondents who viewed this concept favorably yet found it challenging to implement provided several explanations. Firstly, many designers lack construction experience, which necessitates the involvement of contractors in the specification writing process; however, coordinating such collaboration is often impractical. Secondly, the limited resources available to consulting firms do not warrant the additional effort required to analyze construction efficiency when drafting specifications. Furthermore, due to project time constraints, consultants typically resort to standard specifications that prioritize quality and performance while giving minimal attention to construction efficiency. Additionally, some respondents deemed this concept "not applicable," arguing that the primary purpose of any specification is to establish standards for quality and performance, rather than addressing the efficiency of work execution.

**Concept 2.3: To shape detail design configured to enable greater construction efficiency.**

The development of a project concept must align with the client's specifications. Various approaches can satisfy the standard criteria, including safety, aesthetics, operability, and maintainability. Additionally, it is crucial to give due consideration to constructability. The Figure 4-13 shows some of the factors should be integral to the evaluation of design from a constructability perspective [59]:

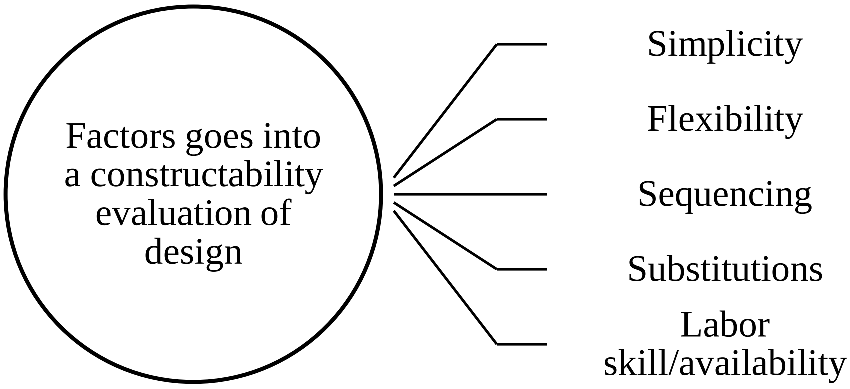


Figure 4-13; Factors take part of a constructability evaluation of design.

Respondents who perceived the concept as "applicable but difficult to implement" identified several key reasons for their hesitation. Firstly, designers often neglect the efficiency of construction during the design phase and are not mandated to prioritize it. Secondly, the potential costs associated with design modifications can deter both designers and clients from pursuing changes. Additionally, evaluating new construction methods or materials can be a time-consuming process that requires considerable effort to obtain necessary approvals. These responses indicate that the successful application of this concept heavily relies on the designer's approach and willingness to consider construction efficiency. Only when designers acknowledge the significance of construction efficiency are they likely to address these concerns during the detailed design phase. While it is understandable that any alterations in detail design may incur cost or time implications, this should not serve as a justification for avoiding alternative designs that could enhance construction efficiency.

***Concept 2.4: To maximize standardization of components and systems in detail design.***

This concept represents a continuous development of earlier ideas, particularly concerning standardization—a process through which project components are utilized consistently and extensively. A significant number of respondents indicated that they find this concept to be well-known within the industry, citing numerous local examples, such as housing projects, where it has been effectively implemented. Consequently, they believe this practice should already be considered standard. One respondent noted that this approach is highly appreciated by many clients in Addis Ababa, as it leads to reduced construction costs, thereby providing financial benefits to the client.

Critics of standardization in architectural design often express the following concerns: while standardization can be beneficial, it may necessitate compromises in design quality, leading to repetitive elements that are not always desirable. Additionally, the specific preferences and requirements of clients frequently render standardization impractical in architectural projects. Effective implementation of standardization is most achievable when designers and builders collaborate closely to identify standardized solutions; however, such collaboration is rarely realized. Responses to this perspective indicate that although there are numerous instances of successful standardization within the local industry, its application is not universally feasible due to the diverse constraints associated with different design projects.

***Concept 2.5: To allow adequate access of personnel, material, and equipment during detail design.***

This concept represents a progression from the conceptual design phase to the detailed design stage. Respondents identified several challenges that hinder the realization of this concept, describing it as "applicable but difficult to implement." Key obstacles include the limited design time available to thoroughly examine construction access details, the impracticality of convening various professionals and specialists for discussions on detailed design—often resulting in protracted negotiations—and the inherent limitations posed by congested site conditions that restrict considerations for construction access. Conversely, those who viewed the concept as "already a common practice" noted that its application is typically confined to specific scenarios, such as ensuring adequate access for permanent use, addressing significant access issues in large civil projects, and instances where the designer and contractor belong to the same organization, facilitating collaborative planning and execution. The feedback on this concept underscores the reality of construction projects, highlighting that while it is commendable to address access issues in detail design, it may not be feasible to account for all access factors in every project.

***Concept 2.6: To design in such that adverse weather conditions have minimum effects on field construction***

The concept in question appears to present significant challenges for project design, which likely explains the overwhelmingly negative feedback received in the questionnaire. One respondent noted that this issue is rarely considered by designers during the design phase. Many participants characterized the concept as “difficult to implement,” providing several explanations:

1. Construction is inherently an open-field operation, limiting the ability of design to mitigate adverse weather conditions effectively.
2. The severity of adverse weather is widely recognized within the industry, leading to a common belief that it is primarily a challenge for contractors to manage.
3. Design considerations typically focus only on extreme weather events.

