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Chair of Construction Management

COMPARATIVE CONSTRUCTION COST ANALYSIS OF SELECTED DESIGN-BID-BUILD AND DESIGN-BUILD ROAD PROJECTS IN ETHIOPIA

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The undersigned have examined the thesis entitled '**Comparative Construction Cost Analysis of Selected Design-Bid-Build and Design-Build Road Projects in Ethiopia'** presented by **Muluken Shibru Zeberga**, a candidate for the degree of **Master of Science,** and hereby certify that it is worthy of acceptance.

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I certify that research work titled '**Comparative Construction Cost Analysis of Selected Design-Bid-Build and Design-Build Road Projects in Ethiopia'** is my work. The work has not been presented elsewhere for assessment. Where material has been used from other sources it has been properly acknowledged.

Muluken Shibru Zeberga

ABSTRACT

Design-bid-build (DBB) and Design-build (DB) are the two common Project Delivery Systems (PDSs) that have been used widely in the international and local construction industry. For DB projects, during tendering, unlike the DBB's contractor, the responsive design-builder offers a lump-sum amount using incomplete detailed engineering design. Although the DB PDS provides better cost certainty, that certainty may come at a higher premium as compared to DBB. This is because the design-builder allocates a certain risk factor to compensate for the design risk as well as for the lack of information to estimate the work quantities. Previous studies have demonstrated the cost certainty in favor of DB projects than DBB; however, it lacks to examine the amount of risk that comes with cost certainty. To fill this gap, this research undertakes a cost comparison between road projects delivered through the DBB and DB PDS using their cost-per-kilometer. It involves seven road projects (three DBB and four DB projects) tendered by the Ethiopian Roads Authority (ERA) from 2009 to 2017. It used a holistic multiple-case study design, primary sources of data, and document analysis. After ensuring the similarity between the projects, the DB's bill quantities for selected pay items were multiplied by the corresponding nearby and similar DBB's bill item-unit rates. The first, second, third, and fourth case analysis shows that DB projects exhibit a higher cost-per-kilometer and they are found to be 12.7%, 17.1%, 11.6%, and 13.5% costly than DBB projects respectively. Therefore, DB PDS can increase the project cost on average by 13.7% than the DBB PDS. This is also expected from the theoretical justification that, due to the lack of detailed information, the design-builder can be argued to include higher markup for possible risks. As a result, unless the project has a high state of urgency, the DBB PDS is the better option than DB PDS from a static cost performance perspective for the ERA context.

Keywords: Comparative Cost Analysis, Design-bid-build, Design-build, Road Project Costs, ERA, Case Study

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ABBREVIATION

AfDB African Development Bank Group

ASL Above Sea Level

AUC African Union Commission

CII Construction Industry Institute

CMAA Construction Management Association of America

CPI Consumer Price Index

CSA Central Statistical Agency

DB Design-Build

DBB Design-Bid-Build

DBIA Design-Build Institute of America

ECA Economic Commission for Africa

ECI Ethiopian Construction Industry

ECoTMPA Ethiopian Construction and Technology Management Professionals Association

EEA Ethiopian Economic Association

EiABC Ethiopian Institute of Architecture, Building Construction, and City Development

ERA Ethiopian Roads Authority

FDRE Federal Democratic Republic of Ethiopia

FIDIC the International Federation of Consulting Engineers

GTP I Growth and Transformation Plan I

MoFEC Ministry of Finance and Economic Cooperation

NBE	National Bank of Ethiopia
PAF (Pn)	Price Adjustment Formula (Factor)
PDS/M	Project Delivery System/Method
PMI	Project Management Institute
PPP	Public-Private Partnership
TCS	Trauner Consulting Service Inc

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CHAPTER 1: INTRODUCTION

1.1 Background of the Research

The construction industry, in the international and local context, is one of the key economic sectors of a given state. It contributes to the development of a state by creating employment opportunities and increasing national income. This is through the process of bringing construction projects, ranging from simple to complex with many forms, and making ready to the end-users (Ranjan & Hinge, 2015). Its output is mainly used as a platform for other economic sectors and allows them to execute their business (Foulkes & Ruddock, 2007). That is why EEA (2008) noted the '*multiplier effect'* of the construction industry and can be explained through the forward and backward linkages of the industry to other economic sectors (Polenske & Sivitanides, 1990).

The industry involves three key stakeholders during the process of delivering the project for its intended purpose(s). These are Employers, Consultants, and Contractors. First, the employer establishes the project objectives and come up with possible procurement decisions such as *'make-or-buy decision'* (DBIA, 2015; CMAA, 2008). The *make decision* allows the employer to execute the project through its own-force account base and is workable when the employer is equipped with the necessary competencies. Conversely, the *buy decision* allows the employer to obtain the project from the external market based on the contractual basis using the varieties of Project Delivery Systems (PDSs) (PMI, 2016). Second, the consultant evaluates the employer's needs and provides expert advice and opinion on what is to be done. Third, the contractor performs the actual construction work.

PDS is a means through which the relationship between the contracting parties is identified, risk-sharing defined, and their role and responsibilities are outlined to provide the required construction projects for its end users. It has been evolved and takes different forms based on the '*integration of activities between key stakeholders* and *source of finance'* (Casady, *et al.*, 2017). Design-bid-build (DBB) and Design-build (DB) are the two common delivery systems that have been widely used in the international (DBIA, 2015; McWhirt, 2007; Gransberg, *et al.*, 2006; Beard, *et al.*, 2001) as well as local construction industry (Habtamu, 2017; Rahel, 2016; Asaminew, 2013; Wubishet, 2003). The former allows the employer to contract with the consultant for design service and with the contractor for construction work separately. The latter allows the employer to get into a contract with a '*design-builder'* for both design and construction tasks through a single contract. However, both delivery systems let the employer get into a contract with consultants for supervision services.

In terms of processes, the DBB lets a chronological order for the design, bid, and construction tasks. The design consultant is mainly responsible for the detailed engineering design, engineering cost estimation, and bid document preparation. Hence, during tendering, the contractor will be provided with the detailed engineering design and un-priced Bill of Quantity (BOQ) to come up with the unit price for the construction work. On the other hand, the DB allows the overlapping of the design and construction processes to a certain extent. The design-builder is fully responsible to come up with the project cost under a condition where the detailed survey data is unknown.

During tendering, the responsive least bidder will be selected by comparing the contractor/design-builder's offer against the Engineering Cost Estimate (ECE). Particularly to ERA, DB projects have experienced an inconsistent cost-per-kilometer. The variation is observed between ECE prepared during concept design and the lump-sum established by the design-builder for the same randomly selected DB road projects. Contractually, often, the DBB and DB PDS uses admeasurement and lump-sum modes of contracts respectively. Under the admeasurement modes of contract, the final project cost can be determined based on the priced BOQ and is known only when the project is completed. As a result, projects delivered through DBB (using the admeasurement mode of payment) can experience variable project costs. Conversely, the responsive design-builder offers a lump-sum project cost for the DB project under incomplete project information. However, it should be noted that the lump-sum cost kept constant in the absence of scope change. In the event of changes in material and equipment base price, the cost of the projects can be modified using the Price Adjustment Formula (PAF) mentioned in the contract document.

In general, the cost of construction projects is usually determined by recognizing the cost-driving factors such as project-related factors; market-related factors; contractor-related factors; consultant-related factors; client-related factors; and legal-related factors (Mishra, 2018; Cunningham, 2013; Akintoye, 2000; EC, 1998). Specific to road construction projects, these cost-driving factors are the sources of risk factors that determine the project's tender price and/or the final project cost. Further, mostly to the DB PDS, it is also affected by the capability of the design-builder to identify and assess the foreseeable risks before the design is completed. Therefore, as long as the cost-driving factors between the two projects, delivered through different PDSs, are kept similar, it is assumed that they should have similar cost-per-kilometer. Otherwise, the cost difference can be argued to be induced due to the adopted PDSs.

To investigate the effect of PDS (particularly DBB and DB) on the cost of the project, it requires converting the given DB project into DBB format. It involves identifying those cost dictating factors and adjust them accordingly; computing the work quantities for DB projects based on Employer's Requirements; endorsing a unit rate submitted for similar DBB projects; and estimating the project cost. Finally, the cost-per-kilometer comparison between DBB and DB projects can be undertaken and the result will portray the amount of risk allocated during tendering concerning the adopted PDS. Consequently, it helps to investigate the effect of DBB and DB PDS on the cost of road projects.

1.2 Research Problem Statement

Scholars such as Plusquellec *et al*. (2017), Habtamu (2017), Rahel (2016), Asaminew (2013), Shrestha *et al.* (2011), Hale *et al.* (2009), Ernzen and Schexnayder (2000), and Konchar and Sanvido (1998) have compared different DBB and DB construction projects to determine the effect of PDSs on project cost and time performance. Concerning project cost performance, their findings have demonstrated the cost certainty of DB projects than DBB and build a theory such that '*as long as a lump-sum mode of contract used, DB projects always outperform than DBB projects with less or no cost growth'*. Although the DB PDS provides better cost certainty, that certainty may come at a higher premium as compared to DBB. This is because the design-builder allocates a certain risk factor to compensate for the design risk as well as for the lack of information to estimate the work quantities. However, studies have demonstrated the cost certainty in favor of DB projects than DBB; however, it lacks to examine the amount of premium that comes with cost certainty. To fill this gap, this research undertakes a cost comparison between road projects delivered through the DBB and DB PDS using their cost-per-kilometer.

In general, exploring the less costly PDS has a paramount purpose for the Authority to adjust the inconsistent cost-per-kilometer practice and for the scientific society as a knowledge contribution. However, to the knowledge of the researcher, no such cost comparison has been conducted in the Ethiopian context. Therefore, to reveal the premium amount induced by the DB as compared to DBB PDS, this research undertakes a cost comparison between road projects delivered through the DBB and DB PDS.

1.3 Research Hypothesis

Based on the research problem statement discussed in the above section, this study posed the following research hypothesis:

- Although DB provides better cost certainty, that certainty may come at a higher premium as compared to DBB.

1.4 Research Objectives

This study has identified the following general and specific research objectives that help to prove or disprove the above-established research hypothesis:

1.4.1 General Research Objectives

- To investigate the effect of PDSs on the cost of road projects.

1.4.2 Specific Research Objectives

- To compare DBB and DB road projects using a cost-per-kilometer to examine the premium amount that comes with the cost certainty.

1.5 Significance of the Research

Although the finding of this study would help the researcher to understand the nature of PDSs (DBB and DB) and their implication on project cost, it has two main purposes. First, it would help the ERA to deliver DBB and DB projects with a reasonable project cost. This would let the Authority to allocate the public projects efficiently and effectively. Second, it would also help the Authority in condition-based selection between the DB and DBB PDSs.

1.6 Scope and Limitation of the Research

This study focuses only on examining the cost of road projects delivered through the DBB and DB PDSs from the Employer Perspective. It identifies the cost driving factors for road projects under the literature review section; analyzes road projects which exhibit relatively similar scope, and compares DBB and DB projects using their cost-per-kilometer obtained from selected pay items. It does not examine the cost that can be saved using either of the two PDS in line with the project duration.

Although the DB PDS is performance-based, due to the time and budget constraints, the research is limited to measure the intangible benefits (like employer satisfaction and less claim occurrence) that have their implication on the cost of the project. Moreover, it does not also consider the cost that can be incurred or saved during the tendering. Further, due to the difficulties to obtain detailed BOQ for certain work items of DB projects, the result only portrays those pay items addressed in the respective case analysis. The research used ERA's Price Adjustment Formula to account for inflation. The researcher has also encountered a problem accessing consecutive DBB and DB projects and it is also the limitation of this research.

1.7 Structure of the research report

This research report is organized into five major chapters:

- Chapter 1: Introduction – presented the introduction part. It gives the background for the research; outlines the problem statement; points out the research hypothesis and the subsequent objectives. It also defines the scope and limitations of the research.
- Chapter 2: Literature Review – presented the theoretical background of the subject under investigation. It also assessed the context of the study and identified the research gap.
- Chapter 3: Research Methodology – presented the methodological part of the research. Based on the nature of the research, it presents and justifies the research paradigm, research type, sources of data, and means of analysis established for the research.

- Chapter 4: Result and discussion – presented the analysis of the data and discusses it accordingly. The results have been discussed with the conceptual and contextual frameworks of the research.
- Chapter 5: Conclusion and Recommendations – presented the conclusion and recommendation of the research. It concludes from the research analysis and discussion in line with the research questions and objectives.

CHAPTER 2: LITERATURE REVIEW

2.1 The Construction Industry's Overview

The term Construction is defined by the UN (2008) as a set of activities such as '*new work, repair, additions and alterations, the erection of prefabricated buildings or structures on the site and also the construction of a temporary nature'.* It further argues that this definition is applicable while dealing with the construction of buildings, roads, railways, utility projects, and other specialized construction activities. For the case of Ethiopia, FDRE-MoFEC adopted the above definition and classified the set of activities observed in its construction industry into three categories such as residential, non-residential, and other construction works (EEA, 2008). This set of activities with its sorts of management describes the extent of the actual construction industry.

This industry has deployed numerous technologies (i.e., the inputs, processes, and outputs) ranging from simple to very advanced ones throughout its development period. This ability makes the construction industry to put a significant socio-economic, cultural, political, and environmental effect on the development of a given state. From '*its contribution to the economy'* perspective, it is one of the key economic sectors of a given state. Foulkes & Ruddock (2007) restate this statement using two phrases: its '*value to the economy'* as well as its '*value in the economy'*. Its '*value to the economy*' means its role to be a means for growth and sustainable development and a promoter for other industries to do well. On another hand, its '*value in the economy'* is defined by its contribution to the growth of Gross Domestic Production (GDP).

Therefore, it has a multiplier and catalyst effect on the development of a state (Ranjan & Hinge, 2015; EEA, 2008) by contributing to national income, employment opportunities, government revenue. CSIR (2003) and Winch (2002), as quoted by Solomon (2015), argued that in most countries the construction industry constitutes more than half of capital investment, contributes up to 10% of GDP, and accounts for almost 28% of all industrial employment. For the case of the Ethiopian economy, during the first Growth and Transformation Plan (GTP I) implementation period it was account for GDP share rise from 4% in 2009/10 to 8.5% by 2014/15 (ECA, *et al.*, 2018; NBE, 2015/16).

Since the construction industry is project-oriented, the economic benefits mentioned can be attainable through the presence of the project. Depending on the level of ownership and financing mechanisms, all construction projects could be categorized as public projects, private projects, or a combination of these two. Public projects are projects which are fully financed by the public budget and its ownership is forward to the public body. As its name implies, on the contrary, private projects are owned and financed by a private entity. In the middle of these two, based on the two entity agreements, projects could be financed and owned by the public and private entities under the Public-Private Partnership (PPP) arrangement.

According to PMI (2016), the main feature of any construction project is to '*deliver a unique product, service, and deliverable*s' under a specified time frame for the sake of the Employer's specified requirements and objectives. This can be operational through proper project management processes and practices. It includes addressing and managing inputs, processes, and outputs. Hence, planning, choosing, and monitoring the project delivery system is one of the key aspects of construction project management that will determine the successful completion of a given project.

2.2 Projects Delivery Systems (PDSs)

Under the project management umbrella, the Employer should enact either of the two fundamental project procurement decisions: *'make'* or '*buy'* (PMI, 2016). As noted by Hosseini *et al*. (2016), it requires a due care to be taken by the designated entity. Hence, the decision will rationally dictate the way how the projects will be delivered, i.e., delivering projects through either own force-account or contractual basis. The own force account approach is the situation when the Employer decides to '*make*' the project by itself. On the other hand, the Employer can '*buy*' the project by outsourcing the project execution to other entities through procuring service and/or work and/or goods outside of its system based on the available contractual basis (PMI, 2016; DBIA, 2015; CMAA, 2008). Once the Employer decided to '*buy*' the work and/or service, the decision enforces to identify and choose the appropriate Project Delivery System (PDS).

Different scholars have been defining the term Project Delivery System (PDS) in different ways and summarized as shown in Table 2-1 given the next page.

Table 2-1: Definitions of Project Delivery System

S.n	Project Delivery System is defined as	Author and Year
1	the way project owners, regulators, and financiers determine the assignment of responsibilities among project stakeholders along the construction process;	(Wubishet, 2018)
2	an arrangement for organizing and financing the design, construction, operations, and maintenance activities and facilitates the delivery of a good or service;	(Hosseini, *et al.*, 2016)
3	the process by which a construction project comprehensively designed and constructed for an owner referring to all contractual relations, roles & responsibilities of the stakeholders;	(Touran, *et al.*, 2009)
4	a means through which the end product will be delivered to the project owner;	(CMAA, 2008)
5	a set of processes through which the project is designed, constructed, and/or maintained;	(TCS, 2007)
6	the process by which a construction project is comprehensively designed and constructed for an owner;	(Gransberg, *et al.*, 2006)
7	a system that defines the relationships, roles, and responsibilities of project team members and the sequence of activities required to provide a facility;	(Konchar, 1997)

Therefore, by referring to the common features of the definitions given above, for this research, PDS[1] is a means through which the relationship between the contracting parties is defined, and their role and responsibilities and risk-sharing are outlined to provide the required construction projects for its end users.

2.2.1 Evolution of Project Delivery Systems

According to Beard *et al.* (2001), the industrial revolution which is introduced in England (in 1760) and World War II (1939 – 1945) are the two distinct marks for the

[1] Some literature uses the terms Project Delivery System (PDS) and Procurement Method (PM) interchangeably. However, Gransberg *et al.* (2006) argue that PDS describes '*the process by which a construction project is comprehensively designed and constructed for an owner'*, while PM is '*the process of choosing [procuring] designers, constructors, and various specialty consultants*' who are responsible to convert Employer's ideas into an object. However, the research uses the term PDSs uniformly throughout the discussion.

advancement of PDS in the international construction industry context. During the pre-modern period, before the Industrial Revolution, the *Master-Builders*[2] were responsible for both design and construction tasks. Through time, during the Industrial Revolution, the classical delivery method known as DBB has evolved due to the request of specialization. It is manifested by two major tasks. First, the architects and engineers team is responsible to prepare the required design and tender documents. Next, the contractor is responsible for converting the provided drawings into a physical structure (Plusquellec, *et al.*, 2017). As a result, the project needs to be organized sequentially. This happens due to three main reasons such as *project complexity*, *technology advancement*, and *incapability of a single expert*. The points bulleted given below were the main reasons to make a paradigm shift from the Master-builder to Design-bid-build (DBB) concept:

- Task specialization;
- Ability to communicate design intent;
- Division of labor;
- Entrepreneurship;
- Need for capital;
- Emerging of professional Societies; and
- Legal separation (*The Miller Act*, Public Contract Laws, Professional Licensing).

After World War II was completed, a huge amount of construction projects were demanded and this induced problems for Employers in managing the risks associated with the fragmented nature of the DBB delivery system. As a result, the Design-build (DB) PDS is introduced (Beard, *et al.*, 2001). The points listed below are the main conditions that dictate the Employer to deliver projects through the DB PDS (Gransberg, *et al.*, 2006).

- When the compressed delivery schedule is required;
- When a single point of responsibility is required;

[2] The Master-Builder practice dated back to ancient civilization. For instance, in the Code of Hammurabi, clauses ranging from 228 to 233 were dedicated to the Master-builder roles and responsibilities. The code said that if a Master-Builder deviates intentionally from the intended design and the project were not properly constructed, then the builder’s son and slave life will be in danger.

- When constructability considerations are taken into account;
- When special knowledge or experience required;
- When the Employer relies on the builder to optimize technology with the least cost;
- When the project allows site-adapt design;
- When the project is a common commercial facility;
- When the project is beyond the owner's technical capability; and
- When risk can be shared to reduce cost.

As Wubishet (2003) stated, DBB was introduced during the '*Fourth Period*'[3] (1987-1997) of the Ethiopian construction industry history. This is because regulatory framework changes had introduced and as a result, the design and supervision task is divided into two different phases. Before this period, the design and construction tasks were mainly undertaken by the master-builder.

For the case of the DB delivery system, three distinct periods can be noticed. It can be classified into before the establishment of the '*Design-Build Directorate';* after the 'Design-Build Directorate' has been established; and after the unit is restructured under the five regional directorates. Each phase has introduced DB road projects in different intensity and level of management.

The first period is known as a trial period and as per Eshete's (2012) discussion, fourteen road projects were awarded for design-builder. However, both the Employer and the design-builder were not satisfied with the result. Particularly, the design-builder encountered cost and time overrun due to unexpected underground conditions, inaccurate quantity estimation, high rock excavation, and absence of construction materials within the project vicinity that were not considered during the original cost estimation.

[3] While discussing the history of the Ethiopian Construction Industry, Wubishet (2003) has classified the Ethiopian construction industry history into six major periods. According to his argument, pre1968, from 1968- 1982, 1982-1987, 1987-1997, 1991-2001, and 2000-2003 are so-called the first, second, third, fourth, fifth, and the six-period respectively. The first period is known for the foreign domination in the entire construction industry; the second period is known for its establishment and enhancing the capacity building efforts for the local contractors; the third period is known due to its economic policy and capsuled the local contractors under state control; the fourth period is known due to the introduction of DBB; the fifth and six periods are known for well-structured regulatory frameworks.

The second period let the ERA to establish a separate responsible '*Design-Build Directorate'* on its Organizational Structure in March 2010. The unit was solely responsible to manage and administer DB Federal road projects. It was begun by involving two individual experienced consultants. These were responsible to assist in project management and conduct on-the-job training for the Authority's engineers (AfDB, 2013). During this period, more than Sixty DB projects were introduced and the DB delivery system attains a certain level of maturity.

Nonetheless, through a pilot survey made on December 29, 2018, for this research, the Authority assumed that the DB delivery system attains a certain level of maturity, and the unit is wiped out and new and on-going projects are transferred into the previous five Regional Directorates[4]. It implies the beginning of the third period within the ERA context.

2.2.2 Types of Project Delivery Systems

As stated in Section 2.2, determining the appropriate PDS is the main important decision supposed to be made by the Employer. Though it is the task of the responsible entity to select the appropriate PDS that would be compatible with the proposed construction projects as well as its organization capability, it should be noted that it is not an easy task. Further, the chosen delivery system has also an impact on the performance of a given project, and thus DBIA (2015) has recommended the employer to assess the possible impacts thoroughly and considers them during PDS selection. If the appropriate PDS is selected after passing through the above and taking other pertinent information into considerations, then many of the project challenges will be reduced (CMAA, 2008).

Not only identifying the appropriate PDS type is the critical task that should be done by the Employer. The Employer should also understand the type of specification supposed to be deployed on a given project. There are two types of construction work specifications such as prescriptive-based specification and Performance-based specification. The difference between these two specifications usually dictates the type of PDS.

[4] There are five regional directorates such as Northern, Eastern, Southern, Western, and Central Directorates which are responsible for the planning and implementing those road projects chosen to be delivered through the DBB approach.

According to Surahyo (2018) and Gransberg *et al*. (2006), *prescriptive-based* (Closed) specification is a type of specification by which the employer '*conveys the requirements of a project through a detailed explanation of the materials that must be used and the activities and procedures of installing those materials to achieve the result*'. It has a dogmatic nature. Hence, the design should be completed before tender and the selected contractor will execute the construction work based on the design documents and the given specification. On the other hand, *performance-based* (open) specification gives the freedom for the design-builder to design, choose materials and methods of construction for the specified project.

The Construction Industry involves different types of PDSs based on the '*integration of activities between key stakeholders* and *source of finance'* (Casady, *et al.*, 2017). These are Design-bid-build, Design-build, Construction Management at agent (CM@ Agent), Management at risk (CM@ Risk), Integrated Project Delivery, and Public-Private-Partnership (PPP). The PPP is a generic name and it involves further different types of PDSs such as Build-Finance (BF), Build-Operate-Transfer (BOT), Build-Own-Operate-Transfer (BOOT), etc. The DBB PDS is considered as the traditional PDS while the remaining are considered as Alternative PDSs. However, among these, DBB and DB are the two common PDS placed on the continuum of two relative specification extremes: *Prescriptive and Performance-based specifications* respectively.

2.2.2.1 Design-bid-build (DBB)

Under the traditional PDS approach, '*owners must hire architectural and engineering designers separately from builders. They, in response to the owner's programs, prepare 100 percent complete construction documents, also referred to as plans and specifications*' (Beard, *et al.*, 2001). Then, the responsive contractor will be selected through a price competition basis[5] and is liable to deliver the project to the owner as per the plan and specification developed by the other entity.

As its name portrays, the DBB PDS has three basic separated but sequential phases: design phase, bid phase, and construction phase. As discussed in Section 2.3.1, it implies that the given project will be executed *'linearly'* or passes through a sequential basis

[5] Obviously, the technical and financial proposal evaluation is usually undertaken during bid price evaluation.

(McWhirt, 2007; Beard, *et al.*, 2001). Hence, according to the Construction Industry Institute (CII) argument, the Employer should contract with a designer and a contractor separately. As a result, Beard *et al*. (2001) point out that there is an '*an arm's-length*' relationship between the designer and contractor (or implementer). Hence, the Employer is liable to play the referee role.

2.2.2.2 Design-build (DB)

The DB PDS allows the Employer to select an organization that will undertake both the design and construction work in parallel rather than sequentially. Hence, there is only a single contract between the Employer and the Design/Builder. However, just like DBB, the Employer can monitor the progress of the given construction work using a separate service contract with the former consultant (who prepared the concept design documents), or somebody else consultant. But, unlike DBB, this consultant takes the naming so-called '*Employer's Representative*'.

Due to different factors such as '*financing structures, procurement procedures, the level of design at the time the design-builder is hired, the teaming arrangements internal to the DB team, and the responsibility for the operation and maintenance of the end facility*' the DB PDS involves many forms; however, transferring '*single point of responsibility'* for an entity who is liable for '*both design and construction*' is the core feature of DB PDS and this makes it too different from DBB (Gransberg, *et al.*, 2006).

2.3 Key Characteristics of Design-Build and Design-Bid-Build

The two prominent delivery systems such as DBB and DB have key characteristics that make one different from the other. This can be addressed through the analysis of their processes, characteristics, governance structure, pricing techniques, forms of contract, strength, and weakness, and analytical framework. Hence, the sub-sections listed hereunder address these key characteristics thoroughly.

2.3.1 Processes

To present the processes involved in the DBB and DB PDS, it is important to recall the project lifecycle's phases given by PMI (2016). As shown in Figure 2-1, it is the sequence of phases that a project goes through from initiation to handover. Initiation is the first stage to select a feasible project from the alternatives. Development is the second phase that involves organizing and preparing the project by preparing full or partial design documents, specifications, engineering estimates, and other relevant reports. Implementation is the third phase and the main stage to construct or carry out the actual project. Handover is the last phase of the project life cycle and grants the readiness of the project for its intended purpose or operation. Except for the development and implementation phases, the two PDSs share the same features during the initiation and handover phase.

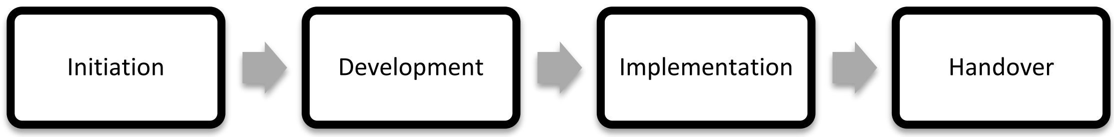

Figure 2-1: Project's Life Cycle

Concerning the DBB, the design and bid processes will be effective at the development stage of the project lifecycle. The project will be constructed at the implementation stage sequentially after the development stage. These three separate tasks are discussed as shown below:

- The **design phase**: at this stage the consultant is fully responsible to provide project design documents ranging from schematic design to 100% completed detailed design. Since the completed design document is the main source to quantify the project's work quantity, the consultant is supposed to provide the design documents with the respective priced or un-priced Bills of Quantity (BOQ). Therefore, according to Ellis *et al*. (1991), these fully (100%) completed design documents determine the scope of a given construction project.
- The **bid phase**: during this stage, the tender documents will be prepared and the responsive contractor will be evaluated and selected after the tender floated for a specified tender period. In other words, according to Gransberg *et al*. (2006) statement, the contractors guarantee the '*[Employer] how much it [the project] will cost to deliver the quality defined in the design within the specified period of performance'* (emphasis added).
- The **construction phase**: at this stage, the above project design will be converted into a tangible physical asset.

