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ABSTRACT

In the conventional approach of construction projects, the design and construction processes are not implemented in integrated approach. The design work often begins with the client's need identification then after discussion and agreement the architect and engineers prepare the design with the available resources and constraints. After the completion of the architectural and the engineering designs the procurement and construction will continue respectively. In the process of the design and construction processes are not integrated. This lack of integration between the two processes is the cause of many problems like cost overrun, delay, less quality, incompatible with the available technology and so on, in general lack of constructability of a project.

Project delivery methods have the major impact on the integration of the design and construction process. According to literatures DB is a better project delivery method with regard to integration of design and construction phases and constructability issues over DBB. The main objective of this study is to review and assess the theory and actual practice of the project delivery methods with respect to the integration of design and construction and the effect of constructability in public building projects in Addis Ababa.

In order to realize the objectives, case study of three selected public building projects in Addis Ababa is reviewed. In contrary to the literatures, the results of the case study indicated that, in public projects, the DB project delivery method is not practiced in proper manner like; the right type of condition of contract is not implemented, the design and construction processes are not integrated and others. Accordingly in the actual case of public buildings in Addis Ababa DB have many problems, even higher than DBB projects with weak quality control, too much variation, time overrun, and dispute between contractual parties. In addition the concept of constructability is not practiced in the studied projects of either in the DBB or DB public building projects.

Keywords: - *Project Delivery Methods, Integration of Design and Construction, Constructability*

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LIST OF ABBREVIATIONS

BOOT: - Build Operate Own Transfer

BOT: - Build Operate Transfer

CII: - Construction Industry Institute

CM: - Construction Management

DB: - Design Build

DBB: - Design Bid Build

DBIA: - Design Build Institute of America

EPC: - Engineering Procurement and Construction

FIDIC: - Federation Internationale des Ingenieurs-Conseils: a French acronym interpreted in English as International Federation of Consulting Engineers

GDP:- Gross Domestic Product

MoWUD: - Ministry of Works and Urban Development

PMBOK: - Project Management Body of Knowledge

PPA: - Public Procurement Agency

ROT: - Rehabilitate Operate Transfer

CHAPTER ONE

1 Introduction

Construction industry plays important role in social, economical and Political development of a country. Nowadays there has been a large scale investment in the Ethiopian construction industry. Ethiopian government and private sectors have been investing widely for the development of infrastructures. Building construction projects of housing development, educational, health institutes, offices, multipurpose buildings and other buildings are among these infrastructures.

Construction of building passes through different phases in a project life cycle, from early initiation to final closing phases. Through the project life cycle, design and construction are the very crucial architectural, engineering and managerial phases.

In the recent Ethiopian context, the building construction projects are awarded with a design-bid-build project delivery method. The PPA 2006 condition of contract is also prepared for this delivery method. In this approach, architects/designers and contractors are hired in separate contracts. The design work is done without integrating with the construction. The architect and engineers prepare the sets of designs without participating the contractor or construction expert. This lack of integration between design and construction phases leads to constructability problems in building projects. Since, in recent time the completion time and cost for completing a construction project have been increasing due to lack of constructability. (Zolfagharian S., 2012)

The aim of this independent project is to investigate the concept of integration between design and construction phases with respect to the delivery methods in the building construction projects and the effects of constructability.

1.1. Statement of the problem

The Construction Industry contributes the leading role in overall development of a country. This contribution is highly important for countries especially, under development like Ethiopia. According to the Amharic version of the Ethiopian construction industry development policy, in the last ten years, the country's construction industry has been grown with an average of 12.43% and has 5.3%

contribution for the GDP (MoUDHC, December, 2014). The increment is shown on the building, transport and communication and water and power sub sectors of the industry.

Nowadays the building construction project delivery method used in Ethiopia is Design-Bid-Build (PPA, 2006). In this procurement method, the architect and engineers prepare the design and the specification for the purpose of the construction and tendering. The tendering, selection of the contractor and signing of the construction contract carry on consequentially. In this process the design and construction works are done in a fragmented way. The design phase is done without the involvement of the doers of the work which are the civil contractor and special sub contractors. The fragmented system can affect constructability of a project, which creates problems such as decrease usability, maintainability, increases construction errors, rework, delays and costs over run.

According to the Ethiopian construction development policy report, even though the construction industry is growing, it is seized with many problems. One of the critical problems of the country is the lack of capacity in design work of road, building, water supply, irrigation and all other construction sub sectors (MoUDHC, December, 2014). Design problems directly affect construction works, which is lack of constructability.

Some studies in AAIT/AAU also demonstrate that design related cases are the main causes of constructability problems of building projects. “Designer’s inexperience, Design changes and revisions, in method and sequence of construction, Poor communication leading to mistakes and errors & lack of knowledge about construction techniques during design activities are the first five major design causes of construction materials waste in Ethiopia” (Asmara Seyoum, 2015). In addition, design related issues are the top causes of delays in Ethiopian Public Building Construction Projects Executed by Local Contractors. (Abatemam & Dinku 2007).

1.2 Research Questions

To realize the objectives of the project, the following questions are asked

- What is the conceptual frame work of integration of design and construction phase?
- How integration of design and construction related with project delivery methods?
- What is the conceptual frame work of constructability?
- How is the design and construction phases related to the constructability of a building project?

- How much is the awareness of constructability concept in the locally and internationally?
- What are the international trends of the concept of constructability in building projects?

1.3 Objective of the Project

- To realize the concept of the integration of design and construction phases with respect to project delivery methods.
- To review the conceptual framework of constructability concepts in the building construction.
- To review the integration between design and construction phases of building construction projects and the effect of constructability.
- To review, the awareness of constructability concept in the national and international building construction industry
- To create awareness and illustrate areas of further studies on the concept of constructability.

1.4 Significance of the Project

The relevance of this project is:-

- To fill the gap in the knowledge of the integration of design and construction phases.
- To develop the concept of constructability in the building construction industry.

1.5 Scope of the Project

- The project will be limited on the selected building projects in the city of Addis Ababa.
- Public building projects in Addis Ababa will be selected for the case study.

1.6 Methodology

1.6.1 Data Sources

The study will use both primary (actual data) and secondary (documented data) to review the integration of design and construction phases and the effect of constructability in public building projects in Addis Ababa.

I. Primary Data

The primary data will be done with a case study on selected building projects in Addis Ababa. The sample projects will consists of government and private owned.

II. Secondary Data

The secondary data for this research will be collected with reviewing literatures including locally and internationally done previous studies of other researchers, books and articles.

1.6.2 Data Analysis

The Secondary data will be used to develop the conceptual frame work of the project. All the primary data collected from the case study will be organized & analyzed in order to give the current situation of the Ethiopian building construction projects regarding the focus of the project.

CHAPTER TWO

2. LITERATURE REVIEW

2.1 Building construction projects

Construction Projects can generally be classified into three sectors; Buildings, Infrastructure, and Process Sectors. Some of building sector project includes commercial buildings, schools, office buildings, and hospitals (Garold D. O. 1993).

Building construction project has its own unique characteristics. The building construction project category includes facilities commonly built for habitation, institutional, educational, light industrial, commercial, social and recreational purposes. Generally Building Construction Projects are usually designed by architects and engineers (Daniel W. et al 1997).

Within this very broad category we find projects that include residential, commercial, institutional and industrial buildings. Residential construction produces buildings for human habitation, including condominiums, multifamily townhouses and apartments. Depending on the project's complexity, such work is usually designed by architects, owners or builders themselves and the construction work is performed by contractors or sometimes may be built by owners themselves (Lawrence F. B., 2003).

Commercial construction includes retail and wholesale stores, markets and shops, shopping centers, office buildings, warehouses and small manufacturing facilities. Examples of institutional construction are medical clinics and hospitals, schools and universities, recreational centers and athletic stadiums, governmental buildings and houses of worship and other religious buildings. Architectural firms usually take the lead in the design of commercial and institutional facilities, with assistance from engineering firms for such specialties as structural, mechanical, sanitary and electrical elements. Because this type of work is usually more complex and time consuming than residential construction, owners usually engage general contractors to perform the field construction; subcontractors usually provide specialty services such as plumbing, painting and electrical work (Lawrence F. B., 2003).

Often categorized separately from general building construction, industrial construction is a special segment of the industry that develops large-scale projects with a high degree of technical complexity. Such events result in facilities that manufacture and process products; examples include steel mills,

electric power-generating plants, petroleum refineries, petrochemical processing plants, ore-handling installations and heavy manufacturing factories that produce such products as vehicles, rolling equipment and various kinds of large machinery. The engineer, rather than the architect, usually assumes the lead responsibility for the designs of these kinds of projects. Often the owner selects a single entity to provide both design and construction services under a ‘design–build’ contract and works closely with the design professional to assure that the owner’s special requirements are met (Lawrence F. B., 2003)).

2.2 Construction Project Life Cycle

PMBok Guide (3rd edition, 2004) defines Project Life Cycle as; it is divided phases of a project to provide better management control with an appropriate links to the continuing operations of the performing organization collectively. It also describes the phases those connect a project from the beginning to the end.

Another researcher defines it as; Project Life Cycle is the sequence of phases through which the project will progress. It is absolutely fundamental to the management of projects. The basic life cycle follows a common standard sequence; Initiation, Design & Development, Construction, Hand-over, Operation and Post-Project Evaluation (R. Max Wideman, 2004).

According to PMBoK Guide (3rd edition, 2004); Construction Project life cycles generally answer the following questions:-

- What technical work to do in each phases of a project? (Engineering and Architects work be performed?)
- When the deliverables are to be generated in each phase and how each deliverable is reviewed, verified, and validated? (For example prepared design)
- Who is involved in each phase? (For example, contractor to be involved with procurement and construction and designers in the imitation and design)
- How to control and approve each phase?

Daniel W. H. and Ronald W. W.(1997) presents graphical illustration of the linear approach of a project life cycle as shown in figure 2.1 below.

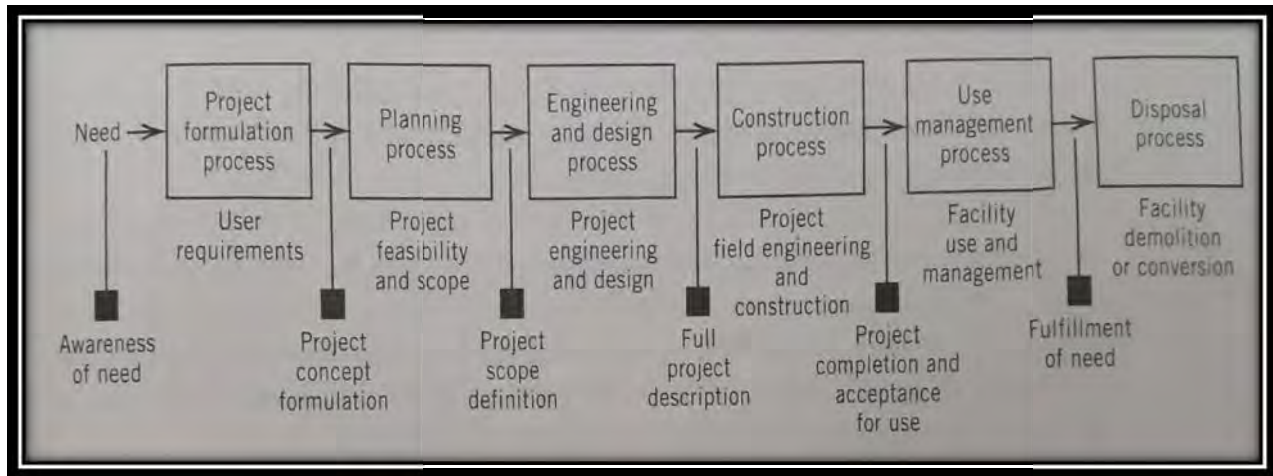


Figure 2.1: Linear nature of project life cycle (Daniel W. H. et al 1997)

As it is shown in the figure 2.1 the sequences of the phases in a construction project life cycle are explained as follows.

1. At the beginning, the need for a facility is identified by the client.
2. Initial feasibility study and cost projections are developed.
3. The decision to proceed with conceptual design is made and the design professionals are retained.
4. The conceptual design and scope of work is developed with including an approximate cost estimate.
5. The decision is made to continue with the development of final design documents, which fully define the project purpose of construction.
6. Based on the final design documents, the project is advertized and proposals to include quotations for construction of work are solicited.
7. Based on the proposals received, a contractor is selected and notice of acceptance is given to the contractor. The proposal and the acceptance of the proposal on the part of the owner constitute the formation of a contract for the work.
8. The process of construction is started. Work is completed and the facility is available for acceptance and utilization.
9. In complex projects, a period of testing decides if the facility operates as designed and planned. This period is typical of industrial projects and is referred to as projects start-up.
10. The facility operates and is maintained during a specified service life.

11. The facility is disposed of if appropriate or maintained in perpetuity.

Another writer Chris Hendrickson (2008) in his book “Project Management for Construction” presented the linear approach of life cycle of construction projects with figure as follows. Figure 2.2 shows that project life cycle as a process through which a project is implemented from start to end. The cycle is decomposed into phases and they are then integrated to obtain the final outcome. All stages from conceptual planning and feasibility studies to the acceptance of a facility for occupancy may be broadly lumped together and referred to as the Design and Construct process, which is the architectural and engineering activities are highly dominating (Chris H., 2008).

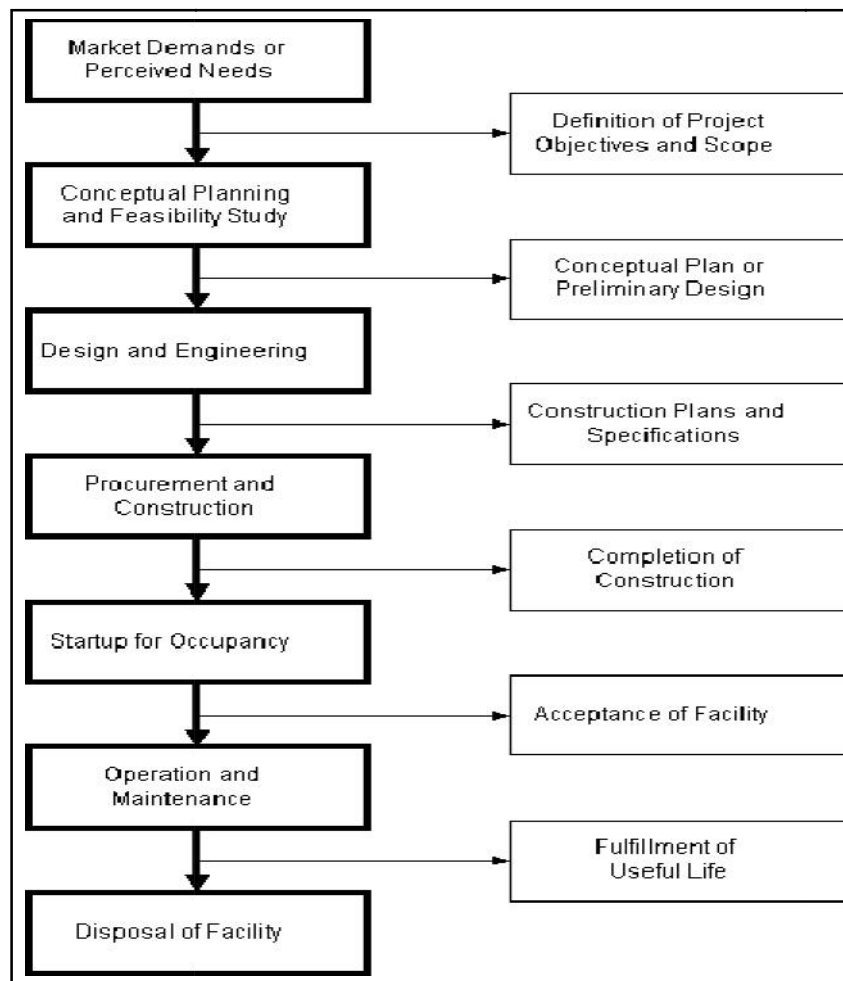


Figure 2.2: Linear nature of project life cycle (Chris H. 2008)

As shown in the figure 2.2, this linear project has main feature deferrers from the previous one is that it adds of the operation and maintenance phase. Maintenance is one of the inevitable phases of a building project life cycle.

In addition to maintenance, demolishing and recycling in a project life cycle is also inevitable. The construction projects can be described as a management system for all the processes of a project from planning, design, and construction to the commissioning, utilization, maintenance, and finally decommissioning of the structure. As shown in Figure 2.3, this process has a cycle approach, rather than the linear approach. After the decomposition and recycling again planning and designing continues and it closes the cycle and the process continues again and again with the same manner (Guo H. L., 2010).