It is clear that adverse weather represents a natural force beyond anyone’s control within the industry, and existing technologies offer limited solutions for mitigating its impacts. Addressing this issue necessitates profound reflection from all professionals involved in both design and construction. A shift away from traditional mindsets in construction operations is essential to effectively confront these challenges. The Concept File [59] has suggested some good examples of factors that can be considered to facilitate construction under adverse weather, indicated in Figure 4-14.

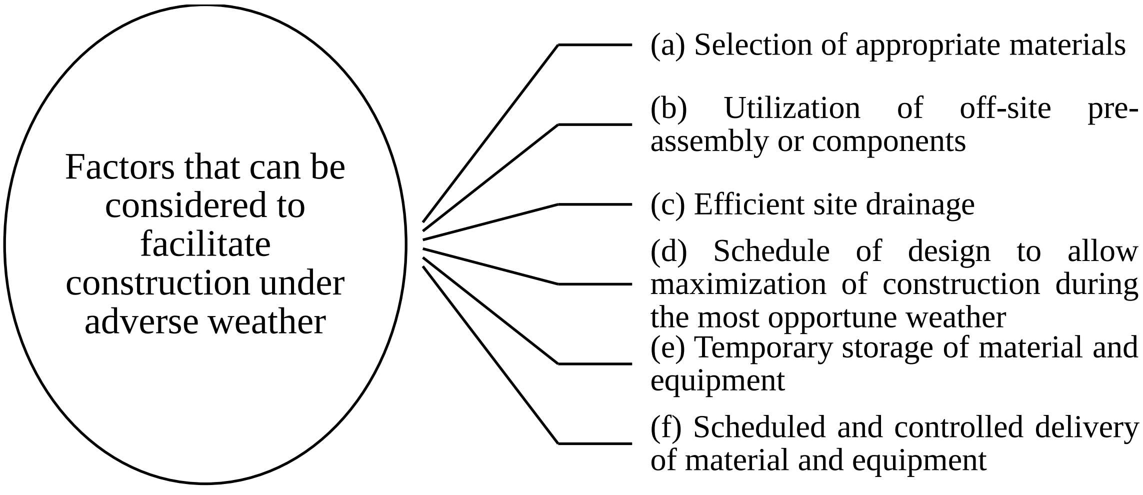


Figure 4-14; Factors considered to facilitate construction under adverse weather.

***Concept 3.1: To use innovative construction methods to improve construction efficiency.***

This concept is primarily directed toward construction organizations. Innovative construction methods are methods that are not generally considered common practice and are creative solutions to field challenges. The Concept File listed following areas to be included as innovation:

(a) Innovative sequencing of field tasks

(b) Innovative uses of temporary construction materials and systems

(c) Innovative uses of hand tools

(d) Innovative uses of construction equipment

(e) Innovative temporary facilities directly supportive of field methods

(f) Using new construction technology [59].

The respondents who viewed this concept as "already a common practice" in Addis Ababa exhibited a strong sense of confidence and pride in the achievements of the local industry. They noted that the construction market in Addis Ababa is arguably one of the most competitive globally, highlighting successful initiatives such as the Airport Core Programme and Mass Transit Railway Projects, which have effectively utilized new technologies and management systems. Furthermore, contractors are willing to adopt innovative technologies when they prove to be cost-effective. Conversely, many respondents expressed that this concept is "difficult to implement," citing a scarcity of locally available innovative construction methods, bureaucratic hurdles in the approval process, and a general skepticism towards untested methods, which complicates the assessment of their costs and benefits. While the responses reflect individual experiences and knowledge regarding innovative practices, there is a consensus that the integration of innovative technology is essential for enhancing construction efficiency and overall constructability. Those who have witnessed the successful application of new technologies tend to be more optimistic about the future of the construction industry.

## 4.4. Specific Experience of Constructability Implementation by Individuals.

This section of the questionnaire builds upon the previous part and delves deeper into the practical aspects of constructability. Initially, participants were asked to identify concepts they have personally encountered in practice, irrespective of the specific terminology used or recognized. Subsequently, they were requested to evaluate the implications of these implementations concerning project cost, time, and quality. Following this evaluation, respondents were invited to outline, based on their experiences and knowledge, the obstacles faced in applying constructability within the context of road corridor development projects in Addis Ababa. Finally, participants were encouraged to propose innovative concepts or applications that they deemed relevant.

### 4.4.1. Experience of Implementation

This section serves as a summary of Part 3 of the Questionnaire based on personal experiences. The findings indicate that all concepts have been encountered in practice at least once. Among these, three concepts emerged as the most frequently observed by respondents: Concept 1.3 emphasizes the importance of involving construction personnel early in the project team to leverage their knowledge and experience during the conceptual phase; Concept 1.4 advocates for the adoption of alternative contracting strategies, such as design-build and project management, to integrate construction insights early in the project; and Concept 1.8 highlights the necessity of reviewing political and legal factors prior to the design stage. Other concepts experienced by respondents, albeit less frequently, include: Concept 2.1, which focuses on designing and procuring schedules that are sensitive to construction needs; Concept 1.5, which involves considering major construction methods during the basic design phase; Concept 1.6, which promotes site layouts that enhance construction efficiency, operation, and maintenance; and Concept 1.1, which pertains to the application of advanced information technologies to facilitate efficient construction. While the small sample size may limit the generalizability of these findings, they nonetheless suggest that the application of these constructability concepts is evident in real projects within the Addis Ababa Construction Industry, with Concepts 1.3, 1.4, 1.8, 1.5, and 1.1 likely being commonly practiced locally.