Unlike the DBB PDS, the DB PDS restructure the above three sequential processes. The bid phase comes first and the design and construction phase will be overlapped. Hence the responsive design-builder will be selected and is responsible for detailed engineering design as well as a construction task. The DB PDS has eleven processes that could be categorized into the four project life cycle phases. These processes, as shown in Table 2-2, are summarized by referring to Beard *et al*.'s (2001) detailed discussion.

Table 2-2: Design-Build's Processes

S.N	Project Lifecycle	Processes	Basic Outputs
1	**Initiation**	Strategic infrastructure planning	Establishing the project's goals and objectives
		Program definition	Formulating project's requirement
2	**Development**	Request For Qualification (RFQ)	Defining, articulating, and Summarizing project's requirements
			Organizing of Design-builder
		Qualification Statement	Submitting of qualification statement by available Design-builder
			Short-listed best-qualified Design-builders
		Request For Proposal (RFP)	Requesting short-listed Design-builder to prepare the project's design and cost proposal
		Proposal Preparation	Developing a preliminary or schematic design in the forms of drawings, written specification, and physical model
		Proposal Submission and Evaluation	Submitting the required proposal by the shortlisted design-builder and the proposal will be evaluated based on the owner's requirements and other factors
		Contract award	signing a contract and Issuing a notice to proceed with the design work
		Design development and Construction document	Proceeding to develop more detailed engineering design and submitting it for Employer's comment and review
3	**Construction**	Construction	Commencing all elements or specific parts of the project
4	**Handover**	Project Handover	Commission project to the end-user

As discussed in Section 2.1, the construction industry has hosted paradigm shifts from being necessarily sequence-based into relatively sequence-independent PDS. This allows the Employer to establish its requirements which will be elaborated at the Request for Specification (RFS) and Request for Proposal (RFP) stages. Under the DB paradigm, the Employer usually formulates the project’s requirements using either ‘*in-house staff*’ or '*outside consultant*' (Beard, *et al.*, 2001). Gransberg *et al*. (2006) call this outside consultant '*Design-Build Criteria Consultant'* and it has different responsibilities as compared to '*Design-Build Bridging Consultant'* and as well as '*Design-Build Oversight Consultant*'.

The first consultants are '*experts in authoring definitive performance criteria'* and help the Employer at the project initiation stage by developing Request for Qualification (RFQ) or Request for Proposal (RFP). In contrast, the DB Bridging Consultant and DB Oversight Consultant have a role in developing the design content of the RFP and design review and construction supervision respectively. The DB Oversight Consultant is also known as the Employer's Representative.

According to Fernance (2011), Gransberg *et al*. (2006), and Beard *et al*. (2001) argument, the document prepared by the DB Bridging Consultant is known as a '*pre-concept or bridging* document' which used in RFP. It used to communicate with the design-builder and probably contain a 15% to 30% design document. It also provides '*the basis of the design that sets forth their expectations for the design and construction of the project'* (Fernance, 2011). Based on the bridging document, RFQ will be advertised. In response to this, interested Design-builder should submit the qualification statement that describes the team's composition and organization.

Only those potential design-builders (like 3 to 5) will be short-listed and are invited to submit their design and cost proposals in response to the Employer's Requirements. Chronologically, the proposal will be evaluated based on the Employer's requirement which might impose: '*quantity, quality, functional efficiency, aesthetics, and price'* and other parameters. The design-builder who submit a proposal better than the other competitors will be selected and get into a contract with the Employer. Afterward, the detailed project scope is supposed to be defined by the responsive bidder in line with the initial requirements (Gransberg, *et al.*, 2006; Beard, *et al.*, 2001).

Once the design-builder has finished the critical design documents required for the given road section and got approval from the Employer's Representative, then the construction work will be commenced accordingly. In the meantime, the remaining design work will proceed (Plusquellec, *et al.*, 2017; DBIA, 2015; McWhirt, 2007; Beard, *et al.*, 2001). This feature makes the design-builder to introduce a *fast-track* construction method or c*onstructability* issue by overlapping the design and construction activities. As a result, it reduces the project duration and lets the Employer achieve time value opportunity benefits.

2.3.2 Features/ Characteristics

As shown in Table 2-3, paradigm shift, point of responsibility, main parties, level of involvement and control, potential benefits, and potential risks are the six key features that are used to differentiate the DBB and DB PDS. Regarding the paradigm shift, Gransberg *et al*. (2006) stated that the DB PDS '*traces its roots back to the master-builder concept'* through the separation of designer and builder. However, it presents many improvements and forms.

Therefore, the DB evolved the master-builder concept to the institution level through the helical approach rather than making a full circle. This paradigm shift determines the type of governance/organizational structure, point of responsibility, project phases, and level of involvement. Further, it introduces the potential associated benefits and risks.

Table 2-3: Unique features of DBB and DB delivery system

S.N	Features	Design-bid-build	Design-build
1	Paradigm shift	The disintegration of the Master-builder concept	Institutional Master-builder concept
2	Point of responsibility	Fragmented	Amalgamated
3	Main parties	Client, Consultant, and Contactor	Client and Design-builder
4	Level of involvement and control	Need owner's involvement at a higher level	Need owner's involvement at a lower level
5	Potential benefits	Well-defined project's scope before construction	Allow fast-track and constructability
6	Potential risks	Owner bear design risk and overzealous contact administration	The design-builder will bear the risk

2.3.3 Governance Structure

2.3.3.1 DBB's Governance Structure

The governance/organizational structure involved in the DBB PDS is determined by the three sequential project tasks such as design, bid, and build. As shown in Figure 2-2, these tasks are assigned to the designer and contractor separately. The interaction between parties and their responsibilities are designated by different arrow types. The solid double arrows represent the type of contractual relationship between the parties. The upward and downward solid single arrows represent a liability of the consultant to the Employer and the Employer to the Contractor in the case of design error respectively. Lastly, the broken double arrow represents, as per Beard *et al*.'s (2001) statement, '*an arm's-length*' relationship and the liability gap between the designer and contractor.

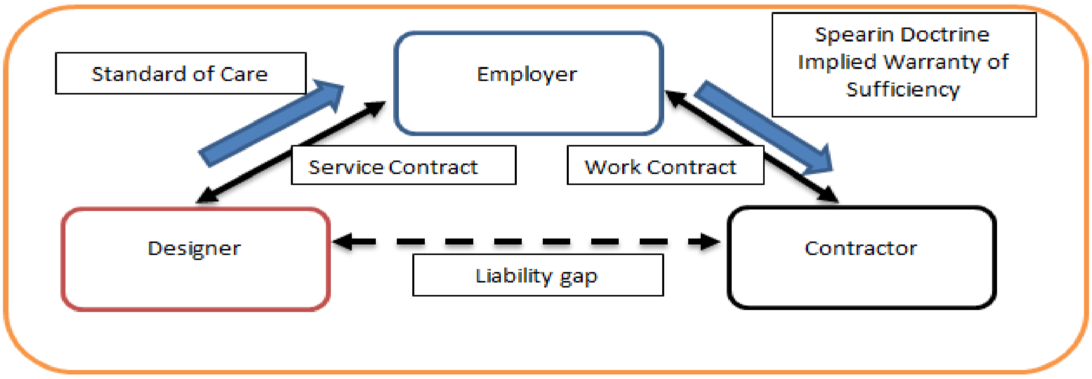

Figure 2-2: Design-bid-build's Governance Structure

Grasberg *et al*. (2006) stated that the consultant is '*legally* [and professionally] *obligated to deliver a project that meets all applicable codes and standards within a reasonable standard of care* [and] *hence, the owner, in essence, owns the details of the design and guarantees that the plans are constructible and free from design errors and omissions*' (emphasis added). As a result, it relieves the contractor from design-related problems and the consequences. This argument is designated by the Phrase so-called '*The Spearin Doctrine*'[6] (Zimolong, 2012).

In general, as shown in Table 2-4 and Table 2-5, the three parties have different responsibilities that allow them to bring the project successfully. Further, each contracting parties execute separate tasks at each project phase, and the required outputs are different.

[6] '*The Spearin Doctrine*'s (roots and name come from a 1918 United Stated Supreme Court decision, United States v. Spearin, 248 U.S. 132 (1918)) states that a contractor will not be liable to the owner for loss or damage that results solely from defects in the plan, design, or specification provided to the contractor.

Table 2-4: Project phase, Required Output and Responsible Party

S. N	Phases	Required Output	Responsible party
1	Pre-design	Selected design firm	Employer
2	Design	Completed design document	Design firm
3	Tender	Estimated project cost & Completed tender document	Consultant
		Accept, open, evaluate, and award project	Employer
4	Construction Phase	Convert the design into a tangible facility	Contractor
		Supervise construction work	Consultant

Table 2-5: Major Stakeholder and their responsibility

Major Stakeholders	Major Responsibility
Employer	Provides financial support to develop the project
	Determine the scope of the work
	Create the necessity to build the facility
	Play a Key role through the process
Engineer	Develops drawings and specification
	Prepare project contract document
	Administer the contract and supervise the work
	Responsible for project design
Contractor	Brings the projects into reality
	Manages different resources to build the facility
	Create the facility based on the design

2.3.3.2 Design-build's Governance Structure

The DB PDS has a governance structure bounded by the two main entities such as the Employer and the design-builder. As shown in Figure 2-3, the solid double arrow represents the contractual relationship between the Employer and the design-builder. Since it advocates a single point of responsibility, the design-builder owns the '*details of the design and is responsible for providing design documents as well as a constructed facility that is free of defects*'. As a result, instead of the Employer, the design-builder will bear the design risk and associated responsibilities for the construction (Gransberg, *et al.*, 2006; Beard, *et al.*, 2001; Lahdenperä, 2001).

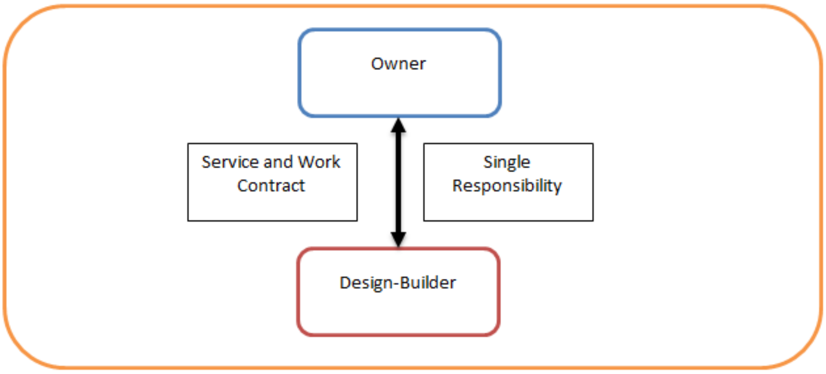

Figure 2-3: Design-build's Governance Structure

Although Figure 2-3 depicts and grant a single point of responsibility, the governance structure can possess different variations depending on the capability of the design-builder. In this regard, Rowlinson (1988) is a pioneer to analyze the Design-builder's governance structures and group them into *Pure*, *Integrated,* and *Fragmented* Design-build governance structure. According to Turina *et al*. (2008), Boudjabeur (1997), and Rowlinson (1988), the Pure DB is a type of governance structure by which the given single entity is fully equipped with the required expertise to execute the design and construction tasks holistically. It advocates for '*holism, a complete and self-contained system*' and can be considered as a '*one-stop shopping service*'. While the Integrated DB entity shares the same features as the former one but it can buy design expertise whenever necessary. Finally, the Fragmented DB entity allows the appointment of external design consultants

Scholars like Gransberg *et al*. (2006), Beard *et al*. (2001), and Lahdenperä (2001) have extended the integrated and fragmented structure classification into a *builder-led*, *design-led*, *joint venture*, and *developer-led* design-build governance structure[7]. Particularly, Lahdenperä (2001) has defined 'Contractor-led DB', 'Designer-led DB', and 'Joint Venture' in the most simplified way as given below.

> Contractor-led design-build means that the party who enters into a contract with the owner for design-build services carries out most of the

[7] They also used the phrase '*integrated design-build'* to refer a company that enters into a contract with the owner for design and build services and has in-house resources for both design and construction. This is similar with the definition given to pure design-build governance structure.

> construction by itself, but involves a separate A/E [Architect/Engineer] to carry out the design as a subcontractor.
>
> Designer-led design-build means that the party who enters into a contract with the owner for design-build services carries out most of the design by itself, but involves a separate contractor to carry out the construction as a subcontractor.
>
> Joint venture design-build arrangement-type refers to a practice where two or more business entities combine resources and form as co-owners a business alliance, which enters into a design-build contract with the owner.

Beard *et al*. (2001) share the above definitions and added one more additional organizational structure which they call '*Developer-led Design-build*'. It shares the same features of contractor or designer-led Design-build but it lacks in-house expertise. Therefore, the Developer who enters into a contract with the Employer for the DB service will carry the design and the construction tasks by subcontracting to other separated design and construction entities.

Therefore, from the above discussion one can note that the main parameters used to categorize the possible organizational structures for the DB PDS are the availability and capacity of design and construction expertise within the given DB firm (Boudjabeur, 1997). If the availability of expertise within the firm is fair enough, then the design and construction work will be executed with the *in-house horizon*. Otherwise, external entities will be entered into a contract with the design-builder to perform the design and/or construction tasks. In general, as shown in Figure 2-4, all DB organizational variations will be fragmented and costly as one goes from the Pure DB to the Developer-led DB.

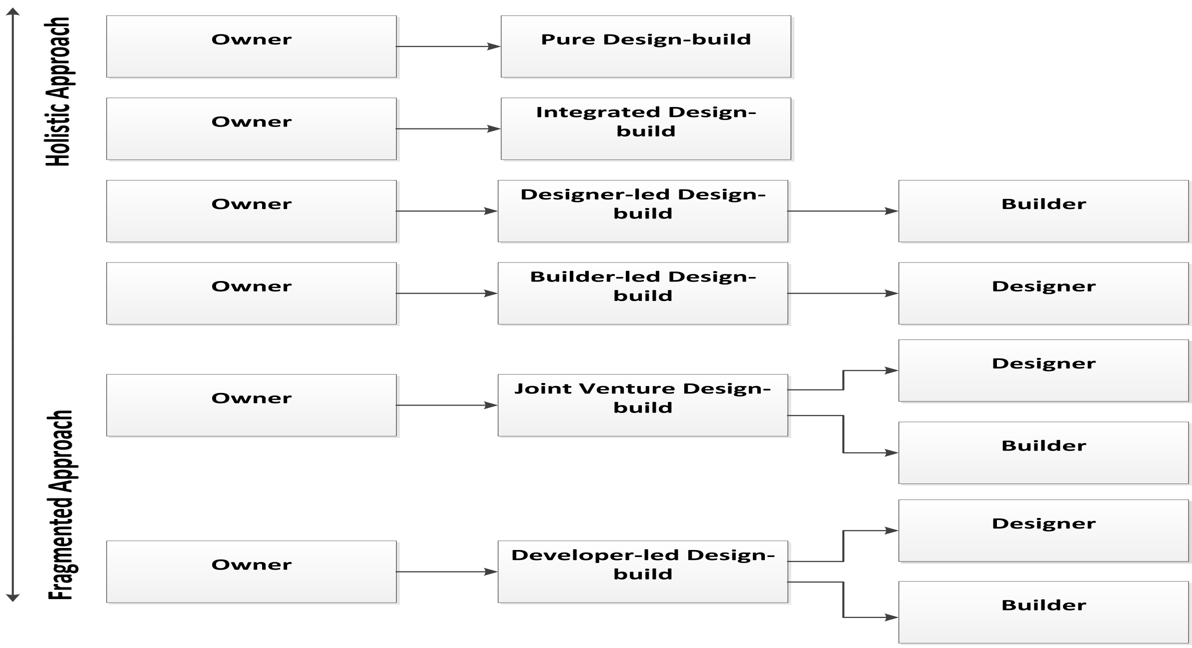

Figure 2-4: Design-build Organizational Structure

2.3.4 Pricing Techniques

Mochtar & Arditi (2000), by quoting Rosenberg (1977) and Bergfield (1961) works, argued that pricing decisions for a specific business are the most difficult but crucial tasks. It is a crucial task because it can decide the company's success or failure. Its difficulty is steamed from the risk and uncertainty events associated with the specific business. This also holds the same for construction companies.

Usually, construction companies are expected to offer the best bid price/cost proposal for the Employer. It is assumed that the offered cost proposal includes the associated risks (uncertainties) and expected profits. Therefore, this is determined through the firm's price strategy (Gransberg, *et al.*, 2006; Mochtar & Arditi, 2000; Akintoye & Skitmore, 1992).

In general, pricing strategy is a process of establishing a rational price offer either to maximize or satisfying the profit under a given scenario (Tellis, 1986). This involves '*establishing pricing objectives, considering factors influencing pricing decisions, examining pricing strategies and competitive responses, attention to methods of price determination, and tactical considerations in setting price*' (Assael, 1985). Hence, pricing strategy is a function of its objectives, factors that affect pricing decisions, and the company's pricing policies. It is used to develop the relevant pricing model and this is summarized by Akintoye & Skitmore (1992) as shown in Figure 2-5.

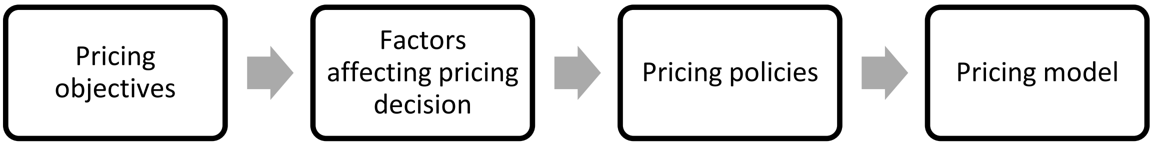

Figure 2-5: Construction Price Determination Approach

2.3.4.1 Pricing Objectives

Having an appropriate pricing objective is the most critical point used to develop a firm's pricing model. It is mainly dictated by the firm's overall business objectives: profit maximization or profit satisfaction. Thus, the price offered by the contractor or consulting firm or a combination of these two has to be logical and strong enough to attain its short or long-term objectives (Geotz, 1985; Shipley, 1981; Davis, 1978). Once the pricing objectives have been addressed, the next step is identifying and assessing those factors which can affect the pricing decision.

2.3.4.2 Factors Affecting Pricing Decision

Empirically it is noted that the project's environment, profitability, the adopted cost estimating techniques, and procurement/delivery systems are the major factors that influence the pricing decision within a given construction project.

- Environmental factors embrace '*key macroeconomic variables such as project's economic, political, social, and technological circumstances'* and a combination of these affect the general business context as well as it '*determines the market situation in the construction industry*' (Akintoye & Skitmore, 1992). The tendering and market price level, construction cost index, level of demand for construction work, the number of construction firms registered, and the degree of competition for construction jobs mainly depends on these macroeconomic variables.
- Project price is mainly a function of project cost and profit margin. Further, the overall firm's capacity, availability of projects, and the level and type of competition between the firms determine the profit margin. That is why the issues

of profitability are usually measured by making a balance between getting the project and as well as making a profit.

- The cost of a project is certainly known when the project is completed; however, the likely cost of projects has to be estimated through different approaches for tendering and other purposes. The estimated project cost and level of accuracy may not necessarily similar for two relatively similar projects proposed to be delivered through different PDS.

2.3.4.3 Pricing Policy

According to Akintoye & Skitmore (1990), the common but acute factors that let the top management to formulate a workable pricing policy are to attain a certain market, to survive during an economic recession, or to penetrate a new market. Mochtar & Arditi (2000) have also identified and ranked eleven different factors that affect the pricing strategies of a given firm. These are project size/complexity, financial goals of the company, company's strength, and weaknesses, expected project on the future from the Employer, need for work, employer's characteristics, project location, demand/economic conditions, competition, owner's consultant characteristics, and subcontractors' characteristics. Therefore, by taking these factors into account, the given construction firm is expected to identify the proper pricing strategy and formulate the pricing arrangement.

An appropriate pricing policy is the best means of establishing a reasonable bid price or cost proposal. It also helps to align the price objective to the overall firm's objectives. In general, it is mostly oriented into three major approaches a *Cost-oriented approach, a Demand-oriented approach,* and *a Competition-oriented approach*.

As per Mochtar & Arditi (2000), Akintoye & Skitmore (1992), and Assael's (1985) discussion, a cost-oriented pricing strategy focused mainly on '*to return on investment'* or '*recoup costs over a particular time'*. It is also used to establish the required total cost of producing that specific product, and add the profit by considering the risk before delivering the product/service to the end-user. In competitive bedding markets, where pre-qualified bidders are selected based on low prices, this approach is very important. However, it lacks a price guarantee; the products can be overpriced or underpriced. The demand-oriented approach aimed '*to meet the expectations of clients and the industry*'. It relies on the '*going price or the customer's perceived value*'. Finally, the competition-oriented approach, also called the '*market-based pricing approach'*, aims '*to retain market share, to discourage competition, and to provide a barrier to entry by other firms*'. According to this approach, the price quoted for the specific product/service mainly depends on market nature.

It implies that a cost-oriented approach is the extreme case of a market-based pricing strategy (Best, 1997; Gabor, 1977). And the other pricing strategies such as the standard rate table-based approach, historical price-based approach, subcontractors' bids-based approach, and cover price[8] are always in between these two extremes (Akintoye & Skitmore, 1992). Nonetheless, it is yet debatable to recommend a better pricing approach due to micro and macroeconomic factors.

Depending on the construction industry structure and its processes nature, for instance, Skitmore (1987) recommended adopting the market-based pricing strategy. Conversely, Mochtar & Arditi (2000) supposed to minimize the weak side of cost-based pricing strategy (being exposed for too high or low pricing) through advocating an alternative pricing strategy; a hybrid of the cost and market-based pricing strategy for the construction industry. However, the above pricing techniques are not merely applicable to all of them. The pricing strategy formulated by the Contractor and Designer may not probably have similar output as compared to the Design-builder. As a result, the given construction firm's pricing strategy which is usually dictated by the cost driving factors would make one PDS costly as compared to the other.

2.3.4.4 Pricing Procedures and Strategy for the Construction Industry

In general speaking, construction project cost estimation is the process of giving an approximate cost that going to be incurred through the process of delivering the project based on certain criteria. Its level of accuracy depends on many factors such as availability of information and its level of completeness, prior experience, macro-economic variables, available resources, the chosen project delivery system, and others

[8] Standard rate table-based approach extract pricing from standard construction price books; historical price based approach uses previous bid prices by adjusting for effects of time and other parameters; Subcontractors' bids based approach allows to submit bid price based on the price offered by the subcontractors; Cover Price approach attained when there is lack of time to develop detail cost estimates (Akintoye & Skitmore, 1992).

issues (Skitmore & Smyth, 2007; Lahdenperä, 2001; Beard, *et al.*, 2001; Mochtar & Arditi, 2000).

Concerning the DBB PDS, the available document project documents such as plans and specifications are the starting point for project cost estimation during a Cost-based pricing approach. Once the detailed project estimate has been obtained, the bid price will be decided by adding a markup or profit. Figure 2-6, adopted from Mochtar & Arditi (2000), depicts the process used to establish the project's bid price.

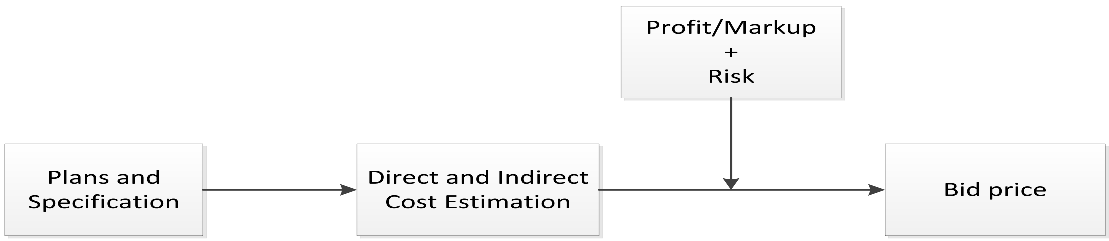

Figure 2-6: Cost-based Pricing (DBB)

As shown in Figure 2-7, again adopted from Mochtar & Arditi (2000), as compared to the above, first-hand project documents such as plans and specifications are replaced by the Employer's requirement and the bid prices replaced by cost proposal respectively. Although the profit/markup incorporates a particular contingency to mitigate the unforeseen risks, it usually incorporates risk factors that have different monetary magnitude and nature as compared to the pricing strategy for DBB PDS.

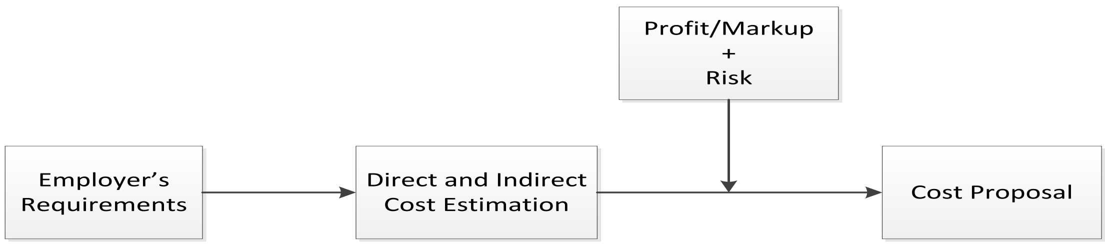

Figure 2-7: Cost-based Pricing (DB)

When the level of the information provided becomes too detail, the project cost estimation also becomes too closer to the actual compilation cost (Gransberg, *et al.*, 2006). As a result, the estimated project cost is not usually kept constant throughout the project life cycle. For instance, in DB PDS, the cost estimation processes involve *feasibility estimates*, *performance criteria estimates*, *conceptual design estimates*, and *detailed estimates* (Beard, *et al.*, 2001). The first three cost estimations are similar to the DBB project cost estimation when the project is at the initiation stage.

- The feasibility estimate is used to determine the feasibility of the project under certain conditions. It let the Employer in allocating an appropriate budget.
- The performance criteria estimate is done without having drawings and detail prescriptive specifications. It requests the estimator to collect sufficient information which is used as a base for the cost proposal.
- The conceptual design estimates were used to quantify the project after developing the conceptual and schematic graphical representation.
- The detailed estimates address the cost which is needed for each component of the projects. This estimate depends on relatively complete drawings, prior experience, accurate historical data, market conditions, previous project cost performance, and level-of-quality performance base specifications, etc.

As per Gransberg *et al.*'s (2006) statement, therefore, the Design-builder is expected to develop and submit their price proposal very quickly based on the Employer's requirements. This could be attained through using some innovative methods such as '*solid parametric database*' that assist to submit the price proposal as quickly as possible; hence, by postulating the associated risks and other factors affecting the pricing strategy to this database, the price proposal can be prepared and submitted to the Employer.

2.3.5 Strength and Weakness of DBB and DB PDS

Knowing the potential strength and weaknesses of PDSs helps to recognize the situation in which one PDS is better than the other. Regarding the DBB and DB PDS, the relative strength and weakness can be assessed based on specification, point of responsibility, cost certainty, tender base price (premium amount), fast-track, constructability, procedures for a change order, and design risks (Mosly, 2016; Fernance, 2011; TCS, 2007; McWhirt, 2007). Table 2-6 summarized the relative strength and weakness of the DBB and DB PDS.

As noted in Section 2.3.3, unlike the DBB, the absence of constructability during the design stage is the main reason for adversarial relationships between the contracting parties. Therefore, the Employer is forced to waste its time in disputes and claims management. The Employer may be also forced to bear design risk due to the low competence of the designer to provide completed design documents, weak expertise level to estimate the true cost and project time, and the adopted procurement method. As a result, project cost and duration growth may be experienced.