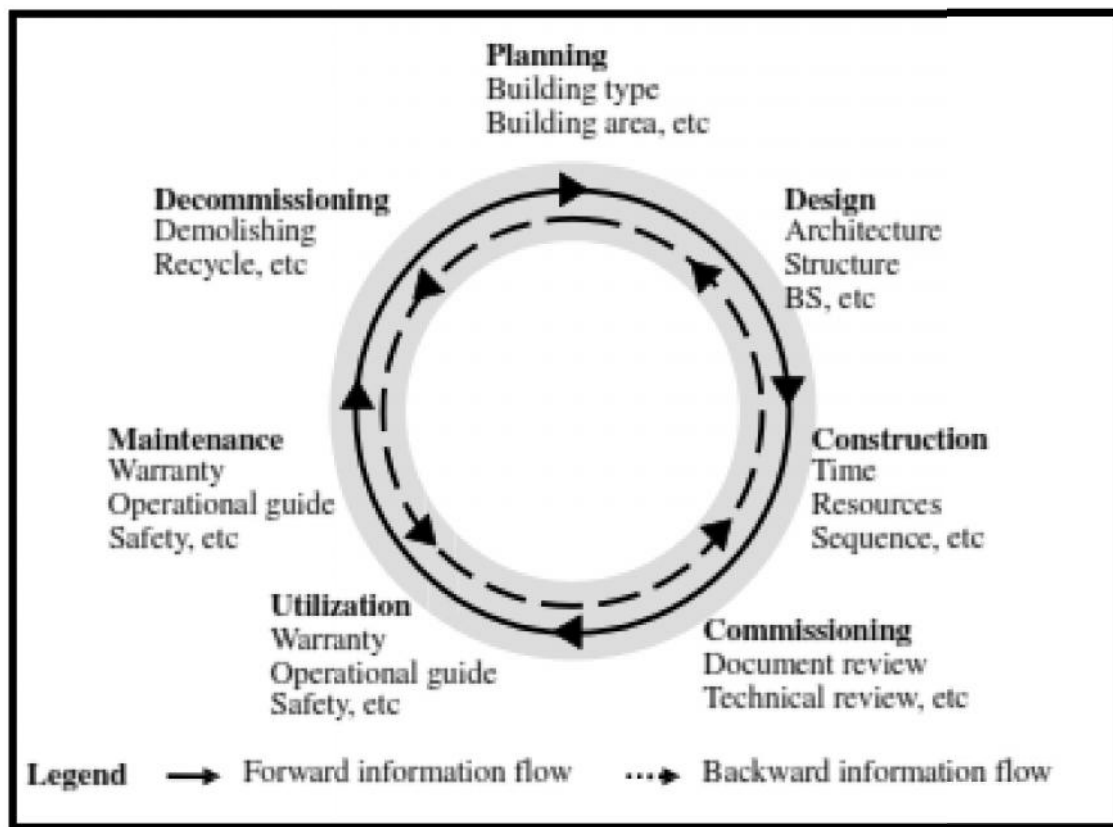


Figure 2.3: Cyclic nature of project life cycle (Guo H. L. et al 2010)

2.3 Design and Construction Phases

2.3.1 Introduction

A construction project provides an asset or a combination of assets. The development of the asset passes through the two major architectural and engineering phases of design and construction. These phases are highly interrelated in their characteristics. Project definition is a predecessor for design work, and design work is for construction work. The project definition phase focus on the identifying and analyzing the client's requirements and the constraints. These client's requirements and constraints are the base to the design work and also to the construction work. Integration of the client's requirements and constraints provides a description of the project and helps to identify a plan for the time, quality and cost of the project (Garold D. Oberlender, 2000).

In the previous chapter the total life cycle of construction project has been discussed. And in this chapter, specifically the design and construction process which are the main focus of this study will be reviewed. Prior to come across to the theoretical background of the design and construction processes, it is important to see the historical development them.

In the ancient time design and construction were done by the "master builder", which one professional is engaged in all the knowledge required to plan, design, and construction of a project. The construction was based on traditions, general rules, and trial and error. This situation continued until the time that architecture profession emerged. During this period, some architects were adding values and aesthetics over the techniques of building. This was the time when the design began to separate from construction. It is also the time of beginning the academics, which were created in France and Italy, and also the beginning of a new system of architectural education (Felix T. and Georgina V. Lores,z 1998).

Beside to this, another important milestone to separates design from construction was the Industrial Revolution. It is the time, new materials, systems and forms of construction were developed. Materials such as cast iron, reinforced concrete, and steel were developed at this time. It was during this period that modern engineering emerged, with the establishment of technical universities in which people were trained to deal with these new materials. This Industrial Revolution was the beginning of design influencing with construction (Felix T. and Georgina V. Lores,z 1998) .

Design and construction phases have sequential nature in a life cycle of a project. Generally, design is the process of creating the description of a new facility, and usually represented by detailed plans and specifications; construction planning is a process of identifying activities and resources required to change the design to physical reality. Hence, construction is the implementation of the imagined design by architects and engineers. In both design and construction phases of a project, numerous operational tasks must be performed with a variety of precedence and other relationships among the different tasks (Leticia S., 2007).

2.3.2 Integration of Design and Construction Processes and Project Delivery Methods

2.3.2.1 Introduction

The construction to be described as a successful building project as one that is completed on time, within budget constraints, and meets a certain quality standard. All of these criteria are dictated by the construction documents which, in turn, are a reflection of the owner's expectations for the project. Success, as defined above, is heavily influenced by the process used to design, construct, manage, and deliver a project. Common approaches to this process are typically referred to as "project delivery methods". Now days there are various project delivery methods in used in the construction industry. Each is designed to optimize results for certain types of projects and owners' business background. No one single method fits all projects. Selecting the optimal project delivery method involves weighing the advantages and disadvantages of each in order to find the best fit for the project. Several studies have been conducted in the past to define and compare different project delivery methods (Donald A. Patterson, 2014).

The increasing complexity of buildings, the need for a greater degree of financial planning, the need to reduce design and construction periods and the increasing difficulty of contract administration has brought pressure to find different methods to deliver the project. The basic term "Project Delivery Methods" relates to the particular contractual arrangements for the approach implemented and utilized to accomplish the goals of a given project including; the project's risk allocation, assignment of responsibilities, pricing and payment obligations. For any given project there is likely to be more than one Project Delivery approach that would be appropriate, but there may be one approach that is

best suited, depending on the Owner's requirements (Charles N., et al, 2005). Choosing a project delivery method is one of the fundamental decisions owners make while developing their acquisition strategy (DBIA, April 2015).

The approach of design and construction phase in a construction project is directly depended on the project delivery method. According to the Publication by Design-Build Institute of America (2015), Project Delivery Method is a full process including planning, design and construction required to execute and complete a building facility or any other type of construction project . Another researcher defined as; Project delivery method is the contractual relationships between the owner, the designer, the contractor and the service management in a construction project. These contracts create the structure in which a project progresses from the initiation to the delivery of the completed facility (Kraig L., 2006). Project delivery method is also the way project owners determine the assignment of responsibilities to the parties for the design and construction works. The method is often determined during the initial planning phase of a construction project (DBIA, April 2015) .

Project delivery method identifies the primary parties taking contractual responsibility for the performance of the work. Thus, the different project delivery methods are distinguished by the way of the contracts between the owner, the designer, and the contractors are formed and the technical and managerial relationships that evolve between each party within those contracts (Ali T., 2009).

Different project delivery methods have been developed to effectively address the unique demands in each project caused by cost, quality and time constraints. The benefits and limitations of each delivery system need to be understood when choosing a delivery method (Kraig L., 2006). Design-Bid-Build (DBB), Design-Build (DB), Construction Management (CM); and the recent one Integrated Project Delivery (IPD) are the fundamental project delivery methods. While other delivery methods may exist, they are often simply variations and minor modifications of these four methods (Donald A. Patterson, 2014).

Now a day the three most common project delivery methods used in the construction industry are Design-Bid-Build (DBB), Design-Build (DB), and construction management (CM). Therefore the following chapter of the study will discuss on these three most common and basic project delivery methods.

2.3.2.2 Design-Bid-Build Project Delivery Method

2.3.2.2.1 Definitions

Design-Bid-Build (DBB) Project Delivery Method was developed during the Industrial Revolution period, which resulted in the creation of specialized professional movements of Architects, Contractors, and Engineers. This approach has been the standard choice of project delivery systems for many years. In this system, the owner procures the services to a design consultant to develop the scope of the project and complete design documents, which are then considered as tendering documents for use in selecting a contractor. The contractor who wins the tender is legally bounded with contract to build the project at a certain price, time and quality (Pekka P., 2002).

Other researchers strengthen the above definition as it is the one which the owner contracts separately with a designer and a constructor. The owner normally contracts with a designer to provide complete design documents. Then prepares bid selection of the contractor. The selected contractor entered to a contract with the owner to do the project in accordance with the design and specifications (Stephen R., et al, 2002).

DBB project delivery method is characterized by the owner enters to separate design and construction contracts with the designer and contractor. As shown in figure 2.4 below, the owner first initiates the project idea and then contracts a designer to prepare the design, then after the design is completed will select and made contact with the contractor for the construction (Kraig L., 2006).

As it is shown in figure 2.4 below, the design and construction phases are fragmented and the owner has contractual relation with both the contractor and designer, and the designer and contractor have administrative relation. As it is also shown in the figure, the owner involves in all phases of the project, the designer also participates in the most portions except the initiation and maintenance phases. But the contractor has involvement only in the selection and construction phases (Kraig L., 2006).

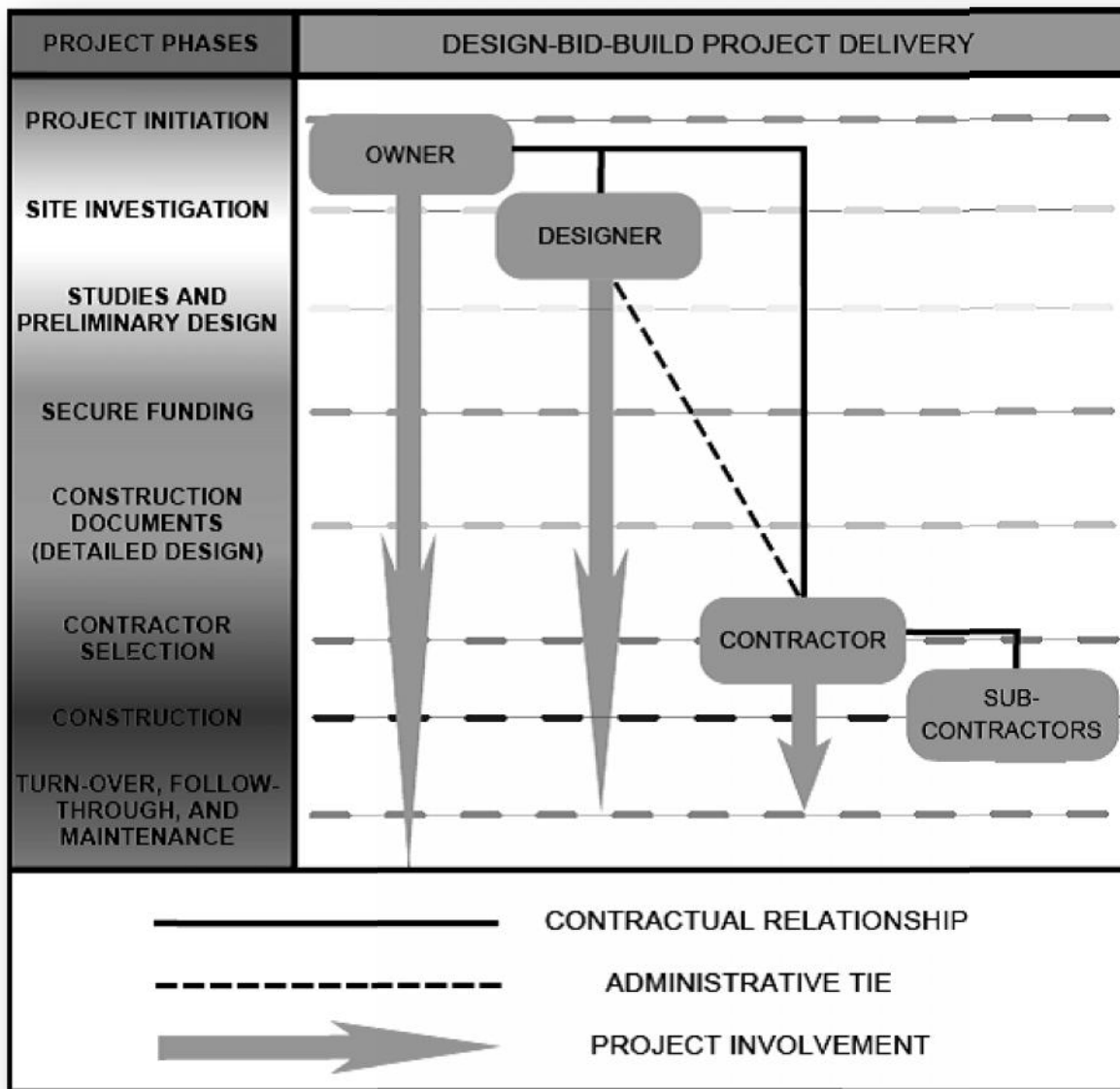


Figure 2.4: Contractual Relationships between Parties and Project Involvement throughout DBB Project Delivery Method (Kraig L., 2006)

Study on overview of DB and DBB Project Delivery in Washington (2015), illustrates the linear life cycle of DBB delivery system as shown in figure 2.5 below. As the figure shows all activities are done with end to start manner. For instance the selection of contractor needs the finishing of final design and document (Michael L., et al 2015).

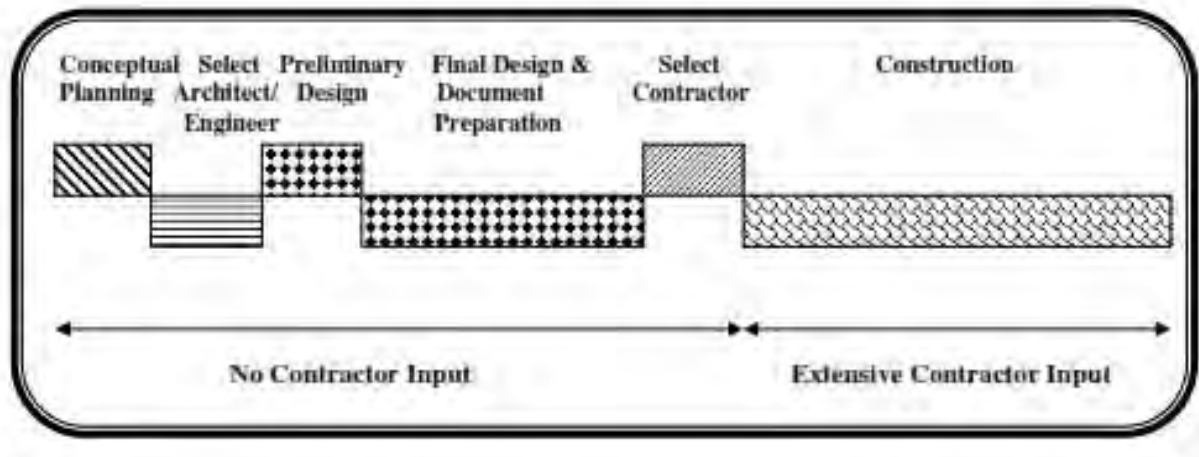


Figure 2.5: Life cycle of DBB Project Delivery Methods (Michael L., et al 2015)

The tri-party relation between the owner, designer and contractor can be illustrated in a triangular shape. As it is shown in figure 2.6 below; the contractual relation between parties in the DBB delivery method is branched in to two directions. Owners enter to contract with the contract with the consultant (Architect/engineer) and the contractor separately. The consultant and the contractor will have only administrative relation (The Alberta Association of Architects, 2005).