### 4.4.2. Implications of Implementing Constructability

In this section of the questionnaire, participants were invited to share their perspectives on the implications of implementing constructability, specifically regarding cost, time, and quality. They were also asked to identify any quantitative benefits based on their experiences. The responses indicated a general agreement among the participants that implementing constructability yields advantages in terms of cost savings, time efficiency, and quality enhancement; however, quantifying these benefits proved to be challenging. One respondent noted that accurately comparing and determining the costs and benefits of new practices requires significant effort, and in real-world project scenarios, design decisions often rely on intuition or quick analyses rather than comprehensive evaluations.

While one participant expressed that quality improvement was not a primary concern in the context of constructability, they later clarified that the main focus of any design alternative, including constructability and value engineering, revolves around project costs and timelines. Overall, the positive feedback aligns with findings from other countries that have demonstrated the benefits of constructability. It is reasonable for industry professionals to view the practice as advantageous, as it facilitates enhancements in design and construction to meet project goals. Nevertheless, assessing these benefits quantitatively remains a complex task, necessitating additional efforts in data collection, comparison, and analysis. Although determining the implications for cost and time may be relatively straightforward, measuring quality improvements presents a more significant challenge.

### 4.4.3. Barriers to Implementing Constructability

The responses gathered from Part 4 of the questionnaire reveal a diverse range of perspectives regarding the implementation of constructability concepts within the local construction industry. It is evident that the integration of constructability faces significant challenges, prompting an inquiry into the specific barriers encountered. In this section, participants were initially asked to identify these obstacles from a pre-compiled list derived from a literature review, followed by an opportunity to contribute additional barriers based on their personal experiences and insights.

Among the barriers identified, the most frequently mentioned by respondents was the "traditional procurement method of separation of design and construction." This longstanding approach has been criticized by both industry professionals and academics as a primary factor contributing to the disconnection between design and construction processes. The division inhibits construction personnel from engaging in the planning and design stages, thereby missing opportunities to enhance project effectiveness through the application of construction expertise. Other notable barriers highlighted by respondents include the reluctance of designers to incorporate contractor input and a lack of commitment from clients.

The construction industry is marked by a variety of disciplines, leading professionals to often prioritize their specific areas of expertise. Designers, in particular, are driven by their vested interests in achieving design objectives related to aesthetics, functionality, and quality. Consequently, they tend to concentrate solely on these goals, viewing external influences as potential disruptions to their work. This inclination can result in resistance to adopting ideas from outside sources, even when those ideas may offer improvements, as such suggestions may challenge their professional authority and expertise.

Additionally, the traditional procurement methods that delineate the roles of design and construction create a contractual divide between designers and contractors, further reinforcing this reluctance. Designers may feel no obligation to consider constructability, as it falls outside their immediate responsibilities. This situation underscores the critical role of the Client's commitment to fostering collaboration between design and construction. By actively engaging in the process or opting for alternative contracting strategies that mandate integration, the Client can help dismantle these barriers. However, in practice, the significance of the Client's involvement in this regard is frequently overlooked.

he remaining barriers identified by a smaller number of respondents include a lack of understanding of the constructability concept, insufficient qualified personnel who are knowledgeable in both design and construction, the perception that the costs of implementation outweigh the benefits, and challenges in quantifying those benefits. Alongside these barriers, respondents also shared additional insights regarding obstacles to the adoption of constructability within the Addis Ababa Construction Industry.

These insights highlight several key issues: the lowest bidding method stifles innovative ideas related to constructability, and designers perceive no tangible benefits from contractors when applying constructability concepts. Furthermore, designers often hesitate to endorse new construction methods due to concerns over liability, and there is a general resistance within the industry to alter established practices. A widespread lack of awareness regarding the advantages of constructability persists, while designers frequently rely on previous designs to minimize costs. Additionally, tight construction timelines hinder the comprehensive application of constructability principles, and conflicts of interest among clients, consultants, and contractors complicate the situation. Lastly, the rigidity of design-build contracts towards new methods and contractors' reluctance to embrace innovative ideas further exacerbate these challenges.

The barriers identified by the respondents may not fully encapsulate the broader challenges faced by the construction industry in Addis Ababa. However, they do highlight the existence of significant issues, some of which may be more critical than others and could have a greater impact on the implementation of constructability principles. In concluding the questionnaire survey, participants were encouraged to contribute innovative ideas to enhance the constructability concept. One respondent suggested that “the environmental aspects of constructability, including environmental standards, awareness, and permits,” should be integrated into this framework. This suggestion reflects an increasing awareness of environmental protection within the industry. Looking ahead, it is anticipated that constructability will evolve to incorporate concepts and practices related to sustainable development, which are poised to shape our future built environment.

## 4.5. Improvement Strategies for Implementing A Highway Constructability Program

The following recommendations should be considered in implementing a highway constructability program [72, 73]:

1) Securing the **commitment of senior management** at both the Division and District levels is crucial for effectively promoting constructability.