Table 2-6: Strength and Weakness of DBB and DB PDS

PDS	Strength	Weakness
DBB	• Full design is made before the project is awarded • Well-defined scope of work • It is well known • The relative ease of implementation • High level of Employer involvement in the design process • Impartial Selection would be attained • Offers marketplace for lower bids • Applicable when fast-tracking is not required • Established procedures for change orders exist • Applicable to a wide range of projects	• Design and construction are sequential • Subjected to an adversarial relationship • Absence of contractor involvement during design • The contractor can claim design errors to recover costs • Requires significant Employer experience and resources • Absence of contractor's input in design and planning • Shared responsibility for project delivery • Cost is known only at the end • Subjected to cost growth
DB	• Cost Certainty • Single point of responsibility • It is a means of fast-tracking • Owner only required to complete preliminary design • Enhance constructability • Reduces change orders • Risk transferred to design-builder • Absence of conflict between designer and contractor • Flexible to accommodate design changes • It requires less owner expertise and resources	• Requires a comprehensive performance specification • Difficult to define qualitative design requirement • Subjected to high bid cost • Design and construction quality may be compromised due to minimal owner control • Limited involvement of the owner in the design process • Claim issues can arise when there is a need for multiple agency approvals on design

2.4 Establishing Project Performance Criteria

2.4.1 Construction Cost Performance Metrics

Wubishet (2003) defines the term performance as a '*means to represent accomplishments through subject-object relationships and their metaphors'*. Based on his discussion, the term performance represents the successful accomplishment of the subject, the objects, or their combinations. Where the people are designated by subject; material(s) and machine(s) including the products are designated by an object; the organization and processes and methods represent the metaphor at which the above subject and object interact to each other and as well as the organization and the processes and the methods itself. Hence, the research defines the term performance by adopting the definition given to object orientation - *how far a given project (i.e., the activities, resources, and processes) is accomplished*.

Exploring the concept of project performance is vital *'to set criteria and standards by which project managers can complete projects with the most favorable outcomes*' (Chan & Chan, 2004). Key Performance Indicators (KPIs) are a set of standards or principles by which the project performance is measured (Sertse, 2015; Chan & Chan, 2004; Lim & Mohamed, 1999). Thus, measuring the performance of a given project is a paramount and strongly recommended practice that should be addressed throughout project management processes (Wubishet, 2003; DeCotiis & Dyer, 1979).

As shown in Table 2-7, project performance is a function of project management and product success. The former aspire for efficiency and the latter for effectiveness (Collins & Baccarini, 2004; Baccarini, 1999). The project's cost, time, and quality are usually used to measure the efficiency of the project or project management success. In contrast, the purpose and goal of the project are used to check its accountability or effectiveness. Further, Solomon (2015) argued to identify the three pillars for project performance such that '*the processes, resource constraints, and the governance system*'. In general, by quoting Kearney and Berman (1999), Wubishet (2003) stated that KPIs have three purposes: *tracking projects* (efficiency-oriented), *accountability* (effectiveness oriented), and *learning*. Therefore, it is very important to identify and decide the perspective from which the project performance can be measured.

Table 2-7: Orientation of Project Success

Description	**Project Performance**	
	Project Management Success	Product Success
Orientation	Efficiency	Effectiveness
Parameters	Cost, Time, Quality	Business benefit or Product Effects

The construction industry usually used KPIs such as cost, time, and quality to measure the efficiency of the project and is usually represented by *'the Iron/Golden Triangle'*. As shown in Figure 2-8, the iron triangle consists of cost, time, and quality in its three vertices and demonstrates the interdependency between them. At a defined scope, any effort made to minimize or maximize one of the vertices elements leads to a possible cost, time, or quality variation.

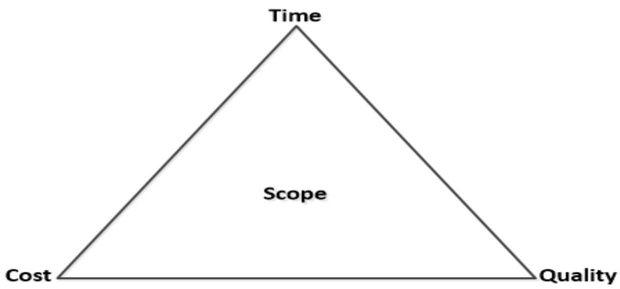

Figure 2-8: Key Performance Indicators (KPIs)

Bubashait and Almehawis (1994), as quoted by Chan *et al*. (2002), define cost performance as the degree to which the conditions promote the completion of a project within the estimated budget. It requires to take any cost the project incurs '*from inception to completion*' into account. As per Gransberg & Villareal (2002) and Chan *et al*. (2002) statement, it can be measured through *absolute, relative, static,* and *dynamic metrics*.

The absolute metrics are the fundamental metrics from which the other three metrics are steamed. Delivery/construction cost, cost growth, unit cost, and cost intensity are the absolute, relative, static, and dynamic cost metrics respectively. The discussion given by Gransberg & Villareal (2002) for the last three cost metrics is given below and summarized as shown in

Table 2-8. In general, relative cost metrics are used to examine how much a given PDS is cheaper as compared to the other PDSs, and the relative metrics examine the cost certainty of a given PDS.

- **Delivery/construction cost** - is an absolute cost performance measuring metrics and refers to the total amount of money incurred from the beginning to the end regardless of the project size or duration. It can be obtained using Equation 2-1 given below:

$$\textbf{Construction Cost} = \textbf{Completion Cost} - \textbf{Intial Cost}$$ **Equation 2-1**

- **Unit Cost** - is a static cost measuring metric obtained by dividing the construction cost by project size regardless of the time effect as shown in Equation 2-2. It could be expressed in terms of the total length of the road for the highway projects and so on.

$$\textbf{Unit Cost} = \frac{\textbf{Construction Cost}}{\textbf{Gross Project Size}}$$ **Equation 2-2**

- **Cost growth** - is a relative cost metric obtained by comparing the initial project cost against the completion cost using Equation2-3.

$$\textbf{Cost growth} = \frac{\textbf{Final Contrcat Sum} - \textbf{Original Contrcta Sum}}{\textbf{Original Contrcat Sum}}$$ **Equation2-3**

- **Cost intensity -** is a dynamic metric that takes the size and construction duration into account. It is used to measure the efficiency of project performance using Equation 2-4.

$$\textbf{Intensity} = \left(\frac{\frac{\textbf{Final Construction Cost}}{\textbf{Gross Project Size}}}{\textbf{Construction Time}}\right)$$ **Equation 2-4**

Table 2-8: Project Performance Metrics and its definition

Metrics	Description	Level of Application	Example
Relative	• Expressed as a percentage • It is project size independent	• Used to compare the small project with the performance of large projects	Cost and Time Growth
Static	• Expressed as a discrete numerical value • It is project size-dependent and doesn't change with time	• Used to compare projects that are roughly the same size	Cost or time per project size
Dynamic	• It is a function of cost and time • It is project size dependent	• Used to measure the efficiency of project performance	Cost per time

2.4.2 Comparative Analysis of Projects Delivered through DBB and DB PDS

A PDS which is adopted for a specific project can affect the project performance in any direction (Tomas, *et al.*, 2002). In this regard, Goftar *et al*. (2014) has summarized the impacts of the DBB and DB PDS on the project's cost, time, and quality performance through *Meta-analysis*[9]. The literature review conducted by Goftar *et al*. (2014) presents the comparison between DBB and DB projects using unit cost, cost growth, delivery time, time growth, and project quality. However, except for the first metrics, the remaining cost, time, and quality metrics are out of the scope of this research. Therefore, Table 2-9 extracted from Goftar *et al*. (2014) report and present the unit cost comparison done by Shrestha *et al.* (2012), Hale *et al.* (2009), Ernzen & Schexnayder (2000), Konchar & Sanvido (1998), Bennett *et al.* (1996), and Roth (1995).

Table 2-9: Unit Cost Comparison for DBB and DB Projects

Reference	Project types	Major findings	Number of projects	Project Location
Shrestha *et al.* (2012)	Highway	DB= $5.1M, DBB=$4.3M	22	Texas
Hale *et al*. (2009)	Military Buildings	DB -4.5%	77	USA
Ernzen &	Highway	DB 2% ↓, DBB 1.2%↑	2	USA

[9] Meta-Analysis is a research method that allows the researcher to reveal the patterns, similarities, and difference between studies around a specific issue by reviewing previously published data and result of studies (Goftar, *et al.*, 2014) and finally to integrates the results of several independent studies to address any trends that could be apparent throughout the whole dataset (Salkind, 2010).

Schexnayder (2000)				
Konchar & Sanvido (1998)	Industrial	DB 6% < DBB	351	USA
Bennett *et al*. (1996)	General	DB 13% < DBB	332	UK
Roth (1995)	NCCF	DB 10% < DBB	6	USA

Shrestha *et al.* (2012) have compared and statically analyzed Sixteen DBB and Six DB projects. They investigated the differences in project performance for large DB and DBB highway projects in cost, schedule, and change orders. The analysis shows that DB and DBB projects experienced an average of 5.1 and 4.3 USD Million per lane mile or 4.3 and 2.7 USD Million per lane kilometer respectively. This implies that the DB projects are 18.6% costly than DBB projects.

Hale *et al.* (2009) have analyzed Thirty-nine DBB and Thirty-eight DB military building projects to see if one project delivery method is superior in regards to time and cost. The study presents the superiority of the DB projects over DBB for cost and all schedule-related metrics. The study concluded that 4.5% cost saving can be attained using DB than DBB PDSs.

Ernzen & Schexnayder (2000) compared two highway projects delivered through DBB and DB PDSs in the USA context. *'The DB project saved 2%, while the DBB project cost 1.2% more than the initial budget. These case studies show about 3.1% cost saving using DB'* (Goftar, *et al.*, 2014).

Konchar and Sanvido (1998) have investigated the effect of PDS on project performance. They have analyzed 351 US general industrial projects delivered through CM at Risk (23%), DBB (33%), and DB (44%) PDS. Numerically, they disclose that construction projects delivered through DB PDS were to be at least 6% less in Unit Cost as compared to those projects delivered through DBB PDS.

Bennett *et al*. (1996) analyzed different 332 projects with U.K. context. The result shows DB projects experienced 13% cost saving than DBB projects. Similarly, Roth (1995) has select and compared a group of six US Naval Child Care Facilities (NCCF) projects delivered through DBB and DB PDSs. The study takes the design, construction, and administrative costs; cost growth; contract modifications; claim, and the procurement time frame into account. The result shows that DB projects have 10% cost saving (less cost-per-bed) as compared to the DBB projects.

Except for Shrestha *et al.* (2012), the above discussions imply that DB projects were experienced on average 7.2% cost saving (less unit cost) as compared to DBB projects. Nonetheless, the above discussion implies that not all of the literature points to superior performance by the DB or DBB PDS (Goftar, *et al.*, 2014). However, it should be noted that all the analyses are undertaken based on the final project cost rather than developing the project cost from scratch using BOQ.

It should be noted that a cost certainty of PDS can grant the absence of work variations but not necessarily how much it is a cost-effective one. Therefore, the cost of certainty of PDS could be expensive or cheapest as compared to the other due to different reasons. Nonetheless, all agree with the timesaving achieved by the DB delivery system.

2.5 Relative factors at which DB is better than DBB against Cost

As stated in the previous section, there is no spotless delivery system. It needs favorable conditions and adjustments to be applicable and successful. But Beard *et al*. (2001) have identified three pre-requests that should be addressed before identifying the conducive factors to select DB than the DBB PDS such as *the needs should exist and identified*, *the needs should be defined*, and *the possible constraints and risk should be recognized*.

The construction industry is well-recognized for its demand dependency. Making sure the existence of the Employer's need is the first and most paramount point during addressing the three prerequisites. In a specific argument, '*the design-build is driven by the owner's needs and not by any limitations on the supply of design or construction services*'.

The DB PDS is required to have a clear and comprehensive Employer's requirements as compared to another delivery system. If the project lacks the Employer's requirement or the need is not well defined, and hence the project performance will be affected. This serves as the most important Critical Success Factor (CSF) for the successful accomplishment of DB projects and is revealed through different scholars' discussions such as Gransberg *et al*. (2006), Beard *et al*. (2001), and Chan *et al*. (2002). Therefore, unlike the DBB, the DB PDS requires a detailed Employer's requirement and also a clear and precise project definition '*prior the design work begins or firm price is determined*' (Beard, *et al.*, 2001).

The last pre-request is to recognize the possible constraints and associated risks. The constraints can be internal or external to the design-builder. Factors such as limitations on resources, staff availability, and their potential are related to the internal capability of the design-builder. While the legal requirements and as such issues are external factors that impose their contributions on the successful accomplishment of DB projects.

Depending on the Employer's and project's specific nature, there are conducive conditions by which the DB PDS can be better as compared to others. The conditions discussed in Section 2.2.1 can be restated here. To mention a few, DB PDS is better to use when time is the main constraint for the Employer, a single point of responsibility is required, constructability considerations are taken into account, the project has a bigger size and complex nature, special knowledge or experience required, the Employer refuses to accept design risk, and the Employer can release the budget progressively (Gransberg, *et al.*, 2006; Beard, *et al.*, 2001).

Most scholars agreed that time-saving is the primary and most benefit of the DB PDS. This is attained because the Design-builder is allowed to introduce a fast-track construction methodology by overlapping the design and construction activities. Therefore, if the Employer required the project within a short period, they are recommended to implement DB PDS.

The project size is usually expressed in terms of its cost – '*cost value of the contract'*. Until it is questioned by Ndekugri & Turner (1994) there was a school of thought so-called the '*garden shed*' school. It considered that DB PDS suitable only for very simple structures such as garden sheds and fails to recall its purpose for the road construction project. Currently, many researchers believe that unless the Employer is a novice and defines its project requirements inadequately the DB PDS would be much suitable for construction projects with a bigger size.

Beard *et al*. (2001) also support the suitable applicability of the DB PDS for too large projects. The logic behind their argument is that bigger construction projects have inherent higher risks associated with construction and design activities. Therefore, the Employer can transfer the design and construction responsibility to the competent design-builder. Tran *et al*. (2016) had conducted an empirical comparison of cost growth between the highways project delivered through DBB and DB based on the project size.

Their research analyzes 2,766 DBB and 210 DB highway projects from five State Departments of Transportation (DOT), including Florida, Indiana, Ohio, Oregon, and Utah. Their descriptive statistics results indicated that DB projects performed better than DBB projects for the project size from $10 million to $100 million. Therefore, it implies that DB PDS is much better for projects with high project size as compared to DBB.

Concerning the project complexity, many scholars mentioned the suitable applicability of the DB delivery system for those complex construction projects which require '*new and untried design solution'*. For instance, '*state-of-art research facilities, high-technology buildings, and manufacturing plants with new technology'* are the best example of the complex project category (Beard, *et al.*, 2001). On the contrary, none of the research mentioned the highway project as a complex project rather than its size.

2.6 Cost of Road Project Construction

Cunningham (2013) states that Employers are alert to some extent about their project should it cost. Initially, they need to know and it's natural; how much the given construction project will be going to cost them and the possible ways to make it any cheaper. As a result, this enables them to make an effective decision.

When the proposed construction project is somewhat large - say road project, financed from the public budget, and subjected to higher public official's approval, the project should be estimated as much accurate as possible. It should be an accurate reflection of reality (Carr, 1989). Of course, the completeness of the project documents and the estimator's level of expertise determine the accuracy of the estimate. Therefore, it should be noted that cost estimating is not a one-time task and exact science. It will be done and refined throughout the project life cycle and used as the baseline of the project's cost (Schmid, 2012).

In principles, construction project cost estimation can be classified into three major categories: *conceptual cost estimation*, *semi-detailed cost estimation*, and *detailed cost estimation* (Schmid, 2012; Elbeltagi, 2009). It contains the continuum of estimates from a project which has an incomplete design to the one which has completed design and specification. Therefore, the availability and completeness of the project information are the main criteria that differentiate one from the other. Ultimately, it determines the project cost or the base bid price.

Empirically it is noted that the Employer uses the term project cost and bid price interchangeably; however, contractors define them in a hierarchal way. As discussed in detail under Section 2.3.4, usually, the construction project cost is obtained by sum-up two major cost types: direct and indirect costs. Direct costs are those costs incurred for labor, materials, and equipment. On the other hand, the site overhead and general overhead cost determine the indirect cost. Finally, the markup such as profit, risk allowance (contingency), and finance charges will be added to the construction project cost to determine the base bid price. However, the research considers the cost of a project as a function of direct cost, indirect cost, markup, and the finance charge. It could be an item rated cost for DBB projects or a lump-sum cost for DB projects.

In principle, cost estimation requires taking key cost-driving factors and assumptions into consideration. It also demands the estimator to carry out rigorous analytical computation to arrive at better accurate cost estimation. Hence, as the detail of the project and factors that affect project costs are known better, the level of precision can be improved accordingly.

Sinclair *et al*. (2002) stated, by quoting Dubner & McKenzie's (2002) study, that the cost of a given construction project is commonly estimated using a Bills of Quantity (BOQ) method and it has more advantage over the other methods. The BOQ is usually organized into bill items that include a list of work items that have a similar work nature. It encompasses each element of the bill items and discusses the specification of the project, the unit of measurement, the estimated work quantity, the unit price, and finally the work amount. The cost of a road construction project offered by a responsive contractor or design-builder is a function of the amount of quantity and unit rate. The amount of work quantity is mainly extracted from the design documents. On the other hand, the unit rate is obtained after taking different cost elements and factors into account (PMI, 2016).

Recalling the definition provided to detail cost estimation, the product of the detailed quantity and its corresponding unit rate gives the cost of items of work. Nonetheless, these two main variables (i.e., quantity and unit rate) are usually influenced by cost dictating factors. Work quantity mainly depends on the completeness of project information; while the corresponding unit rate is a function of cost, productivity, and availability of resources. Therefore, the quantity survivor is responsible to assess cost-driving factors thoroughly and estimate the project cost precisely.

2.7 Key Factors That Dictate the Cost of Road Projects

The key factors that dictate the cost of road projects can be absolute or relative. The absolute cost factors are those factors that command the initial cost of road construction projects during detailed cost estimation; while, the latter affiliate with the cost performance as an increase/decrease concerning the initial budget. With relative cost factors, a review of the literature shows that extensive studies have been undertaken in identifying key cost factors that affect the cost of the project against the initial cost. Conversely, there are limited studies about the absolute cost factors. Even these limited studies try to address cost-driving factors for the construction projects in general and infrastructure and building projects in particular. This implies that the key factors that dictate the absolute cost of road construction projects not yet addressed holistically.

Nonetheless, the key factors that can determine the absolute cost of a road construction project can be identified systematically. These involve identifying and extracting factors that are also common for the road construction project by referring cost estimating manual developed by local and international agencies and as such related sources. Sources like '*A User's Guide'* developed by the European Commission in 1998; '*Factors Influencing the project Cost Estimating Decisions*' and 'Analysis of *Factors Influencing Project Cost Estimating practice*' studied by Akintoye in 1999 and 2000; '*Factors Affecting the Cost of Building Work - An overview*' conducted by Cunningham (2013), and as such studies were reviewed to identify key factors that dictate the cost of road projects as discussed in the next section.

EC (1998) listed eight key determinants that affect the cost of infrastructure projects when the project is at the initial stage. It also identifies ten key factors that affect the cost during the construction period. It states that the initial absolute cost of an infrastructure project is dictated by the project specification, project location, site characteristics, type of work (New or improvement), form of procurement/contract, tax liabilities, timescale, and inflation.

Akintoye (2000) has conducted an empirical study to identify major factors that can influence the cost estimating decisions of construction contractors in the United Kingdom (UK) context. The study discloses the ten most important factors and recommends cost estimators to take these factors into account. These factors are the complexity of the project, scale, and scope of construction, market condition, method of construction, site characteristics, client financial position, durability, location of the project, and form of contract.

Similarly, Cunningham (2013) outlines twenty-nine key factors affecting the cost of building work within the Irish context. These are client priorities, quality consideration, cost consideration, time consideration, the nature of the project, the choice of the designer, the function of the building construction project, the cost of design, choice of material, attitudes towards sustainability, the nature of the site, location of the project, physical site considerations, availability of services, resource availability, climate, the method of procurement, payment arrangement, tendering arrangement, the clarity of requirements, legislative constraints, environmental considerations, market conditions, method of construction, labor cost, productivity, material price, site overheads and the project program.

Mishra (2018) also identifies fourteen factors that affect construction cost estimation. These are similar construction projects, construction material cost, labor wage rates, construction site conditions, inflation factor, project schedule, quality of plans and specifications, engineer's reputation, regulatory requirements, insurance requirement, size and type of construction project, location of construction, engineering review, and contingency.

The factors mentioned by different scholars as listed above; concerning the cost of construction projects rather than the estimation technique and process, are interlinked with each other and have a cause and effect relation. Most importantly, almost all factors mentioned above are also observed practically in road construction projects. Furthermore, for the sake of simplicity, they can be grouped into seven major categories: *Client related factors; Contractor related factors; Designer related factors; Project-related factors; Market attributes related factors; Legislative-related factors; and other factors*.

It is also important to notice that some of these factors encompass other sub-divisional factors. Hence, Figure 2-9 (the fishbone diagram) was developed through content analysis after analyzing the frequency of cost-driving factors identified by former scholars. It represents the causal relationship between these factors by taking the cost of a road construction project as an effect.

In general, the literature review shows that, though most of the above factors are interlinked to each other, they are mainly affected by three main factors such as physical characteristics, market conditions, and work methodology. Therefore, a good project cost estimation demands to know, *inter alia*, the key project characteristics that affect the cost, market attributes that affect price/cost as well as methodology to be adopted in executing project work. It could be also discussed against selected ERA's bill items tabulated by Table 2-14 given in Section 2.9. However, Table 2-10 given below summarizes the relationship between the cost elements and the key factors that affect the absolute cost.

Table 2-10: Key Factors that affect the absolute cost

Cost Elements		Key factors that affect the absolute cost		
		Project Characteristics	Market Condition	Work Methodology
Direct Cost	Labor cost	√	√	√
	Material cost	√	√	√
	Equipment cost	√	√	√
Indirect Cost	Site overhead	√	√	√
	General overhead	√	√	√
Markup	Profit	√	√	√
	Contingency	√	√	√
	Financial costs	√	√	√

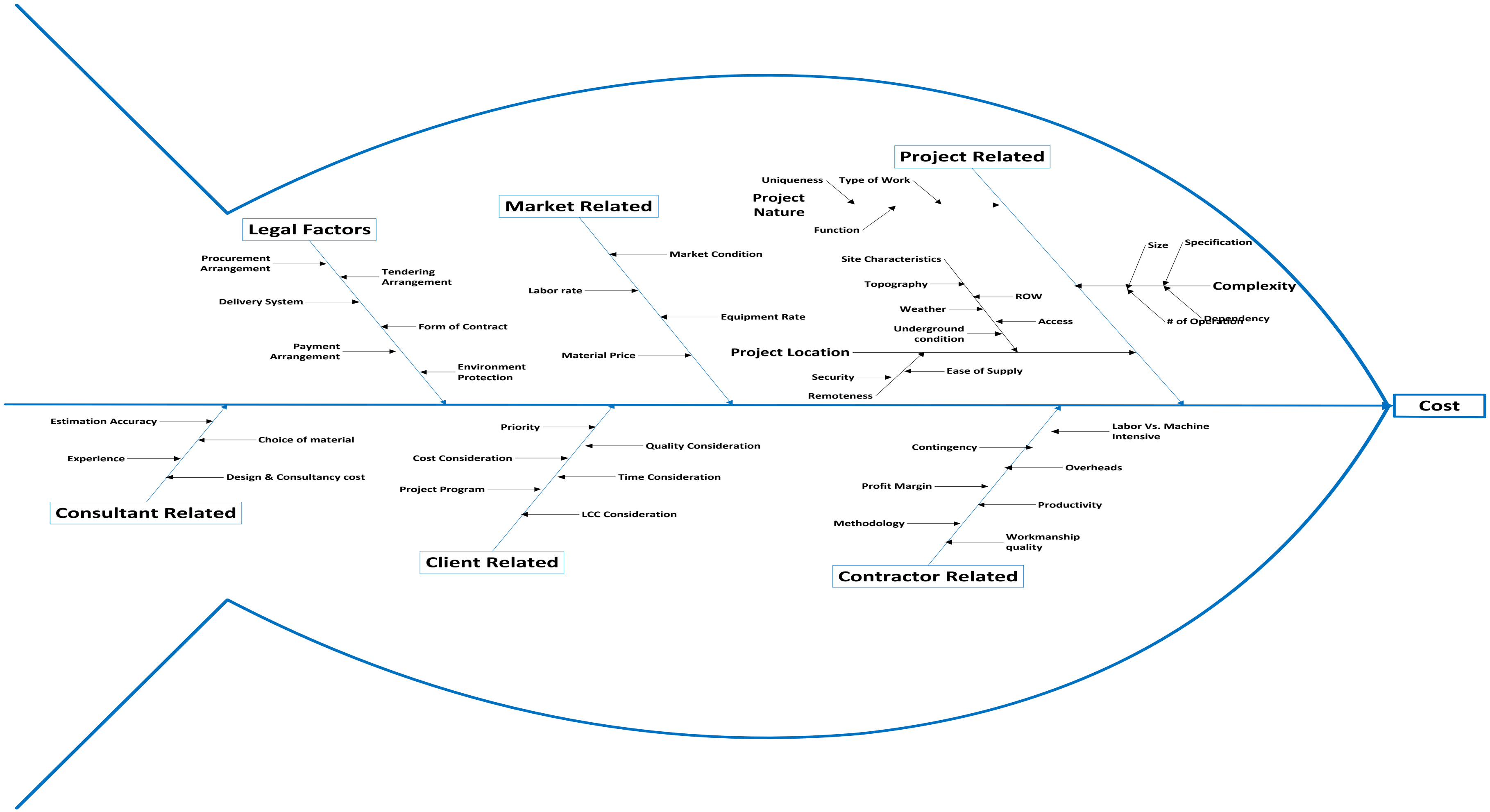

Figure 2-9: Factors That Affect the Cost of Road Project

2.7.1 Project Physical Characteristics

As per Mahamid (2013) discussion, the physical characteristics of a project is usually described through its project size, road length and width, terrain conditions [through which the road section is going to pass], soil and rock suitability [of the actual road section site], and soil and rock drillability. Hence, these and as such refined factors can be categorized into three basic parts such as project nature, complexity, and location. They are key attributes of project physical characteristics and have a direct relation with the cost of road construction projects. As shown in Figure 2-9, project-related factors depict that the cost of road construction projects is mainly influenced by the nature, complexity, and location of the project. Each of these key project factors can be also affected by other factors.

2.7.1.1 Project Complexity

Understanding the project nature and its level of complexity helps the Employer as well as the project manager to improve their decision making and ways of goal attainment (Remington, *et al.*, 2009). However, the definition given to project complexity is not yet cleared and different scholars have been defining differently what is mean by project complexity. Starting with Baccarini (1996), project complexity is not merely related to the project characteristics such as size and uncertainty rather explains project complexity concerning the number of interrelated parts and how they '*can be operationalized in terms of differentiation and interdependency*'. On the other hand, Gidado (1996) considers project complexity as the measure of the difficulty of executing a complex construction process.

Nonetheless, by considering the above discussion, any type of construction project is usually considered as complex due to the state of being formed by the interaction of various inputs. The state of being difficult to understand the number of inputs and their interaction greatly influences the accuracy of the project cost estimation as well as the actual project cost. In this regard, Remington *et al*. (2009) and Akintoye (2000) consider project complexity as one of the most ranked factors influencing cost estimating decisions.

More in detail, by quoting Bennett & Fine's (1980) report, Akintoye (2000) stated that the project work breakdown, unit costs, and durations are influenced by the size of the project. The size of the project not only means by the project size that can be described numerically, rather it requires more resources and activities that should be interrelated. This enables him to elaborate on Baccarini's (1996) argument. As per his statement, the project complexity is usually manifested through the technical complexity of the task, the amount of overlap and interdependencies in construction stages, project organization, site layout, and unpredictability of work and site conditions.

As per Turochy *et al*. (2001) and EC (1998) statement, the road project specification defines the physical attributes of a project. These physical attributes are mainly determined by the forecasted volume and type of traffic and encompass the length, depth, and width of the road pavement. It also involves the material to be used for the surfacing and the type and number of structures. Hence, the project will be more expensive when the project specification is too detailed and complex. Therefore, for this research, the project complexity can be viewed in terms of the size of the task which determines the scale and scope of the road construction project; the technical complexity which emanated from the project specification; and the number of operations and their dependency.

2.7.1.2 Project Nature

While the ultimate purpose of the road is to provide access, but their nature is different based on their function, types of work, and uniqueness. Usually, the political, economic, social, technological, environmental, and legal aspects of the project can determine the function of the project. A road which is designed for high traffic density area has different features against the one which is designed for low traffic density. Hence, the function of a project and its level of uniqueness determine the project's nature along with the type of work (Cunningham, 2013). The work type can be new construction, rehabilitation, or upgrading. The proposed pavement type can be Asphalt Concrete (AC), Double Bitumen Surface Treatment (DBST), Cement Concrete (CC), or gravel road.