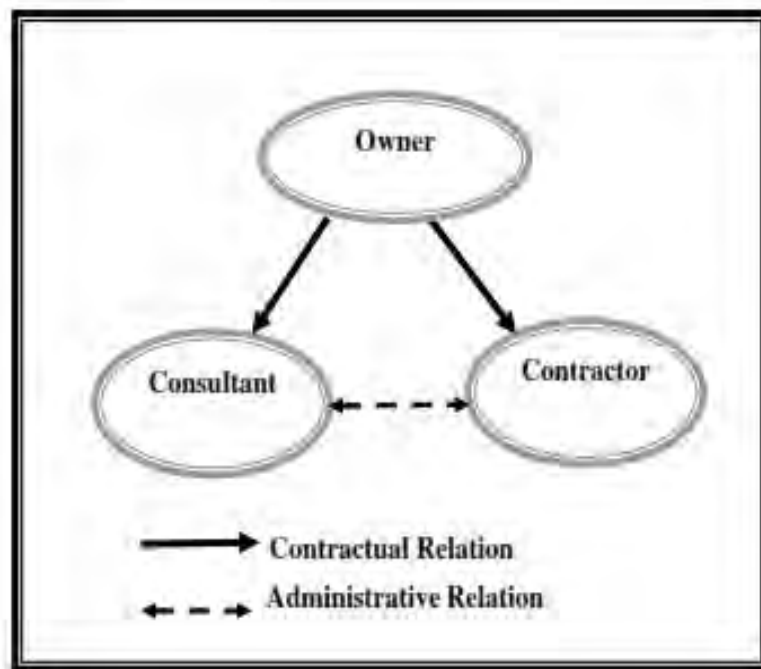


Figure 2.6: Parties relation in DBB Project Delivery (The Alberta Association of Architects, 2005)

2.3.2.3 Design-Build Project delivery Method

2.3.2.3.1 Definitions

Literatures imitate the concept of Design-Build (DB) delivery method with the older “Master Builder”, in which design and construction was executing with a single experienced person and it was practiced in the ancient time as old as the days during the construction of the pyramids. DB is simply a project delivery method in which the client selects a party that will complete both the design and construction under a single contract. Upon completion of the construction, the Owner is then responsible for operations and maintenance of the project. The Owner is also responsible for financing aspects (Pekka P., 2002).

Sidney M. Levy in the book “Design-Build Project Delivery” has supported the above perception as; the DB project delivery method employed today is an advancement of the principles and practices behind a single source responsibility with a long and successful history of “Master Builders”. In the first half of the 20th century Master Builders used their knowledge and experience to offer clients a package that included a design and construction to fit the owner’s needs. (Sidney M. L., 2006).

Wikipedia, the free encyclopedia (2015) defined DB as it is a method used to deliver a project in which the design and construction services are contracted by a single entity known as the design–builder or design–build contractor. It relies on a single point of responsibility contract and is used to minimize risks for the project owner and to reduce the delivery time by overlapping the design and construction phase of a project.

DB project delivery method is the one which the owner contracts with a single party to perform both design and construction under a single contract. Contractually, DB offers the owner a single point of responsibility for design and construction services. Parts or all of the design and construction may be performed by a single DB entity, joint-venture or may be subcontracted to other companies (Stephen R. et al, 2002).

Some literatures interpret DB and turn-key delivery systems alternatively. And others differentiate them with clarifying the basic points of variation. “Turn-key” is a general name for Build-Operate-Transfer (BOT); Build-Operate-Own-Transfer (BOOT); Rehabilitate-Operate-Transfer (ROT) and other similar delivery systems (Tony Gibbs, 2008). According to the New Dictionary of Civil

Engineering (Penguin 2005 edition); “Turnkey contract is a design and build contract in which a single contractor is responsible for providing all services, including finance” (Tony Gibbs, 2008). Another study by, Leticia Soto (2007) explicitly supported the above concepts as; in Turnkey, the client awards both the design and the construction to the same company as DB but the company doesn't get paid until the project is finished. This situation is effective for some sort of long term financing. Mostly infrastructures and revenue generating projects can use this delivery method.

DB contracts include any combination of building work together with civil, mechanical and electrical engineering works. On the other hand, turnkey contracts include the provision of a fully-equipped facility, ready for operation at the turn of a key. Turnkey contracts typically include design, construction, fixtures, fittings and equipment to the extent defined in the contract documents. The foreword goes on to indicate that turnkey contracts are often financed by the contractor and may require him to operate the works for a few period of time until the commissioning, or for some year operation on a build-operate-transfer basis (Nael G. B., 2005).

Another book explains the term Turn-key as it is a delivery method used for projects with the manner of design, build, and operates before the project is handed over to the owner. Sometimes The contractor, providing the turn-key services may secure the land for the project, perform or coordinate all aspects of the design, arrange and administer construction contracts, manage construction of the project, staff and train the personnel to operate the facility, and then turn the project over to the owner (Garold D., Oberlender, 1993).

In other side, some literatures also used the term Engineer-Procure-Construct (EPC) and DB delivery methods similarly. Even if the basic principle of EPC is the same as pure DB they have some basic differences. Gordon R., (2015) in the article titled “Differences between EPC and design-build delivery”, Engineer-Procure-Construct (EPC) and Design-Build (DB) have both existed as typical delivery methods for decades, but there are some similarities and differences between them. In both cases, the owner has a single point of contact on the construction side, the contractor is responsible for the design, and the contractor takes on more risk than a design-bid-build delivery. But there are also some differentiate between the two and the main are:

1. EPC contractor hands over a working facility that is ready to go. DB contract closes out similarly to DBB contracts, with the owner and its construction manager or designer taking an active role.
2. EPC contractors are focused more on performance requirements than design, whereas most DB contracts provide at least some preliminary design detail in the bid documents.
3. EPC is not equivalent to the DB with the owner's involvement, which is less in the EPC.
4. In the EPC more risk is transferred to the contractor. DB contracts tend to take either a DBB approach to unknowns like hidden site conditions, or to share that risk between the owner and the design-builder.

As it is stated above, DB delivery method is attributed by a single contract between the owner and a design-build entity, figure 2.7 also shows this concept. The owner first initiates the project idea and then contracts with a single party for the design and the construction works. In the system, the design-build company is responsible for both the design and the construction, and involves in the whole phases except maintenance (Kraig L., 2006).

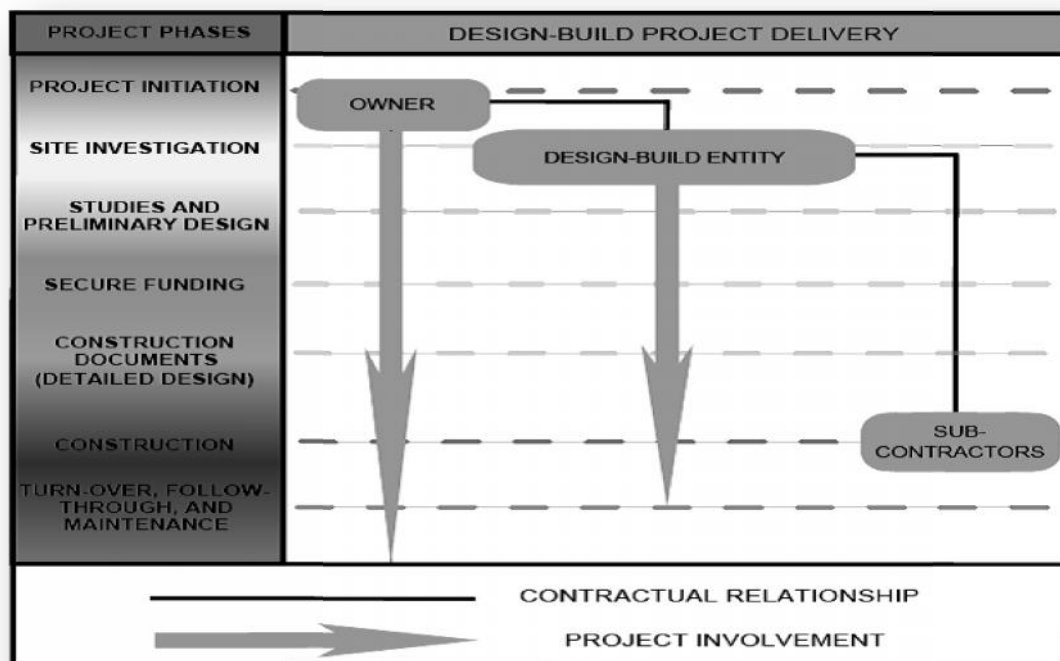


Figure 2.7: Contractual Relationships between Parties and their Involvement throughout DB Project Delivery (Kraig L. 2006)

Study on Overview of DB and DBB Project Delivery in Washington (2015), illustrates the linear life cycle of DB delivery system as shown in figure 2.8 below. As the figure shows the construction work can be commence prior to the completion of the final design and the absence of contractor selection minimizes the total project completion with significant time. Another attribute of DB shown in the figure is the early involvement of the contractor in the project life cycle. Hence, these are the two basic characteristics which defer DB from DBB (Michael L., et al 2015).

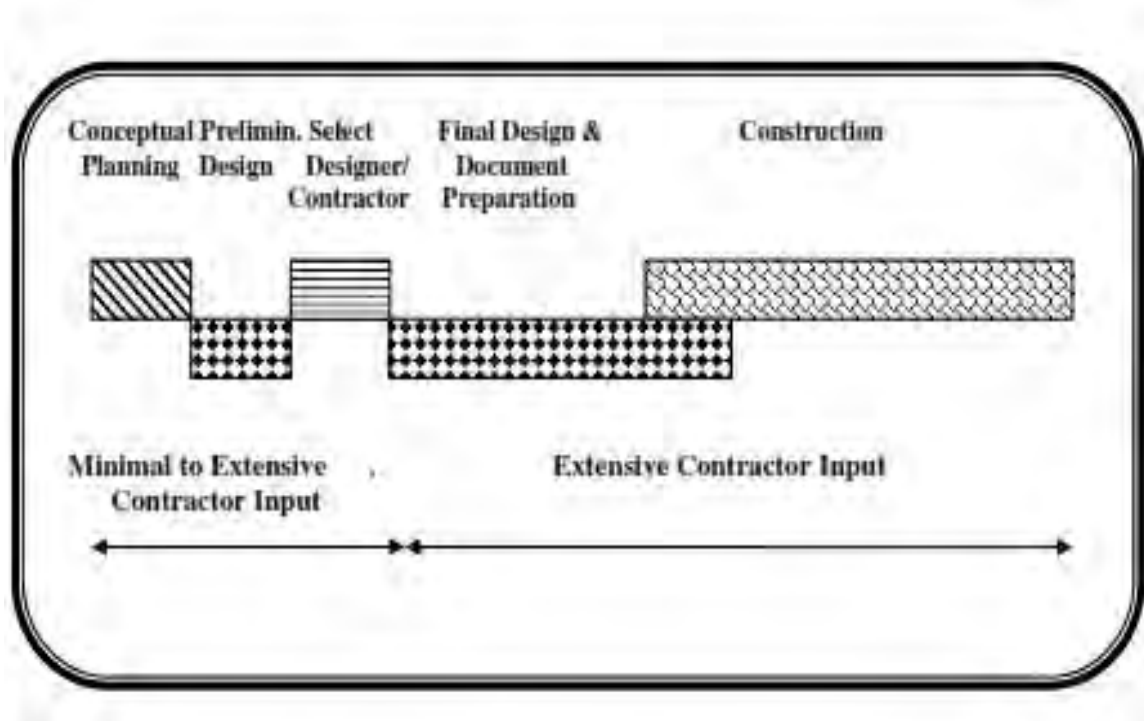


Figure 2.8: Life cycle of DB Project Delivery Methods (Michael L., et al 2015)

The relationship between the contracting parties can be illustrated as it is shown in figure 2.9 below; the owner has a contract with a single entity (design-builder), to provide both design and construction services. The DB entity will have dual contract with design consultant and contractor. But the design and build entity may also be a single firm, to design and construct or may have a joint venture. In the later case the contractor most often leads the design-build team (The Alberta Association of Architects, 2005).

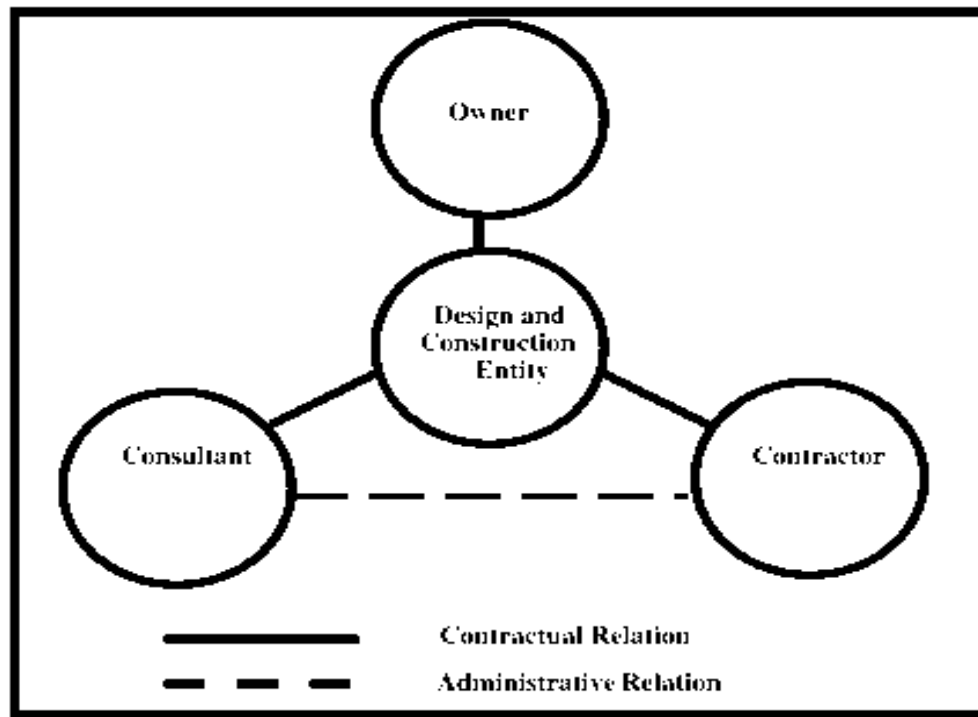


Figure 2.9: Parties relation in DB Project Delivery (The Alberta Association of Architects, 2005)

When contractors lead the Design-Build delivery system, they may organize their design and construction team in different ways. Study done in Croatia, on DB delivery method presents three different forms of organizing design-build Company (Natasa T., et al, 2007).

- 1. Pure design and build:** - here, the contractor applies his capacity for a complete and self-contained approach where all the necessary design and construction professionals exist in the company itself that has sufficient resources to complete all task that arises. In such organizations, all aspects of design and construction have the capacity to be highly integrated.
- 2. Integrated design and build:-** in this form, a main designers and project managers exists within the company itself, but this type of contractor is prepared to hire in additional design expertise whenever necessary. Although more effort is needed to integrate the internal and external designers and construction team. The internal project manager is assigned to organize these functions.

- 3. Fragmented design and build:-** many contractors apply this approach to design and construction. As the name implies, the external design consultants are appointed and the management is done by internal project managers whose other main task is to take and refine client briefs. Under this system, many of the integration and co-ordination problems of DBB are likely to visible themselves along with some function ambiguity among the professions as they come to terms with the builder as leader of the design and construction team.

In general the DB Company is responsible for both the design and the construction. Although DBB approaches are still well-known, some owners have shifted to DB. DB approaches are beneficial because the contractor is involved in design, fast-track scheduling is possible, and firms have more control over their product as most services are provided internally (Kraig L., 2006).

A survey has been done on 332 construction projects in UK; strengthen the above argument with figure that DB contracting is 12% faster than the traditional DBB project delivery method. And also they are 13% cheaper and 50% more likely to finish on time (Sharmin Khan, 2015).

2.3.2.4 Construction Management Delivery System

Construction Management (CM) has been widely used in the United States and sometimes in Australia. According to Patrick T.I et al, (1995) with referring Bennett and Grice (1990) defines Construction Management system as “a project delivery method where the client appoints designer and consultants and additional management consultant to manage the project. The CM entity is a Specialist contractor, selected by negotiation or in competition.”

According to Sidney M., (2006) the CM is a system used to fulfills a critical role in the DB project delivery. Mostly it is beneficial when an owners lack the professional staff to guide them or when an owners prefer not to assign engineering staff when they have construction projects.

CM organization undertakes the responsibility for administration & management, constructability issues, daily activities, and assumes an advisory role to the Owner. The CM organization has no contractual obligation to the Design and Construction parties. Again, the Owner is responsible for operations and maintenance of the project as well as the financing aspects (Pekka P. 2002).

Another study by Kraig L., (2006), describes as; CM project delivery system is used to provide professional management assistance throughout the project acting as an agent of the owner. As the study illustrated in Figure 2.10 below, the owner has contractual relation with the contractor, designer, and construction manager, the construction manager has administrative relation with the designer and contractor. The role of the construction manager is as an agent of the owner without bearing any financial risk. The construction manager works closely with the designer and contractor during the design and construction phases in the interest of the owner. The CM entity has expertise in design and construction, and agrees to execute complex projects which require extensive coordination between project participants.