2) A robust strategy for project management should **prioritize a single point of responsibility.**

3) **Project execution plans** must be formulated for large and intricate projects during the project concept conference. It is essential to incorporate additional planning sessions and design evaluations into the conventional preconstruction process. Certain issues should be addressed at an earlier stage, necessitating increased involvement from all stakeholders.

4) A **proactive approach** to constructability needs to be taken. Over reliance on late, reactive design reviews should be avoided.

5) **Feedback from the field**, if not forthcoming, should be solicited on a periodic basis, both prior to, during, and alter construction. This feedback should involve both **Department personnel, contractors and suppliers**.

6) "**Post-mortems**" should be conducted upon completion of all projects. They should be attended by representatives from both the Department and the contractor. Other interested parties should also be invited. These meetings should be utilized to report on "**failures**" as well as "**successes**." Increased opportunities for site visits should be made available.

7) Management training programs that promote **communication and integration** between design and construction should be conducted. Project "team building" should be initiated on a trial basis and should include exercises for developing team leadership skills.

8) An accessible and current **knowledge base of "lessons learned"** should be maintained. Advanced, computerized systems are being developed for storing and retrieving the information.

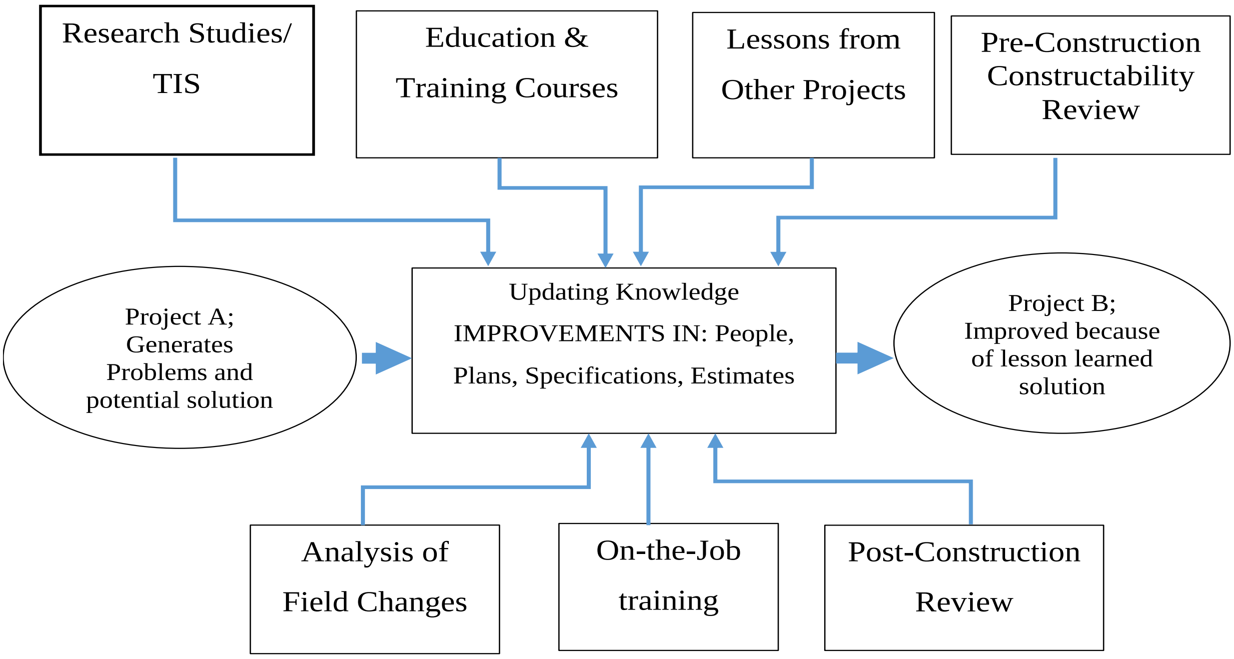


Figure 4-15; Improving strategies for constructability program;

The practice of constructability enhancement is also illustrated by Figure 4:15, which shows various activities and interactions within the Department that lead to improvement in the constructability of a project [73].

# CHAPTER 5. Conclusion and Recommendations

## 5.1. Conclusion

The core principle of constructability revolves around integrating construction expertise and knowledge at the early stages of a project's life cycle. This approach seeks to foster collaboration between design and construction teams, ultimately leading to more feasible and cost-effective solutions for construction endeavors. Research identified 40 constructability concepts developed by the Construction Industry Institute (CII) and associated researchers, which serve as a comprehensive reference for addressing a wide array of constructability challenges.

The findings indicate that implementing a robust constructability review process within a framework of best practices enables owners and contractors to optimize costs, timelines, quality, and safety while minimizing disruptions to ongoing site operations. This approach is crucial for sustaining high construction performance levels within the Addis Ababa construction sector. Notably, the concepts emphasizing the application of advanced information technologies, the incorporation of construction knowledge in project planning, and the early identification of team members responsible for constructability are deemed particularly significant.

This research employed surveys and case studies to assess the current state of constructability implementation in the Addis Ababa construction industry, focusing on the understanding, perception, and application of constructability concepts. It examined effective practices and the benefits derived from their implementation while also identifying obstacles to constructability in the local context.