EC (1998) point out the nature of the given construction project concerning its impact on project cost. New projects may not necessarily require construction costs like improvement or upgrading. It is also unwise to maintain a damaged road section with a relatively higher cost as compared to the cost of new construction. Hence, these things have a contribution to the cost of road construction projects. Further, when the proposed road construction project is unique and can not be constructed using the available professionals and equipment, and the cost of the road project will be higher than the same size road project. That is why the cost of road projects, say in ETB/Km, has a different figure for different PDS.

2.7.1.3 Project Location

The location of a project can also affect the cost of road construction. It can be through '*institutional factors and geographical realities'* (EC, 1998). The institutional factors such as '*consent procedures, allowance for public construction services, and cost allowed for environmental mitigation measures*' request the responsible entity to plan and schedule necessary resources which could be expressed in terms of monetary value. Some of these factors can be categorized under the indirect cost of a road project. On the other hand, the geographical realities of the project reveal the physical location at which the project is supposed to be located with many possible variables. These variables can be presented through a discussion that can portray the actual site characteristics and the relative distance between the project and the necessary resource locations.

Site Characteristics

Cunningham (2013), Akintoye (2000), and EC (1998) have discussed the multiplicity of factors and limitations induced by the place where the site is located, the condition it conquers, and the difficulty it poses for easy access. It includes distinguishing variables such as site topography, underground conditions, Rights-of-Way (ROW), weather, ease of access, and security issue. Each of these variables dictates the cost of road construction projects. Hence, it implies that these variables should be thoroughly checked to undertake a proper decision. As a result, decisions regarding the geometric design will be relying on these findings.

For instance, the topography and underground conditions determine the volume of earthworks. Cunningham (2013) believes that

> heavily sloped sites require extensive stepping or cut and fill operations and such sites may be dangerous and adversely affect the working conditions and productivity of operations and plan output. A site with poor load-bearing capacity will require a more extensive foundation while exposed or waterlogged sites will also reduce overall productivity.

Since road construction is a horizontal construction and follows the natural ground slope, it is highly affected by the type of the topography (or terrain type) and poor ground conditions. Hence, the terrain type, as well as the underground condition, needs to be identified before a road is designed. According to ERA's Geometric Design Manual, released in 2013, the natural terrain type is classified into four categories based on the number of contours per km. If 0 to 10, 11 to 25, 26 to 50, and above 50 contours spaced with 5 meters are observed per km, then the terrain will be classified into Flat/plain, Rolling, Mountainous, and Escarpment respectively. The more difficult topography and underground condition encountered the more project would it cost. Similarly, the presence of unforeseen ground conditions also affects the cost of the road project. Table 2-11 given below summarize the terrain type, slope range, and the corresponding description.

Table 2-11: Terrain Classification

S.n	Terrain Type	Slope	Description
1	Flat / Plain	up to 5%	Flat /gently rolling, less obstacle for Geometric features
2	Rolling	5-25%	Hilly of foothill, rise & fall slope, some restriction to GDF
3	Mountainous	25-50%	Rugged, hilly, mountain & river gorges, impose a restriction
4	Escarpment	> 50%	Require special geometric standards

Probably there would be many towns and villages located within the right-of-way of roads due to the peculiar socio-economic conditions of the areas. The ROW issues are usually related to the house, fence and gates, farmland, trees, and utilities that can be affected by the road section. These elements could be owned by private or public entities; however, they should be compensated. It is the most prevailing factor that affects the cost as well as the duration of the road project. Concerning the remoteness, a project site located at a remote place is not highly affected by the ROW due to less presence of the above-listed elements. However, the cost of resources can be increased dramatically due to the difficulty of access to the local market (Cleveland, 1995).

Adverse weather/climate condition is also the other parameter of site characteristics. Hypothetically, for instance, two projects: *'Project A'* and *'Project B'* could be constructed at two different locations which have similar site characteristics except for the climate conditions. Due to only *'project A'* is exposed to adverse weather conditions, its cost is higher than *'Project B'*. Therefore, the climate and weather condition of the specific location has its impact on the project cost (EC, 1998).

Security is also the other component of specific site characteristics manifested by the socio-political setup of the project area. No one will not be interested, and it is natural, to work at a place where security is a big issue. But, if constructing the road project is a must due to emergency or the other twinge situations, then the contractor or design-builder will be forced to bear the foreseeable security risks by allocating reasonable monetary value for the compensation. Thus, automatically, the cost of road construction will be high.

Availability of local materials

According to Mathew's (2009) statement, road pavement is a structure consisting of layers of processed materials above the natural soil subgrade and whose primary function is to distribute the applied vehicle loads to the natural subgrade. Depending on the load transferring system and the materials used, a given pavement could be flexible (AC and DBST), rigid (AC), or a composite of these two. Flexible and rigid pavement transfer the applied vehicle load to the subgrade through grain-to-grain connection and slab action respectively. In terms of the binding material, flexible pavement uses Bitumen. While Portland Cement (PC) is used for rigid pavement. Therefore, the composite pavement is made by applying a thin layer of flexible pavement over the rigid pavement.

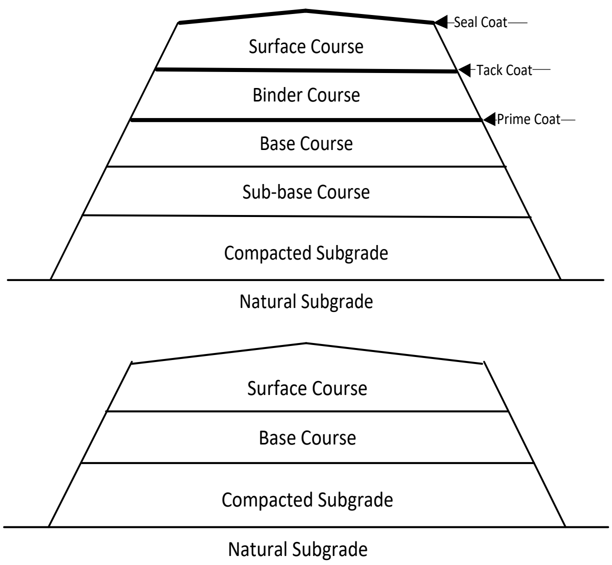

Figure 2-10: Typical Cross-section for Flexible and Rigid Pavement

In general, whether it is flexible or rigid, a given pavement should safely transfer the vehicle load to the subgrade by having sufficient thickness. Figure 2-10 shows a typical flexible (on the left side) and rigid (on the right side) pavement cross-section. It comprises layers of materials with variable thickness, different material types, and quality. Materials placed on the top layers should have excellent quality as compared to materials used for lower layers to withstand the compressive stress, wear, and tear.

Based on the method of construction, flexible pavements can be attained through Bitumen Surface Treatment (BST) or Asphalt Concrete (AC). In both cases, binding materials and aggregates are used but in different ways to produce the intended pavement. In addition to its binding purposes, as its name implies, materials such as emulsion, cut back, and asphalt cement is also used as a waterproofing and surfacing purpose. The aggregates such as crushed rock, aggregate, sand, and slap are the granular materials used differently during pavement layer construction.

BST and AC pavement have different design standard as well as work approach. In principle, BST is the process of creating a thin layer of bitumen using a pressure distributor on top of the road surface. It followed immediately by an application of mineral aggregate and finished by rolling. Depending on the repetition of this process BST could be Single, Double, Triple, Racked-in, and other. However, it is not a pavement by itself and intended to increase the strength of the existing base rather it is used to protect the underlying pavement structure from changes in moisture and abrasion by traffic (ERA, 2013; Burke, 1994).

On the other hand, AC is the other type of flexible pavement made from aggregates and asphalt cement. The aggregate and asphalt cement constitutes 90 - 95% and 5 - 10% of the total mixture of the asphalt pavement respectively. Usually, these pavement materials are mixed at a specified Asphalt Batching Plant (ABP) and hauled to a project site using convenient hauling means. Depending on the temperature, AC is classified into Hot Mix Asphalt (150^0c - 190^0c), Warm Mix Asphalt (20^0c - 40^0c), Cold Mix asphalt (don’t require heat) (Speight, 2016).

In general, a typical road pavement requires a substantial volume of materials that could be grouped into bounded and unbounded materials. The bounded material involves binder materials such as bitumen and portland cement. Other materials such as sand, soil, natural gravel, and crushed rocks are the unbounded material. In addition to these, materials such as stabilizers and water are also important materials for road construction.

The presence or absence of the above pavement materials within acceptable distance is critical for the successful accomplishment of road construction. Gautam *et al*. (2013) argue the cost advantage of using the local source of base materials in pavement construction. But it requires ensuring its suitability for the given project as well as compliance with the standard specification. A reserve of high-quality materials could not be always adequate in a given project location and it would be a must to haul from the prevailing quarry site. Therefore, hauling distances have a major impact on the final cost of the works (Johannessen, 2017; Cunningham, 2013; EC, 1998).

Therefore, the relative distance of the project from the source of materials such as sand, stone, and water; from the batching plant; from the suppliers; from the waste material damp area; from camp and required facilities; from client access; from the contractor’s other projects and head offices; from security officials is the critical parameter that determines the cost of the road project. Hence, the direct relationship between the cost of the road project and the relative distance between the project location and the above-mentioned elements is an undeniable fact. The more the project is located in a remote area the more expensive it will be. That is why Cleveland (1995) recommends analyzing thoroughly and completely the remoteness of the site from the local market while dealing with the project cost.

In general, road construction projects are merely exposed to the above realities. The direct as well as the indirect cost is highly affected by the project's geographical location. For instance, with the site overhead cost, the cost is supposed to be incurred for resource mobilization, camp establishment, utilities, office consumables, office furniture, and types of equipment highly affected by the remoteness of the project location. Under extreme conditions, the contractor could be forced to assign highly paid professionals for a single site and it would be difficult to use them by rotation. This leads the contractor to submit a high bid price. Therefore, the quality of these materials and their level of availability within a reasonable distance are the critical factors and it should be taken into consideration during developing the cost of a given road project.

2.7.2 Market Condition

The construction industry is highly affected by changes in economic outlook and activity in the local and national economy. Construction activities increased during the general economic growth and decreased during the economic recession. The bid price submitted by the contractor for the given road construction project depends on the number of works available on the market. This affects the contractor’s profit margin and as a result, the project cost too (Cunningham, 2013).

The effect of market conditions can be easily identified on the cost of road construction projects. The trends in the market conditions and its implications on the cost of the resources for the project need to be assessed thoroughly. The market attributes that determine the cost of road construction projects are related to material, labor, types of equipment, and plants. Their price/cots, availability, supply, quality, performance, productivity, and physical conditions are the key parameters used to discuss the effect of market conditions on the basic construction resources. Further, the interest and inflation rate and as well as the stability of the market condition also define the market condition (Elhag & Boussabanie, 1999).

It is also important to notice the relation between project location and market attributes. As discussed in the above section, projects located at remote sites request a high cost of transportation. The inherent nature of the market condition such as stability and its dynamism describes the market condition in a very well manner. When the resources are supposed to be imported from the international market using foreign currency, then the cost of the project will be increased dramatically.

2.7.3 Work Methodology

Although the market attributes, the project location, and other related factors dictate the cost of road construction projects, ultimately the cost of the road construction project is highly determined by the responsive contractor. The bid price submitted by the successful contractor is obtained mainly due to the cost of resources, productivity, and management. In this regard, Akintoye (2000) has mentioned that the construction program, organizational structure, and successful execution of the project is affected to a large extent by the work methodology.

Work methodology is a proposed road map to deliver the project to the Employer by utilizing the available resources to its acceptable productivities. It describes in detail how the contractor planned to execute the projects with the available budget and time horizon. It discusses how the contractor plan to organize the project; establish its camp and facilities; select the supplier; transport and stock the materials; form the crews with the optimum consideration; locate and layout crushing and asphalt plant; and so on. It also discusses how the crews and their work are managed and supervised to assure quality control. Further, the health, safety, and environmental issues will be discussed in detail.

The work methodology discusses the techniques of how the contractor plan to execute each item of works. For instance, the contractor submits a work statement on how the site clearance is planned to be executed. The statement describes how the setting out, clearing, and grubbling works executed, how the excavated materials will be stocked, and the spoiled materials will be disposed of. It also discusses the crew arrangement and the quality of each item of work that would be controlled.

The methodology chosen by the contractor is highly influenced by the project's physical characteristics and market conditions. The cost and productivity of the resources employed in the construction determine the cost of the road construction project. A project which is executed under the labor-intensive strategy will not have a similar cost with a machine intensive one. Further, the way the contractor organizes its project affects the site overheads and ultimately the cost of the road construction project will be high. The project work methodology also tells the contractor technical and financial capacity. Purchasing material in bulk; hauling construction materials using the company’s hauling devices; Easy of accessing Letter of Credit (LC); executing works in parallel and as such capacity-related factors will determine the cost of the road construction projects.

2.8 Project Cost Normalization

To ensure a reliable and commensurable comparison, the cost of projects should be normalized to account for factors such as location, scope, time, and currency difference. That is why DAI *et al*. (2012) has claimed that ‘*without cost normalization, comparison results are misleading’*. The project cost normalization process involves four distinct stages such as initial stage - data collection; second stage - scope adjustment; third stage - cost adjustment; fourth stage – normalizing and comparing project cost.

2.8.1 Data Collection Stage

The initial stage requires collecting and compiling project information from different sources. To facilitate the next step, it is advisable to sort a list of road projects against each delivery system and finally to select projects which have similar work nature.

2.8.2 Scope Adjustment Stage

Scope adjustment is the second stage and the most critical step in the process. As discussed below, it can be adjusted systematically by selecting projects with similar features. These are mainly having commensurable location/site conditions, specification, material availability, contractor/design-builder capacity, and socio-politics issues.

2.8.2.1 Geographical Proximity between Projects

The geographical proximity of road projects refers to the tendency of similarity between projects concerning the project's location physical characteristics. Since road projects are a horizontal construction project which crosses different geographical locations, the geographical proximity between road projects can be addressed through the weather condition the projects traverses through, the availability of local material, the easy of supply accesses, the socio-politics issues, and the terrain type[10].

a) Weather Conditions

Concerning the weather condition, ERA's Site Investigation Manual, released in 2013, classified the country's climatic conditions, as shown in Table 2-12, into five basic climate zones. These are Wurch, Dega, Weina Dega, Kola, and Berha depending on the elevation variations. Due to the elevation difference, the average temperature and annual

[10] The main purpose of discussing the terrain type at this stage is just for the sake of providing full information about the project rather than not mentioning it as a cost-driving factor during the comparison. It is important to note the phase of the project under which the comparison is undertaken. The terrain classification has a significant purpose to forecast the probable cost of the project based on historical cost database while the project is at the planning and development stage. In addition to this, the terrain type might have cost implications on the proposed methodological approach for excavation and earthwork work items undertaken at the high mountainous area. However, comparing projects which are found at implementation or operating stage, using their actual volume of work rather than its terrain type is one step advanced and rational. Therefore, the cost implication of terrain type is less important for cost normalization.

rainfall vary for each climatic zone. Projects located at Wurch climatic zone may not have similar working conditions as compared to Kola, and vice-versa.

Due to only the weather variation between the project's locations, even though other cost dictating factors kept similar, productivity loss would be observed ranges from reduced labor productivity to work stoppage which affects the project performance in large (Moselhi, *et al.*, 1997). Hence, the same contractor/design-builder will be forced to introduce different unit rates and this will make the project comparisons to be difficult. Therefore, to reveal the cost difference between DBB and DB PDS, projects located in a similar climatic zone can be a potential candidate and should be selected for the cost analysis.

Table 2-12: Ethiopian's Climate Zones

It No	Climatic Zone	Elevation (m) ASL	Ave. Temperature (^{0}C)	Avg. Annual Rainfall (mm)
1	Wurch (Cold)	> 3300m	< 10	< 800
2	Dega (Cool-cold)	2300 - 3300	10 -16	1000 – 2000
3	Weina Dega (Warm cold)	1500 - 2300	16 -20	1200
4	Kola (Hot warm)	500 - 1500	20 - 28	600 (1000 in places)

b) Availability of Local Material

A road construction project requires different types of construction materials (borrow materials, natural gravels, quarry materials, sand, and water) from different sources for subgrade improvement, embankment, and pavement construction. The naturally occurring borrow and granular materials are used for the construction of the sub-base and shoulder of the pavement. It is also used as a backfill material for major and minor drainage structures. The quarry materials are used for the pavement layer (Asphalt Surfacing and Base Course) construction, Cement Concrete pavement, and stone masonry.

As stated in Section 2.7.1.3, the cost of the projects depends on the availability of construction materials within a reasonable offset distance from the centerline of the project and hauling distance between the successive sources with the required material type, quality, and quantity. A project positioned with such local materials could not have a similar cost as compared to other projects whose local construction materials are hauled from a distance. Therefore, by taking the offset and hauling distance into consideration, projects which have comparable sources of construction materials both in type and quantity should be selected for a cost comparison.

c) Easy of Supply Access

As stated in the above section, the contractor/design-builder can possess earthwork materials from the approved borrow and quarry sites in such a way that minimizes the cost of the project. The cost of the road project is also determined by its proximity to the supply access. It involves the supply of materials, labor, and equipment from local and/or international markets. For instance, materials such as bitumen, fuel, cement, reinforcement bar, civil explosives, and such likes are critical materials for road projects. It also includes the availability of equipment, machinery, spare parts, and labor in the required quality and quantity in the local and/or international market. The project may also require raw materials for camp consumption in bulk from the local market with the possible maximum efforts.

Supply access is the most determinant factor for the cost of the project and depends on the relative distance between the project and the prevailing local and/or international market. The cost of transportation would be increased as long as the project is located far away from the prevailing market. As a result, the contractor/design-builder would be forced to submit a high unit rate in respect of the work items. Therefore, projects located at different supply access scenarios would have different cost and makes the cost comparison to be difficult. To identify the amount of money incurred due to only the adopted PDS, the projects need to have similar supply access. As a result, projects which have comparable supply access should be selected for the cost analysis.

d) The Socio-Politics Issues

Socio-politics is the behavioral aspect of the given society. Societies boarded in a certain location would possess a relatively similar economic interest, working culture, security issues, and ease of doing business than the others who boarded far away. The level of society's awareness for the economic benefit that could be obtained from the proposed project; the level of local administrative's cooperativeness with the major project parties;

working culture of the labor; and the level of security between the project locations need to be similar.

Therefore, the researcher believed that these factors are highly associated with geographical proximity. Accordingly, ensuring the geographical proximity between projects helps to obtain similar socio-politics issues. This is because constructing road projects within a similar socio-politics environment is different from working on different scenarios. Thus, to identify the amount of money incurred due to only the adopted PDS, projects need to exhibit such socio-politics similarity.

2.8.2.2 Scope of Project

Usually, the project's scope is represented by using the project's volume of works. From experience it is noted, the project's volume of work affects the unit rate decision made by the contractor during tendering. When the volume of work is relatively large the contractor/design-builder usually offers relatively less unit rate by assuming to obtain profit using the project's bulk quantity. On the contrary, when the project scope is relatively low, the contractor/design-builder may assign a high unit rate due to assigning the required resources for the projects. As a result, the project cost is supposed to be high. To find out the cost difference between the adopted PDSs, projects which have a comparable volume of works are a potential candidate for the cost comparison.

2.8.2.3 Contractor's/Design-builder's Capacity

The contractor's/Design-builder's technical and financial capacity determine the cost of the project. A contractor/design-builder who is capable to purchase bulk materials from a factory and can transport it using the factory and/or company's pieces of equipment would provide less rate than those who purchase from a local reseller.

A contractor/design-builder who has a similar project in the adjacent area can use the adjacent project's camp as a temporary/permanent camp or office and mobilize machinery, equipment, and plants into the tendering project. Due to less amount of money incurred for the camp establishment and mobilization the contractor/design-builder could offer a certain amount of rebate on total project cost. The number of projects at hand could also help the project to minimize his/her profit margin.

In terms of critical local and imported goods, the contractor/design-builder could enter into a contract with suppliers to obtain sufficient quantities of these goods ahead of the commencement of the works. It could depend on the contractor's prior experience to avoid the possible time delay that may happen with the customs clearance. The contractor's competency in terms of shorting the supply chain management is also the other critical parameters. Therefore, it minimizes the associated cost that occurred due to poor supply chain management.

The contractor's/design-builder's prior experience (i..e., organizational learning curve) also determine the project cost. Being familiar with similar PDS, geographical location, and project scope could help the bidder to submit a realistic unit rate than the less experienced one. Therefore, the researcher believes that an experienced contractor/design-builder who can formulate a proper work methodology[11] tailored to the specific project would request less cost than the less experienced one. Thus, DBB and DB projects delivered by the same or relatively similar contractor/design-builder are a potential candidate for the cost analysis.

2.8.2.4 Types of Works

As stated in Section 2.9, ERA's Site Investigation Manual-2013 classifies the types of road construction projects into three categories such as new construction, rehabilitation, and upgrading. The cost of the project is substantially determined by the types of works. This is because work methodology has different cost implications when the work type is different. That is why new construction projects should be compared to the new construction project to make sure '*apple to apple*' comparison between projects.

[11] Employer demands the contractor to formulate a proper work methodology that used to ensure the execution of activities based on project's aspects such as project scope, resources deployment, sequential flow of works, productivity and relative time constraint, quality control, and all relevant features. It is also describes the camp establishemnt and resource mobilization issues. The ERA's Standard Technical Specification stresses the contractor/design-builder to establish a construction site, mobilize key resources, and set up better working conditions within a mobilization period of 120 calendar days. Site establishment involves camp selection and providing the stipulated site facilities such as office, laboratory, and housing accommodation all furnished with fixtures, types of equipment, and the provision of continuous services required. It also requires providing surveying and communication equipment and as well as vehicles for transportation.

Therefore, projects which have similar types of works are potential candidates for case analysis.

2.8.2.5 Project Status

The project's status can be expressed as ongoing or substantially completed projects based on the physical and/or financial progress. Depending on the types of PDS, especially for DBB projects, the final cost of the project is known only when the project is substantially completed. This is due to the possible scope change and unforeseen conditions. In this regard, DB PDS allows the project cost to adhere to the lump-sum contract amount than the DBB projects. This is still an assumption that there won't be a variation for the DB. Therefore, it is possible to select and compare completed DBB projects against either completed or on-going DB projects which have a similar work type.

2.8.3 Price Adjustment

As shown in the above, the first two stages of the cost normalization done qualitatively, and the remaining two stages can be addressed through a quantitative approach. Particularly, price adjustment requires to take into account the increase and/or decrease in the costs of resources. Hence, it helps to compensate the contractor and/or client properly for the increase and/or decrease in the cost of resources and services as compared to the base date. It is also used for cost comparison purposes between projects delivered at different time references. It can be addressed through the Price Adjustment Formula (PAF) and/or Cost Index (CI) approach to bring cost data into the same reference point. Both PAF and Cost Index (CI) approaches share the same principles but have different approaches.

Unlike the CPI, the PAF approach is applicable only for the selected adjustable component of the contract payment items. In the case of Federal road projects, ERA has published a report called '*Contract Price Adjustment Review and Procedure Report'* in 2019. This report discusses how the price adjustment could be undertaken using the formula given below.

$$Pn = a + b\left(\frac{Fn}{Fo}\right) + c\left(\frac{Bn}{Bo}\right) + d\left(\frac{Sn}{So}\right) + e\left(\frac{Cn}{Co}\right) + f\left(\frac{Zo}{Zn}\right)\left(\frac{En}{Eo}\right) \quad \textbf{Equation 2-5}$$

Where

- Pn - Price Adjustment Factor needs to be applied to the particular pay items;
- a - a fixed constant representing a non-adjustable portion of contractual payments;
- b, c, d, e, and f - coefficients representing the estimated portion of each cost elements;
- F_n, B_n, S_n, C_n, and E_n - the current cost indices/reference prices of the cost elements;
- F_o, B_o, S_o, C_o, and E_o - the base cost indices corresponding to the cost elements;
- Z_o and Z_n - the base and the current exchange rate indices respectively;

In general, the unit rate adjustment process for DBB's projects involves four basic steps. First, define the base and current cost index. Second, determine the price adjustment coefficients for each particular payment items. Third, compute the Price Adjustment Factor (PAF). The PAFs (or usually called Pn value) are obtained by inserting the coefficients for both non-adjustable and adjustable cost components and also the base and current indices into Equation 2-5.

The report also recommends a certain range of coefficients used for projects after addressing local and international best practices. It also presents the recommended standard coefficient extracted from the report. The report noted picking a single coefficient value from the range is depends on the project's nature such as location, terrain, climatic conditions, etc. However, it is a difficult task and subject to the experience of the contract and project administrator.

Table 2-13: Recommended Coefficient for Price Adjustment

Pay Item Series	Recommended Standard Coefficient Range (%)						
	Non-Adjustable	Labor	Fuel	Bitumen	Rebar	Cement	Equipment
1000	10 - 20	10 - 20	10 - 50	-			10 - 40
2000	10 - 20	10 - 25	20 - 50	-			20 - 60
3000	10 - 20	10 - 25	10 - 25	-	10 - 35	10 - 25	5 - 20
4000	10 - 20	10 - 20	20 - 40	-		0 - 20	20 - 70
5000	10 - 20	10 - 20	20 - 40	-			20 - 70
6000	10 - 20	10 - 20	15 - 30	30 - 50			20 - 60

8000	10 - 20	5 - 20	10 - 25	-	20 - 40	10 - 35	10 - 20
9000	10 - 20	10 - 25	10 - 25	-	20 - 40	10 - 35	10 - 20

On the other hand, the Cost Index is the other useful cost adjustment approach. DAI *et al*. (2012), by quoting Humphreys (2004) and McCabe *et al*. (2002), has classified cost index into input and output indices. The input indices are used to measure '*a basket of construction process inputs, such as materials, equipment and labor hours'*, whereas the output indices compare the *'construction cost of a hypothetical structure by location and/or time'*.

The Cost Index (CI) approach is usually used for a single project to consider inflation and/or deflation between two different time references or for two projects delivered at different time frames for cost comparison purposes. The '*Ratio Method'* is the known approach used to compute the cost adjustment using the equation given below:

$$\frac{Index\ value\ for\ Project\ 2}{Index\ value\ for\ Project\ 1} = \frac{Cost\ of\ Project\ 2}{Cost\ of\ Project\ 1}$$ **Equation 2-6**

For the case of Ethiopia, the Central Statistic Agency (CSA)[12] has been publishing the Consumer Price Index (CPI) periodically for a different basket of goods and services at the national and regional levels. It considers the effect of inflation and deflation, *inter alia*, for house rent, construction materials, water, fuel, and power. However, by analyzing these items with the road construction projects, the CSA's CPI is found to be too generic and skew to building projects. As a result, if it is possible, it is better to adjust the time difference between two road projects using ERA's *Price Adjustment Formula*.