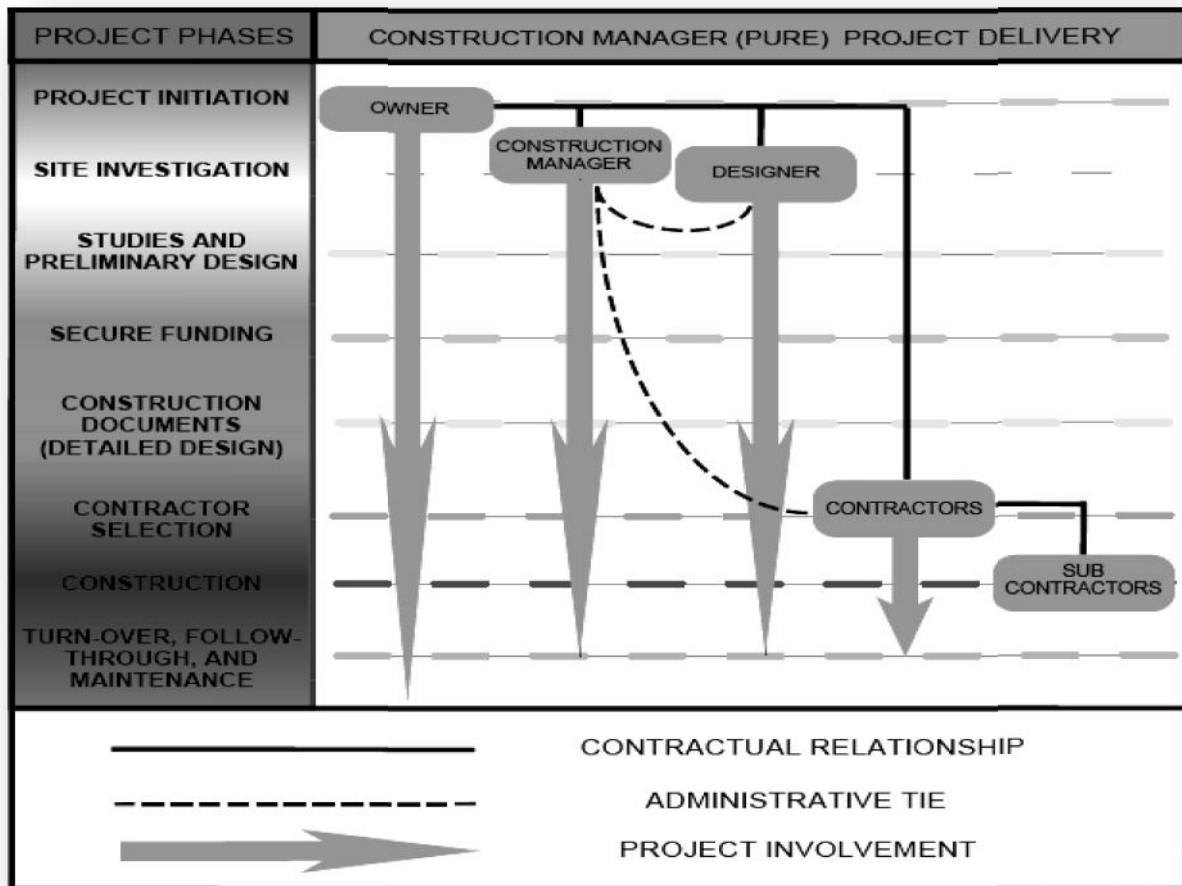


Figure 2.10: Contractual Relationships among Parties and their Involvement throughout CM Project Delivery (Kraig L., 2006)

The involvement of construction manager entity's expertise improves the efficiency of the projects by minimizing rework, change orders, and cost overruns. The construction manager advises the owner in the design and construction stage allowing the owner to have influence on the project. This involvement facilitates constructability issues, integrating construction knowledge during the design phase. The construction manager oversees design implementation during construction, often diminishing the designer's role in construction, but the involvement of the designer in construction differs in each project (Kraig L., 2006).

2.3.3 Comparison of the Project Delivery Methods

The three methods, stated in the last chapter are the basic types used in most projects, others, not stated delivery methods are modifications of DBB and DB delivery methods. From each of these types many variation and similarity have been observed. There is no delivery approach that is best in every situation. The selection criteria for the best project delivery system will deal with the unique needs and characteristics of each project (Kraig L., 2006). As it is discussed in the previous chapter the CM is not self-standing project delivery system by itself, rather it is a complementary for DB delivery method. Hence, in this chapter the comparison is focused only on the DBB and DB project methods, which are the base for remaining delivery methods.

Study in University of Kansas compares the DBB and DB delivery methods, with stating their main characteristics on projects as it shown in the table 2.1 below (Michael L. et al., 2015).

Table 2.1: Project Characteristics for DB and DBB Use (Michael L. et al., 2015)

DBB Project Characteristics	DB Project Characteristics
Lowest initial cost is the primary driver	Early cost certainty is desirable
Design must be at or near 100% completion before a contractor could be hired	Project scope can be adequately defined without 100% complete plans, specifications, and estimates
The project type is typical and common (i.e. limited opportunities for innovation, constructability or value engineering)	Project allows for innovative design or constructability solutions
Third party risks and unknowns exist that are best managed by owner	Project is complex, requiring early contractor involvement
	Major project risks can be mitigated by having the contractor and designer in a direct contractual relationship

Literatures presented the advantages and disadvantages of DBB and DB delivery methods in different ways. But their basic ideas are similar. In this study, the summary of advantages and disadvantages of DBB and DB projects delivery methods according to four literatures are summarized and presented in the following table 2.2 and 2.3 (Natasa T., et al, 2007, Sidney M. L., 2006, Charles N. J, 2005 and Samir B., 1997).

Table 2.2: Advantages and disadvantages of DBB (Natasa T., et al, 2007, Sidney M. L., 2006, Charles N. J, 2005 and Samir B., 1997)

Advantages	Disadvantages
1. The project is fully defined.	1. The whole process may be slower. The linear approach requires more time for overall project cycle. Greater potential for time overrun.
2. Competitive bidding results in lowest cost. Owner obtains reasonable security of pricing when the competitive bidder is accepted.	2. The contractor is not involved in design process. And Design Professionals may not have sufficient construction experience to provide appropriate constructability reviews.
3. Objective bid competition and award. (Based on cost criteria.)	3. Designers may have limited knowledge of the true cost and scheduling consequences of design decisions.
4. Presents orderly approach to the sequence of design and construction work.	4. Least-cost approach requires higher level of inspection of the work by the owner's staff
5. Due to the high degree of design completion, changes in the work should be minimal.	5. The price is not certain until bid is received. Bids may exceed the Designer's estimate. The Initial low bid might not result in ultimate lowest cost or final best value.
6. Relatively ease of assuring quality control. (Owners retain significant control over the end product.)	6. Owner manages two contracts. Separation of contracts tends to create an adversarial relationship among the contracting parties.
7. Clearly defined roles for all parties.	7. Owner largely bears risk of design problems
8. Construction features are typically fully designed and specified	8. Tends to yield base level quality
9 Applicable to a wide range of projects	9. Parties may need more technical staff.
10. Good access for small contractors. (Doesn't need design specialists)	10. No built-in incentives to provide enhanced performance (cost, time, or quality)
11. Extensive litigation has resulted in well-established legal precedents	11. Greater potential for litigation
12. Insurance and bonding are well defined.	12. All parties are focused on their rights and obligations under the contract, which creates an inherently adversarial situation.

Table 2.3: Advantages and disadvantages of DB (Natasa T., et al, 2007, Sidney M. L., 2006, Charles N. J, 2005 and Samir B., 1997)

Advantages	Disadvantages
1. As integrated procurement systems, enables design and construction to be overlapped and should result in improved communications being established between client and contractor.	1. May be difficult to the clients to prepare an adequate and sufficiently comprehensive brief. Insufficiently defined brief does not address precise needs, and it is so difficult to evaluate the proposals and tender submissions by bidders.
2. The integrated communication and team work brings all parties towards the same side and to satisfy the interests of the client.	2. The client is required to give a conceptual design and performance requirements at an early stage.
3. It enables fully contractor contribution to the design and construction at early stage. The early involvement helps for constructability review and also encourages the contractor for innovation.	3. As the contractor being responsible for the design and construction of the building, the client is at risk if the contractor does not have full indemnity insurance cover.
4. Significant savings in project time due to the overlapping the stages of design with the early start of construction. And it also leads to considerable savings in cost.	4. The construction is allowed to start on site before design is completed. The limitation of this is that the client may have to commit him/herself at an early stage to contractual and financial arrangements.
5. Provided that the client's requirements are accurately specified, certainty of final project costs. And this cost is usually less than using other types of procurement method.	5. Since the price offered by DB Contractors are typically predicated on conceptual designs and performance specifications, the bid price is likely to be higher than in a DBB, as the DB Contractor needs to add contingency for design and other unforeseen construction risks .
6. As the contractor is responsible for design and construction, the client has the advantage of dealing with one single party for all aspects. Accordingly, the need to assign resources and time to contracting with separate party is significantly reduced. It also helps for efficient risk transfer.	6. Changes of the client's requirements once the contract has been signed are likely to be more expensive on both indirect cost and in disruption costs if the contractor's building sequence is affected.
7. The project Price is certain. The Owner can obtain an early commitment to an overall project price and the total financial commitment before commencing the onsite work.	

As presented in the above tables, both delivery methods have their own advantages and disadvantages. So it is difficult to judge one is the perfect type of the delivery method and the other is not. But the selection criteria of the delivery method can be depended on the type and unique characteristics of the project with respect to these advantages and disadvantages.

Saeed T. (2014) also presented with comparing the advantages and disadvantages of the two methods, with strengthening the above concepts. In DBB method, the client is able to receive competitive bids and constructs the project at the lowest competitive possible cost. Another benefit is that the designer seeks only the client's interests and is also impartial. On the other hand, the contractor does not have any impact during the design phase, thus the contractor's knowledge of constructability, material availability, value engineering and so forth in a very limited way can be incorporated into the project execution. During the construction stage some design problems may happen due to the fragmentation of the two and lead to overhead costs, time delays and increased tension among the project teams.

On other side in the DB delivery method, the contractor is involved in early design stage of the project life cycle and it is useful for constructability issues. Consequently, the amount of money and time needed during the project life cycle are reduced. However, in this method, it is difficult for client to obtain comparable competitive bids from different DB teams and subsequently the method is not suited for projects that require a complex and elaborative design for aesthetical and technical purposes. In addition, since the designer and builder work together, quality control assurance is limited and cost could become a priority over quality (Saeed T., 2014).

2.4 Integrated Design and Construction Process

2.4.1 Definition

In simple meaning the term “Integration” is defined as combination or cohesion. When applying to the construction industry, which is known by the involvement of a variety of professionals and organizations, the integration aspects will occur on various dimensions and at different phases;

- Between different designers at design stages and construction stage and
 - Between design teams and construction teams at both the design and construction stage.
- (Zainuddin H., 1997)

The separation of design from construction process leads to a certain amount of isolation of the professionals from technical development in construction projects. This division is also suggested as being the cause for the lack of constructability of the construction projects, which will be a reason for projects exceeding budgets and scheduled time. By separating construction from design, parties ignore the opportunities of significant savings in project cost and completion time resulting from the careful interaction of planning, design, and engineering with construction (Trigunarsyah, Bambang 2006).

A typical characteristic of construction is the fragmentation between design and construction, which in general is considered to be problematic and often argued that design and construction should, in one way or another, become better integrated. Integration is the desire to improve the performance of architectural-engineering design and construction of projects (Jorgensen, B. et al, 2009). The problems of work sequence between design and construction activities have been discussed for many years. The main problems that have been detected are the lack integration among design and construction and also among the designers. The main consequences are substandard solutions, lack of constructability and a great number of change orders. The impacts of changes are not understood and rarely recognized, in terms of costs and schedule. The work hours invested by the designers in the changes have been estimated in a 40 to 50% of the total of a project design time. In Latin American countries, it is estimated that between 20 to 25% of the total construction period is lost with a reason of design deficiencies. Hence it is

clear that the design and construction integration offers a great potential for improvement (Jorgensen, B. et al, 2009).

A Case study on “The Integrated Design Process” in Illinois State University, Norway explains as; the integrated design process which is also known as whole building process, is a type of process assumes that architectural, engineering and construction professionals have different and complementary knowledge and can work together to achieve higher levels of performance, simplify construction, decrease costs, and shorten the build schedule. These are the necessary results of any construction project, and which are also known as the three fundamental criteria of project management; namely cost, time and quality (Rebecca M. R. et al, 2009).

Integrated design processes needs participation of experts from a number of disciplines, including the owners and end users, in the earliest phases of the planning and design process. Team members work together through design and other communication channels to clarify project performance goals, owner’s requirements and to come up with design ideas. As the process develops, design meetings and other forms of communication become more technical in nature with each team member contributing their knowledge to the highest performance of the project within the constraints of the project goals and objectives (Rebecca M. R. et al, 2009).

Whole Building Design lays on two concepts, which are an integrated design approach and an integrated team process. The integrated design approach asks all the members of the project participants, and the technical planning, design, and construction team to look at the project objectives, and building materials, systems, and assemblies from many different perspectives. This approach is a deviation from the typical planning and design process of relying on the expertise of specialists who work in their respective specialties somewhat isolated from each other. To create a successful high-performance building, an interactive approach to the design process is also required. It means all the parties involved in the planning, design, construction, operation, and maintenance of the facility must fully understand the issues and concerns of all the other parties and interact closely throughout all phases of the project (Abimbola O. W. and Olabode E. O. 2014).

2.4.2 Delivery Method and Integrated Design and Construction Design Processes

The integration of design and construction process is highly affected by the delivery methods. In the previous chapters the definitions, advantages and disadvantages of the two basic delivery methods of DBB and DB are discussed from the general point of view. As it is discussed above, DB project delivery method has advantage over DBB with respect to the design and construction integration. On the other hand both have their own advantages and disadvantage the other parameters. In this chapter the integration of design and construction processes with respect to project delivery methods will be discussed.

Design-Bid-Build

In this delivery method, the employer first awards an architect/engineer contract to design the project based on subjective criteria of qualifications and experience of the architect/engineer. After completion of the detailed project plans and drawings are prepared based on pre-defined needs and the existing constraints. After the approval of the drawings a contractor is selected to perform the construction work. So the two phases are performed in different time in a fragmented manner. the fragmentation of the two phases become a cause for the contractor not apply the knowledge of constructability, material availability, value engineering and others in the design phase and which can be incorporated into the project execution (Saeed T. 2014, Sidney M. L. 2006).

Design- Build

Under this method, the owner contracts with a single Design-Build (DB) team. Unlike to DBB, the primary benefit for the client is the simplicity of having one party responsible for the design and construction of the project. As a result, projects are often carried out faster time. In addition knowledge of a contractor, properly applied for better performance of the project. The DB team submits the design to client according to a set of preliminary descriptions including client's requirements and estimated cost and time. After approval by the client, the DB team can immediately begin the construction in order to reduce the project lead time. In this method, all design modifications can be made in early stage of the process. Consequently, amount of money and time needed to apply changes during project life cycle are reduced. However, it is difficult for client to obtain comparable competitive bids from different DB teams and subsequently the method is not suited for projects that require a complex and elaborative design for aesthetical

and technical purposes. In addition, since the designer and builder work together, quality control assurance is limited and cost could become a priority over quality (Saeed T. 2014).

2.5 Constructability

2.5.1 Definition

As it is discussed in the previous chapter one of the major problems in construction project is lack of integration between design and construction. Development of integrated planning and controlling of design and construction is the most important issue in construction projects. A construction project is characterized with a complex and fragmented process. These characteristics have produced a decrease in the quality and cost efficiency of projects. It has been proven that this problem can be overcome with implementing constructability in a project, which is based on the integration of construction knowledge and experience into the design of a project (Felix T. U. et al 1998). The scheduled time and cost for completing a construction project have been increasing due to lack of applying constructability. Therefore, implementation of constructability, which involves the knowledge and experiences of construction experts, is a vital trend in the industry (Samanah Z. et al, 2012).

Literatures define the term constructability in different way but the basic concept ends at the same point of view. Constructability is defined as the optimum use of construction knowledge and experience in planning, design, procurement, and construction processes to achieve the overall objective of the intended project (Felix T. U., 1998). Franky W.H. et al. (2006) also supports this definition with defining as constructability is integrating construction knowledge, resources, technology, and experience into the architectural and engineering design of a project.

Constructability is the application of the construction related aspects of a project during the planning, design, procurement, construction, test, and start-up phases by knowledgeable, experienced, construction personnel who are part of a project (Robert H. M., 1991). Constructability is a process that utilizes experienced construction personnel with extensive construction knowledge early in the design stages of projects to ensure that the projects are buildable, while also being cost effective, and maintainable (Lawrence F.B., 2003). In general as per the above definitions, constructability is the implementation of construction knowledge and experience to the design of a project.