## 5.2. Major Findings of the Research

The major findings from this research can be summarized as follows:

- The concept of constructability is not a novel idea within the Addis Ababa construction industry. Local construction professionals generally accept the fundamental principles of constructability.
- Several commendable practices related to constructability have been identified within the local industry, including:
    a. Early Inclusion of Construction Personnel: Engaging construction personnel at the initial stages of project development allows for the integration of their knowledge and experience during the conceptual phase.

b. Adoption of Alternative Contracting Strategies: Utilizing alternative contracting strategies such as design-build and project management facilitates early input from construction experts, enhancing project outcomes.
c. Consideration of Major Construction Methods: It is essential to take into account significant construction methods during the basic design phase to ensure feasibility and efficiency.
d. Efficient Site Layouts: Developing site layouts that promote efficient construction, operation, and maintenance is crucial for optimizing project execution.
e. Construction-Sensitive Design and Procurement Schedules: Ensuring that design and procurement schedules are sensitive to construction needs and are factored into project sequencing is vital for successful project delivery..

## 5.3. Importance and Limitations of the Study

There is an increasing global consensus that constructability serves as an effective and practical method for integrating the design and construction processes, ultimately leading to more efficient and cost-effective solutions for delivering construction projects. However, the study on constructability in Addis Ababa reveals several limitations that may impact its findings and implications. These limitations include:

1. **Gaps in Awareness:** There is a lack of understanding among stakeholders regarding the principles of constructability, which can hinder its adoption in local practices.
2. **Barriers to Implementation**: Various obstacles exist that prevent the effective implementation of constructability principles, such as regulatory constraints or insufficient training.
3. **Reliance on Subjective Perceptions**: The findings may be influenced by personal opinions rather than objective data, leading to potential biases in assessing constructability's effectiveness.
4. **Geographical Constraints:** The unique geographical context of Addis Ababa may limit the applicability of constructability principles derived from studies conducted in different environments.
5. **Challenges in Quantifying Benefits**: Measuring the tangible benefits of implementing constructability can be difficult, complicating efforts to advocate for its broader use.

Each of these factors can significantly influence how constructability principles are applied within local construction practices. While the study offers valuable insights, it is crucial to consider these limitations when interpreting its conclusions. A wider perspective may indicate that similar challenges are present in other regions, highlighting the necessity for customized approaches to effectively implement constructability..

## 5.4. Recommendation for Further Research

Despite the previously mentioned limitations, the present study aims to stimulate reflection and enhance engagement among local professionals concerning constructability. It would be beneficial for the local industry to pursue further research in the following specific areas:

- Researching and developing comprehensive constructability concepts specific to the Ethiopia Construction Industry.
- Studying the effect of project management system on the constructability implementation.
- Quantifying the benefits achieved on projects that have implemented constructability.
- Developing industry guideline for constructability implementation,
- Establishing information system to accumulate constructability knowledge

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77. “Sample Size Calculator” [CheckMarket] I believe this answer has an accuracy probability of about 95%.↩

# APPENDIX A: QUESTIONNAIRE

Dear Sir/ Madam,

I am undertaking this research study entitled "**Study on Application of Constructability Principles in Addis Ababa's City Road Corridor Development Projects.**" in partial fulfillment of the requirements for the degree of masters of Construction Engineering and management, at Adama Science and Technology University. The study mainly attempts to Assessment practice of Highway Constructability, Identifying barriers and develop improvement strategies on Highway construction projects during pre-construction period in Addis Ababa City

Please help me in making this research worthwhile from your experience in the Industry practices. It won't take more than 10 minutes to complete this questionnaire I would appreciate also if you could please send in your responses by 30th of March 2024. I appreciate if you can also forward the survey to whomever you think close to the topic and can participate in this survey.

Be assured that the information provided shall be used only for academic purpose and as well be treated as highly confidential. The outcomes summary of the research will be shared with you once finalized upon request.

Should you need any further information, please contact me at +251 912634729 or via *aminesafeside2000@gmail.com*

Appreciate your help and time

# Survey Questionnaire

## PART 1, GENERAL INFORMATION

Please, choose the appropriate choice by putting (√) on one box fill in the blank select other.

1. Your Organization Name: ___________________________________

Address: ___________________________________

2. Type of Your Organization

- ☐ Client ☐ Consulting Engineer
- ☐ Contractor ☐ other, Please Specify…………………………………

3. State Your Position in the Organization: -

- ☐ Project Manager ☐ Office Engineer ☐ Site Engineer
- ☐ Contract Administrator ☐ Resident Engineer ☐ Site Supervisor
- ☐ Project Coordinator ☐ other, please specify………..

4. Level of education:-

- ☐ Diploma ☐ Bachelor's Degree
- ☐ Master's Degree ☐ Doctorate's Degree
- ☐ other, Please Specify…………………………………

5. Level of experience in years in highway projects:-

- ☐ 0-5 ☐ 5-10
- ☐ 0-15 ☐ 15-20 ☐ > 20

6. Have you ever been aware of the concept of "Constructability" or "Buildability"?

- ☐ Yes. ☐ No, never.
- ☐ No, but I know the concept of "value engineering, , or "value management"

7. The Construction Industry Institute of USA (CII) defines the Constructability as "The optimum use of construction knowledge and experience in planning, design, and procurement and field operations to achieve project objectives"
Do you think this definition best describes the concept?