2.8.4 Cost Normalization

Finally, the adjusted project cost needs to be normalized using the project size (i.e., kilometer for the case of road projects). It is dividing the adjusted project cost by the project size. As a result, it helps to compare one project against another project in terms

[12] The FDRE National Development and Planning Commission Central Statistical Agency (CSA) used Consumer Price Index (CPI) to measure the average change in the price paid by consumers for a fixed market basket of goods and service based on household expenditure weights of the goods and services in the basket and their current market prices.

of the *Cost-Per-Kilometer*. Finally, the above discussion is summarized using Figure 2-11 as shown on the next page.

$$Normalized\ project'Cost = \frac{Adjusted\ Project\ Amount}{Project\ length} \qquad \textbf{Equation 2-7}$$

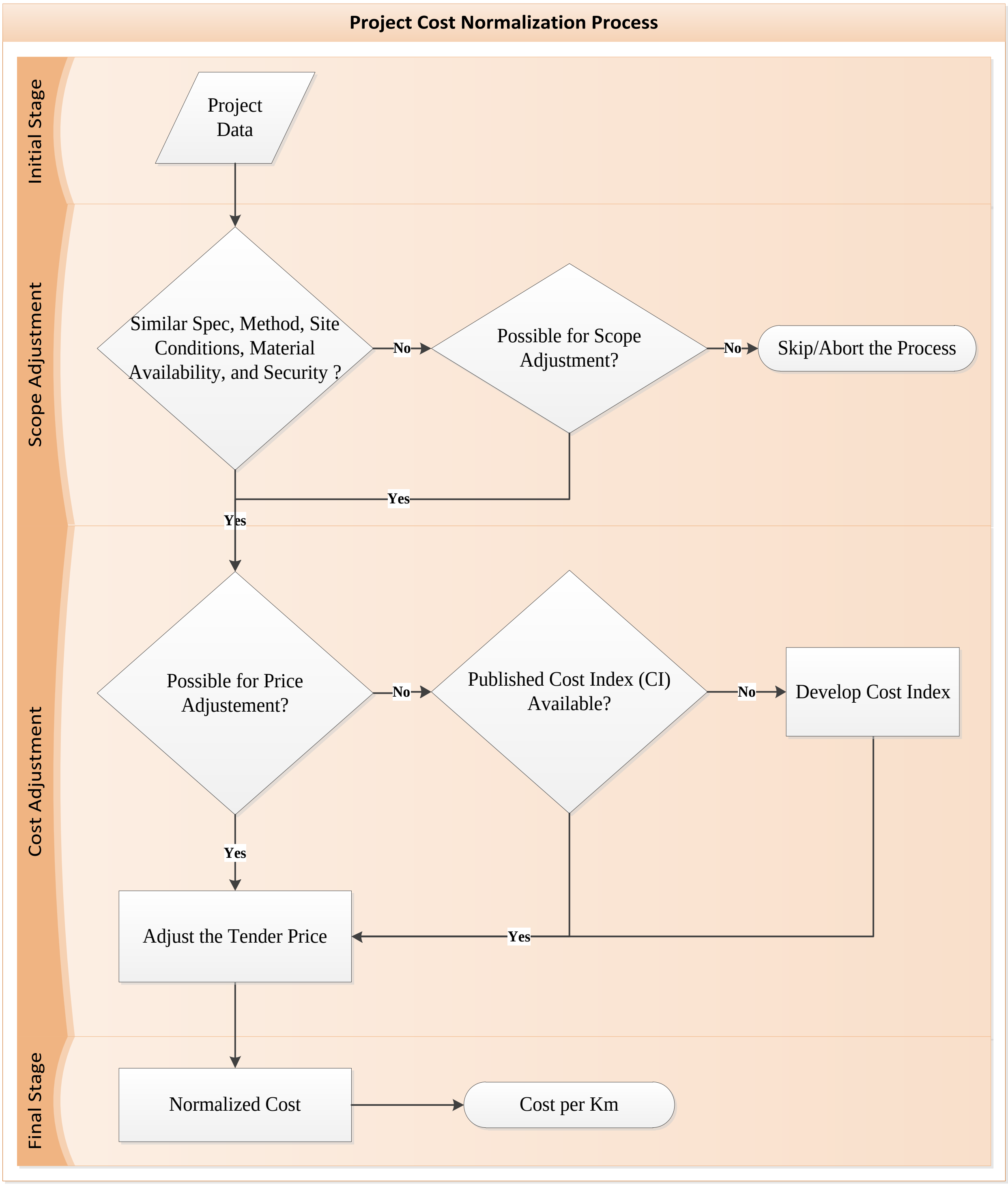

Figure 2-11: Cost Normalization Process

2.9 Exploring the Context (ERA)

The Ethiopian Roads Authority (ERA), which represented the FDRE, has been placed strong efforts on improving the backlog of the road infrastructure in terms of size and quality since its establishment. By taking the year 1951 as a threshold point, many distinct proclamations and regulations were enacted to define the Authority's role and responsibility and these are the reasons that assert the Authority to pass through different names and organizational structures.

In addition to this, the Authority also formulated Six Highway Programs during the Imperial Monarchy Regime for 27 years; Two Road Sectors Programs during the Derg Regime for 17 years; and Road Sector Development Program (RSDP) for the last 20 years. By now, the Authority is implementing the fifth phase of the RSDP - where each phase covers five years and it is responsible to develop and administer roads by ensuring the standard of road construction and creating proper conditions on which the road network is coordinately promoted at Federal level. As stated previously, due to different re-establishment proclamation and regulation acts, the Authority passed through different organizational structures. Taking the last change, the Authority's operation and regulatory tasks were separated into two independent organizations such as the Ethiopian Roads Construction Corporation (ERCCO) and the Ethiopian Roads Authority (ERA) by the Council of Ministries through Regulation No: 248/2011 and 247/2011 respectively. However, in terms of the organizational structure, borrowing Solomon's (2015) statement, the Authority is '*a project-based organization'* and structured accordingly.

Based on the national experience and international best practices, the Authority has been released more than fifteen series of documents for practicing engineers in Ethiopia into three categories - technical manuals, standard specifications, and bidding documents. The documents describe the recently recommended practices; set out national standards for roads and bridges, and enforce the responsible entities to use it properly while doing their tasks. However, these four documents, *inter alia*, such as ERA's Standard Technical Specification and Methods of Measurement, Standard Bidding Documents for Road Work Contract, Alternative Project Delivery Methods Manuals, and Site Investigation Manual has potential information about the project regarding the research objectives.

ERA's Standard Bidding Documents for Road Work Contract-2013 is the other important document that is applicable for various projects ranging from small to large scale works for both the local and international bidding scenario. It encompasses different sections which are classified into different volumes and have some variation for the case of DBB and DB projects. The main difference observed between the two delivery systems is the presence of Employer's Requirement within DB contract documents, while BOQ and drawings within the DBB contract document. Besides this, as stated previously, the Standard Technical Specification is prepared by the consultant for DBB projects and design-builder for DB projects; however, both are included in the particular contract document.

ERA's Standard Technical Specification and Methods of Measurement-2013 describe the quality of material and the required level of workmanship in line with its payment measurements. It comprises eleven series ranges from Series 0000 to Series 10000 with the subsequent divisions and Pay Item Clauses as shown in Table 2-14 given below. The Authority allows the consultant and the design-builder to tailor this document for specific requirements of DBB and DB projects respectively. During adaptation, the agreement or disagreement phases are done by deleting and/or replacing a less-significant paragraph with the relevant one.

Table 2-14: ERA's Pay Item Series

Series	Description	Series	Description
0000	Method of Measurement	6000	Bituminous Surfacing and Road-base
1000	General	7000	Rigid Pavements
2000	Site Clearance	8000	Structures
3000	Drainage Structure	9000	Ancillary Works
4000	Earthwork and Material Stabilization	10000	Testing Materials and Workmanship
5000	Sub-base, Road-base, and Gravel Wearing	11000	Day works

Unlike the others, ERA's Alternative Project Delivery Methods is the latest manual which is released in February 2019, and from its Foreward one can notice that the Authority entertaining a paradigm shift in project delivery culture. The manual is designed to assist the procurement directorate to develop Project Delivery Matrix that is used to identify the proper PDS for the given project. It also outlines the advantage, disadvantages, suitable conditions, and critical success factors of various PDS by referring to recent studies and best practices.

Though ERA's Alternative Project Delivery Method Manual is developed recently and the Authority looks forward to its application, the Authority has been delivering road projects with the two most dominant approaches such as DBB and DB based on professional judgments. Following the increasing demand for projects which need to be finished faster than the previous trend, as stated in Section 2.2.1, the Authority has established a separate responsible unit: *'Design-Build Directorate'* in March 2010 in addition to the five regional directorates.

ERA's Site Investigation Manual-2013 outlines the points that should the practicing engineer adhere to before, during, and after conducting site investigation. The manual presents in-detail the construction material survey along with the source of materials and its investigation procedures. It also classified the types of road projects into three categories such as new construction – construction of pavement system on a new alignment that has not been previously constructed; rehabilitation – repairing or upgrading the existing pavement section; upgrading – removing the existing pavement and replace with a new one.

Table 2-15: Project Delivered from 2009 to 2019

Construction Type	DBB Projects		Total	DB Projects		Total
	Completed	Ongoing		Completed	Ongoing	
New	44	81	**125**	20	35	**55**
Rehabilitation	12	4	**16**	1	3	**4**
Upgrading	72	52	**124**	3	9	**12**
Total	**128**	**137**	**265**	**24**	**47**	**71**

Table 2-15 presents the list of road projects delivered by the Authority from 2009 to 2019. It shows that 47.2%, 6%, and 46.8% of 265 DBB projects are new, rehabilitation, and upgrading respectively. While, 77.5%, 5.6%, and 16.9% of 71 DB projects are new, rehabilitation, and upgrading respectively. In general speaking, the Authority has delivered 79% and 21% of road projects using DBB and DB PDS respectively.

During tendering, the responsive least bidder will be selected by comparing the contractor/design-builder's offer against the Engineering Cost Estimate (ECE). Particularly to DB projects, the Authority has experienced an inconsistent cost-per-kilometer. The difference is observed between ECE prepared during concept design and the lump-sum established by the design-builder for the same DB road projects. Figure 2-12 depicts the uneven cost-per-kilometer pattern for randomly selected seven DB projects. The red curve represents the cost-per-kilometer which is obtained by dividing the lump-sum offered by the least responsive design-builder by the project length. Conversely, the blue curve denotes the cost-per-kilometer obtained from the ECE for the same projects.

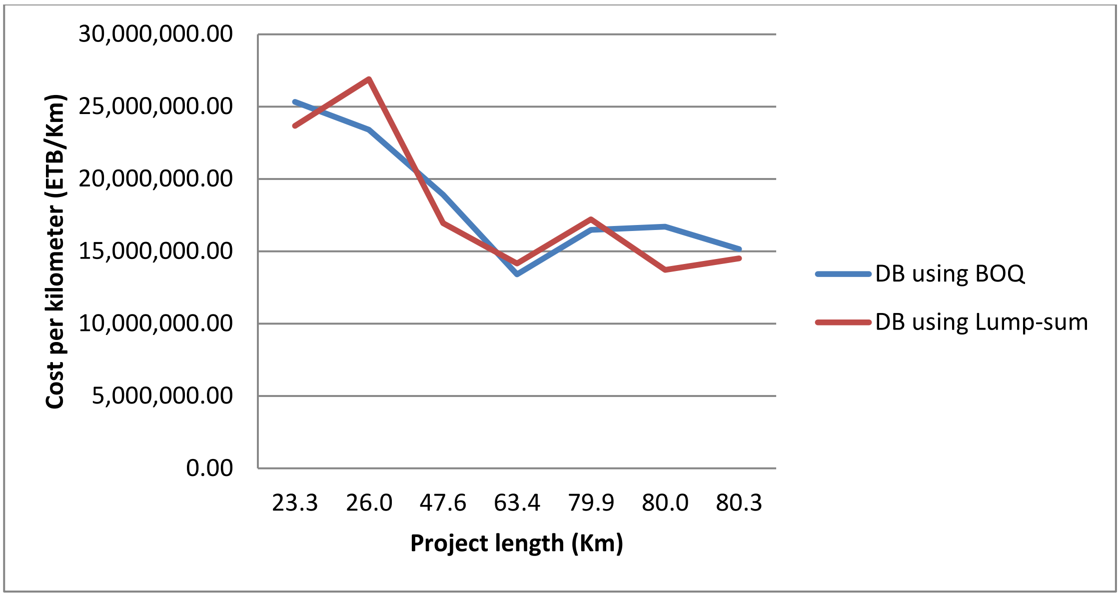

Figure 2-12: Cost-per-kilometer for DB Projects

2.10 Research Gap

As discussed thoroughly in the previous sections, measuring the performance of a given construction project is one of the paramount and strongly recommended practices that should be addressed throughout project management processes. This process helps to measure project success through cost, time, and quality performances. Although the preceding studies equate the efficiency of the DBB PDS against the DB based on the relative metrics for both cost and time performance, as Goftar *et al.* (2014) stated, '*not all of the literature points to superior performance'* of the PDS. Akintoye & Skitmore (1992) said different projects with different PDSs possess different costs.

Scholars such as Shrestha *et al.* (2011), Hale *et al.* (2009), Ernzen and Schexnayder (2000), Konchar and Sanvido (1998), Bennett *et al.* (1996), and Roth (1995) have examined different types of DBB and DB projects using the relative and static cost metrics. Their studies reveal the cost certainty of the DB projects than the DBB projects. Further, except Hale *et al.* (2009), they present the amount by which the cost certainty increases the project cost. Nonetheless, the unit cost analysis was entirely dependent on the lump-sum amount offered by the design-builder rather than considering the DB projects through DBB format.

For the case of Ethiopia, Habtamu (2017), Rahel (2016), and Asaminew's (2013), findings show that road projects delivered through the DBB PDS are subjected to cost and time growth than projects delivered through the DB PDS in the context of the ERA. Predominantly, their analysis mainly used the relative metrics (cost growth) rather than the static metrics (unit cost) and lacks to reveal the amount of risk associated with the adopted PDS. To the knowledge of the researcher, the amount of risk associated with the adopted PDS (i.e., the cost certainty that may come with a higher premium) has not yet been examined for the Ethiopian Construction Industry context.

Thus, the essence of the research is to fill this gap by analyzing the unit cost of road projects delivered through DBB and DB PDS and to present the amount of risk associated with the endorsed PDSs. In other words, it examines the cost of a given project if it is delivered through DBB as well as DB PDS. It requires to keep those cost-driving factors to be similar and compute the cost-per-kilometer.

CHAPTER 3: RESEARCH METHODOLOGY

3.1 Introduction

Research is a purpose-driven process that begins with a question that needs an answer or a problem that must be solved (Sue & Ritter, 2012). It helps to acquire new knowledge and increase the researcher and/or the audience's understanding of reality. However, it requires establishing a proper research methodology (Abate, 2018; Saha, 2010; Marczyle, *et al.*, 2005; Kothari, 2004).

According to the Oxford Learners Dictionary, a methodology is a system of methods and principles used to perform a particular activity. Its essence is to structure one's actions according to the nature of the question at hand and the desired answer one wishes to generate (Jonker & Pennink, 2010; Kothari, 2004). It is underpinned by the philosophical orientation about the nature of the issues to be explored and the ways of exploring it.

Smith *et al*. (2015) listed the importance of understanding and explaining the different philosophical assumptions/ research paradigm. First, the researcher is accountable to understand the basic issues of epistemology to have a clear sense of reflexive role in research methods. Second, it is used to clarify the research design starting from identifying the required evidence, the means of data collection, and analysis. It is also used to correlate the result with the initial research objectives. Third, appreciating the strength and weaknesses of each philosophical assumption helps the researcher to design the research properly. Four, the researcher may discover new research designs and present a way of adaptation.

A research paradigm is a set of philosophical assumptions, theories, or beliefs that provides the process of carrying out research. In scientific inquiry, there are four types of research paradigms or schools of thought which have different ontological, epistemological, methodological, and technical stands. These are positivism, post-positivism, critical theory, and social-constructivism. The fundamental factors that dictate a researcher to adopt a ceratin research methodology are profoundly connected with the nature of the problem taken to be solved; the hypothesis/question/objectives supposed to be proved or disproved/answered/addressed; the availability of research data; and the researcher's position to the available research paradigms.

This research has formulated a research hypothesis and established a research objective to investigate the effect of the DBB and DB PDSs on the cost of road projects. It requires mainly quantitative data for cost comparison and relies on project related documents rather than behavioral responses. As a result, the research has adopted a positivist school of thought. Its ontological positions state that DBB and DB PDSs do not have a similar cost impact due to their level of risk allocation. Its epistemological positions state that the cost comparison between these two PDSs can be examined by computing the cost of DB's project using BOQ format.

In general, the purpose of this chapter is to set out the research methodology and justification for the choices made. The subsequent sections are organized into four major parts. The first part addresses the philosophical aspects of research and justify the adopted research paradigm. The second part describes the constructs of the research type and method. The third part justifies the chosen research method thoroughly. Finally, the fourth part presents how research quality is addressed.

3.2 Types of research

Research can be classified into different types based on its goal, objectives, approaches, design, data, and field of study (Alemayehu, *et al.*, 2009). Based on the goal of the research, the researcher attempts to solve the problem which has theoretical or practical nature and as a result, the research type can be either pure or applied. Research's specific objective is also used to classify the research type into another category such as exploratory, descriptive, and explanatory research types. In addition to these, research can be classified into deductive and inductive based on the approach or quantitative and qualitative based on the research design.

- **Exploratory research** – is usually undertaken when little or nothing is known about the phenomenon under investigation. The researcher will formulate the background information using diversified research methods such as interviews, focus groups, case studies, and pilot studies (Yin, 2018; Alemayehu, *et al.*, 2009). Theoretically, it is assumed as a base for descriptive and explanatory research types.
- **Descriptive research** – it is a type of research used to define, categorize or classify, compare, contrast, analyze, and interpret the phenomena under study. It

is dedicated to identifying the correlation between two or more variables rather than its causal aspects (Vaus, 2001) and as result known as a correlational study. The researcher can examine the correlation between variables through a variety of research methods such as surveys, correlational studies, observation studies, and case studies (Gay, *et al.*, 2012; Alemayehu, *et al.*, 2009; Marczyle, *et al.*, 2005; Kothari, 2004).

- **Explanatory research** – it is the highest order next to exploratory and descriptive research type and highly depends on the existing phenomena and facts to analyze and explain critically why or how something is happening. It is oriented to explain the causal relationship (cause and effect) between variables by developing causal explanations (Sue & Ritter, 2012). It can be classified into '*experimental'* and '*Ex post facto'* research type. The former allows us to identify the effect from possible causes and the latter goes backward from the effect to the cause (Marczyle, *et al.*, 2005; Salkind, 2010). The varieties of research methods mentioned for descriptive as well as exploratory research types are also applicable for explanatory research types.
- **Deductive and Inductive research approach** – deductive and inductive research approaches are oriented to test existing theory and develop new theory respectively. The former select a theory, build a hypothesis, observe the hypothesis on the collected data, and finally provide confirmation about the theory. While, the latter begins from observation, look for the pattern, postulate a tentative hypothesis, and finally build a theory (Salkind, 2010).
- **Quantitative and Qualitative research design** - quantitative research design deals with numbers, amount, frequency, and applicable to phenomena that can be expressed in terms of quantity. While, the qualitative research deals with attributes that are difficult to quantify their results through numbers (Jonker & Pennink, 2010; Alemayehu, *et al.*, 2009; Kothari, 2004). As compared to qualitative research design, the quantitative research method '*traced back historically to natural science which assumes reality can be obtained through the eyes of the researcher and occur in terms of quantities*' (Jonker & Pennink, 2010).

As stated above, the first three research types have a hierarchical nature. The exploratory research lays a foundation for the descriptive type. And the descriptive research output is used as an input for explanatory research type. Further, the last two bulleted research types are also related to each other. For instance, concerning the research paradigms, the deductive research approach aligns itself purely to the positivism research paradigm and the inductive approach is more likely to social constructivism. Relating to the research approach, the deductive theory testing approach is mainly a quantitative approach and the inductive theory-building research approach is a qualitative approach (Creswell, 2014). Therefore, by referring to the above discussion in line with the research objective and hypothesis, the research has used a descriptive and to some extent exploratory research type; deductive research approach; and quantitative research design. It has also an applied research nature rather than a basic research type.

3.3 Justification for Research Method and Sources of Data Used

The overall quality of the research output depends on the choice of research methodology; however, it is a difficult task in the research process (Walker, 1997). Chau *et al*. (1998) also mention the difficulty to argue in '*favor of any single approach based purely on epistemological grounds'*. They claimed to choose the research method that can generate practical solutions for practical subjects.

As per Yin (2018) argument, a research method should not be chosen randomly. Rather, it is governed by three key aspects such as the type of research hypothesis/question posed, the extent of the control an investigator has over actual behavioral events, and the degree of focus on contemporary as opposed to historical events. In general, *Experiments, Survey, Case Study*, and *Action Research* are well-known research methods. According to Alemayehu *et al*. (2009), these varieties of research method are different from each other as stated below:

- **Experiment –** it is the best-fit research method when the research problem requires investigating the cause and effect relation between the identified variables.
- **Survey** – it is used to measure the given phenomena with wide coverage but with shallow depth to obtain descriptive, inferential, and explanatory information about the phenomena. It provides behavioral responses.
- **Case Study** – it is an empirical research method used to examine the case under consideration in depth and within its real-life context.

- **Action Research** – it is a type of research method and known as research-by-doing. It requires an experienced researcher, a longer time frame, and enough budgets. The result will be generalized to the

In general, except survey, the above-listed research methods used Analytical generalization (i.e., it compare the findings against the previously established theory). Conversely, surveys draw inference from data to the population through statistical generalization. Particularly to the case study, Salkind (2010) recommends ensuring whether the conclusion is obtained from the data collected and it is in line with the research objectives.

Therefore, based on the nature of the problem, specific objective, and availability of data, this research requires a detailed contextual investigation within the ERA context. In this regard, Yin (2018), Merriam (2009), and Stake (1995) - the authorized authors of Case Study, recommend using a case study as a research method. Further, a case study is a contemporary research method.

3.3.1 Case Study and Its Research Design

According to Yin (2018), a case study requires proper research design in such a way that addresses five main things. These are the form of study questions, study hypothesis/propositions, the case to be studied, the logic that links the data to the propositions, and criteria for interpretation. The form of the research questions dictates the researcher to select and adopt the appropriate research method to be used. Research's propositions/hypothesis directs the researcher's '*attention to something that should be examined within the scope of the study'.* The case[13] to be studied needs proper definition and its boundaries should be demarcated. Linking the collected data to the research's starting point (question or hypothesis) is also significant and the findings obtained from the collected data should be interpreted based on a certain criterion to check how much the data is aligned with the proposition or not.

By acknowledging the above five issues, a case study research design requires to take two vital issues into account. These are the number of cases (can be single-case or

[13] A case is an object of the study identified as the entity interest such as program, individual, group, social situations, organization, event, phenomena, or process (Harrison, *et al*., 2017).

multiple-cases) and units of analysis (can be single or multiple units of analysis). A single-case study[14] research design relies on a single-case and a multiple-case study uses many-cases for the investigation. Unlike the single case-study, when methodological replication is required, the multiple-case study is recommended (Yin, 2018; Salkind, 2010; Merriam, 2009; Stake, 1995). However, depending on the unit of analysis, as shown in Table 3-1, both single-case and multiple-case studies can be designed either in a holistic or embedded manner. The holistic case design allows the researcher to examine the given case within its context globally and an embedded approach lets the researcher investigate the phenomena by taking subcases within that entity.

Table 3-1: Case Study Design Matrix

Case Study Design		**Unit of Analysis**	
		Holistic	**Embedded**
Number of Cases	**Single-case**	One case with one unit of Analysis	One case with many units of Analysis
	Multiple-case	Many cases with one unit of Analysis	Many cases with many units of Analysis

3.3.2 Case Selection

A case study requires defining the research context within which the cases can be analyzed. Thus, as discussed in Section 2.9, the research identified ERA as a research context because of three main reasons. First, the Authority has delivered 336 (i.e., 79% DBB and 21% DB) road projects from 2009 to 2019. Second, it had established a separate unit that is responsible for the management of DB road projects. Third, it

[14] Yin (2018) well noted the minimum conditions under which a single-case study can be chosen as a research approach than multiple-case studies. These are being critical, unusual, common, revelatory, and longitudinal. He also suggests the selected case should be related to the identified theory or theoretical prepositions or good enough to introduce a new theory. The essence of the first condition is to confirm, challenge, or extend previously known theory by selecting a single critical case. The second condition allows using a single-case study when the case has unusual nature and the result could deviate from the previous known theory. The third condition allows the researcher to use the single-case study as his/her research method if the selected case is considered as a typical or representative one. The fourth conditions allow using a single-case study if the selected case can let the researcher observe and analyze the previously inaccessible phenomenon. The fifth condition allows using a single-case study if the researcher is interested to reveal the nature of the theory through time.

develops and released the Alternative Project Delivery Methods (APDM) manual to the end-users in 2019. These all imply that the ERA has rich experience in both the DBB and DB PDSs as compared to the other two City Administrations and Nine Regional States's Road Enterprises in Ethiopia Construction Industry.

To address a particular interest or theoretical consideration, a case study requires selecting a best-fit case(s) based on predefined selection criteria (Mills, *et al.*, 2010). Although Yin (2018) recommends using a single case under a situation where a critical case is observed, Eisenhardt (1989) recommends using '*four to ten cases for better external validity'* under multiple-case study design. To arrive at best-fit cases, as shown below, the research has rearranged Table 2-15 into Table 3-2. The projects were sorted and classified based on PDSs, Work Types, Pavement Surfacing, and Functional Classification.

Table 3-2: Project Population for DBB and DB Projects

PDS	No of Projects	Work Type		Pavement Type		Functional Class	
						Link	Trunk
DBB	128	New Construction	44	AC	21	21	-
				Gravel	15	13	2
				NA	8	8	-
		Rehabilitation	12	AC	10	-	10
				NA	2	-	2
		Upgrading	72	AC	51	35	16
				Gravel	2	2	-
				NA	19	13	6
DB	71	New Construction	55	AC	43	43	-
				Gravel	7	7	-
				NA	5	5	-
		Rehabilitation	4	AC	4	2	2
		Upgrading	12	AC	12	9	3

As shown in Table 3-2, the ERA has delivered a total of 128 completed DBB (34% New Construction, 9% Rehabilitation, and 56% Upgrading) and 71 DBB (77% New Construction, 6% Rehabilitation, and 17% Upgrading) projects from 2009 to 2019. However, during a document review, a disagreement was noted between the RSDP reports and the respective project's contract document concerning work type and functional classification. Thus, to minimize this disagreement, the research has inclined to those upgrading, Asphalt Paved, and link projects.

Accordingly, the research initially identified 35 completed DBB and 9 on-going DB road projects. However, based on the case selection criteria stated from Section 2.8.2.1 to 2.8.2.5, the research identified three DBB and four DB Upgrading-Asphalt Concrete (AC)-Link road projects. To keep contractor/design-builder's confidential issues, the three DBB projects were designated by Project-A, Project-B, and Project-C. Similarly, the four DB projects were represented by (Project-D, Project-E, Project-F, and Project-G).

Further, the above seven projects were classified into four cases group based on their possession of similar geographical proximity, specification, methodology, site conditions, material availability, contractor/design-builder capacity, types of works, and socio-politics. As a result, as shown in Figure 3-1, Case I involves Project-A and Project-D; Case II Involves Project-A and Project-E; Case III involves Project-B and Project-F; Case IV involves Project-C and Project-G. Since Project-A, Project-D, and Project-E situated possess similar features, Project-A is used for Case I and Case II analysis. Further, except for Project-C and Project-G, the remaining five projects were delivered by the same contractor/design-builder. Accordingly, the research used a multiple-case study design.

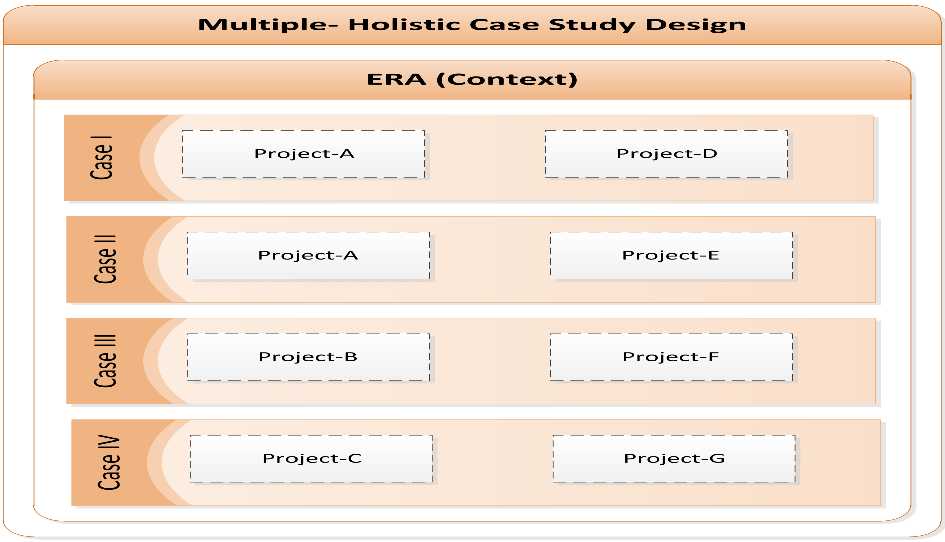

Figure 3-1: Case Study Design for the Research

3.3.3 Sources of Data, Means of Collection, and Analysis Techniques

As stated previously, a research design is used as a blueprint for given research. It does not only specify a set of data required for the analysis but it also specifies its sources and the instruments used to collect them. In general, depending on its originality and the source accessed, the sources of data are classified into primary and secondary sources. However, they could have any forms but are recorded without a researcher's intervention (Bowen, 2009) and used also for the case study research method (Yin, 2018; Mills, *et al.*, 2010).