The term “Buildability” sometimes used as an alternative for “constructability” but some literatures differentiate them with respect to their scope of application. For instance study by Franky W. H. and Wong, et al (2007) differentiated their application in different countries. In the United Kingdom the term “Buildability” is defined as it is the extent to which the design of a building facilitates ease of construction, to fulfill the overall requirements for the completed building. On the other hand, the term “Constructability” in the United States and Australia, refers as the theory used to a wider scope of considerations including the management system employed.

Another researcher with strengthening describes the alternative usage of the term constructability to buildability in UK with defining as, “constructability is the extent to which the design of building facilitates ease of construction, subject to the requirements of construction methods. (Sharmin K. 2006).[40] In the United States and Australia, the term constructability is broadly used and defined as “a system for achieving optimum integration of construction knowledge in the construction process and balancing the various project and environmental constraints to achieve maximization of project goals and building performance”. (Natasa T., et al 2009).

Franky W.H. et al. (2006) with referring different literatures explicitly clarified the main difference of buildability and constructability. Regarding the stages of implementation,” buildability” focuses itself at the design stage. On the contrary, the term “constructability”, covers all project stages and thus overcomes the narrowed scope of “buildability”. Although some constructability improvement measures do take place at particular stages of a project, e.g. the carrying out of constructability analysis at tender stage, it is commonly recognized that “constructability” is concerned with the whole process of project development to facilitate construction efficiency and achieve project goals. By contrast, “Buildability” deals with only the design stage for construction efficiency.

Sometimes the meaning of constructability is also confuses with value engineering (VE). Erman S. B. et al (2001) clarifies the confusion with briefing the difference and similarities of the terms. Value engineering is defined as “the systematic effort aimed at analyzing the functional requirements of systems, equipments, facilities, procedures, and supplies for the purpose of achieving the essential function at the lowest total (life cycle) cost of a project”. On the other hand, they can be similar in their effect, but differ in scope and manner of analysis. VE tend to focus of functional analysis and life-cycle cost, while constructability is achieved by fully exploiting construction experience in a

timely and structured fashion. [13] Constructability involved construction oriented input into the planning, design and field operations of a construction project to make the work easy, to improve quality, safety, productivity, to shorten construction time schedules and to reduce rework, but VE involves in the design stage of a project (Franky W.H. et al, 2006). Hence the scope of constructability is wider than VE.

2.5.2 The Birth and Evolution of Constructability

The separation between design and construction began after the renaissance; at the time architects began to differentiate their role as practitioners of the liberal art of decoration. This separation was reinforced by the Industrial Revolution with modern engineering techniques contributing to project complexity and the fragmentation of roles. The 1960s and 1970s were the periods in which most of the construction industries in the world experienced failures in providing projects efficiently, at the appropriate cost and satisfactory quality. The complexity of today's projects has led to increased specialization, and the growth of legislation aggravates the fragmentation and isolation of the design and construction stages. In the past, experienced professionals were usually capable of solving constructability problems on site. The need for constructability has emerged in parallel with the increase in complexity of construction processes and applications of various plants (Sharmin K. 2006).

In order to know the beginning of constructability, it is necessary to mention the results of the evaluation of the UK and American construction industry performed at that time. In both countries, one of the complex problems faced by the construction industry was the lack of integration between construction and design. In 1979, a comparison of the design and contract procedures in the construction industries of the United Kingdom and the United States was prepared with the form of report. The report covered how the American construction industry inserted construction knowledge into design and the benefits achieved. The report also recognized that both countries have been implementing changes to bring the contractor into the detail design stage. In the America this was manifested by the coming out of construction management as a method of project delivery, and in the UK by the use of a contractual arrangement similar to DB (Felix T. U., et al, 1998).

According to Felix T. U., et al (1998) with referring research done in the United States Construction Industry Institute (CII), the development of constructability concept demonstrated in the time from the 1980s and mid-1990s with dividing into two groups. The first group (first and second stages); which deals with the principles of constructability, definition of the term, and guidelines for the implementation of a constructability program. The second group (third and fourth stages) focuses on the implementation and assessment of constructability programs, as stated below.

First Stage: - During this stage efforts were made to determine the principles. These could be used in each phase of the project to improve the constructability. In addition, thoroughly analyses of the use of prefabrication, preassembly, and modularization were made to illustrate how these methods affect construction and the benefits that could bring to projects.

Second Stage: - This stage was used to gather all the principles obtained from the previous stage and to define the term constructability. Also during this stage, the guidelines for the implementation of a constructability program were developed. In 1989 CII formed the constructability implementation force.

Third stage: - This stage was used to define the type of benefits that can be obtained from constructability. In addition, during this stage researchers created a framework able to estimate the cost and the benefits of the implementing a constructability program. It was used to assess the constructability practices in the industry and the creation of guidelines to facilitate the implementation and evaluation of a constructability program.

Forth Stage:- The fourth stage was dedicated to creating a tool that permitted the evaluation of a constructability program. This tool was developed for the successful implementation of the programs in the industry.

2.5.3 Concept of Constructability

Constructability is used as a management tool, which can save time, money and can also aid with a lot many tangible and non-tangible benefits in a project, when applied properly. Constructability is still not a very popular concept amongst the parties and has not even reached in the developing countries, as it should have been. There is a need to understand the concept, its practices, benefits and barriers, in order that for a proper and timely implementation (Erman

S.B., 2001).

The successful completion of a construction project requires a detailed understanding of all phases of the project, and can be enhanced through integration of design and construction during the pre-construction stage. Constructability, or buildability (UK), is a major factor in measuring the success or failure of construction projects. Several constructability problems to accomplish a successful project may be addressed in the life cycle of a project. During the pre-construction stage, lack of construction knowledge and lack of integration in the planning, design and construction processes is a major factor that leads to constructability problems. This is because many designers have little experience in construction practices, methods of construction, availability of different resources, and in general they are not necessarily experts in construction. On the other hand during the construction stage, the contractor is dependent on the contract documents and the construction method is limited to the contract drawings and specification. And it also leads to constructability problems.

The constructability concept integrates knowledge and experience of construction managers and design engineers in order to eliminate the redesign and rework in construction stage. Most literatures present the concepts of constructability with referring the different versions of Construction Industry Institute (CII) Publications. The amount in number of the concepts in the literatures differs from one another. But most of the literatures categorize the constructability concepts in three broad groups. Accordingly, the summarized constructability concepts of different literatures with explanation of their major group are presented in the tables (Table 2.4, 2.5 and 2.6) as follows. (Bo Wang, 2003; CII, 2016; Felix T., et al,1998; George Jergeas, et al 2001; Samaneh Z., et al 2012)

I. Constructability Concepts During Conceptual Planning

Conceptual planning involves defining functional and performance requirements, evaluating project feasibility, and studying criteria for preliminary engineering. The decisions made during this phase have a major impact for the remaining phases of the project, particularly of the construction. The concepts concerning the benefits of construction knowledge involvement in project planning, development of the contracting strategy, and selecting major construction methods that influence the design approach clearly indicate the need to involve those who will

build the project at the beginning of the conceptual planning. (Bo Wang, 2003; CII, 2016; Felix T. et al1998; George Jergeas, et al 2001; Samaneh Z., et al 2012)

Table 2.4: Constructability Concepts during Conceptual Planning (Bo Wang, 2003; CII, 2016; Felix T. et al1998; George Jergeas, et al 2001; Samaneh Z., et al 2012)

Concept C1	The project constructability program should be discussed and documented within the project execution plan, through the participation of all project team members.
Concept C2	A project team that includes representatives of the owner, engineer and contractor should be formulated and maintained to take the constructability issue into consideration.
Concept C3	Individuals with current construction knowledge and experience should involve in the early project planning and design stage.
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 should be determined 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 these methods. This could include recovery and recycling methods as well as sustainable and final disposal planning.
Concept C7	Site layout should be studied carefully so that construction, operation and maintenance can be performed efficiently, and to avoid interference between the activities performed during these phases.

II. Constructability Concepts During Design and Procurement

Design and procurement is the phase in which most serious practitioners of constructability will address their efforts. In comparison to the phase of conceptual planning, the cost impact of decisions here is still many opportunities exist for enhancing constructability. This phase tends to focus on project objectives, organization, and execution plans, design and procurement; hence

constructability is manifested in the drawings, specifications, purchase orders, and schedules.

Table 2.5: Constructability Concepts during Design and Procurement Phases (Bo Wang, 2003; CII, 2016; Felix T. et al 1998; George Jergeas, et al 2001; Samaneh Z., et al 2012)

Concept C8	Design and procurement schedules should be guided by construction sequence. Thus, the construction schedule must be discussed and developed prior to the design development and procurement schedule.
Concept C9	The use of advanced information technologies will overcome the problem of fragmentation into specialized roles in this field, and enhance constructability.
Concept C10	Designs simplification by designers and design review by qualified construction personnel must be configured to enable efficient construction. This will help minimize material waste, recycling and cost-effectiveness.
Concept C11	Project elements should be standardized to an extent that will never affect the project cost negatively.
Concept C12	The project technical specifications should be simplified and configured to achieve efficient construction without sacrificing the level or the efficiency of the project performance.
Concept C13	The implementation of modularization and preassembly for project elements should be taken into consideration and studied carefully. Modularization and preassembly design should be prepared to facilitate fabrication, transportation and installation.
Concept C14	Project design should take into consideration the accessibility of manpower, materials and equipment to the required position inside the site.
Concept C15	Design should facilitate construction during adverse weather conditions. Efforts should be made to plan for the construction of the project under suitable weather conditions.

III. Constructability Concepts during Field Operations

Table 2.6: Constructability Concepts during Field Operations Phases (Bo Wang, 2003; CII, 2016; Felix T. et al 1998; George Jergeas, et al 2001; Samaneh Z., et al 2012)

Concept C16	Field tasks sequencing should be configured in order to minimize damages or rework of some project elements, minimize 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 will contribute positively to the enhancement of constructability.
Concept C18	Incorporating innovation of new methods in using the market available hand tools, or modification of the available tools, or introduction of a new hand tools that reduce labor intensity, increase mobility, safety and accessibility will enhance constructability at the construction phase.
Concept C19	Introduction of innovative methods for using the available equipment or modification of the available equipment to increase their productivity will lead to a better constructability.
Concept C20	In order to increase the productivity, reduce the need for scaffolding, or improve the project constructability under adverse weather conditions, constructors should be encouraged to use any optional preassembly.
Concept C21	Constructability will be enhanced by encouraging the contractor to carry out innovation of temporary facilities.
Concept C22	Good contractors, based on quality and time, should be documented, so that contracts for future construction works would not be awarded based on low bids only, but by considering other project attributes, i.e. quality and time.
Concept C23	Evaluation, documentation and feedback of the issues of the constructability concepts should be maintained throughout the project to be used in later projects as lessons learned.

2.5.4 Benefits of Constructability

Implementation of Constructability concepts in a construction project has deferent benefits. Literatures state the benefits of constructability with categorizing in different manner. Erman S.B., (2001), with referring different literatures listed and classified them in to two groups of quantitative and qualitative benefits of constructability.

I. Quantitative Benefits

- Reduce design cost
- Reduce schedule time
- Reduce construction cost (labor, material, equipment)

II. Qualitative Benefits

- Increase focus on common goal
- Increase construction flexibility
- Increase problem avoidance
- Improve site accessibility
- Reduced disruption to current production
- Improve safety
- Reduced amount rework
- Increase the understanding of effect of individual's involvement
- Increase commitment on team members.
- Increase communication
- Enhance team building and cooperation
- Reduce maintenance cost
- Reduce amount of material handling of inventories
- Improved production efficiencies
- Accounted for future expansion of project

Bo Wang, (2003) explains the benefits of constructability as it contributes essential benefits due to early integration of construction knowledge and experience into the design process of a project. Constructability has a role in minimizing the frequency and magnitude of changes, disputes, cost overturns, and delays during construction. Shortening construction time and improving project management by using constructability is expected to decrease overall project cost and thus reduce capital investment risk. In addition he classified them in another way to the

above as direct and indirect benefits of constructability.

A. Direct benefits

- Construction planning is made easier
- Both design and construction costs can be reduced
- Likewise the construction schedule may be shortened
- Better quality can be required and expected
- More realistic commitments can be made to subsequent trades
- Earlier owner occupation

B. Indirect benefits

- Building a collaborative team committed to project goals
- Parties working for mutual benefit
- Cross discipline training
- Transfer of expertise from other projects
- Contractor better understanding design intent, and vice versa
- Increased innovation in both design and construction
- Competitive advantage

2.5.5 Barriers of Constructability

According to Hiley A. and Yagci O. (2001) with referring different researches presents factors promote and barriers of constructability. Design efficiency, education, feedback systems, awareness of the importance of early design decisions and the establishment of conditions to promote the integration of design and construction are the very widely known factors can promote constructability. On the other hand there are also barriers to constructability; which include procurement methods, a lack of equity in contracts, a lack of team building and the time pressure on the design stage, lack of training of the workforce due to the lack of permanency in employment, poor working conditions, and lack of education.

Barriers to constructability may be classified into different categories with respect to their general characteristic and the involved parties as general barrier, owner barrier, designer barrier, contractor barrier etc. They are listed as follows: (Sharmin K. 2006).

i. General barrier

- Satisfaction with the existing situation
- "Right people" are not available
- Discontinuity of key project team personnel
- No documentation of lessons learned
- Failure to search out problems and opportunities

ii. Owner Barrier

- Lack of awareness of benefits, concepts, etc.
- Perception that constructability delays project schedule
- Unwillingness to spend additional money in early project stages
- Separate design and construction operations
- Lack of construction experience
- Disregard of constructability criteria in selecting contractors and consultants
- Lack of financial motivation for designer
- Unwilling to listen to contractor's innovation

iii. Designer Barrier

- Perception that they have considered constructability in their design
- Lack of awareness of benefits, concepts, etc.
- Lack of construction experience
- Lack of awareness of construction technologies
- Lack of mutual respect between designers and constructors
- Perception of increased designer liability
- Construction input is requested too late to be of value

iv. Contractor Barriers

- Unwillingness of field personnel to offer preconstruction advice
- Poor communication skills
- Lack of involvement in tool and equipment development

v. Supplier Barriers

- Fragmentation and difficult communication interfaces
- Restrictions on proprietary designs

vi. Code Authority Barriers

- Rigid, outdated codes and design standards

vii. Researcher Barriers

- Difficulty in proving the economics of constructability

2.5.6 Methods of Constructability Improvement

Constructability covers all project stages, which is concerned with the whole process of project development to facilitate construction efficiency and achieve project goals. Researchers propose different methods of constructability improvement. Gabriel, et al (2012) proposed the methods of improving constructability in a project, which appears more appropriate when procedures such as employment of a constructability champion are considered. The methods are sorted and categorized by their group of characteristics and approach of implementations.

1. **Formal corporate policy statements:** - statements that develop the intention of the organization in implementing constructability.
2. **Checklists:** - including corporate procedures, lessons learned technical issues, etc. Checklists are specified to ensure a comprehensive performance of tasks without overlooking vital issues.
3. **Organizational measures:** - these are administrative measures taken by the organization in order to establish management teams that are bound to be dedicated to implementing constructability.
4. **Contractual measures:-** measures taken within recognized procurement methods or innovative procurement methods, such as design-build, partnering or the Integrated Project Delivery (IPD) method, through which all parties involved (owners, general contractors, sub contractors, etc.) share risk and reward.
5. **System modeling and analysis methods:** - procedures and methods used to perform or analyze actions related to the project. Typically such methods are Value Engineering (VE), which focuses on function/performance; cost-benefit analysis within the VE process; and the use of the Critical Path Method (CPM) to define and schedule formal constructability review process steps.
6. **Reviews:** - a review is a step of a quality assurance method performed during design and construction. Constructability design reviews at set percentages of design completion using formal design checklists. Peer reviews are popular within design firms.
7. **Advanced technology methods:** - these methods take the advantage of the remarkable progress in project modeling in recent years. They include Building Information Modeling (BIM), multimedia, virtual reality, geographic information systems, and databases, analytical simulation tools such as artificial intelligence, decision support systems, and expert systems.

2.5.7 Awareness of the Concept of Constructability in Ethiopia and the International Experience

The constructability concept was born out of the realization that designers and contractors see the same project from different perspectives. To narrow the gap of the difference, the application of knowledge and experience of both parties is highly required in the planning and design stages. Especially the implementation of constructability, which is the integration of construction knowledge and experience in the design stage, is vital to fill this gap. However many owners, engineers, and contractors in the worldwide are still not aware of the potential benefits of constructability. Opportunities to reduce the schedule, improve the functionality of the final product, and reduce costs are lost with the fragmentation of design and construction (Erman S. et al 2001).