- ☐ Yes, I think so.
- ☐ No, but I think the following statement better describe the concept of constructability: {Please fill in)

**PART 2. OPINIONS**

In your opinions what is the degree of importance of the following concepts? (Tick one, please)

1= Not Important, 2= Little Important , 3 = Moderately Important, 4= Important, 5= Very Important

| | **Constructability Principles during pre-construction phase** | **level of Important** | | | | |
|---|---|---|---|---|---|---|
| No. | **A. During Conceptual Planning Phase** | **1** | **2** | **3** | **4** | **5** |
| 1 | Constructability programs are made an integral part of project execution plans. | [ ] | [ ] | [ ] | [ ] | [ ] |
| 2 | A project team that includes a representation of the owner, the engineer, and the contractor should be formulated and maintained to consider the constructability issues in all phases. | [ ] | [ ] | [ ] | [ ] | [ ] |
| 3 | Project planning actively involves construction knowledge and experience to avoid interference between design and construction. | [ ] | [ ] | [ ] | [ ] | [ ] |
| 4 | Early construction involvement is considered in the development of contracting strategies. | [ ] | [ ] | [ ] | [ ] | [ ] |
| 5 | Project schedules are construction-sensitive and assigned as early as possible. | [ ] | [ ] | [ ] | [ ] | [ ] |
| 6 | Basic design approaches consider significant construction methods. | [ ] | [ ] | [ ] | [ ] | [ ] |
| 7 | Site layouts promote efficient construction, operation and maintenance. | [ ] | [ ] | [ ] | [ ] | [ ] |
| 8 | Advance information technologies are applied throughout the project. | [ ] | [ ] | [ ] | [ ] | [ ] |
| 9 | To accomplish the field operations quickly and efficiently, primary construction methods should be analyzed in-depth as early as possible. | [ ] | [ ] | [ ] | [ ] | [ ] |
| 10 | Operability and maintainability phases are integrated into project planning and design stages. | [ ] | [ ] | [ ] | [ ] | [ ] |
| 11 | Political and legal factors are reviewed prior to the design stage. | [ ] | [ ] | [ ] | [ ] | [ ] |
| 12 | Environmental factors are reviewed and addressed. | [ ] | [ ] | [ ] | [ ] | [ ] |
| 13 | Construction methods are comprehensively reviewed to include the recovery and recycling methods along with sustainable and final disposal planning. | [ ] | [ ] | [ ] | [ ] | [ ] |
| 14 | Simplify and separate building systems and components to facilitate maintenance and future renovations | [ ] | [ ] | [ ] | [ ] | [ ] |

| | **Constructability Principles during pre-construction phase** | Scale of Agreement level | | | | |
|---|---|---|---|---|---|---|
| No. | **B. During Design and Procurement Phase** | **1** | **2** | **3** | **4** | **5** |
| 1 | Design and procurement schedules are construction sensitive and considered in project sequencing | [ ] | [ ] | [ ] | [ ] | [ ] |
| 2 | The use of Advanced information technologies will overcome the problem of fragmentation into specialized roles in the field, and enhance constructability. | [ ] | [ ] | [ ] | [ ] | [ ] |
| 3 | Project Designs, through design simplification by designers and design review by qualified construction personnel, must be configured to enable efficient construction. | [ ] | [ ] | [ ] | [ ] | [ ] |
| 4 | Project elements should be standardized. | [ ] | [ ] | [ ] | [ ] | [ ] |
| 5 | The project technical specifications should be simplified and configured to achieve efficient construction. | [ ] | [ ] | [ ] | [ ] | [ ] |
| 6 | Module/preassembly designs are prepared to facilitate fabrication, transportation, and installation | [ ] | [ ] | [ ] | [ ] | [ ] |
| 7 | Designs considering construction accessibility of personnel, material, & equipment to the required position inside the site. | [ ] | [ ] | [ ] | [ ] | [ ] |
| 8 | Design should facilitate construction during adverse weather conditions. | [ ] | [ ] | [ ] | [ ] | [ ] |
| 9 | Design & construction sequencing must facilitate system turnover & start-up. | [ ] | [ ] | [ ] | [ ] | [ ] |
| 10 | Safety and health reviews are considered comprehensively within the design specifications. | [ ] | [ ] | [ ] | [ ] | [ ] |
| 11 | Project design considers operability and maintainability of the project. | [ ] | [ ] | [ ] | [ ] | [ ] |
| 12 | Standardize repeatable components. | [ ] | [ ] | [ ] | [ ] | [ ] |
| 13 | Ensure proper sizing and specification of equipment, products, and materials. | [ ] | [ ] | [ ] | [ ] | [ ] |
| 14 | Optimize dimensions to utilize entire product/material | [ ] | [ ] | [ ] | [ ] | [ ] |
| 15 | Use methods and materials that allow for ease of reconfiguration, renovation, or deconstruction | [ ] | [ ] | [ ] | [ ] | [ ] |
| 16 | Designs are reviewed by construction personnel regarding minimizing material waste, recycling, and cost-effectiveness. | [ ] | [ ] | [ ] | [ ] | [ ] |