- **Primary data sources** - as its name implies, are first-hand sources that are collected by the researcher for a specific research purpose to obtain original or previously unfiltered information. First-hand sources such as documents, archives, interviews, speeches, diaries, correspondence, government documents, research reports, creative artwork, and as such materials are primary sources.
- **Secondary sources** - are sources that interpret, critiques, and analyze the primary or first-hand data (Salkind, 2010; Kothari, 2004). It includes textbooks, dictionaries, encyclopedias, and materials that analyze and interpret any type of primary data.

More specific project information was collected from the respective project's Contract Documents, Soil and Material Investigation Report, Contractor's Work Statement, Topographic Surveying Report, Progress Report, Contract Completion Report. DBB's BOQ was extracted from the Contractor completion report; however, the BOQ for DB projects had been kept as a design-builder company secret. Therefore, the detailed BOQ for each DB project was computed based on the approved section template, which describes the engineering aspect of the project.

Research data collected from both primary and secondary sources can be analyzed by examining, categorizing, tabulating, testing pieces of evidence, or any of these combinations (Yin, 2018). For case study research, Bowen (2009) recommends using a systematic procedure so-called document analysis to review or evaluate the existing documents. It can provide a window into various dimensions of the case than interview and observation (Mills, *et al.*, 2010). Therefore, the research used project-related documents and archives, as discussed below, as a primary source of data. The required data from these sources are also collected and analyzed side by side using the method called document analysis.

- **Contract Documents -** give the project scope, the requirements (BOQ and Specification for DBB and Employer's requirement for DB projects).
- **Soil and Material Investigation Report** - describe the availability and chainage distance between the source of construction materials to determine the relative hauling distance between projects.
- **ERA's Standard Technical Specification** - used to compare one project against the other based on the required type and quality of the material.
- **Contractor's Work Statement -** portrayed the work methodology prepared by the contractor for a given project and used to compare one project against the other.
- **Topographic Surveying Report -** gives information about the terrain classification which can be read in line with the work methodology.
- **Contract Completion Report -** present the detailed information and final status of the projects compiled by the contractor and consultant about the project from the initial to the end of the project.
- **Project Progress Report –** present the physical and financial status of the project against its contract period.
- **RSDP Assessment Report -** give the number of completed and on-going projects within a certain RSDP implementation period.

During analysis, the corresponding work items are eliminated from the computation under the situation when these factors are not similar or difficult to adjust. Further, to ensure the so-called *'apple-to-apple'* comparison principle, projects tendered at different time frames are adjusted for time difference to treat the economic inflation and/or deflation.

As a summary, to arrive at the research's findings, the research is oriented into a positivist research paradigm; it endorsed a combination of exploratory (to some extent) and descriptive research type, quantitative research design, and deductive research approach. DBB and DB road projects delivered by the Authority need to be selected systematically and analyzed against the criteria set above. They are compared against each other using a multiple-case holistic design approach to identify the cost impact of PDS on the cost of road projects in the context of the ERA. Therefore, the subsequent Chapter analyzes the selected projects based on the criteria established in Section 2.8.2 and undertake the cost comparison between the projects using the primary data obtained from different documents using the document analysis method.

3.4 Research Reliability and Validity

Research reliability and validity are the two important concepts used to ensure the research quality (Kirk & Miller, 1986). Reliability refers to the extent to which the formulated research methodology can produce similar results under consistent conditions. It explains the precision of the research tools used to replicate the research findings. Conversely, validity refers to the extent to which the research tools can measures what it claims to measure. It explains the accuracy of the research tool. As a result, research validity can ensure research reliability; however, reliability does not necessarily ensure research validity (Salkind, 2010).

Reliability is about replication logic. There are two types of replication logic: literal replication and theoretical generalization. According to Yin (2018), the literal replication ensures the occurrence of similar findings while the theoretical replication implies the opposing results between multiple case analyses. However, research reliability is prone to bias and errors that can be induced by the participant (the research subject) and/or the researcher (Shipman, 1997).

Validity is all about accuracy. It assessed the research findings according to the recognized theories and other measures of the same concept. This can be addressed through construct validity, internal validity, and external validity. Construct validity examines the degree to which the research tool used can test the research theory or hypothesis. It can be addressed by ensuring the logical links between the adopted research paradigm, research type, approach, and design. Internal validity is concerned to demonstrate a causal relationship between two variables. Lastly, external validity discusses the relevance of the results beyond the investigated situation (i.e., generalizability). It is all about generalizing the research findings to other relevant groups (Jonker & Pennink, 2010; Walker, 1997).

Therefore, based on the above discussion the research has minimized the subject's error and bias by selecting case projects and comparing their cost-per-kilometer based on the predefined selection criteria stated in Section 3.3.2. The particular pay items, in the event of difference, should be eliminated from the analysis. Further, the researcher's bias has been minimized due to the adopted research paradigm (i.e., positivism). Because it does not allow the researcher's involvement that could create an observer's bias.

CHAPTER 4: Result and Discussion

4.1 Introduction

As stated in Section 3.3.2, the research identified three completed DBB (Project-A, Project-B, and Project-C) and four ongoing DB (Project-D, Project-E, Project-F, and Project-G) Upgrading-Asphalt Concrete (AC)-Link road projects. For cost comparison purposes, the researcher used these three DBB projects as a control project for respective DB projects. All case analysis involves a pair of DBB and DB projects tendered at different time frames and have different monetary value due to economy and other factors. However, the effect of inflation and/or deflation was adjusted using the PAF and CPI accordingly. It should be noted that, the total project cost as well as the cost-per-kilometer figures shown by each case only portray those selected pay items. As a result, due to discarding non-similar pay series, the cost figures are lower than the actual/expected total project cost shown on the project's contract documents. The next sections present thoroughly the analysis and discussion section of the research through six sections. The first section describes the basic project information, availability of materials, and work volume holistically. The second, third, fourth, and fifth sections present the case analysis by presenting the case project's contract information, methodology, time adjustment, and cost-per-kilometer comparison. The last section summarize and tabulated the four case analysis results.

4.2 Case Description

4.2.1 Basic Project Information

The ERA was entered into a contract with the same construction company for construction/design-build of Project-A, Project-B, Project-D, Project-E, and Project-F. These all five projects were located in the northwestern part of Ethiopia and administered by the ERA's North Regional Directorate. Particularly, Project-A, Project-D, and Project-E are located closer to each other and Kola climatic zone. Moreover, Project-B and Project-F are consecutive projects and situated in Kola and Weina Dega climatic conditions. Whereas Project-C was delivered by Chinese Construction companies and Project-G is under construction by domestic joint-ventured design-builders. Both projects are located in the Southern Part of Ethiopia and administered by the ERA's

South Regional Directorate. These two projects start at the same point, branch out in a different direction, and are situated in Kola climatic conditions. In general, each case project is situated in a similar geographical location. They cope with similar local administrators, security issues, and remoteness. Thus, the influence of socio-politics attributes on the cost of the project is eliminated.

Although all projects involve different design and supervision consultants, the research neglected their effect on the project cost relating to the PDS. Hence, the supervision contract difference was not taken into consideration during cost comparison. In addition to this, it should be noted that DBB’s project unit rate does not include detailed engineering design fees. As a result, the cost-per-kilometer comparison only portrays the construction cost of the projects.

As shown in Table 4-1, except Project-C, all case groups involve projects with similar pavement surfacing. It has also a similar carriage and shoulder-width at both rural and urban sections. However, except for the rural section of Project-A and Project-E, all road projects exhibit different shoulder surfacing in rural and kebele/town sections. To ensure a similar comparison, their respective cost was not considered during cost estimation.

4.2.2 Availability of Construction Material

In general, by taking the offset distance from the centerline of the project and hauling distance between the successive sources into consideration, all the case projects possessed reasonable construction materials both in type as well as quantity. Referring to the projects’ Soil and Material Investigation Final Reports, the following points are noted for the respective case projects.

- Project-A and Project-D had 49 and 43 potential sources of construction materials with abundant quantity along the project corridor respectively. 32 sources for borrow material; 6 sources for natural gravel; 7 sources for crushed stone and masonry; 2 sources for sand; and 2 sources for water were approved for Project-A. While 20 sources for borrow material; 14 sources for natural gravel; 4 sources for crushed stone and masonry; 2 sources for sand; and 3 sources for water were approved for Project-D.

- Project-E accessed 66 potential construction material sources (i.e., 55 sources for borrow material; 7 rock sources quarries, 1 source for sand; and above three sources for water within project vicinity. However, unlike Project-A, sand is generally scarce in the area where Project-E is stretched. The rivers in the project area do not bear sand except a single River which has very fine sand. As a result, the design-builder used that single River as a sand source for the project works.
- Project-B and Project-F had abundant construction materials from 67 and 48 potential sources. For instance, Project-B was approved for 51 sources of borrow material; 13 sources of natural gravel; 3 sources of crushed stone and masonry; 2 sources of sand; and 2 sources of water. Similarly, Project-F used 41 sources for borrow material; 4 rock sources quarries, 1 source for sand; and two sources for water. It should be noted that the contractor identified natural river sand that fulfills the contract specification requirements located around 50 Km from the end of the project and stocked at the base camp.
- Except for the quarry source for Project-G, both Project-C and Projec-G were approved for abundant sources of local construction materials within the project vicinity area. Specific to Project-G, two quarry sources of basaltic stone suitable for the production of asphaltic and concrete aggregate, were located at 10.5 km from the starting point along the project-C route and the other one 17.5 km away from the end of the project.
- On all projects, the respective contractors/design-builders were set up the construction site with material production and stock area at a convenient place. To mention a few, during the crushed stone production required for base course construction, the crushed stone has been stockpiled using a loader and a dump truck next to the crushing site. The bitumen is also stored outside next to the asphalt decanting plant within a reasonable distance. Cement and reinforcement bar is also planned to be carefully stored under a well-ventilated store at a given site in such a way to avoid possible wastage that could be occurred due to moisture and direct physical contact with the ground. These all imply that the contractors/design-builders articulate proper material handling methodology in such a way that minimizes the hauling distance on both projects.

4.2.3 Project's Work Volume

As discussed above, the research addressed the scope adjustment by ensuring the presence of similar site conditions and security issues, availability of materials, and work methodology between the respective case projects. The research accessed the final work quantities for each pay item of each DBB projects from the completion report. However, the research was limited to estimate certain pay items of DB projects. Consequently, the research has computed the construction cost of 41 pay items, 38 pay items, 34 pay items, and 49 pay items for the first, second, third, and fourth case projects respectively.

Concerning Series 1000, the work quantities along each payment clauses are estimated based on the anticipated project's duration and the Employer's requirements. The volume of works under each payment clause listed on other Series was computed by the respective project's quantity surveyors against DBB's Bills of Quantity (BOQ). The detailed BOQ for each case project is presented from Annex-1 to Annex-4. In general, by looking at the proportion of each Series shown in Table 4-7, Table 4-11, Table 4-15, and Table 4-19 against the project cost, the research has assumed that the case projects had a relative work scope.

Table 4-1: Project's Basic Information

Project Parameters		Case I		Case II		Case III		Case IV	
		Project-A	**Project-D**	**Project-A**	**Project-E**	**Project-B**	**Project-F**	**Project-C**	**Project-G**
Employer		ERA	ERA	ERA	ERA	ERA	ERA	ERA	ERA
Designer (D)	Name	D1	C1	D1	C1	D2	C1	D3	C1
Works Contract	Contractor (C)	C1		C1		C1		C2	
	Contract Type	BOQ	Lump-Sum	BOQ	Lump-Sum	BOQ	Lump-Sum	BOQ	Lump-Sum
	Total Amount (Mil ETB)	1767.85	1548	1767.85	1432.21	950.06	1025.56	794.86	897.01
	Commencement date	24-Dec-13	19-Oct-17	24-Dec-13	30-Nov-17	1-Aug-10	16-Oct-17		
	Estimated Completion	25-Dec-16	18-Apr-21	25-Dec-16	30-Nov-19				
	Contract Duration (Cal. Days)	1096	1278	1096	1096	1095	1095	1095	1095
	Actual completion	25-Jul-16	On-going	25-Jul-16	On-going	12-Aug-14	On-going	12-Aug-14	On-going
Supervision	Consultant (SC)	SC-1	SC-2	SC-1	SC-3	SC-4	SC-5	SC-6	SC-7
	Contract Type	Time-based	Time-based	Time-based	Time-based	Time-based	Time-based	Time-based	Time-based
	Total Amount (Mil ETB)	14.086	31.84	14.086	18.786	15.851	18.242	14.228	19.861
	Date	25-Nov-13	9-Oct-17	25-Nov-13	21-Nov-16	8-Mar-10	13-Sep-13	30-Apr-13	21-Jul-17
Types of Work (N=New, UG=Upgrading, R=Rehabilitation)		UG	UG	UG	UG	UG	UG	UG	UG
Project Delivery Systems		DBB	DB	DBB	DB	DBB	DB	DBB	DB
Project length (Km)		118.45	117.3	118.45	92	76.6	69.37	91	63.35

Carriage width (m)	7 (2X3.5)	7 (2X3.5)	7 (2X3.5)	7 (2X3.5)	7 (2X3.5)	7 (2X3.5)	7 (2X3.5)	7 (2X3.5)
Shoulder Width (Rural/Keble Section) (m)	1.5/2.5	1.5/2.5	1.5/2.5	1.5/2.5	1.5/2.5	1.5/2.5	1.5/2.5	1.5/2.5
Pavement Surfacing	AC	AC	AC	AC	AC	AC	DBST	AC
Shoulder Surfacing (Rural/Keble Section)	Gravel/DBST	DBST/AC	Gravel/DBST	Gravel/AC	Gravel	SST/Tiles	Gravel	DBST/AC
Climate Zone (K=Kola, WD=Weina Dega, D=Dega)	K	K	K	K	K & WD	K, WD	K	K
Project Location (Ethiopia)	North-West	North-West	North-West	North-West	North-West	North-West	South	South
Supply access	Similar	Similar	Similar	Similar	Similar	Similar	Similar	Similar
Socio-politics	Similar	Similar	Similar	Similar	Similar	Similar	Similar	Similar
Material availability	Enough	Enough	Enough	Enough	Enough	Enough	Abundant	Abundant
Project Status (Completion)	100%	95%	100%	94%	100%	85%	100%	60%
Project Scope	OK!	OK!	OK!	OK!	OK!	OK!	OK!	OK!

4.3 Case-I Analysis

4.3.1 Project's Contract Information

Project-A is delivered through a quantity-based approach. It involves three separate contract agreements for design consulting service, construction supervision service, and construction works. The Employer signed a Service Contract agreement with the construction supervision consultant on November 25, 2013, with a time-based contract amount of ETB 14,086,962.92 including 15% VAT. Similarly, the Employer signed a Works Contract agreement with the contractor on November 26, 2013, with admeasurement forms of contract and with a fixed unit price contract amount of ETB 1,607,687,055,79 including 15% VAT. Further, the contractor is certified for ETB 1,650,305,603.04 including 15% VAT and two variation orders. The first variation order was issued for the provisions of additional Engineer's facility which amounts to ETB 3,018,750.00 including 15% VAT. The second variation order was issued due to the additional 14.1 km of the road which amounts to ETB 92,166,453.36 including 15% VAT. As a result, the research has taken the final quantities for selected pay items.

Project-D is delivered through a non-quantity based approach. It involves two separate contract agreements such as Design-build and Construction Supervision Contract with domestic design-builder and consulting firms respectively. The Design-build contract agreement was made on May 23, 2017, between ERA and the Design-builder with a Lump Sum contract amount of ETB 1,548,000,000.00 including 15% VAT to be completed within 42 calendar months. Similarly, the Consultancy Service Contract agreement was made on 9th October 2017 with a Time-based contract amount of ETB 31,840,510.00 including 15% VAT.

Both Project-A and Project-D are upgradings of Asphalt Concrete (AC) road projects with a total length of 118.45 Km and 117.3 Km respectively. They have similar carriage and shoulder-width at rural, kebele, and town sections. Both projects were financed by the Government of Ethiopia (GoE) and predominately traverses through flat and rolling terrain types.

Although Project-A's project duration was estimated to be 36.6 calendar months (1096 calendar days), the project was 100% completed five months earlier than the contract period. On the other hand, as of October 2019, Project-D has physical progress of 95.22% and the time elapsed was 743 Calender days.

4.3.2 Project's Work Methodology

Site establishment and resource mobilization are the major part of the project's work methodology. As long as similar requirements have been drafted, projects which have similar site setup can have a similar cost of establishment. Conversely, as stated in Section 2.8.2.3, the decision made to mobilize key resources from adjacent projects has its implication on the project contract price and it can be taken as a winning strategy during tendering.

In this regard, as shown in Figure 4-1, the construction site for Project-A was established for both Contractor's and Engineer's site staff. Two independent but equivalent Contractors and Engineers' crews boarded at two different camps which are located at Station 38+600 and Station 81+000 of the project respectively. The first contractor's team was responsible to construct the road section from Station 0+000 to Station 60+000 and the second team was responsible for the second section stretched from Station 60+000 to Station 118+450. Major construction equipment and plants owned by the contractor were mobilized from nearby completed projects which are undertaken by the same contractor. The figure also shows the relative position of construction materials

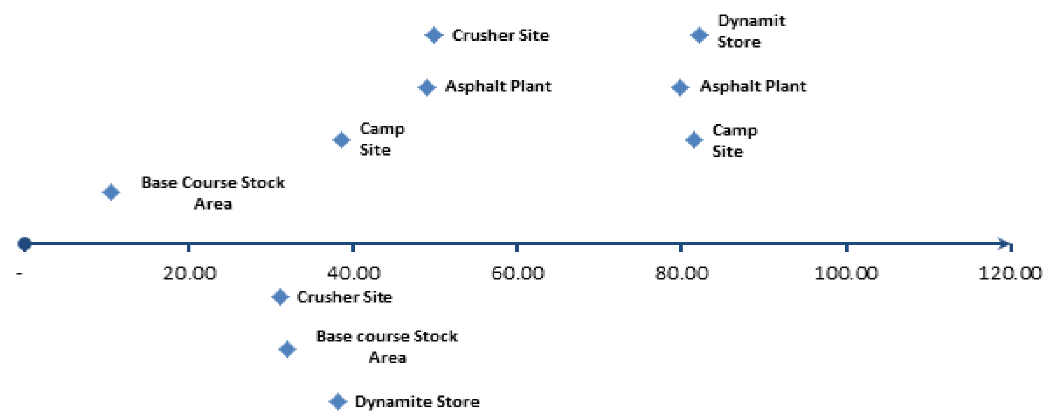

Figure 4-1: Project-A's Site Layouts

For Project-D, the same contractor (design-builder) formulated a work methodology that addresses the site establishment and mobilization of resources. Accordingly, as shown in Figure 4-2, the design-builder has established an advance camp at Station 31+500 and a base camp at Station 83+000 on the Left Hand Side (LHS) of the project. A temporary camp for staff accommodation and store had been also arranged at Station 93+000 and Project-E's (a case project used in the second case analysis) camp also served as a temporary office and store location.

On the other hand, the Employer's representative's site staff boarded adjacent to the design-builder on base camp. The design-builder approached the whole stretch of the project from four directions using four independent teams. The first two teams which boarded at advance camp are responsible to execute the construction work from Station 0+000 to Km 31+500 side and from Station 31+500 to Station 83+000 side respectively. Similarly, the remaining two teams settled at the main camp are arranged to proceed from Station 83+000 to Station 109+000 side and from Station 109+000 to Station 117+300 side respectively. Major construction equipment and plants owned by the design-builder were also mobilized from adjacent projects such as Project-A and Project-E which are undertaken by the same design-builder.

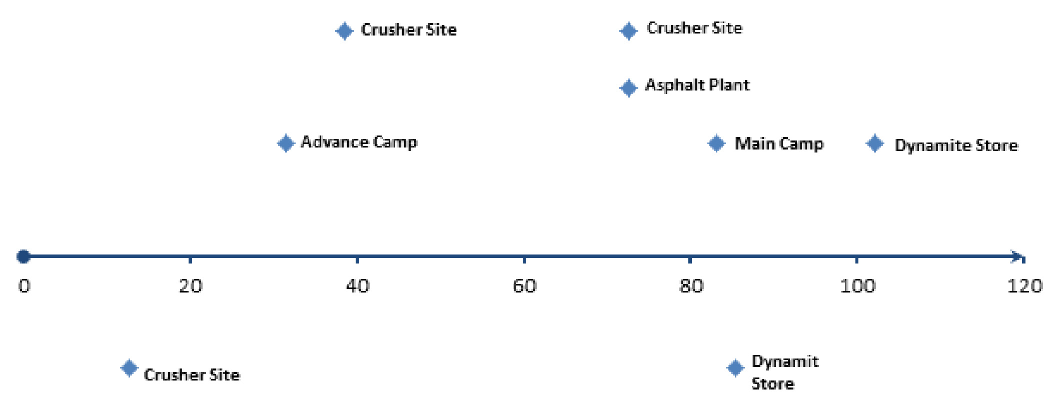

Figure 4-2: Project-D's Site Layouts

4.3.3 Time Adjustment for Project-A's Unit Rate

Projects delivered at a different place and time prospect could have a different unit rate. Further, due to market fluctuations, contractor capacity changeability, and other inconsistent factors, the unit rate offered by the contractor is granted only for a certain location and time horizon. Identifying the same contractor helps to normalize the effect of the contractor's capacity difference on the cost of the two selected projects. Although the contractor capacity and resources price at two different time frames may not be similar, the variance can be treated using the time adjustment.

In this regard, Project-A and Project-D tendered in April 2013 and March 2017 respectively, and were built at two different but having similar geographical locations. However, the research has demonstrated their geographical proximity. Hence, to ensure the trustworthiness of the analysis, Project-A's unit rates were adjusted for inflation and/or deflation (if any) observed between 2013 and 2017. As stated in Section 2.8, the effect of time variation was adjusted using the Price Adjustment Factor (PAF) or Consumer Price Index (CPI).

As shown in Table 4-2, by recalling the price adjustment process mentioned in Section 2.8.3, the research defined April 22, 2013 (Project-A's latest bidding date) as the base date, and the base price for the mentioned materials are taken from the price adjustment report. Due to the limitations to access Project-A's contract document, the researcher interpolates the base date by cross-checking the price index for equipment and exchange rate backward. While, the research defined March 21, 2017 (Project-D's latest bidding date) as the current date for the first case analysis. The current price, as well as the sources mentioned in the table, are taken from Section II (Letter of Acceptance and its attachment) of the contract document and the same sources assumed for Project-A.

Table 4-2: Cost Index (For Case I)

List of Materials	Cost Index		Sources
	Base Date (22/04/13)	Current Date (21/03/17)	
Diesel Fuel	17.12	16.59	Government diesel fuel price
Pen Grade 60/70	19,241.95	13,043.48	Libia Oil Ethiopia Limited
Reinforcement	18.52	15.12	Habesha Steel Mills Plc.
Cement	234.78	217.39	Messebo Building Materials Production Plc.
Equipment	210.00	220.70	US Bureau of Labor Statistics
Currency (USD to ETB)	18.7334	22.9244	National Bank of Ethiopia (NBE)

The research has recognized the price adjustment coefficients utilized for Project-A's pay items[15] as shown in Table 4-3. It also computed the Pn value as shown in Table 4-4 for each pay item based on the data obtained from Table 4-2 and Table 4-3. As shown in Table 4-5, by referring to CSA reports, the base and current index are found to be 131.2 and 179.8 for the years 2013 and 2017 respectively. Therefore, by plugging the base and current index value into Equation 2-6 the adjustment factor was found to be 1.37.

Table 4-3: Coefficient for Price Adjustment

Payment Items	Price Adjustment Coefficient						Total
	Fixed	Fuel	Bitumen	Steel	Cement	Equipment	
Series 1000	0.15	0.20				0.65	1.00
Series 2000	0.15	0.20				0.65	1.00
Series 3000	0.15	0.05		0.20	0.30	0.30	1.00
Series 4000	0.15	0.20				0.65	1.00
Series 5000	0.15	0.20				0.65	1.00
Series 6000	0.15	0.10	0.25			0.50	1.00

[15] It is also endorsed for the remaining three cases.

Table 4-4: Price Adjustment Factor for Case One

Bill No.	Non - Adjustable Factor	Fuel (F_o)	17.12	Bitumen (B_o)	19,241.95	Steel (S_o)	18.52	Cement (C_o)	234.78	Equip.(E_o)	210.00	USD to ETB		Adj. factor
		Weight	Fn	Weight	Bn	Weight	Sn	Weight	Cn	Weight	En	Z_o	Z_n	
1000	0.15	0.20	16.59							0.65	220.70	0.0534	0.0436	1.1798
2000	0.15	0.20	16.59							0.65	220.70	0.0534	0.0436	1.1798
3000	0.15	0.05	16.59			0.20	15.12	0.30	217.39	0.30	220.70	0.0534	0.0436	1.0254
4000	0.15	0.20	16.59							0.65	220.70	0.0534	0.0436	1.1798
5000	0.15	0.20	16.59							0.65	220.70	0.0534	0.0436	1.1798
6000	0.15	0.10	16.59	0.25	13,043.48					0.50	220.70	0.0534	0.0436	1.0594
8000	0.15	0.05	16.59			0.20	15.12	0.30	217.39	0.30	220.70	0.0534	0.0436	1.0254
9000	0.15	0.05	16.59			0.40	15.12	0.20	217.39	0.20	220.70	0.0534	0.0436	0.9675

Table 4-5: Consumer Price Index

Year	2011	2012	2013	2014	2015	2016	2017
CPI	100	117.4	131.2	142.4	156.5	173.1	179.8

4.3.4 Cost-per-kilometer Comparison

As long as Project-A and Project-D shared similar features and used a similar unit rate but delivered differently, the researchers assumed that the cost difference observed between them is caused by the adopted PDSs. To investigate the cost amount induced by the PDSs, the cost-per-kilometer for project-A and Project-D compared against each other. In this regard, the research has assessed that save for the need for adjustment for time differences. Project-A and Project-D have relatively similar features under the selected pay items except for the way they being delivered. Accordingly, the cost induced by the endorsed PDSs can be revealed based on Project-A's unit rate with adjustments as well as without adjustment.

As shown in Table 4-6, the research has estimated the total cost as well as the cost-per-kilometer for Project-D depending on the unit rate offered by the same contractor for Project-A (an adjacent DBB project). The computation is done by assuming what if Project-D delivered in the same year of Project-A (i..e, in 2013) and at the same place. Hence, the total cost and cost-per-kilometer (including 15% VAT) for Project-A (before adjustment for inflation and/or deflation) are found to be ETB 1,118,634,138.59 and 9,443,138.09 ETB/Km respectively. Similarly, the total cost and cost-per-kilometer (including 15% VAT) for Project-D are found to be ETB 1,242,356,106.37 and 10,591,271.15 ETB/Km respectively. Therefore, as shown below, if Project-D delivered in the same year and place of Project-A (i..e, in 2013), it is found to be approximately 12.2% costly than Project-A.

$$A = \frac{B - C}{C} * 100\% = \frac{10{,}591{,}271.15 - 9{,}443{,}138.09}{9{,}443{,}138.09} * 100\% = 12.16\%$$

After applying the PAF for the corresponding Pay Items (i.e, bring both projects into 2017 and same place), Projet-A's cost has increased from ETB 1,118,634,138.59 to ETB 1,257,385,605.28 and the cost-per-kilometer has also increased from 9,443,138.09 ETB/Km to 10,614,431.92 ETB/Km. Similarly, Projet-D's cost has increased from ETB 1,242,356,106.37 to ETB 1,403,361,352.62 and the cost-per-kilometer has also increased from 10,591,271.15 ETB/Km to 11,963,864.00 ETB/Km. Again, as shown below, Project-D is found to be approximately 12.7% costly than Project-A.

$$A = \frac{B - C}{C} * 100\% = \frac{11{,}963{,}864.00 - 10{,}614{,}431.92}{10{,}614{,}431.92} * 100\% = 12.71\%$$

In the same approach, the CPI has increased the project cost as well as cost-per-kilometer for Project-A from ETB 1,118,634,138.59 and 9,443,138.09 ETB/Km to ETB 1,532,528,769.87 and 12,937,099.19 ETB/Km respectively. Similarly, the project cost as well as cost-per-kilometer for Project-D are increased from ETB 1,242,356,106.37 and 10,591,271.15 ETB/Km to ETB 1,702,027,865.72 and 14,510,041.48 ETB/Km respectively. Therefore, as shown below, Project-D is found to be approximately 12.2% than Project-A.

$$A = \frac{B - C}{C} * 100\% = \frac{14{,}510{,}041.48 - 12{,}937{,}099.19}{12{,}937{,}099.19} * 100\% = 12.16\%$$

Although the result obtained using the CPI and the one computed before the adjustment is similar, due to the type of items the CPI constitutes, the researcher argued that the CSA’s CPI is too generic and skew to building projects. As presented previously, the result obtained by considering the effect of inflation is sound enough than the one without the effect of inflation. Therefore, the researcher has argued to use the result obtained using a price adjustment approach to reveal the amount of cost induced by the two PDSs.