2.5.7.1 Ethiopian Practice

When we look our country Ethiopia, as far as the finding of this study, there is no available written document stating about the implementation of the constructability concept. Some studies strengthen this perception not only in Ethiopia but also in other African countries. Abimbola O. W. et al (2014) in their study described that in construction industries of Nigeria and Sub-Saharan African Countries; generally there has been a lack of research on the constructability practices of designers and contractors, and possible barriers to the use of appropriate methods of constructability.

But some local researchers in AAIT/AAU mentioned the term and parts of the concepts of constructability in their studies on building and highway constructions. To mention some of them; Lema M. (2006) in his finding on the study a Road Projects in Oromia Region with DB delivery method concluded that most of projects faced lack of constructability inputs in their life cycle.

Asmera S. (2015) in his study, even if he doesn't mentioned the term constructability. He concluded that the lack of knowledge of construction in the design phase and other design related factors can be causes of material wastage in building projects. [4] Mekonnen A. (2013) in his findings on study of Design-Build and Design-Bid-Build Project Delivery Method in Federal Road Construction, concluded that, the suitability of DB for constructability review which minimizes design risks is more apparent than DBB, if it is widely used for Federal road projects. Nejbel M. A. (2014),

recommended in his research that Constructability review teams have to be organized in projects team development in order to benefit from the modern thinking of project management. [30]

The above studies mentioned the necessity of constructability concepts in highway projects. And there is no other locally done research which describes the practices, concept, benefits and necessity, barriers of constructability in either the building or in general the construction industry of the country.

2.5.7.2 International Practices

Studies in different countries show that the awareness on the concept of constructability is different from country to country. It is also differs in between the parties to parties in the industry. According to studies in different countries, the perception on the concept of constructability is discussed as follows.

i. United States of American

In the United States of American study shows that most design firms are aware of the concept of constructability to 95.7%. Almost 50.7% of them have formal corporate philosophy of constructability in their organization, 87% of design firms used constructability reviews during developed design stage. 95% of the design firms believed that construction engineers should be involved in the design phase, in addition to other professionals, who are already participating at this stage. Of these 57% of them believed that they should be involved, regardless of project conditions, whereas 38% indicated that the involvement should depend on size, complexity and type. And the study also has shown that constructability has gained importance and it is increasingly being adopted and applied in early project stages (Sharmin K. 2006).

ii. United Kingdom

As it is discussed above, the term “buildability” was invented after a number of studies in the UK on the negative effects brought by the lack of integration of design and construction in the 1960s and 1970s. Thereafter, the definition of buildability was criticized for its narrowness in scope, in that it essentially confined to the design phase. Subsequently, further studies on buildability in the UK were carried out by many researchers. However, after so many years, too much time and effort were still

spent trying to make design works in practice and there was little emphasis placed on buildability of designs (Franky W.H. et al 2006).

iii. Australian

According to Franky W.H. et al. (2006) with referring different literatures, Australian researchers were also aware of problems being caused by the lack of integrated design and construction. Through studies on constructability, attempt to encourage contractors' involvement in design and efficient communication, thereby enhancing the quality of project management during the whole building process, with the aims to facilitate ease of construction and achieve better project performance. Similar to the CII in the USA, the CII Australia published the Constructability Principles in 1992, including a system which involves the whole project parties (including contractors) from the very beginning of the project for improving constructability, and the Constructability Manual in 1996, providing guidelines for implementing the constructability system, in the form of 12 constructability principles, implementation strategies and case studies.

iv. India

A survey of four construction companies in India identified that most of the time the problem occurred with designs because of a thorough review was missing. According to the survey, it was found that 25% of the design firms performed constructability analysis throughout the entire design process (from conceptual to the final design). It was also observed that 51% firms start performing constructability reviews as early as conceptual planning stage. And the most significant factors those affects constructability are project complexity (87%) and design practices and philosophy (75%) and the third important factors that is found to cause constructability problems is faulty, ambiguous or defective working drawings and adversarial relationships (Sharmin K. 2006).

v. Singapore

The Singapore Government has enacted legislation to require minimum buildability scores of designs before approvals of building plans in 2001. The buildability scores are calculated based on the Buildable Design Appraisal System (BDAS), which was devised to measure buildability performance of designs in country. The “3S” principles of Standardization, Simplicity and Single Integrated Elements form the cornerstones of the BDAS. These represent the considerations that designers

should take in developing designs, including determination of the most appropriate building systems to be used (Franky W.H. et al 2006).

vi. Malaysia and Indonesia

On the other side, studies are being conducted in Malaysia and Indonesia all aiming at the better application of buildability and constructability through various methodologies (Franky W.H. et al 2006).

vii. Nigeria

According the study by Benedict A. (2016), the level of awareness of constructability concepts and principles among industry professionals in Nigeria is somehow appreciable. The general principles of constructability are accepted by professionals. However, the level of knowledge and application of formal constructability concepts by sampled population of the study is very low as discovered from the findings. For instance, Formal Implementation Process ranked (7th). This includes scheduled constructability reviews. Other formal techniques also scored low such as use of constructability resources and feedback systems which were ranked (8th) respectively. The most commonly used constructability techniques as indicated by the order of their mean score values are; corporate lesson learned, Brainstorming, Peer reviewing, Graphical computer based tools (CAD), and Discussions with clients, contractors, suppliers.

viii. South Africa

In South Africa, study shows that, it is found that 84% design firms are aware of constructability concept. And 76% of them indicated that they require contractors experience in their design because they had better knowledge about material availability and application technology that affects quality and cost (Sharmin K. 2006).

As it is shown in the above the awareness of constructability is more practiced in United States and Australia, and it is developing with researches. CII of the two countries play much role with creating and updating the concepts of constructability. In UK, even if the concept of buildability has narrower scope, many researches are carrying out to develop it as constructability.

In Asian countries, especially in Singapore, the awareness is supported developing constructability measuring tools. In India, Malaysia and Indonesia, the awareness and application of buildability and constructability is in a better stage with developing different methodologies.

In Africa, Nigeria and South Africa are applying the concepts of constructability in a better way in comparing with Sub Saharan countries including Ethiopia. In Sub Saharan countries the awareness and implementation of constructability is not well practiced.

2.6 Summary of Literatures

In the last five subchapters the conceptual frame works of project delivery methods, integration of design and constructability and concepts of constructability are broadly with referring different literatures. And in this subchapter the short summary will be presented.

Project Delivery Method is a full process including planning, design and construction of a construction project. DBB and DB are the basic types of project delivery methods and others are the modifications of DBB and DB. The integration of design and construction phases of a building project is directly depended on project delivery method.

According to the literature review, in DBB the design and construction phases are fragmented, in the other side in DB delivery method the two phases are interfaced. Hence with regard to the integration of design and construction DB is more better than DBB with reasons like early start of the construction before full completion of the design will shorten the project completion period, encourages the contractor for innovation, early certainty of project cost and others. On the other hand DBB also have some advantages over DB like, relatively easier for quality control, easier for financial bid competition and competitive bid results lowest price.

A typical characteristic of many construction constructions is the lack of integration between design and construction, and which is the cause of many problems. The lack of integration of the two phases affects cost, time and quality of a building construction project, and which are known as the three fundamental criteria of project management.

The problem of integration between the design and construction phases can be overcome with implementing constructability in a project, which is the integration of construction knowledge

and experience into the design phase of a project. Constructability is a construction management concept created to fill the gap on the integration of design and construction phases. Its concept is first demonstrated and developed in the United States in the time from the 1980s and mid-1990s and then practiced in Australia. Now a day it is spread and practiced in UK, Asian and even if in few African countries. But in Sub-Saharan countries including Ethiopia, the awareness on the concepts of constructability is insignificant.

The conceptual frame works of the study is summarized according to the literature review. Then, the actual practice, with focusing public building projects in Addis Ababa will be assessed with the aid of method of case study in the following chapters.

CHAPTER THREE

3. RESEARCH METHODOLOGY

3.1 Introduction

This chapter presents the methodology used to review and analyze the lack of integration between design and construction phases of building projects and the effect of constructability. As it is directly related to integration of design and construction processes, the study impress on the project delivery methods especially on DBB and DB. Case study is the preferred method of this research, as the concept of constructability is a contemporary experience. And the case study focuses on sample public projects in Addis Ababa.

3.2 The Study Design

The study design is the overall plan to find answers for the questions of the study and for handling some of the difficulties encountered during the research process. The first strategy is formulating the study design. Then data and information sources will be determined based on the formulated research design. On the basis of the data and information sources the research instruments will be decided. Then the required data will be collected and analyzed. Finally, the available documentary sources will be reviewed for cross-checking the validity and conformity of the information obtained through the overall research work.

This study can be both qualitative. It is qualitative, because the study focused to obtain the perceptions of participants of public building construction relative to the impact of regarding the concept of design and construction integration and its impact on the constructability. Case studies will be conducted on specific selected public building projects in Addis Ababa.

Case study is the preferred method of this study, because of constructability is contemporary concept in the construction industry. Three public projects are selected for the case. The first criteria of selection is the project delivery method, because of the main focus of the study, projects are selected in the category of DBB and DB. The second selection criteria is focused on public building on their project cost more than 50 million birr, financial progress of more than 90% in order to observe the overall effects and employed by government entities.

3.2.1 Sources of Data

The study utilized both primary and secondary data. Primary data is gathered from first-hand data collected by the case study on the selected DBB and DB delivered projects. The secondary sources of data were obtained using relevant books, journals, magazines, web sites and research papers

3.2.2 Data Collection

In this study, the method of primary data collection used is questionnaire and with personal interview.

3.3 Data Analysis

In the case study on the selected projects, the collected data is analyzed with investigative the questionnaire and interview.

3.4 Limitation of the Study

This study is limited and focused on selected public building construction projects in Addis Ababa under delivery methods of DBB and DB, in which their financial progress is more than 90%.

CHAPTER FOUR

4. CASE STUDY ANALYSIS AND DISCUSSION

4.1. Introduction

In this chapter the data collected for the case study is analyzed and discussed. As the method is described in chapter 3, the collected data with the questionnaires and interviews from the selected projects of the case study is analyzed. The objective of this chapter is to assess the actual experience of the issues of the study and to find correlation with the literature review.

4.2. Study Population

The study population was drawn from eight private and public agencies in the study area (Addis Ababa), contractors, consultants, and clients. As much as possible attempts have been made so that the samples drawn from the population are representatives. The following table 4.1 presents the samples and their distributions, including the response rate of the respondents.

Table 4.1 Distribution of interviews and questionnaires and percentage of respondents

Item No.	Respondent Party	No. of Interviewees	Questionnaires		
			Distributed	Collected	Response Rate (%)
1	Contractors	2	3	2	66.67%
2	Consultants	3	3	1	33.33%
3	Clients	1	3	1	33.33%

In the above distribution Professionals engaged in the construction industry of having academic level from first to second degree are addressed.

4.3. Case Study

This chapter states the data that have been collected with the questionnaires and interviews collected from the projects reviewed in the case study. The results are prepared with the information collected on the project delivery methods, integration of design and construction and implementation of constructability of the projects.

4.3.1 Case Study I: Oromo Cultural Center Complex, at Addis Ababa

a. Project details

Employer:- Oromia National Regional State Industry and Urban Development Bureau

Owner:- Oromia National Regional State Culture and Truism Bureau

Main Consultant (Design and supervision):- Geretta Consult plc

Subcontract-designers:-

MH engineering plc (Structural Designer)

FASTEK consult plc (Electrical Designer)

SANMECH consult plc (Sanitary and Mechanical Designer)

Contractor: Afro-Tsion Construction plc

Contract Amount (Birr): - 168,704,566.33

Commencement Date: -November 5th, 2008

Original Contract Time: - 900 Cal days

Total Built up Area: - 27,000m²

Blocks :- Museum, Regional library, Public library, Language Academic Center, Music Training Center, Oromo National Art Center, Cinema Hall and Restaurant and Bar

b. Contract Administration Related Issues

Project Delivery Method: - DBB

Procurement Type: - Lowest bidder

Contract Type: - Unit Rate

Condition of Contract: - FIDIC 1987 (Red Book)

Contract Amount (Birr): - 168,704,566.33

Net Variation approved to date (Birr): - 28,936,571.86

Final Amount (Birr): - 197,641,138.19

Percentage Increased: - 17.15%

Commencement Date: -November 5th, 2008

Original Contract Time: - 900 Cal days

Actual Completion Time: - 1862 Cal days

Percentage Increased: - 106.89%

c. Design Related Issues

As the name indicates, the project design is as such a complex type. All the architectural design factors are initiated from the culture of Oromo people. Especially they reflect Geda System, Irrecha Celebration and other typical culture of the people. All blocks are interconnected in a style of cycle.

The main consultant has done the architectural design and the structural, electrical, electromechanical and sanitary designs are prepared in the manner of sublet under the architect. The Subcontract designers are specialized independent firms and they have prepared the different designs as per the architectural design. In addition to the design, they were supervising the project periodically and were approving materials submitted by the contractor.

d. Major Design and Construction Related Problems Caused with Lack Integration

Table 4.2 Major Design Related Problems with the Reason of Lack of Integration (Case Study I)

Item No.	Design Problems	Description of the Design Problems	Effects of the Design Problems	Cause of Problem	Initiator (Party)	Taken Remedial Action
1	Capacity of the Cinema hall	The actual capacity hall is 900 seats, but the people representative's need was 1800 to 2000 seats.	Dissatisfaction of the user	Defining Need	User, Employer and Designer	For future the client decided to construct new bigger hall.
2	Roof Truss of Cinema hall	The roof truss of the cinema hall was not designed in such a way to much with the pattern of the ceiling, was not structurally designed to hold the sound system equipments and the member of the truss blocked the electro-mechanical ducts and units.	Time delay and additional steel structure works cost incurred by the contractor.	Lack of Integration between design and construction	Architect and Engineering Designers	Structural design modification of the truss
3	Data/Telephone and Security System	The Data/telephone and CCTV and	Chiseling and rework on painted walls, ceiling and tiled floors. (Delay and cost overrun)	Defining Need	Employer	Additional payment and time to the contractor for the rework

e. Major Construction Problems Caused with Lack Integration

Table 4.3 Major Construction Related Problems with the Reason of Lack of Integration (Case Study I)

Item No.	Description of the Construction Problems	Description of the Design Problems	Effects of the Design Problems	Cause of Problem	Initiator (Party)	Taken Remedial Action
1	Multiples of finishing items	As the project was a complex project and having many and different types of finishing items; and most of the materials were not available and not yet used in the country (For instant Curved Cinema Screen and others)	Time delay and financial loss to the contractor.	Even if the contact is DBB, the project needs early involvement of the contractor in the design phase.	User, Employer and Designer	
2	The geometry and complexity of the project	The geometry of project has many curvatures and the interface between the blocks is so complex, the construction took long time.	Time delay and additional overhead cost to the contractor.	Even if the contact is DBB, the project needs early involvement of the construction expert in the design phase.	User, Employer and Designer	
3	Art Work	The art work, which is beyond the knowledge and experience of the contractor, took long time for the subletting, historical study, approval and execution.	Time delay and additional overhead cost to the contractor.	Need early involvement artists (Start from preliminary design stage)	User, Employer and Designer	As the contactor has prepared the bid offer without enough knowledge of the art work or losses are not compensated.

Item No.	Design Problems	Description of the Design Problems	Effects of the Design Problems	Cause of Problem	Initiator (Party)	Taken Remedial Action
4	Roof Truss of Cinema hall	The roof truss of the cinema hall was not designed in such a way to much with the pattern of the ceiling, was not structurally designed to hold the sound system and the member of the truss blocked the electro-mechanical ducts.	Time delay and additional steel structure works cost incurred by the contractor.	Lack of Integration between design and construction	Architect, Structural and Mechanical Designers and the contractor	As the contract states all necessary supports and accessories, there was no additional payment to the contractor.
5	Data/Telephone and Security System	The Data/telephone and CCTV and	Rework on painted walls and tiled floors. (Delay and cost overrun)	Defining Need	Employer	The contactor has done the rework with additional cost and time.
6	Forgotten fair faced concrete below the grade beam.	The fair faced concrete wall under the grade beam in all blocks was done with conventional C-30 concrete.	The required fair faced concrete appearance of the complex is missed.	Sequence and methods of activities are not configured	Contractor and consultant	All area is clad with granite with the additional cost of the contractor.

f. Constructability Issues

According to the case study, the constructability concept is totally not applied and not properly known with the participants. But the following table 4.4 states whether the concepts of constructability applied or not unknowingly.