| | **Constructability Principles during pre-construction phase** | Scale of Agreement level | | | | |
|---|---|---|---|---|---|---|
| No. | **C. During Field Operations Phase** | **1** | **2** | **3** | **4** | **5** |
| 1 | Constructability will be enhanced using innovative construction methods. | [ ] | [ ] | [ ] | [ ] | [ ] |
| 2 | Tasks Sequencing is configured to minimize rework of project elements, scaffolding needs, formwork used, or congestion of labors & materials | [ ] | [ ] | [ ] | [ ] | [ ] |
| 3 | Innovation in temporary construction materials/systems that have not been defined by the design drawings and technical specifications. | [ ] | [ ] | [ ] | [ ] | [ ] |
| 4 | Incorporating new methods of innovation through the use of off-the-shelf hand tools or modifying available tools. | [ ] | [ ] | [ ] | [ ] | [ ] |
| 5 | Innovative methods for using the available equipment or modification of the available equipment to increase their productivity. | [ ] | [ ] | [ ] | [ ] | [ ] |
| 6 | Use preassembly to increase productivity, reduce the need for scaffolding, or improve the project constructability under adverse weather conditions. | [ ] | [ ] | [ ] | [ ] | [ ] |
| 7 | Constructability will be enhanced by encouraging the constructor to carry out the innovation of temporary facilities. | [ ] | [ ] | [ ] | [ ] | [ ] |
| 8 | Good contractors, based on quality and time of their work should be documented. Subsequently, future contracts for construction work would not solely be awarded based on low bids, but also by considering other attributes, i.e. quality and time. | [ ] | [ ] | [ ] | [ ] | [ ] |
| 9 | Evaluation, documentation and feedback of the issues of constructability concepts should be maintained throughout the project and used in later projects as learned lessons. | [ ] | [ ] | [ ] | [ ] | [ ] |

## PART 3. CONSTRUCTABILITY APPLICATIONS

Note: In this part of questionnaire you will be asked your view on some major applications of constructability adopted in other countries including UK, USA and Australia. These examples are representative of **40** constructability concepts developed by CII US in 1987, from literature review on constructability [60] addressed and Industry expert review, they include:

- 14 concepts for the conceptual planning phase.
- 16 concepts for the design and procurement phase.
- 10 concept for the field operation phase.

Please give **your view** on each application in terms of its applicability in the context of **Addis Ababa** construction industry. The response scale ranges from *"Not applicable" "Applicable but difficult to implement"* , to *"Already a common practice"*. However space is provided below each question for your free expression of other comments if you have.

---

## I. During Conceptual Planning

| | Already a common practice | Applicable but difficult to implement | Not Applicable |
|---|---|---|---|
| **Q.1**. To establish a specific constructability program during conceptual stage of a project. | ☐ | ☐ | ☐ |

Other comment on this application, if any;

______________________________________________

______________________________________________

__________________________________

**Q.2.** To include construction personnel early in the project team so as to make full use of construction knowledge and experience during conceptual stage. ☐ ☐ ☐

Other comment on this application, if any;

______________________________________________

______________________________________________

__________________________________

**Q.3**. To use alternative contracting strategy e.g. design build, project management etc. as a way to have construction knowledge input early in a project. ☐ ☐ ☐

Other comment on this application, if any:

______________________________________________________________

______________________________________________________________

___________________________

**Q.4.** To study construction duration, along with times, for design and procurement, during conceptual stage to determine overall duration of project, and prepare initial development program. ☐ ☐ ☐

Other comment on this application, if any:

______________________________________________________________

______________________________________________________________

___________________________

**Q.5**. To consider major construction methods during basic design of a project. ☐ ☐ ☐

Other comment on this application, if any:

______________________________________________________________

______________________________________________________________

___________________________

**Q.6.** Design of general layout takes into account construction efficiency through considering both permanent and temporary facilities. ☐ ☐ ☐

Other comment on this application, if any:

______________________________________________________________

______________________________________________________________

___________________________

## II. During Design and Procurement

| Already a common practice | Applicable but difficult to implement | Not Applicable |
|---|---|---|

**Q.7.** To adjust design and procurement programme as much as possible to suit construction programme. ☐ ☐ ☐

Other comment on this application, if any:

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**Q.8.** To shape detail design to enable greater construction efficiency. ☐ ☐ ☐

Other comment on this application, if any:

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**Q.9.** To maximize standardization of components and systems in detail design. ☐ ☐ ☐

Other comment on this application, if any:

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**Q.10.** In writing specification, consider construction efficiency simultaneously with other factors like quality, aesthetics, operation, maintenance, reliability, and expandability. ☐ ☐ ☐

Other comment on this application, if any:

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**Q.11.** To consider factors of fabrication, transport, and installation in modular/pre-assembly design. ☐ ☐ ☐

Other comment on this application, if any:

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**Q.12.** To allow adequate access of personnel, material, ☐ and equipment during detail design. ☐ ☐ ☐

Other comment on this application, if any:

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**Q.13.** To design in such that adverse weather conditions have minimum effects on field construction. ☐ ☐ ☐

Other comment on this application, if any:

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## III. During Field Operations

| Already a common practice | Applicable but difficult to implement | Not Applicable |
|---|---|---|

**Q.14.** To use innovative construction methods improve construction efficiency. ☐ ☐ ☐

Other comment on this application, if any:

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## PART 4. YOUR SPECIFIC EXPERIENCE OF CONSTRUCTABILITY

**Q.15.** which of the 14 applications listed you personally have seen its use in projects you were/are involved, irrespective of the term of "constructability/buildability" or the name of concept was used or known?