In general, by keeping other things constant (i.e., geographical proximity, time proximity, scope proximity, contractor capacity, types of work, and as such factors), Project-D is found to be approximately 12.71% costly than Project-A after PA and this is due to the adopted PDS.

Table 4-6: Cost-Per-Kilometer (For Case I)

Pay Item	Description	Non-adjusted (2013)		Adjusted using PAF (2017)		Adjusted using CPI (2017)	
		Project-A	Project-D	Project-A	Project-D	Project-A	Project-D
1000	General Item	70,402,010.00	74,571,900.00	83,057,019.84	87,976,462.29	96,450,753.70	102,163,503.00
2000	Clearing and Grubbing	10,668,000.00	10,557,000.00	12,585,610.66	12,454,658.02	14,615,160.00	14,463,090.00
3000	Drainage	105,987,939.80	89,905,896.51	108,674,941.85	92,185,187.23	145,203,477.53	123,171,078.22
4000	Earthworks	300,192,541.90	355,515,033.20	354,153,211.10	419,420,115.52	411,263,782.40	487,055,595.48
5000	Sub base and base course	171,114,138.00	214,869,964.00	201,872,508.40	253,493,598.60	234,426,369.06	294,371,850.68
6000	Bituminous surfacing	314,360,708.20	334,889,864.00	333,035,495.35	354,784,198.01	430,674,170.23	458,799,113.68
Sub-total (ETB)		**972,725,337.90**	**1,080,309,657.71**	**1,093,378,787.20**	**1,220,314,219.67**	**1,332,633,712.93**	**1,480,024,231.06**
VAT (15%) (ETB)		**145,908,800.69**	**162,046,448.66**	**164,006,818.08**	**183,047,132.95**	**199,895,056.94**	**222,003,634.66**
Grand Total (ETB)		**1,118,634,138.59**	**1,242,356,106.37**	**1,257,385,605.28**	**1,403,361,352.62**	**1,532,528,769.87**	**1,702,027,865.72**
Project Length (km)		**118.46**	**117.30**	**118.46**	**117.30**	**118.46**	**117.30**
Normalized Cost (ETB/Km)		**9,443,138.09**	**10,591,271.15**	**10,614,431.92**	**11,963,864.90**	**12,937,099.19**	**14,510,041.48**
DB > DBB		**12.16%**		**12.71%**		**12.16%**	

Table 4-7: Work item proportion (For Case I)

Pay Item	Description	Adjusted using PAF (2017)			
		Project-A	Proportion	Project-D	Proportion
1000	General Item	83,057,019.84	8%	87,976,462.29	7%
2000	Clearing and Grubbing	12,585,610.66	1%	12,454,658.02	1%
3000	Drainage	108,674,941.85	10%	92,185,187.23	8%
4000	Earthworks	354,153,211.10	32%	419,420,115.52	34%
5000	Sub base and base course	201,872,508.40	18%	253,493,598.60	21%
6000	Bituminous surfacing	333,035,495.35	30%	354,784,198.01	29%
Sub-total (ETB)		**1,093,378,787.20**	**100%**	**1,220,314,219.67**	**100%**

4.4 Case-II Analysis

The same contractor has entered into a contract with the employer for the construction works of Project-A and a design-build contract for Project-E. To minimize redundancy, please refer to the information provided for Project-A from the previous case analysis.

4.4.1 Project's Contract Information

Project-E is delivered through a non-quantity based approach. It involves two separate contract agreements such as Design-Build and Construction Supervision Contract with domestic design-builder and consulting firms respectively. The Design-build contract agreement was made on May 26, 2016, between ERA and the Design-builder with a Lump Sum contract amount of ETB 1,432,205,652.00 including 15% VAT to be completed within 36.5 calendar months. Similarly, the Consultancy Service Contract agreement was made on November 21, 2016, with a Time-based contract amount of ETB 18,786,400.00 including 15% VAT.

Project-E was upgrading Asphalt Concrete (AC) road projects with a total length of 92 Km. It has a similar carriage and shoulder-width like Project-A at rural, kebele, and town sections. It was financed by the Government of Ethiopia (GoE) and predominately traverses through flat and rolling terrain types.

As of June 2019, Project-E has physical progress of 93.88% (86.37 Km) and the time elapsed was 572 Calender days which is 52.2% of the contract time. It implies the project can be completed ahead of the estimated completion date.

4.4.2 Project's Work Methodology

The design-builder formulated a work methodology for Project-E similar to Project-A. It addresses the site establishment and mobilization resources. As shown in Figure 4-3, the design-builder has established the main camp at Station 47+000 which is approximately the mid-point of the project section. As a result, both the entire Contractor's and Employer's Representatives' staff have made to reside at this main camp. The crusher plant, explosive site, asphalt plant, and precast production site organized in such a way that allows smooth workflow. The design-builder has also deployed material production and stock pilling mechanism for Project-E the same as Project-A. Hence, both projects shared similar work methodology.

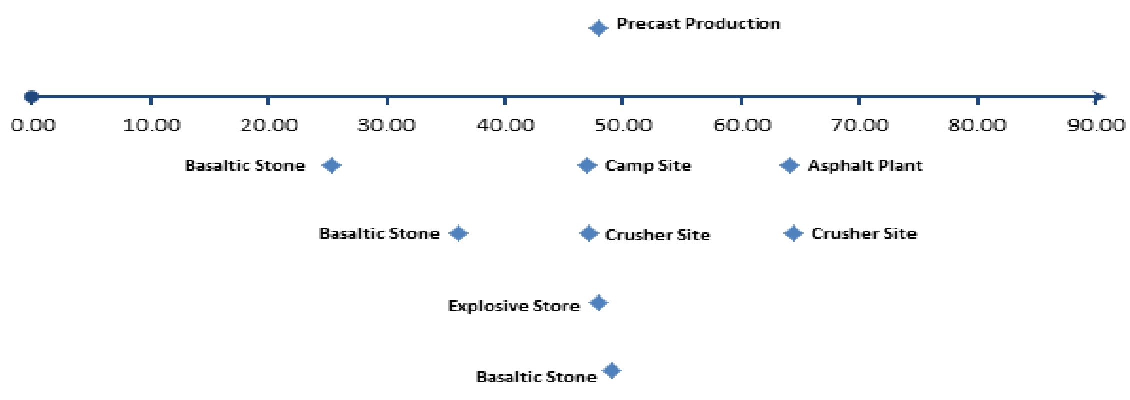

Figure 4-3: Project-E's Site layout

4.4.3 Time Adjustment for Project-A's Unit Rate

Although Project-A and Project-E tendered in April 2013 and March 2016 respectively, the research demonstrated their geographical proximity. They are two projects with closer geographical locations. Here again, Project-A's unit rates were adjusted for the time difference and used to compute the cost required for each pay item.

As shown in Table 4-8, the research has defined April 22, 2013 (Project-A's latest bidding date) as the base date, and the base price for the mentioned materials are taken from the price adjustment report. The same source approach was used to determine the base date. Hence, the same source assumption is also used in this case analysis. While, the research has defined March 10, 2016 (Project-E's latest bidding date) as the current date for the second case analysis.

As stated in footnote number 15, the researcher used the same price adjustment coefficients utilized for Project-A (See Table 4-3). The Pn value was computed as shown in Table 4-9 using the base and current index price shown in Table 4-8. On the other hand, by referring to CSA's reports, the base and current were 131.2 and 179.8 for the years 2013 and 2017 respectively. Hence, the CPI value becomes 1.37.

Table 4-8: Cost Index (for Case II)

List of Materials	Cost Index		Sources
	Base Date (22/04/13)	**Current Date (10/03/16)**	
Diesel Fuel	17.12	14.37	Government diesel fuel price
Pen Grade 60/70	19,241.95	17,085.22	NOC
Reinforcement	18.52	16.96	Guna Trading House Plc
Cement	234.78	217.39	Messebo Building Materials Production Plc.
Equipment	210.00	218.70	US Bureau of Labor Statistics
Currency (USD to ETB)	18.7334	21.701	CBE

Table 4-9: Price Adjustment Factor for Case Two

Bill No.	Non - Adjustable Factor	Fuel (F_o)	17.12	Bitumen (B_o)	19,241.95	Steel (S_o)	18.52	Cement (C_o)	234.78	Equip.(E_o)	210.00	USD to ETB		Adj. factor
		Weighting	Fn	Weighting	Bn	Weighting	Sn	Weighting	Cn	Weighting	En	Z_o	Z_n	
1000	0.15	0.20	14.37							0.65	218.70	0.0534	0.0461	1.1020
2000	0.15	0.20	14.37							0.65	218.70	0.0534	0.0461	1.1020
4000	0.15	0.20	14.37							0.65	218.70	0.0534	0.0461	1.1020
5000	0.15	0.20	14.37							0.65	218.70	0.0534	0.0461	1.1020
6000	0.15	0.10	14.37	0.25	17,085.22					0.50	218.70	0.0534	0.0461	1.0591

4.4.4 Cost-per-kilometer Comparison

To investigate the cost amount induced by the PDSs, the cost-per-kilometer for project-A and Project-E compared against each other. In this regard, the research has assessed that save for the need for adjustment for time differences. Project-A and Project-E have relatively similar features under the selected pay items except for the way they being delivered. Accordingly, the cost induced by the endorsed PDSs can be revealed based on Project-A's unit rate with adjustments as well as without adjustment.

As shown in Table 4-10, the research has estimated the total cost as well as the cost-per-kilometer for Project-E depending on the unit rate offered by the same contractor for Project-A (an adjacent and parallel DBB project). The computation is done by assuming what if Project-E delivered in the same year of Project-A (i..e, in 2013). Hence, the total cost and cost-per-kilometer (including 15% VAT) for Project-A (before adjustment for inflation and/or deflation) are found to be ETB 1,054,400,007.46 and 8,900,894.88 ETB/Km respectively. Similarly, the total cost and cost-per-kilometer (including 15% VAT) for Project-E are found to be ETB 957,531,812.91 and 10,407,954.49 ETB/Km respectively. Therefore, as shown below, if Project-E delivered in the same year and place of Project-A (i..e, in 2013), it is found to be approximately 16.9% costly than Project-A.

$$A = \frac{B - C}{C} * 100\% = \frac{10{,}407{,}954.49 - 8{,}900{,}894.88}{8{,}900{,}894.88} * 100\% = 16.93\%$$

After applying the PAF for the corresponding Pay Items (i.e, bring both projects into 2016 and same place), Projet-A's cost can be increased from ETB 1,054,400,007.46 to ETB 1,146,764,769.43 and the cost-per-kilometer can be also increased from 8,900,894.88 ETB/Km to 9,680,607.54 ETB/Km. Similarly, Projet-E's cost has increased from ETB 957,531,812.91 to ETB 1,042,861,624.21 and the cost-per-kilometer has also increased from 10,407,954.49 ETB/Km to 11,335,452.44 ETB/Km.

Again, as shown below, Project-E is found to be approximately 17.1% costly than Project-A.

$$A = \frac{B - C}{C} * 100\% = \frac{11{,}335{,}452.44 - 9{,}680{,}607.54}{9{,}680{,}607.54} * 100\% = 17.09\%$$

In the same approach, the CPI has increased the project cost as well as cost-per-kilometer for Project-A from ETB 1,054,400,007.46 and 8,900,894.88 ETB/Km to ETB 1,391,808,009.84 and 11,749,181.24 ETB/Km respectively. Similarly, the project cost as well as cost-per-kilometer for Project-E are increased from ETB 957,531,812.91 and 10,407,954.49 ETB/Km to ETB 1,263,941,993.04 and 13,738,499.92 ETB/Km respectively. Therefore, as shown below, Project-E is found to be approximately 16.9% than Project-A.

$$A = \frac{B - C}{C} * 100\% = \frac{13{,}738{,}449.92 - 11{,}749{,}181.24}{11{,}749{,}181.24} * 100\% = 16.93\%$$

As discussed previously, the result obtained by considering the effect of inflation is sound enough than the one without the effect of inflation. Therefore, the researcher has argued to use the result obtained using a price adjustment approach to reveal the amount of cost induced by the two PDSs.

In general, by keeping other things constant (i.e., geographical proximity, time proximity, scope proximity, contractor capacity, types of work, and as such factors), Project-E is found to be approximately 17.1% costly than Project-A after PA and this is due to the adopted PDS.

Table 4-10: Cost-Per-Kilometer (For Case II)

Pay Item	Description	Non-adjusted (2013)		Adjusted using PAF (2016)		Adjusted using CPI (2016)	
		Project-A	Project-E	Project-A	Project-E	Project-A	Project-E
1000	General Item	70,402,010.00	72,145,000.00	77,582,910.01	79,503,682.39	92,930,653.20	95,231,400.00
2000	Clearing and Grubbing	10,668,000.00	8,280,000.00	11,756,120.09	9,124,547.65	14,081,760.00	10,929,600.00
4000	Earthworks	328,052,741.70	343,755,103.45	361,513,632.02	378,817,611.24	433,029,619.04	453,756,736.56
5000	Sub base and base course	200,076,221.80	158,448,529.20	220,483,697.98	174,610,042.83	264,100,612.78	209,152,058.54
6000	Bituminous surfacing	307,670,598.20	250,007,726.40	325,850,395.93	264,780,310.86	406,125,189.62	330,010,198.85
Sub-total (ETB)		**916,869,571.70**	**832,636,359.05**	**997,186,756.02**	**906,836,194.97**	**1,210,267,834.64**	**1,099,079,993.95**
VAT (15%) (ETB)		**137,530,435.76**	**124,895,453.86**	**149,578,013.40**	**136,025,429.25**	**181,540,175.20**	**164,861,999.09**
Grand Total (ETB)		**1,054,400,007.46**	**957,531,812.91**	**1,146,764,769.43**	**1,042,861,624.21**	**1,391,808,009.84**	**1,263,941,993.04**
Project Length (km)		**118.46**	**92.00**	**118.46**	**92.00**	**118.46**	**92.00**
Normalized Cost (ETB/Km)		**8,900,894.88**	**10,407,954.49**	**9,680,607.54**	**11,335,452.44**	**11,749,181.24**	**13,738,499.92**
DB > DBB		**16.93%**		**17.09%**		**16.93%**	

Table 4-11: Work item proportion (For Case II)

Pay Item	Description	Adjusted using PAF (2016)			
		Project-A	Proportion	Project-E	Proportion
1000	General Item	77,582,910.01	8%	79,503,682.39	9%
2000	Clearing and Grubbing	11,756,120.09	1%	9,124,547.65	1%
4000	Earthworks	361,513,632.02	36%	378,817,611.24	42%
5000	Sub base and base course	220,483,697.98	22%	174,610,042.83	19%
6000	Bituminous surfacing	325,850,395.93	33%	264,780,310.86	29%
Sub-total (ETB)		**997,186,756.03**	**100%**	**906,836,194.97**	**100%**

4.5 Case-III Analysis

4.5.1 Project's Contract Information

Project-B is delivered through a quantity-based approach. It involves three separate contract agreements for design consulting service, construction supervision service, and construction works. The Employer signed a Service Contract agreement with the construction supervision consultant on March 8, 2010, with a contract amount of ETB 15,851,569.18 including 15% VAT. Similarly, the Employer signed a Works Contract agreement with the same contractor on February 10, 2013, with item rate forms of contract and with a revised contract amount of ETB 950,059,444.61 including 15% VAT. Project-B request 501 Calendar days for Extention of Time (EoT) due to issuing of four Variation Orders (i.e., VO#1 increasing the width of the road from 6.8m to 7m; provision of vehicles for the Engineers; additional construction of a road to provide access for nearby Suger factory; reconstruction of slide area). It was 100% completed on August 12, 2014.

Project-F is delivered through a non-quantity based approach. It involves two separate contract agreements such as Design-Build and Construction Supervision Contract with local design-builder and consulting firms respectively. The Design-build contract agreement was made on June 7, 2017, between ERA and the Design-builder with a Lump Sum contract amount of ETB 1,025,555,000.01 including provisional sum, 10% contingency, and 15% VAT to be completed within 36.5 calendar months. Similarly, the Consultancy Service Contract agreement was made on September 13, 2017, with a Time-based contract amount of ETB 18,242,834.10 including 15% VAT. As of November 2019, Project-E has physical progress of 85% (77.35 Km).

Project-B and Project-F are both upgrading Asphalt Concrete (AC) road projects with a total length of 76.60 Km and 69.37 Km respectively. They have similar carriage and shoulder-width at rural, kebele, and town sections. Both projects were financed by the Government of Ethiopia (GoE) and predominately traverses through flat and rolling terrain types.

4.5.2 Project's Work Methodology

For Project-B, both the Contractor and Engineer's main camps were established at Station 24+000. It is just about 3 Km from a River that bisects the project road into two parts and poses a challenge until the bridge construction is completed. It was difficult to cross the river even during the dry season. To solve this problem, to reside in a separate crew, the contractor established an advance camp situated at a town just about 2 km from the project starting point. In addition to this, to cross the river, the contractor also arranges a private boat to transport supervision staff, light construction materials, and crew from the main camp to advance camp.

For Project-F, the same contractor (design-builder) formulated a work methodology similar to Project-B that addresses the mobilization and site establishment and major construction work items by considering the project nature into account. The design-builder has established the main camp at Station 31+700 which is approximately mid-point of the project section. As a result, both the entire Contractor's and Employer's Representatives' staff have made to reside at this main camp. The crusher plant, explosive site, asphalt plant, and precast production site organized in such a way that allows smooth workflow.

In addition to the site organization, the design-builder has also deployed material production and stock pilling mechanism for Project-F the same as Project-B. Hence, both projects shared similar work methodology. As a result, the cost induced due to the methodological difference is assumed to be similar.

4.5.3 Time Adjustment for Project-B's Unit Rate

Although Project-B and Project-F tendered in September 2009 and March 2016 respectively, the research has demonstrated their geographical proximity. They are two projects with consecutive geographical locations. In addition to this, due to the unique nature of DB projects, the cost of Project-F has been computed based on Project-B's unit rate.

As shown in Table 4-12, the research has defined September 10, 2009 (Project-B's latest bidding date) as the base date, and the base price for the mentioned materials are taken from the project contract document. While, March 21, 2017 (Project-F's latest bidding date) as the current date for the third case analysis. The same source assumption is also used under this case analysis.

Table 4-12: Cost Index (for Case III)

List of Materials	Unit Price		Source
	Base Date (10/09/09)	Current Date (21/03/17)	
Fuel (Gas Oil)	8.20	16.63	Total Ethiopia Plc
Pen Grade 60/70	187.90	166.90	US Bureau of Labor Statistics
Reinforcement	193.70	213.70	US Bureau of Labor Statistics
Cement	218.50	250.00	Messebo Building, Material Production Plc
Equipment	189.90	220.70	US Bureau of Labor Statistics
Currency (USD to ETB)	12.5750	22.9244	National bank of Ethiopia

The price adjustment coefficients identified for the above two case analyses were also used for this case analysis. As shown in Table 4-13, the same approach was used to calculate the Pn value using Equation 2-5. However, as shown in Table 4-12, the base cost index for bitumen and reinforcement requires further adjustment for the corresponding foreign exchange rate just like the equipment. Therefore, to ensure a logical cost-per-kilometer comparison, Equation 2-5 was modified as shown in Equation 4-1. On the other hand, unlike the previous case analysis, the CPA's CPI has a different base index for the Year 2009 and 2017. Hence, the CPI was not used for this case analysis.

$$Pn = a + b\left(\frac{Fn}{Fo}\right) + c\left(\frac{Bn}{Bo}\right)\left(\frac{Zo}{Zn}\right) + d\left(\frac{Sn}{So}\right)\left(\frac{Zo}{Zn}\right) + e\left(\frac{Cn}{Co}\right) + f\left(\frac{Zo}{Zn}\right)\left(\frac{En}{Eo}\right) \quad \text{Equation 4-1}$$

Table 4-13: Price Adjustment Factor for Case Three

Bill No.	Non - Adjustable Factor	Fuel (F_o)	8.20	Bitumen (B_o)	187.90	Steel (S_o)	193.70	Cement (C_o)	218.50	Equip.(E_o)	189.90	USD to ETB		Adj. factor
		Weighting	Fn	Weighting	Bn	Weighting	Sn	Weighting	Cn	Weighting	En	Z_o	Z_n	
	a	b		c		d		e		f		1/12.5750	1/22.9244	
1000	0.15	0.25	16.63							0.6	220.70	0.0795	0.0436	1.9283
2000	0.15	0.35	16.63							0.5	220.70	0.0795	0.0436	1.9192
3000	0.15	0.2	16.63			0.3	213.70	0.2	250.00	0.15	220.70	0.0795	0.0436	1.7057
4000	0.15	0.25	16.63							0.6	220.70	0.0795	0.0436	1.9283
5000	0.15	0.25	16.63							0.6	220.70	0.0795	0.0436	1.9283
6000	0.15	0.15	16.63	0.4	166.90					0.3	220.70	0.0795	0.0436	1.7376
8000	0.15	0.2	16.63			0.3	213.70	0.2	250.00	0.15	220.70	0.0795	0.0436	1.7057

4.5.4 Cost-per-kilometer Comparison

To investigate the cost amount induced by the PDSs, the cost-per-kilometer for project-B and Project-F compared against each other. In this regard, the research has assessed that save for the need for adjustment for time differences. Project-B and Project-F have relatively similar features under the selected pay items except for the way they being delivered. Accordingly, the cost induced by the endorsed PDSs can be revealed based on Project-B's unit rate with adjustments as well as without adjustment.

As shown in Table 4-14, the research has estimated the total cost as well as the cost-per-kilometer for Project-F depending on the unit rate offered by the same contractor for Project-B. The computation is done by assuming what if Project-F delivered in the same year of Project-B (i..e, in 2009). Hence, the total cost and cost-per-kilometer (including 15% VAT) for Project-B (before adjustment for inflation and/or deflation) are found to be ETB 490,716,418.70 and 6,405,885.05 ETB/Km respectively. Similarly, the total cost and cost-per-kilometer (including 15% VAT) for Project-F are found to be ETB 495,290,067.05 and 7,139,830.86 ETB/Km respectively. Therefore, as shown below, if Project-F delivered in the same year and place of Project-B (i..e, in 2009), it is found to be approximately 11.5% costly than Project-B.

$$A = \frac{B - C}{C} * 100\% = \frac{7{,}139{,}830.86 - 6{,}405{,}885.05}{6{,}405{,}885.05} * 100\% = 11.46\%$$

After applying the PAF for the corresponding Pay Items (i.e, bring both projects into 2017 and same place), Projet-B's cost can be increased from ETB 490,716,418.70 to ETB 919,464,468.17 and the cost-per-kilometer can be also increased from 6,405,885.05 ETB/Km to 12,002,825.81 ETB/Km. Similarly, Projet-F's cost has increased from ETB 495,290,067.05 to ETB 929,359,753.23 and the cost-per-kilometer has also increased from 7,139,830.86 ETB/Km to 13,397,142.18 ETB/Km.

Again, as shown below, Project-E is found to be approximately 11.6% costly than Project-A.

$$A = \frac{B - C}{C} * 100\% = \frac{13{,}397{,}142.18 - 12{,}002{,}825.81}{12{,}002{,}825.81} * 100\% = 11.62\%$$

Therefore, by keeping other things constant (i.e., geographical proximity, time proximity, scope proximity, contractor capacity, types of work, and as such factors), Project-F is found to be approximately 11.6% costly than Project-B and this is due to the adopted PDS.

Table 4-14: Cost-Per-Kilometer (For Case III)

Pay Item	Description	Non-adjusted (2009)		Adjusted using PAF (2017)	
		Project-B	Project-F	Project-B	Project-F
1000	General Item	53,399,172.60	48,212,064.00	102,969,624.52	92,967,323.01
2000	Clearing and Grubbing	1,984,893.88	2,353,251.75	3,809,408.33	4,516,360.75
4000	Earthworks	177,715,947.44	216,128,680.28	342,689,661.44	416,760,934.19
5000	Sub base and base course	71,573,344.85	46,880,065.26	138,014,880.87	90,398,829.83
6000	Bituminous surfacing	122,036,570.54	117,112,953.54	212,050,744.97	203,495,468.07
Sub-total (ETB)		**426,709,929.31**	**430,687,014.82**	**799,534,320.15**	**808,138,915.85**
VAT (15%) (ETB)		**64,006,489.40**	**64,603,052.22**	**119,930,148.02**	**121,220,837.38**
Grand Total (ETB)		**490,716,418.70**	**495,290,067.05**	**919,464,468.17**	**929,359,753.23**
Project Length (km)		**76.60**	**69.37**	**76.60**	**69.37**
Normalized Cost (ETB/Km)		**6,405,885.05**	**7,139,830.86**	**12,002,825.81**	**13,397,142.18**
DB > DBB		**11.46%**		**11.62%**	

Table 4-15: Work item proportion (For Case III)

Pay Item	Description	Adjusted using PAF (2017)			
		Project-B	Proportion	Project-F	Proportion
1000	General Item	102,969,624.52	12.9%	92,967,323.01	11.5%
2000	Clearing and Grubbing	3,809,408.33	0.5%	4,516,360.75	0.6%
4000	Earthworks	342,689,661.44	42.9%	416,760,934.19	51.6%
5000	Sub base and base course	138,014,880.87	17.3%	90,398,829.83	11.2%
6000	Bituminous surfacing	212,050,744.97	26.5%	203,495,468.07	25.2%
Sub-total (ETB)		**799,534,320.15**	**100%**	**808,138,915.85**	**100%**

4.6 Case-IV Analysis

4.6.1 Project's Contract Information

Project-C is delivered through a quantity-based approach. It involves three separate contract agreements for design consulting service, construction supervision service, and construction works. The Employer signed a Service Contract agreement with the construction supervision consultant on the 30th day of April 2013 with a time-based contract amount of ETB 14,228,375.00 including 15% VAT. Similarly, the Employer signed a Works Contract agreement with a Chinese contractor on March 7, 2013, based on a fixed unit price arrangement with a contract amount of ETB 794,855,085.55 including 15% VAT. It was 100% completed.

Project-G is delivered through a non-quantity based approach. It involves a separated Design-build and Consultancy Service contract agreement with local joint-ventured design-builder and consulting firms respectively. The Design-build contract agreement was made on July 3, 2017, between ERA and the Design-builders with a Lump Sum contract amount of ETB 897,005,974.61 including 15% VAT to be completed within 36.5 calendar months. Similarly, the construction supervision service contract agreement was made on July 21, 2017, with a Time-based contract amount of ETB 19,869,652.23 including 15% VAT. As of April 2020, Project-G has physical progress of 59.86% (34.21 Km) and the time elapsed was 775 Calender days.

Project-C and Project-G were upgrading Asphalt Concrete (AC) road projects with a total length of 91 and 63.35 Km respectively. They have a similar carriage and shoulder-width at rural and kebele/town sections. Project-C traverse through 56% rolling, 3.3% rolling to flat, and 40.7% flat. While Project-G traverses through 15% rolling and 85% flat terrain types; however, the cost comparison relies on the volume of work, and the degree of similarity or difference on terrain types are assumed to be insignificant.

Although both Project-C and Project-G have similar design standards, they exhibit different materials for pavement and shoulder surfacing. Hence, to ensure similar comparison items, their respective cost was not considered.

4.6.2 Project's Work Methodology

Comparing projects awarded for entities which have different capacity and working culture is a very complex, difficult, and sometimes impossible task. However, the researcher supposed the two projects to be delivered using a single entity. But the work statements drafted by the above entities are thoroughly analyzed to minimize and ensure similar cost implication being similar/or single contractor.