Table 4.4 Application of constructability concepts (Case Study I)

Oromo Cultural Center Complex Project Case Study I		
Item No	Constructability Concepts	Application
	Constructability Concepts during Conceptual Planning	
C 1	Discussed and documented project constructability program within the project execution plan, through the participation of all parties.	Not applied
C 2	Formulation and maintaining of a project team, including representatives of the owner, engineer and contractor in order to take the constructability issues.	Not applied
C 3	Involvement of individuals with construction knowledge and experience or a contractor in the early project planning and design stages.	Not applied
C 4	Preparing the master project schedule to be construction-sensitive and to be implemented as early as possible.	Not applied
C 5	Discussing and analyzing major construction methods as early as possible in order to accomplish the activities easily and efficiently, and implementing the design according to these methods. This also includes recovery, recycling and final disposal planning.	Not applied
C 6	Site layout should be studied carefully so that construction, operation and maintenance can be performed efficiently, and to avoid interference between the activities performed during these phases.	Not applied

Item No	Constructability Concepts	Application
Constructability Concepts during Design and Procurement Phases		
C 7	Design and procurement schedules should be dictated by construction sequence. Thus, the construction schedule must be discussed and developed prior to the design development and procurement schedule.	Not applied
C 8	The use of advanced technologies to overcome the problem of fragmentation into specialized roles in the actual construction and to enhance constructability.	Not applied
C 9	Design simplification by designers and design review by qualified construction personnel, in order to enable efficient construction.	Not applied
C 10	Project elements should be standardized to an extent that will never affect the project cost negatively.	Not applied
C 11	Simplified and configured technical specifications in order to achieve efficient construction without sacrificing the level or the efficiency of the project performance.	Not applied
C 12	The implementation of modularization and preassembly for project elements should be taken into consideration and studied carefully.	Not applied
C 13	Consideration of Project design for accessibility of construction manpower, materials and equipment to the required position .	Not applied
C 14	Design facilitate for construction during adverse weather conditions.	Not applied
Constructability Concepts during Field Operations		
C 15	Configuring of activity sequences in order to minimize damages or rework of some project elements, minimize scaffolding needs, formwork used, or congestion of construction personnel, material and equipment.	Partially applied
C 16	Innovation in temporary construction materials/systems, or implementing innovative ways of using externally available materials/systems that have not been defined or limited by the design drawings and technical specifications for the enhancement of constructability.	Not applied
C 17	Incorporating innovation of new methods in using or modification of the available tools, or introduction of a new hand tools that reduce labor intensity, increase mobility, safety or accessibility to enhance constructability.	Not applied
C 18	Introduction of innovative methods for using the available equipment or modification of the available equipment to increase their productivity to a better constructability.	Not applied
C 19	Improving the project constructability under adverse weather conditions.	Not applied
C 20	Evaluation, documentation and feedback of the issues of the constructability concepts to be used in later projects as lessons learned.	Not applied

4.3.2 Case Study II: Addis Ababa Police Commission

a. Project details

Employer:- Addis Ababa City Administration Police Commission

Designer: - Gereeta Consult Plc

Supervision: - A.A.C. Admin. Inf. & Construction Authority

Contractor:- Afro Tsion Construction PLC

Contract Amount (Birr): - 99,444,398.79

Commencement Date: - Nov. 5, 2008

Completion Time :- 730 Cal Days

Completion Date: - October 31, 2010

Location: - Addis Ababa

b. Contract Administration Related Issues

Project Delivery Method: - DBB

Procurement Type: - Lowest Bidder

Contract Type: - Unit Rate

Condition of Contract: - MoWUD December, 1994

Contract Amount (Birr): - 99,444,398.79

Net Variation approved to date (Birr): - 14,726, 864.64

Final Amount (Birr): - 114, 171,263.34

Percentage Increased: - 14.81%

Commencement Date: - Nov. 5, 2008

Original Contract Time: - 730 Cal days

Actual Completion Time: - 1040 Cal days

Percentage Increased: - 42, 47%

c. Project Delivery, Procurement and Contract Format Related Issues

As stated above the project is DBB delivered, in addition the designer and the supervision parties are different. The designer's contract was closed after the approval and submission of the final design. But after some progress of the construction work the client agreed with the designer to work with the supervision body to give some design clarifications and minor modifications.

d. Major Design Problems

Table 4.5 Major Design Related Problems with the Reason of Lack of Integration (Case Study II)

Item No.	Design Problems	Description of the Design Problems	Effects of the Design Problems	Cause of Problem	Initiator (Party)	Taken Remedial Action
1	Roof Truss structural design of Assemble hall	The structural design of the 18metet Assemble hall's truss was re-checked with the contractor's structural designer and the design failed.	The re-checking, discussion and approval process with the supervision consultant and designer has taken more than six months. Finally the design is changed as per the contractor's recommendation.	Lack of proper design checking	Designer	New design and additional cost.
2	Aluminum partition wall panel	The aluminum partition wall thickness was 70mm and the majority of the partition walls are this material. And the building has many electrical connection boxes, their thickness is more than 120mm.	The thickness of the partition wall can't hold the electrical boxes.	Lack of integration between different designs. (Architectural and Electrical)	Designer	All wall mounted electrical boxes are changed to floor boxes which have higher cost.
3	Specification problem on electrical items	Electrical items, particularly Audio Communication System between Inmates and Visitors and Electrically controlled doors have major specification problems. The specified items do not match with the intended requirement.	Changed to variation and the final new price exceeds the contingency.	Lack of participating special subcontractors and suppliers in the design stage	Designer	The items are omitted.

Item No.	Design Problems	Description of the Design Problems	Effects of the Design Problems	Cause of Problem	Initiator (Party)	Taken Remedial Action
4	Site work design changes	The site work, especial fence and drainage design has taken more than eight months.	Long time taken for redesign and modification	.Lack of integration between different designs.	Designers	

e. Major Construction Problems Caused with Lack Integration

Table 4.6 Major Construction Related Problems with the Reason of Lack of Integration (Case Study II)

Item No.	Description of the Construction Problems	Description of the Design Problems	Effects of the Design Problems	Cause of Problem	Initiator (Party)
1	176% increment of marble cladding	The quantity of 1cm thick marble external wall cladding increased with 176 % (Contract = 3,934 meter square Final= 10,863 meter square)	The production of this much area of marble has taken more than one year.	1st The designer (Quantification) 2nd The contractor (Even if the bid period is too short to check quantities, the contractor shall check the quantity in the construction time and order the material in the early stage)	Designer and contractor

f. Constructability Issues

As same as the previous case study, the constructability concept is totally not applied and not properly known with the participants. But the following table4.7 states whether the concepts of constructability applied or not unknowingly.

Table 4.7 Application of constructability concepts (Case Study II)

A.A.C.A. Police Commission Case Study II		
Item No	Constructability Concepts	Application
	Constructability Concepts during Conceptual Planning	
C 1	Discussed and documented project constructability program within the project execution plan, through the participation of all parties.	Not applied
C 2	Formulation and maintaining of a project team, including representatives of the owner, engineer and contractor in order to take the constructability issues.	Not applied
C 3	Involvement of individuals with construction knowledge and experience or a contractor in the early project planning and design stages.	Not applied
C 4	Preparing the master project schedule to be construction-sensitive and to be implemented as early as possible.	Not applied
C 5	Discussing and analyzing major construction methods as early as possible inured to accomplish the activities easily and efficiently, and implementing the design according to these methods. This also includes recovery, recycling and final disposal planning.	Not applied
C 6	Site layout should be studied carefully so that construction, operation and maintenance can be performed efficiently, and to avoid interference between the activities performed during these phases.	Not applied

Item No	Constructability Concepts	Application
Constructability Concepts during Design and Procurement Phases		
C 7	Design and procurement schedules should be dictated by construction sequence. Thus, the construction schedule must be discussed and developed prior to the design development and procurement schedule.	Not applied
C 8	The use of advanced technologies to overcome the problem of fragmentation into specialized roles in the actual construction and to enhance constructability.	Not applied
C 9	Design simplification by designers and design review by qualified construction personnel, in order to enable efficient construction.	Not applied
C 10	Project elements should be standardized to an extent that will never affect the project cost negatively.	Not applied
C 11	Simplified and configured technical specifications in order to achieve efficient construction without sacrificing the level or the efficiency of the project performance.	Not applied
C 12	The implementation of modularization and preassembly for project elements should be taken into consideration and studied carefully.	Not applied
C 13	Consideration of Project design for accessibility of construction manpower, materials and equipment to the required position.	Not applied
C 14	Design facilitate for construction during adverse weather conditions.	Not applied
Constructability Concepts during Field Operations		
C 15	Configuring of activity sequences in order to minimize damages or rework of some project elements, minimize scaffolding needs, formwork used, or congestion of construction personnel, material and equipment.	Not applied
C 16	Innovation in temporary construction materials/systems, or implementing innovative ways of using externally available materials/systems that have not been defined or limited by the design drawings and technical specifications for the enhancement of constructability.	Not applied
C 17	Incorporating innovation of new methods in using or modification of the available tools, or introduction of a new hand tools that reduce labor intensity, increase mobility, safety or accessibility to enhance constructability.	Not applied
C 18	Introduction of innovative methods for using the available equipment or modification of the available equipment to increase their productivity to a better constructability.	Not applied
C 19	Improving the project constructability under adverse weather conditions.	Not applied
C 20	Evaluation, documentation and feedback of the issues of the constructability concepts to be used in later projects as lessons learned.	Not applied

4.3.3 Case Study III: Integrated Land Administration, at Addis Ababa

a. Project details

Employer:- Addis Ababa City Integrated Land Administration

Users:- Ten Sub-Cities Land Administration Developments

Consultant:- Addis Ababa City Administration Work Urban Development

Contractor (DB):- Defense Construction and Engineering

Contract Amount (Birr): - 150,000,000.00 (Each ten block 15,000,000.00)

Net Variation approved to date (Birr): - 36,750,000.00

Final Amount (Birr): - 186,750,000.00

Commencement Date: -November 5th, 2008

Original Contract Time: - 365 Cal days

Total Built up Area: - 500m²

Location: - In the ten sub-cities (Similar Package Blocks)

b. Contract Administration Related Issues

Project Delivery Method: - DB

Procurement Type: - Negotiation

Contract Type: - Lump Sum

Condition of Contract: - PPA 2006

Contract Amount (Birr): - 150,000,000.00

Net Variation approved to date (Birr): - 36,750,000.00

Final Amount (Birr): - 186,750,000.00

Percentage Increased: - 24.5%

Commencement Date: - September 2011

Original Contract Time: - 240 Cal days

Actual Completion Time: - 540 Cal days (Up to March 2013)

Percentage Increased: - 125 %

c. Project Delivery, Procurement and Contract Format Related Issues

Regarding the procurement system, the employer has chosen the government design and construction entity and the cost of design and construction is fixed price with negotiation. The client has chosen the government DB contractor with two reasons. The first was the urgency of the project and the second reason was trust on government the entity with respect to quality.

The project delivery method is DB and the contract form is in lump sum. But the condition of contract used for this contract is PPA 2006, which is used for DBB and admeasurements. The miss usage of the condition of contract, created some contract administration problems and as both are government parties, it was solved amicably. In addition the contractor prepared item rated bill of quantity after the completion of final design and has claimed additional cost. Finally the client accepted the bill of quantity and unit rate and also agreed to add the difference amount again as lump price.

d. Design Related Issues

The design was prepared according to the terms of reference (TOR) prepared by the consultant (Another department of the City Administration) and the design progress was checked on each stages.

e. Major Design Problems

The design was prepared according to the TOR and repeatedly checking and modification by the consultant. But the preparation and the checking process doesn't participate the users of the buildings. The lack of participation was not only among the client and consultant; it is also between the design and construction departments of the contractor. Even if the design-build enterprise has two independent design and construction units, the construction unit did not participate in the whole design process.

The construction work was started with partially completed design to expedite the project with achieving one of the main targets , which was urgency. But as it is stated above, the finally the project is delayed with 125%. In addition the major design problems observed in these package projects is discussed in the table 4.8 below.

Table 4.8 Major Design Related Problems with the Reason of Lack of Integration (Case Study III)

Item No.	Design Problems	Description of the Design Problems	Effects of the Design Problems	Cause of Problem	Initiator (Party)	Taken Remedial Action
1	Site work was missed	The site work was missed in the TOR prepared by the employer. And the site work is added as a supplementary contract after the building construction work started.	Long time for design and price negotiation	Proper need identification	Employer	Site work is included in the contract with additional cost and time.
2	Room arrangement and day light	All the buildings have room arrangement and day light problem (some internally oriented buildings have day light problem)	Dissatisfaction of the end user. (The sub-cities Land Administration Departments)	The end users have not participated in the planning and designing stages.	Design-Build Contractor and the Employer	Nothing

f. Major Construction Problems Caused with Lack Integration

Table 4.9 Major Construction Related Problems with the Reason of Lack of Integration (Case Study III)

Item No.	Description of the Construction Problems	Description of the Design Problems	Effects of the Design Problems	Cause of Problem	Initiator (Party)	Taken Remedial Action
1	Sewer pipes leakage problems	The buildings have major problem of internal sewer pipes leakage .	Smell out throughout the building	The main reason was lack of proper supervision either with the design-build contractor or with the employer	Design-Build Contractor and the Employer	Nothing

g. Constructability Issues

Here in this case also, the constructability concept is totally not applied and not properly known with the participants. But the following table 4.10 states whether the concepts of constructability applied or not unknowingly.

Table 4.10 Application of constructability concepts (Case Study III)

A.A.C.A. Integrated Land Administration Case Study III		
Item No	Constructability Concepts	Application
	Constructability Concepts during Conceptual Planning	
C 1	Discussed and documented project constructability program within the project execution plan, through the participation of all parties.	Not applied
C 2	Formulation and maintaining of a project team, including representatives of the owner, engineer and contractor in order to take the constructability issues.	Partially applied
C 3	Involvement of individuals with construction knowledge and experience or a contractor in the early project planning and design stages.	Not applied
C 4	Preparing the master project schedule to be construction-sensitive and to be implemented as early as possible.	Applied
C 5	Discussing and analyzing major construction methods as early as possible in order to accomplish the activities easily and efficiently, and implementing the design according to these methods. This also includes recovery, recycling and final disposal planning.	Not applied
C 6	Site layout should be studied carefully so that construction, operation and maintenance can be performed efficiently, and to avoid interference between the activities performed during these phases.	Not applied

Review on Lack of Integration in Design and Construction Phases of Building Projects and the Effect of Constructability (A Case Study on Selected Public Buildings in Addis Ababa)

Item No	Constructability Concepts	Application
Constructability Concepts during Design and Procurement Phases		
C 7	Design and procurement schedules should be dictated by construction sequence. Thus, the construction schedule must be discussed and developed prior to the design development and procurement schedule.	Applied
C 8	The use of advanced technologies to overcome the problem of fragmentation into specialized roles in the actual construction and to enhance constructability.	Not applied
C 9	Design simplification by designers and design review by qualified construction personnel, in order to enable efficient construction.	Not applied
C 10	Project elements should be standardized to an extent that will never affect the project cost negatively.	Not applied
C 11	Simplified and configured technical specifications in order to achieve efficient construction without sacrificing the level or the efficiency of the project performance.	Not applied
C 12	The implementation of modularization and preassembly for project elements should be taken into consideration and studied carefully.	Not applied
C 13	Consideration of Project design for accessibility of construction manpower, materials and equipment to the required position.	Not applied
C 14	Design facilitate for construction during adverse weather conditions.	Not applied
Constructability Concepts during Field Operations		
C 15	Configuring of activity sequences in order to minimize damages or rework of some project elements, minimize scaffolding needs, formwork used, or congestion of construction personnel, material and equipment.	Partially applied
C 16	Innovation in temporary construction materials/systems, or implementing innovative ways of using externally available materials/systems that have not been defined or limited by the design drawings and technical specifications for the enhancement of constructability.	Not applied
C 17	Incorporating innovation of new methods in using or modification of the available tools, or introduction of a new hand tools that reduce labor intensity, increase mobility, safety or accessibility to enhance constructability.	Not applied
C 18	Introduction of innovative methods for using the available equipment or modification of the available equipment to increase their productivity to a better constructability.	Not applied
C 19	Improving the project constructability under adverse weather conditions.	Not applied
C 20	Evaluation, documentation and feedback of the issues of the constructability concepts to be used in later projects as lessons learned.	Not applied

4.4 Discussion on Case Study

Each of these projects has passed unique challenges and opportunities with regard to the delivery methods and in the design and construction phases. These situations resulted benefits and problems in the life of the projects. The following section will discuss the summary of the outcomes in different parameters.