- ☐` 1. To establish a specific constructability program in conceptual stage of a project.
- ☐ `2. To involve construction personnel early in project team to get construction knowledge & experience.
- ☐ `3. To use alternative contacting strategies e.g. design-build or project management as a way to have construction knowledge input early in a project.
- ☐ `4. To study construction duration along with times for design and procurement during conceptual stage to determine overall duration of project.
- ☐ `5. To consider major construction methods during basic design of a project.
- ☐ `6. Design of general layout takes into account construction efficiency through considering both permanent and temporary facilities.
- ☐ `7. To adjust design and procurement programme as much as possible to suit construction programme.
- ☐ 8. To shape detail design to enable greater construction efficiency.
- ☐ 9. To maximize standardization of components and systems in detail design.
- ☐ 10. In writing specification, consider construction efficiency simultaneously with other factors like quality, aesthetics, operation, maintenance, reliability, and expandability.
- ☐`11. To consider factors of fabrication, transport, and installation in modular/pre-assembly designs.
- ☐`12. To allow adequate access of personnel material, and equipment during detail design.
- ☐`13.To design in such that adverse weather conditions have minimum effects on field construction.
- ☐ 14. To use innovative construction methods to improve construction efficiency.

**Q.16**.Is there any cost saving as a result of these constructability applications?

- ☐ Yes, and it is quantifiable.
- ☐ Yes, but it is not quantifiable'
- ☐ No.

**Q.17**.Is there any time saving as a result of these constructability applications?

- ☐ Yes, and it is quantifiable.
- ☐ Yes, but it is not quantifiable'
- ☐ No.

**Q.18**.Is there any quality improvement as a result of these constructability applications?

- ☐ Yes,

- ☐ No.

**Q.19**.What factors you think are barriers to apply constructability in Addis Ababa?

- ☐ General lack of knowledge of the constructability concepts.
- ☐ Lack of commitment by owners.
- ☐ The traditional method of contracting which separates design and construction.
- ☐ Lack of qualified people understanding both design and construction.
- ☐ Designers' reluctance to have input from contractor during design stage.
- ☐ The cost of implementing constructability is greater than possible benefits.
- ☐ It is difficult to quantify the benefits of implementing constructability.
- ☐ Other barriers: (Please list below)

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Q, 20. What other constructability applications/concepts not mentioned in this questionnaire, but you think is relevant to Addis Ababa construction industry? {Please list below)

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# APPENDIX B: Outline of Highway Project Execution Plan for Complex Projects [73]

I. **Purpose**
- -Sets forth what is to be done, by whom, in what time frame, and with what resources?
- -Documents all relevant facts, assumptions, and policies. -Identifies all internal and external influences which will bear on the project.
- -Communicates relevant project information to all project participants.
- -Identifies unanswered questions/unresolved issues and assigns responsibility for action with the necessary completion date.

II. **Scope of Work**
- -Provides detailed definition of all work to be performed as a part of the project, including supporting utilities and facilities.
- -Defines interfaces and interactions with other facilities, systems, or projects.
- –Where scope is indefinite, identifies the conditions required for its specific definition.

III. **Project Objectives**
- -Provides a statement of objectives/ policies such as
- -balance between cost and schedule
- -completion date
- -quality
- -safety
- -specific operational requirements
- -design life
- -maintenance
- -constructability
- -productivity

IV. **Project Team and Organization**
- -Identifies all personnel assigned to the Project Team, either full-time or part-time, including consultants.
- -As contracts are awarded, identifies appropriate contractor personnel.
- -When necessary, includes descriptions of responsibilities will be included.
- -Includes organization charts for the Project Team to varying levels of detail.
- -As contractors are brought on board, includes their organization charts to an appropriate level of detail.

V. **Basis for Design**
- -Utility Requirements
- -Aesthetic Requirements
- -People Loading/Structural Loading
- -Traffic Loading
- -Weather Assumptions
- -Functional Requirements
- -Owner Standards/Design Criteria/Specifications
- -Price/Budget Target for Scope of Work

- -ROW requirements

VI. **Project Schedule**

- -At first, presentation of an overall project schedule derived from required completion data allocating the total project duration to all functions specifically, including the conceptual planning by the owner.
- -As project proceeds, this section will be expanded to set forth critical milestones for the project. The implications of missing a milestone will be set forth.
- Long-load procurements.

VII. **Project Budget**

- -Statement of the financial budget approved for the budget at the level of detail by which financial review will be conducted.
- -Estimates of cash flow from the owner throughout the life of the project.

VIII. **Design**

- -By Owner (SDHPT)
- -By Consultants
- -Design Interfaces
- -Design Schedules
- -Design Quality Assurance
- -Constructability Considerations

IX. **Constructability**-How will construction knowledge and experience be integrated into project planning and design?

X. **Material Control**

- -Procurement Policies, Procedures, Responsibilities
- -Vendor Shop Inspection
- -Temporary Storage Facilities/Areas

XI. **Construction**

- Sequence of Operations
- -Construction Schedule
- -Training Requirements
- -Safety
- -Temporary Facilities
- -Community Relations
- -Progress Measurement/Reporting
- -Quality Assurance/Control