4.4.1 Project Delivery method and Integration of Design and Construction Phases

The delivery method implemented on the first two projects is DBB and the third one is delivered with DB. According to the study the delivery methods have impact on the performance of the projects with respect to design and construction integration. And the following section will discusses it on each case.

a. Case I

The project delivery method is DBB and the condition of contract was FIDIC Red book, which is appropriate for this delivery method. As it is DBB the design was prepared by the main consultant (the Architect) and by the others engineering designers (Structural, Electrical and Sanitary-Mechanical). The procurement and construction is started after the final approval of the full design. As stated above the lack of integration in the designs and construction observed in two directions. The first is among the different designers like between the structural and mechanical designs of the roof truss of Cinema hall. The other is between the design and construction. Because of this, the main parts of the project like the structure work, finishing and art work took long time for study, procurement and construction.

The other problem of integration of design and construction is observed on the not clear and not well defined client's need , one of these problems is the dissatisfaction of the end users with the capacity of the cinema hall.

b. Case II

The project delivery method is also DBB; the condition of contract was MoWUD 1994, which is appropriate for this delivery method. As it is DBB the design was prepared by the main designer (the Architect) and by the others engineering designers (Structural, Electrical and Sanitary-Mechanical). The procurement and construction is started after the final approval of the full sets of designs.

As stated above the lack of integration in the design and construction observed in three ways. The first is among the supervision firm and the designer. Because of this minor and major design questions, clarifications and modifications were taking long time. The second is lack of integration between different designers, and this is the cause for change and omission of electrical items, aluminum partition and site work. The third is among the design and construction phases, too much increment of marble cladding and taking long time procurement, production and fixing.

c. Case III

The project delivery method is DB and the initially the contact was lump sum, but the condition of contract was PPA 2006, which is appropriate only for DBB delivery method. For instance the PPA 2006 condition of contract sub-clause 1.1 states that the drawings are prepared by the engineer, but in DB the design is prepared with the contractor. As far as this study's reached, there is no local condition of contract prepared for the implementation of the DB project delivery system. But in the international situation, the FIDIC Silver Book is recently used condition of contact for DB delivered projects Nael G. Bunni (2005).

According to the study the client preferred this delivery method with two reasons. The first one is trust on the government entity regarding quality and cost; the second reason is need for short time of completion. But, with regarding the cost, it is increased because of need identification of the client particularly in the site work and with the contractor's claim after preparation of the bill of quantity. Regarding the quality, with in contrary to the employer's interest, the end users are not satisfied. Even if the project is started before the full sets of the design drawings are completed, the final completion of the project is delayed from the scheduled time.

Even if the contract is DB and the contractor organized with design and construction unit, the integration of the two units were not integrally participated in the project. The construction unit has not participated in the design stage and started the project after some drawings are prepared for the construction. The only benefit observed here is the single contract, which decreases the need of resources for the employer to administer the contract.

In general there are two major gaps observed in the contract administration of this project. The first one is miss usage of the condition of contract and the other is the change of the contract form from lump sum to itemed rate and again after price adjustment the contract is tied with lump sum with the

new total price. Even if it is solved amicably the misapplication of the condition of contract created contractual dispute on the final project cost. These two gaps are created with the public bureau which is organized to lead the whole construction and construction related activities of the City of Addis Ababa.

4.4.2 Concepts of Constructability

In the study all respondents have no any knowhow regarding the concept of constructability in the building construction industry. But they agree on the necessity of the concepts stated in the questionnaire, especial on the early involvement of either the contractor or the construction experts as it is suitable for both delivery methods. In addition few of the constructability concepts were implemented in the project unknowingly at the construction phase. And the implementation of constructability concepts in the three case studies is stated as follows.

a. Case I

Preparing the master project schedule to be construction-sensitive and to be implemented at early stage; and configuring of activity sequences in order to minimize damages or rework of some project elements, minimize scaffolding needs, formwork used, or congestion of construction personnel, application of material and equipment in some amount are applied. But most of the concepts of constructability are not applied.

b. Case II

Here most concepts of constructability are not applied except preparing the master project schedule to be construction-sensitive and to be implemented as early as possible.

c. Case III

Here also, most of them are not applied except discussion and development of the construction schedule prior to the design development and procurement schedule and preparation of the master project schedule to be construction-sensitive and to be implemented as early as possible. Even if the ten sites are identical and delivered in one package and it was a good opportunity to implement modular and preassembly way of construction. it is not implemented on these projects . But it will be beneficial for the performance of the project to facilitate efficient production, ease of installation, time and cost saving.

CHAPTER FIVE

5. CONCLUSIONS AND RECOMMENDATIONS

5.1. Introduction

This chapter includes the conclusion and the recommendations that review the design and construction integration and effect of constructability in public building construction projects in Addis Ababa.

5.2 Conclusions

The study is focused on the review of the lack of integration between design and construction design and construction phases of building projects and its effect on Constructability, with focusing on selected projects in Addis Ababa. Based on the objectives of the study the following conclusions are taken out.

1. The case study has shown the lack of integration between design and construction stages in both DBB and Db projects. In both DBB projects the lack of integration is observed between different designers, between the design and construction stages; furthermore in the case study II the lack of integration between the designer and supervision firm is also observed. On the other hand in the case study I, a gap on need identification at the project briefing stage is also observed. These lack of integration and improperly defined need result some problems on the performance of the projects; such as delay, cost overrun, less quality products and dissatisfaction of the end user. In the DB project, even if both the design and construction departments are organized in the construction firm, the two departments have been working separately in the design and construction stages. Hence the lack of integration and gap in need identification and their effects are observed same as the DBB projects.
2. On both DBB and DB projects the lack of construction knowledge and experience in the design stage is observed. The nature of DBB project does not allow the participation of contractor in the design stage. In the other side the main feature of DB delivery method is implementation of both design and construction with the same firm. But in the case study, regardless of the DB contractor has both departments, they have not been doing the design and construction with cooperation. Because of this, the project missed the advantages of DB

delivery methods and faced the disadvantages such as the gap on quality control and assurance. The other main problem observed in the DB project is misapplication of condition of contract. PPA 2006, which is prepared for DBB projects, is used for the DB project. This creates gap in the contract administration and opens for unnecessary financial claim by the contractor. Even if it was settled amicably this gap was also a cause for dispute between the employer and the contractor.

3. The lack of integration between design and construction in either DBB or DB can be overcome by implementing constructability in a project, which is the integration of construction knowledge and experience into design of a project. Constructability is the optimum use of construction knowledge and experience in planning, design, procurement, and construction processes to achieve the overall objective of the intended project. It is a contemporary construction management tool used to increase the performance of projects, and which can save schedule time, money and also have a lot of tangible and intangible benefits. But in the case study, in the three projects all concepts of constructability in the conceptual planning and in the design and procurement phase are not applied. Very few of the concepts are applied in the construction stage.
4. The concept constructability is still not well popular in the worldwide, as it should have been, except in the some developed countries. In the United States, UK, Australia, Nigeria, South Africa and some Asian Countries, the awareness and implementation is in a better state, especially in United States and Australia the concept is growing with the assistance research and development. In Ethiopia the concept of constructability is not implemented and its concepts are not well known in construction industry. According to the case study, the concept is totally not applied and not properly known in the building construction projects.

5.3 Recommendations

Based on the findings of the study, it is shown that the local building construction industry lacks the implementation of project management discipline with respect to the delivery methods and integration of design and construction processes. Accordingly, the following recommendations are presented for improvement of the current practices.

1. As it is vital for successful completion of construction projects, selection of project delivery method shall be the most decisive management decision and needs too much attention. In addition to this selection of the right type of condition of contract for the right type of project delivery method is also need much attention with the public bodies, employers and consultants.
2. Early involvement either a contractor or construction expert with respect to the type of delivery method is very important for the insertion of construction knowledge and experience in the design stage of a project for a better performance of construction project.
3. Further studies on the concepts, benefits and implementation constructability shall be done in order to create awareness and to be beneficiary from the modern thoughts of construction project management.

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APPENDICES

APPENDIX –A

Questionnaire Case Study For Study on

Integration of Design and Construction Phases of Building Projects and its Effect on Constructability

(A Case Study on Selected Public Buildings in Addis Ababa)

I. Type of firm

a. (Eng. Consultant/Developer/Contractor/Others):- _____

II. General Project and Contract Information

a. Project(s) Name : _____

b. Name of Design-Build Contractor: _____

c. Name of Consultant: _____

d. Project Location : (Better to be in Addis Ababa or nearer) _____

e. Type of Client(public/ privet) : _____

f. Project Gross Area : _____

g. Initial Cost of Project(Sign of Contract): _____

h. Final Cost of Project(Close the Contract): _____

i. Initial contract time of the Project (Sign of Contract): _____

j. Final completion time of the Project (Close Contract): _____

k. Under which type of delivery system does the project managed?

[DBB (Design-Bid-Build), DB (Design-build), EPC (Engineer-Procure-Construct) or Turn-Key]:

l. Under which type of condition of contract your project is administered?

[PPA (Local), FIDIC (Which book (Red, Yellow, Orange or Silver))]:

III. Contact Administration Information

a. Why the above project Delivery system is preferred?

b. How are Feasibility, design and construction phases going on?

c. Who prepare the conceptual design? _____

d. Who prepare the final design? _____

e. How does the design approval process go on? _____

f. Who approves the design? _____

g. What is the role of the client in the design work? _____

h. What is also the role of the consultant in the design preparation? _____

i. How is the measurement for payment prepared? _____

IV. Integration of Design and Construction

a. According to literatures, DB has advantage of integration between design and construction phases over DBB (Minimizes fragmentation of the two processes). In your projects, do you fill the reliability of argument?

b. According to literatures, DB has advantage of integration between design and construction phases over DBB (Minimizes fragmentation of the two processes). In your projects, do you fill the reliability of argument?

V. Constructability Issues

Constructability has been defined as: "the integration of construction knowledge into the planning, design, procurement, and construction phase of project in order to increase the success of the execution of the works" (Success on cost, quality and time).

a. In your educational background or past experience do you have any knowledge about constructability or its concept?

b. In your project, have you faced any constructability benefits (Cost, time and quality) because of the early involvement the contractor?

☐ Yes

☐ No

c. If the above answer is yes, what is your understanding about the concept of constructability?

d. Based on your experience. Please select from the following list the barriers to constructability. Check all that apply.

☐ The concept is unknown by the owner

☐ Owners do not care about constructability in the contracting strategy

☐ Design without construction input-bid-construction is the traditional form of contracting

☐ Owners do not choose constructability in their projects

☐ The concept is unknown by designers

☐ Designers lack of construction experience and construction technologies knowledge

☐ The concept is unknown by contractors

☐ Unwillingness of field personnel to offer pre-construction advice

☐ There are no proven benefits of Constructability

☐ Other (explain) _____

e. Where do you think constructability should be implemented? Check all that apply.

☐ Complex Projects

☐ Small Projects

☐ Large Projects

☐ All Projects

☐ Certain type of Projects

f. Do you agree that the participation of contractors or construction knowledge during the design of a project can help to produce better drawings, specifications, and buildable projects?

☐ Yes

☐ Sometimes

☐ No

g. Do you think construction concern should be included as another specialty during the design-phase of the project same as; architectural, structural, mechanical, electrical, etc?

☐ Yes

☐ Sometimes

☐ No

Application of Constructability Concepts during:-

Conceptual Planning Phase

1. Discussed and documented project constructability programme within the project execution plan, through the participation of all parties.
☐ Applied ☐ Not Applied ☐ Sometimes
2. Formulation and maintaining of a project team, including representatives of the owner, engineer and contractor in order to take the constructability issues.
☐ Applied ☐ Not Applied ☐ Sometimes
3. Involvement of individuals with construction knowledge and experience or a contractor in the early project planning and design stages
☐ Applied ☐ Not Applied ☐ Sometimes
4. Preparing the master project schedule to be construction-sensitive and to be implemented as early as possible.
☐ Applied ☐ Not Applied ☐ Sometimes
5. Discussing and analyzing major construction methods as early as possible in order to accomplish the activities easily and efficiently, and implementing the design according to these methods. This also includes recovery, recycling and final disposal planning.
☐ Applied ☐ Not Applied ☐ Sometimes
6. Site layout should be studied carefully so that construction, operation and maintenance can be performed efficiently, and to avoid interference between the activities performed during these phases.
☐ Applied ☐ Not Applied ☐ Sometimes

Design and Procurement Phases Phase

7. Design and procurement schedules should be dictated by construction sequence. Thus, the construction schedule must be discussed and developed prior to the design development and procurement schedule.
- ☐ Applied ☐ Not Applied ☐ Sometimes
8. The use of advanced technologies to overcome the problem of fragmentation into specialized roles in the actual construction and to enhance constructability.
- ☐ Applied ☐ Not Applied ☐ Sometimes
9. Design simplification by designers and design review by qualified construction personnel, in order to enable efficient construction.
- ☐ Applied ☐ Not Applied ☐ Sometimes
10. Project elements should be standardized to an extent that will never affect the project cost negatively.
- ☐ Applied ☐ Not Applied ☐ Sometimes
11. Simplified and configured technical specifications in order to achieve efficient construction without sacrificing the level or the efficiency of the project performance.
- ☐ Applied ☐ Not Applied ☐ Sometimes
12. The implementation of modularization and preassembly for project elements should be taken into consideration and studied carefully.
- ☐ Applied ☐ Not Applied ☐ Sometimes
13. Consideration of Project design for accessibility of construction manpower, materials and equipment to the required position.
- ☐ Applied ☐ Not Applied ☐ Sometimes
14. Design facilitate for construction during adverse weather conditions.

☐ Applied ☐ Not Applied ☐ Sometimes

Field Operations Phases Phase

15. Configuring of activity sequences in order to minimize damages or rework of some project elements, minimize scaffolding needs, formwork used, or congestion of construction personnel, material and equipment.

☐ Applied ☐ Not Applied ☐ Sometimes

16. Innovation in temporary construction materials/systems, or implementing innovative ways of using externally available materials/systems that have not been defined or limited by the design drawings and technical specifications for the enhancement of constructability.

☐ Applied ☐ Not Applied ☐ Sometimes

17. Incorporating innovation of new methods in using or modification of the available tools, or introduction of a new hand tools that reduce labor intensity, increase mobility, safety or accessibility to enhance constructability

☐ Applied ☐ Not Applied ☐ Sometimes

18. Introduction of innovative methods for using the available equipment or modification of the available equipment to increase their productivity to a better constructability.

☐ Applied ☐ Not Applied ☐ Sometimes

19. Improving the project constructability under adverse weather conditions.

☐ Applied ☐ Not Applied ☐ Sometimes

20. Evaluation, documentation and feedback of the issues of the constructability concepts to be used in later projects as lessons learned.

☐ Applied ☐ Not Applied ☐ Sometimes

APPENDIX –B

Interview Questions for Case Study For Study on

Integration of Design and Construction Phases of Building Projects and its Effect on Constructability

(A Case Study on Selected Public Buildings in Addis Ababa)

I. General Project Information

- a. Type of firm (Eng. Consultant/Developer/Contractor/Others)
- b. Project(s) Name
- c. Project delivery method (DBB/DB)
- d. Name of DBB/DB Contractor
- e. Name of Consultant: Project Location : (Better to be in Addis Ababa or nearer)
- f. Type and name of the Client(public)
- g. Project Gross Area
- h. Initial Cost of Project(Sign of Contract)
- i. Final Cost of Project(Close the Contract)
- j. Initial contract time of the Project (Sign of Contract)
- k. Final completion time of the Project (Close Contract)
- l. Under which type of condition of contract your project is administered? [PPA (Local), FIDIC (Which book (Red, Yellow, Orange or Silver))]:

II. Contact Administration Information

- a. Why the above project Delivery system is preferred?
- b. How are Feasibility, design and construction phases going on?
- c. Who prepare the conceptual design?
- d. Who prepare the final design?
- e. How does the design approval process go on?
- f. Who approves the design?
- g. What is the role of the client in the design work?

- h. What is also the role of the consultant in the design preparation?
- i. How is the measurement for payment prepared?

III. Integration of Design and Construction and Project Delivery Methods

- a. In your projects, do you have faced the integration between design and construction phases affected with the delivery method? Explain
- b. Do the phases of design and construction in your project fragmented with the reason of the delivery method? Explain how it happened? Explain

IV. Constructability Issues

- a. In your educational background or past experience do you have any knowledge about constructability or its concept? Explain
- b. In your project, have you faced any constructability benefits (Cost, time and quality) because of the early involvement the contractor? Explain
- c. If the above answer is yes, what is your understanding about the concept of constructability? Explain
- d. Has your organization participated in the conceptual phase of ? Explain
- e. In the project, have you participated in the design-procurement phase? Explain
- f. During the construction phase of the project, do you have applied any constructability activities? List them.