As shown in Figure 4-4, the Chinese Contractor has established a construction site for both Contractor's and Engineer's site staff for Project-D. During the mobilization period, the Contractor provided temporary housing and offices to the Engineer and his staff at a place located 4 km away from the project starting point. The contractor has divided the project length into three sections and possessed them accordingly. As a result, four camps were established, such as the main camp at station 13+500, sub-camp at station 31+000, second camp at station 49+000, and rented camp at station 66+000. The rented camp is also used as Engineer's main office.

Residential and office accommodations; laboratory building and equipment; offices, surveying, and communication equipment; and vehicles were also provided as per the requirements stipulated on the contract document. Major construction equipment and plants owned by the contractor has mobilized into the project site. Although there was no specific stockpile area and pipe yard site, the precast elements were produced and stockpiled near the crushed site. In addition to this, the crushers were also installed concerning the basaltic stone sources.

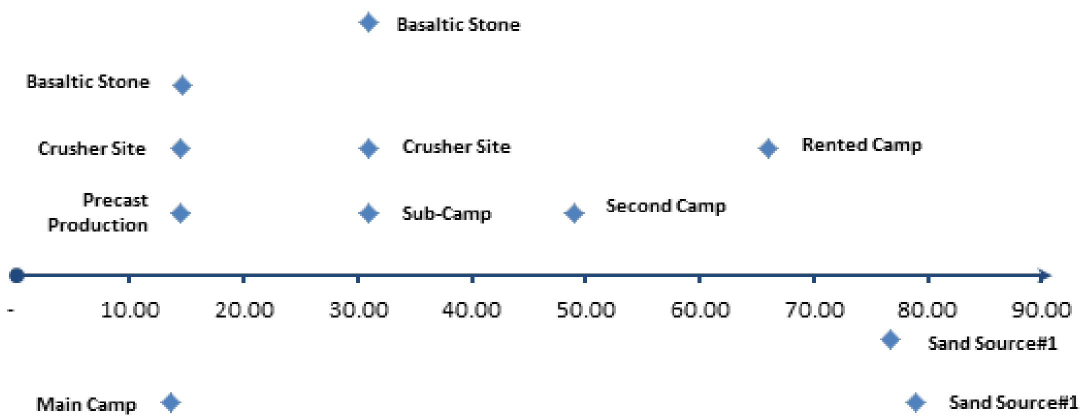

Figure 4-4: Project-C's Site Layouts

For Project-G, the domestic joint-ventured design-builder has formulated a work methodology that addresses the mobilization and site establishment and major construction work items by considering the issues. Accordingly, as shown in Figure 4-5, the design-builder has established the main and sub-camp at Stations 32+300 and 43+300 and approached the whole stretch of the project from two different fronts. Until the Design-builder substantially completed the main camp, a temporary camp for the Employer's Representative's and his staff accommodation had been also arranged in the same place as Project-C. Major construction equipment and plants owned by the design-builder have been mobilized from completed projects.

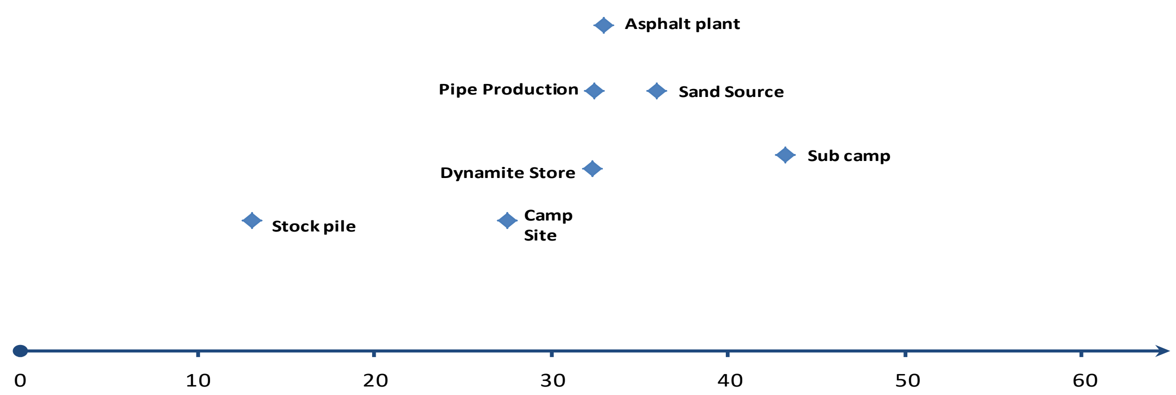

Figure 4-5: Project-G's Site Layouts

4.6.3 Time Adjustment for Project-C's Unit Rate

Although Project-C and Project-G tendered in August 2012 and December 2016 respectively and built at two different but starting from the same geographical locations, they shared the same starting point and hence the research has demonstrated their geographical proximity. In addition to this, due to the unique nature of DB projects, the cost of Project-G has been computed based on Project-C's unit rate. This implies what if Project-G is supposed to be constructed at the same location as Project-C. Accordingly, Project-C's unit rates need to be adjusted for inflation and/or deflation observed between 21st August 2012 and 27th December 2016 using ERA's PAF and CSA's CPI.

As shown in Table 4-16, the research has defined August 21, 2012 (Project-C's latest bidding date) as the base date, and the base price for the mentioned materials are taken from the contract document. While December 27, 2016 (Project-G's latest bidding date) as the current date for the fourth case analysis. Due to limitations to access Project-C's price index for the reinforcement bar, the researcher used the same price index of Project-G. The foreign exchange rate (i.e., the equivalent ETB for one USD) is taken from the National bank of Ethiopia (NBE) at these two specific dates.

As shown in Table 4-17, the same approach used to calculate the Pn value with modification as shown in Equation 4-2 given below. Using Equation 2-6, the CPI was also computed and found to be 1.47. As a result, Project-C's unit rate was multiplied by these PAF and CPI to ensure a logical cost-per-kilometer comparison.

Table 4-16: Cost Index for Case IV

It.no	List of Materials	Unit Price		Source
		21-Aug-12	27-Dec-16	
1	Fuel (Gas Oil)	17.45	14.14	Total Ethiopia Plc
2	Pen Grade 60/70	544.30	442.54	California Paving Asphalt Price Index
3	Reinforcement	233.2	196.4	US Bureau of Labor Statistics
4	Cement	252.17	239.13	Muger Cement Factory
5	Equipment	206.00	219.40	US Bureau of Labor Statistics
6	Currency (USD to ETB)	18.0629	22.6029	National bank of Ethiopia

$$Pn = a + b\left(\frac{Fn}{Fo}\right) + c\left(\frac{Bn}{Bo}\right)\left(\frac{Zo}{Zn}\right) + d\left(\frac{Sn}{So}\right)\left(\frac{Zo}{Zn}\right) + e\left(\frac{Cn}{Co}\right) + f\left(\frac{Zo}{Zn}\right)\left(\frac{En}{Eo}\right)$$

Equation 4-2

Table 4-17: Price Adjustment Factor for Case IV

Bill No.	Non - Adjustable Factor	Fuel (F_o)	17.45	Bitumen (B_o)	544.30	Steel (S_o)	233.2	Cement (C_o)	252.17	Equip.(E_o)	206.00	USD to ETB		Adj. factor
		Weighting	Fn	Weighting	Bn	Weighting	Sn	Weighting	Cn	Weighting	En	Z_o	Z_n	
	a	b		c		d		e		f		1/18.0629	1/22.6029	
1000	0.15	0.25	14.14							0.6	219.40	0.0554	0.0442	1.1523
2000	0.15	0.35	14.14							0.5	141.70	0.0554	0.0442	0.8640
3000	0.15	0.2	14.14			0.3	196.4	0.2	239.13	0.15	141.70	0.0554	0.0442	0.9309
4000	0.15	0.25	14.14							0.6	141.70	0.0554	0.0442	0.8691
5000	0.15	0.25	14.14							0.6	141.70	0.0554	0.0442	0.8691
6000	0.15	0.15	14.14	0.4	442.54					0.3	141.70	0.0554	0.0442	0.8550
8000	0.15	0.2	14.14			0.3	196.4	0.2	239.13	0.15	141.70	0.0554	0.0442	0.9309

4.6.4 Cost-per-kilometer Comparison

To investigate the cost amount induced by the PDSs, the cost-per-kilometer for project-C and Project-G compared against each other. In this regard, the research has assessed that save for the need for adjustment for time differences. Project-C and Project-G have relatively similar features under the selected pay items except for the way they being delivered. Accordingly, the cost induced by the endorsed PDSs can be revealed based on Project-C's unit rate with adjustments as well as without adjustment.

As shown in Table 4-18, the research has estimated the total cost as well as the cost-per-kilometer for Project-G depending on the unit rate offered by the Chinese contractor for Project-C. The computation is done by assuming if Project-G tendered in the same year of Project-C (i..e, in 2012). Hence, the total cost and cost-per-kilometer (including 15% VAT) for Project-C (before adjustment for inflation and/or deflation) are found to be ETB 564,103,668.98 and 6,198,941.42 ETB/Km respectively. Similarly, the total cost and cost-per-kilometer (including 15% VAT) for Project-G are found to be ETB 441,380,686.70 and 6,967,335.23 ETB/Km respectively. Therefore, as shown below, if Project-G tendered in the same year and place of Project-C (i..e, in 2012), it is found to be approximately 12.4% costly than Project-B.

$$A = \frac{B - C}{C} * 100\% = \frac{7{,}6{,}967{,}335.23 - 6{,}198{,}941.42}{6{,}198{,}941.42} * 100\% = 12.40\%$$

After applying the PAF for the corresponding Pay Items (i.e, bring both projects into 2016 and same place), Projet-C's cost can be increased from ETB 564,103,668.98 to ETB 519,346,085.48 and the cost-per-kilometer can be also increased from 6,198,941.42 ETB/Km to 5,707,099.84 ETB/Km. Similarly, Projet-G's cost has increased from ETB 441,380,686.70 to ETB 410,411,472.95 and the cost-per-kilometer has also increased from 6,967,335.23 ETB/Km to 6,478,476.29 ETB/Km.

Again, as shown below, Project-G is found to be approximately 13.5% costly than Project-C.

$$A = \frac{B - C}{C} * 100\% = \frac{6{,}478{,}476.29 - 5{,}707{,}099.84}{5{,}707{,}099.84} * 100\% = 13.52\%$$

In the same approach, the CPI has increased the project cost as well as cost-per-kilometer for Project-C from ETB 564,103,668.98 and 6,198,941.42 to ETB 829,232,393.41 and 9,112,443.88 ETB/Km respectively. Similarly, the project cost as well as cost-per-kilometer for Project-G are increased from ETB 441,380,686.70 and 6,967,335.23 ETB/Km to ETB 648,829,609.45 and 10,241,982.79 ETB/Km respectively. Therefore, as shown below, Project-G is found to be approximately 12.40% than Project-C.

$$A = \frac{B - C}{C} * 100\% = \frac{10{,}241{,}982.79 - 9{,}112{,}443.88}{9{,}112{,}443.88} * 100\% = 12.40\%$$

As discussed previously, the result obtained by considering the effect of inflation is sound enough than the one without the effect of inflation. The researcher has argued to use the result obtained using a price adjustment approach to reveal the amount of cost induced by the two PDSs. Therefore, by keeping other things constant (i.e., geographical proximity, time proximity, scope proximity, contractor capacity, types of work, and as such factors), Project-G is found to be approximately 13.5% costly than Project-C and this is due to the adopted PDS.

Table 4-18: Cost-Per-Kilometer (For Case IV)

Pay Item	Description	Non-adjusted (2012)		Adjusted using PAF (2016)		Adjusted using CPI (2016)	
		Project-C	Project-G	Project-C	Project-G	Project-C	Project-G
1000	General Item	68,985,640.32	67,007,100.00	79,492,153.34	77,212,281.33	101,408,891.27	98,500,437.00
2000	Clearing and Grubbing	8,693,000.00	9,502,500.00	7,511,621.30	8,211,110.25	12,778,710.00	13,968,675.00
3000	Drainage	29,003,071.55	21,402,035.79	27,468,809.06	20,269,868.10	42,634,515.17	31,460,992.62
4000	Earthworks	212,415,286.20	155,854,356.47	184,610,125.24	135,453,021.21	312,250,470.71	229,105,904.01
5000	Sub base and base course	122,340,447.79	92,429,663.01	106,326,083.18	80,330,620.12	179,840,458.25	135,871,604.63
6000	Bituminous surfacing	28,568,563.25	21,479,164.40	26,763,030.05	20,121,681.21	41,995,787.97	31,574,371.67
8000	Structure	20,518,920.45	16,134,473.11	19,433,469.55	15,280,959.48	30,162,813.06	23,717,675.46
Sub-total (ETB)		**490,524,929.55**	**383,809,292.78**	**451,605,291.72**	**356,879,541.70**	**721,071,646.44**	**564,199,660.39**
VAT (15%) (ETB)		**73,578,739.43**	**57,571,393.92**	**67,740,793.76**	**53,531,931.25**	**108,160,746.97**	**84,629,949.06**
Grand Total (ETB)		**564,103,668.98**	**441,380,686.70**	**519,346,085.48**	**410,411,472.95**	**829,232,393.41**	**648,829,609.45**
Project Length (km)		**91.00**	**63.35**	**91.00**	**63.35**	**91.00**	**63.35**
Normalized Cost (ETB/Km)		**6,198,941.42**	**6,967,335.23**	**5,707,099.84**	**6,478,476.29**	**9,112,443.88**	**10,241,982.79**
DB > DBB (%)		**12.40%**		**13.52%**		**12.40%**	

Table 4-19: Work item proportion (For Case IV)

Pay Item	Description	Adjusted using PAF (2016)			
		Project-C	Proportion	Project-G	Proportion
1000	General Item	79,492,153.34	17.6%	77,212,281.33	21.6%
2000	Clearing and Grubbing	7,511,621.30	1.7%	8,211,110.25	2.3%
3000	Drainage	27,468,809.06	6.1%	20,269,868.10	5.7%
4000	Earthworks	184,610,125.24	40.9%	135,453,021.21	38.0%
5000	Sub base and base course	106,326,083.18	23.5%	80,330,620.12	22.5%
6000	Bituminous surfacing	26,763,030.05	5.9%	20,121,681.21	5.6%
8000	Structure	19,433,469.55	4.3%	15,280,959.48	4.3%
Sub-total (ETB)		**451,605,291.72**	**100%**	**356,879,541.70**	**100%**

4.7 Summary

The problem statement presented in the first chapter was developed based on the research gap discussed in the literature review section. To examine the premium amount that comes with the cost certainty, the research has formulated a specific research objective: comparing the absolute cost of a unit length of road projects delivered through the DBB and DB PDS. Hence, using the data obtained from project-related documents (such as contract document, completion report, soil and material investigation report, progress report); four cases were analyzed. Data were collected from project-related documents based on the criteria established by reviewing scientific articles. The research has analyzed seven projects which are categorized into four cases based on the similarity they exhibit. By adjusting the cost dictating factors between comparable projects, the amount by which the DB PDS is higher than the DBB PDS has been examined thoroughly. Therefore, by taking the limitations into account, four case analyses show that the specific objective outlined under Section 1.4.2 has been fully achieved.

Although a separate unit rate was used for each case group, the final result of the case analysis proved the research hypothesis as summarized in Table 4-20. From the previous discussion, it is noted that all DBB projects are tendered before DB projects. Hence, if DB projects are assumed to be delivered with the same year of DBB projects, the cost-per-comparison implies that the selected DB projects were 13.24% costly on average than DBB projects. Conversely, if the DBB projects had delivered in the same year of DB projects, the cost-per-comparison implies that the selected DB projects were 13.74% costly than DBB projects. In both scenarios, based on the cost of selected pay items, the DB projects were costly than the DBB projects. The difference between these two figures implies that the effect of economic inflation (for fuel, bitumen, cement, steel, and equipment) was 0.5% amount.

By referring to Table 2-9 stated in Section 2.4.2, except Shrestha *et al*. (2012), the international practice (particularly the USA and the UK) implies that different DB projects were experienced on average 7.3% less unit cost than DBB projects. If the unit cost computed by Shrestha *et al*. (2012) and Ernzen & Schexnayder (2000) for Highway projects taken for consideration, DB highway projects were experienced on average 7.8% higher cost-per-kilometer than DBB projects.

In this regard, DB road projects delivered by ERA were experienced on average 5.92% and 6.44% higher cost-per-kilometer than different projects delivered in the USA. Against Shrestha *et al*. (2012) and Ernzen & Schexnayder (2000), the research finding also implies that DB projects experienced on average 5.49% higher cost-per-kilometer than DBB highway projects in the USA.

Table 4-20: Finding Summary

Case	Project	Length (Km)	Cost-Per-Kilometer (ETB/Km)		DB > DBB (%)	
			Before PA	After PA	Before PA	After PA
1	A	118.46	9,443,138.09	10,614,431.92	12.16%	12.71%
	D	117.3	10,591,271.15	11,963,864.90		
2	A	118.46	8,900,894.88	9,680,607.54	16.93%	17.09%
	E	92.00	10,407,954.49	11,335,452.44		
3	B	76.60	6,528,980.86	12,097,390.77	11.46 %	11.62%
	F	69.37	7,353,435.83	13,669,960.16		
4	C	91.00	6,198,941.42	5,707,099.84	12.40%	13.52%
	G	63.35	6,967,335.23	6,478,476.29		

The research established case selection criteria and used non-behavioral sources of data; hence, it is assumed that the subject and observer's error and bias are minimized. The four case analysis also presents the amount of premium that comes with the DB PDS. As a result, it is rational to consider the reliability of the adopted research method and the research finding as well. Therefore, in terms of research reliability, the multiple case analysis grants literal replication.

The nature of the research problem dictates to adopt a positivist research paradigm. The research objectives as well as the research hypothesis also claim the research type, approach, and design that should be designed. In this regard, no previous local studies have examined the premium amount that comes with the cost certainty using the static cost metrics. The cost-per-kilometer comparison also requires to describe the detailed contextual analysis. As a result, the research has select exploratory (to some extent) and descriptive research type. Therefore, the research has construct validity. It is also believed that the established research methodology (i.e. the case study) has measured what it claims to measure (i.e., the impact of PDS on the cost of road construction).

One can note that the cause and effect relationship between the PDS and cost of road projects (i.e., the impact of DBB and DB PDSs on the cost of road projects). The results all imply the selected DB projects experience a higher cost-per-kilometer than DBB projects due to the adopted PDS. This implies the research's internal validity. Although the research has analyzed four cases (also Eisenhardt (1989) claimed to select four to ten cases to ensure external validity), the research findings can not be inferred statically to other DBB and DB projects. However, the external validities are not attained due to their irrelevance to the research nature. The research has selected multiple case projects using selection criteria; however, the result only represents themselves rather than the population. In short, it does not use statistical generalization for the remaining population from which the selected samples are drawn.

CHAPTER 5: CONCLUSION AND RECOMMENDATION

5.1 Conclusion

The following conclusions of the research are drawn in line with the specific objective respectively.

- From the meta-analysis (as shown in section 2.6 and also used as a conceptual framework for the case selection), it is noted that the cost of a road project is mainly affected by the project’s physical characteristics, availability of materials, and work methodology. The project’s physical characteristics mainly comprised the project's geographical location, weather conditions, availability of material, ease of market access, and the local administrative collaboration with the project implementer (i.e., the socio-politics aspect). The availability of materials is mainly described by the material volume obtained from the reasonable offset distance from the road centerline and the hauling distance between the identified borrow pits. The work methodology comprised the contractor capabilities in line with the project-specific nature.

- For the case analysis part, projects which have comparable features and delivered through the two common PDSs were selected. The selected DB Projects which have similar Employer’s requirements as compared to the DBB specifications were converted into the BOQ approach using the corresponding DBB’s unit rate. As long as the cost driving factors between projects are kept constant, they should experience a similar cost-per-kilometer otherwise it is due to the adopted PDSs. Accordingly, the discussions presented in the previous chapter show that the cost of road projects can be affected by the adopted PDSs. In this regard, as shown in Table 4-20, the selected DB projects imply that, excluding the supervision and as such related costs, the project cost has increased the project cost on average by 13.74% than the DBB projects and this is due to the adopted PDS. This result implies that the selected DB projects experienced on average 5.5% higher unit cost than DB highway projects in the USA and UK.

5.2 Recommendation

As a result of this research, unless time is not the only constraint, the Authority should review the decision in entertaining a paradigm shift in project delivery culture. Further, the procurement directorate should use the research findings while using the Project Delivery Matrix to identify the proper PDS for the given project. This could be attained by extending and justifying the Engineering Cost Estimates (ECE) to cover the full project section appropriately. Hence, the work quantity for the DB projects should be checked against the nearest comparable completed DBB projects with a reasonable unit rate before deciding to be delivered in any of the PDS. In general, the research findings asserts the Authority to achieve a monetary advantage that can be saved by not using the DB PDS as long as similar selection factors are formulated.

The ERA is floating consecutive projects classified into lots but to be delivered with the DB and DBB approach. This strategy would allow collecting data from projects which share similar geographical location, material availability, weather, methodology, security, and as such critical features. Therefore, interested researchers can continue this research by collecting data from these consecutive projects to tune the cost induced due to the adopted PDS. Further, he/she can also examine the DBB and DB PDSs against the time and quality performance metrics. The research also recommends an interested researcher to investigate the suitable conditions for which one PDS can be less expensive than the other.

REFERENCE

Abate, D., 2018. *Research Methodology: Handbook for Research Students and Practitioners.* 1st ed. Addis Ababa: Mega Publishing and Distribution P.L.C.

AfDB, 2013. *Modjo – Hawassa Highway Project (Phase I) - Project Appraisal Report.* Ethiopia: OITC DEPARTMENT.

Akintoye, A., 2000. Analysis of factors influencing project cost estimating practice. *Construction Management and Economics,* 18(1), pp. 77-89.

Akintoye, A. & Skitmore, M., 1992. Pricing Approaches in the Construction Industry. *Industrial Marketing Management,* Volume 21, pp. 311-318.

Akintoye, A. S. & Skitmore, M. R., 1990. *A Conceptual Model of Construction Contractors' Pricing Strategies.* UK, Salford University.

Alemayehu, A., Daniel, T. & Melese, Y., 2009. *Introduction to Research Methods.* Ethiopia: Addis Ababa University.

Allen, L. N., 2001. *Comparison of Design-Build to Design-Bid-Build as a project delivery method.* USA: Dudley Knox Library, Naval Postgraduate School.

Asaminew, M., 2013. *Assessment on the Effectiveness of Design-Build versus Design-Bid-Build Project Delivery Method in Federal Road Construction Projects.* Addis Ababa: Addis Ababa University.

Assael, H., 1985. *Marketing Management: Strategy and action.* 1st ed. Boston: Kent Publishing.

Baccarini, D., 1996. The concept of project complexity-a review. *International Journal of Project Managemen,* 14(4), pp. 201-204.

Baccarini, D., 1999. The Logical Framework Method for Defining Project Success. *Project Management,* 1999(4), pp. 25-32.

Beard, J. C., Wundram, E. C. & Loulakies, M. C., 2001. *Design-Build: Planning through development.* First ed. U.S.A: McGraw-hill Companies.

Bennett, J., Pothecary, E. & Robinson, G., 1996. *Designing and Building a World-Class Industry,* UK: The University of Reading Design and Build Forum Report. The University of Reading, Centre for Strategic Studies in Construction..

Best, R. J., 1997. *Market-based Management strategies for Growing Customer Value and Profitability.* Englewood Cliffs: Prentice-Hall.

Boudjabeur, S., 1997. *Design and build defined.* Cambridge, Association of Researchers in Construction Management.

Bowen, G. A., 2009. Document Analysis as a Qualitative Research Method. *Qualitative Research Journal,* 9(2), pp. 27-40.

Burke, W. E., 1994. *User's Guide: Double Bitumen Surface Treatment.* Alexandria: U.S. Army Center for Public Works.

Carr, R. I., 1989. Cost Estimating Principles. *Construction Engineering and Management,* 115(4), pp. 545-551.

Casady, C., Levitt, R. E., Erikson, k. & Scott, W. R., 2017. Examining the State of Public-Private-Partnership (PPP) Institution in the United States. *The Engineering Project Organization Journal,* Volume 8, pp. 1-22.

Chan, A. P. & Chan, A. P., 2004. Key Performance Indicators for Measuring Construction Success. *Benchmarking: An International Journal,* 11(2), pp. 203-221.

Chan, A. P., Scott, D. & Lam, E. W., 2002. The Framework of Success Criteria for Design/Build Projects. *Management in Engineering,* 18(3), pp. 120-128.

Chau, K. W., Raftery, J. & & Walker, A., 1998. The baby and the bathwater: research methods in construction management. *Construction Management & Economics,* 16(1), pp. 99-104.

Cleveland, B. W., 1995. Definitive estimating for construction projects at remote sites. *Cost Engineering,* 37(10), pp. 34-39.

CMAA, 2008. *Project Delivery Systems: Pro vs. Con,* California: CMAA.

Collins, A. & Baccarini, D., 2004. Project Success - Survey. *Construction Research,* 5(2), pp. 211-231.

Creswell, J. W., 2014. *Research Design.* 4th ed. USA: SAGE Publications.

Cunningham, T., 2013. *Factors affecting the cost of building work - An overview,* Dublin: Dublin Institute of Technology.

DAI, J., MULVA, S., SUK, S.-J. & KANG, Y., 2012. Cost Normalization for Global Capital Projects Benchmarking. *Construction Research Congress,* pp. 2400-2409.

Davis, J. R., 1978. Determining the 'Plus' in cost-plus pricing. *Management Accounting,* pp. 198-201.

DBIA, 2015. *Choosing a Project Delivery Method,* Washington, DC: Design-Build Institue of America.

DeCotiis, T. A. & Dyer, L., 1979. Defining and Measuring Project Performance. *Research Management,* 22(1), pp. 17-22.

EC, 1998. *Understanding and Monitoring the Cost-determining Factors of Infrastructure Projects: A User's Guide.* s.l.: European Commission.

ECA, AUC & AfDB, 2018. *African Statistical Yearbook,* Addis Ababa: s.n.

EEA, 2008. *Report On The Ethiopian Economy 2006/07,* Addis Ababa: Ethiopian Economic Association.

Eisenhardt, K. M., 1989. Building Theories from Case Study Research. *The Academy of Management Review,* 14(4), pp. 532-550.

Elbeltagi, E., 2009. *Cost Estimating.* Mansoura: Unpublished.

Elhag, T. M. S. & Boussabanie, A. H., 1999. Evaluation of construction cost and time attributes. *Association of Researchers in Construction Management,* Volume 2, pp. 273-80.

Ellis, R. D., Herbsman, Z. J. & Kumar, A., 1991. *"Evaluation of the FDOT design/build program,* s.l.: Florida Department of Transportation.

ERA, 2013. *Pavement Design Manual Vol I: Flexible Pavement,* Addis Ababa: Ethiopian Roads Authority.

Ernzen, J. J. & Schexnayder, C., 2000. One Company's Experience with Design/Build: Labor Cost Risk and Profit Potential. *Journal of Construction Engineering and Management,* 126(1), pp. 10-14.

Eshete, M., 2012. *Consultants' view of the Design/build (Turnkey) Delivery of Projects.* Addis Ababa, ECoTMPA.

Fellows, R. F. & Liu, A. M. M., 2015. *Research Methods for Construction.* 4th Edition ed. USA: Wiley Publishing.

Fernance, J. D., 2011. *Comparison of design-build and design-bid-build performance of public university projects,* Las Vegas: University of Nevada.

FHWA, 2006. *Design-Build Effectiveness Study,* USA: USDOT - Federal Highway Administration.

Foulkes, A. & Ruddock, L., 2007. *Defining the Scope of the Construction Sector.* The UK, Salford Center for Research & Innovation.

Gabor, A., 1977. *Pricing Principles and practice.* London: Heineman Educational.

Gautam, B., Yuan, D. & Nazarian, S., 2013. Optimal use of local materials for roadway Base and Subbase. *Airfield & Highway Pavement,* pp. 1348-1357.

Gay, L. R., Mills, G. E. & Airasian, P., 2012. *Educational Research: Competencies for Analysis and Applications.* 10th ed. United States of American: PEARSON.

Geotz, J. R., 1985. The Pricing Decision A Service Industry's Experience. *Journal of Small Business Management,* pp. 61-62.

Gidado, K. I., 1996. Project Complexity: The Focal point of Construction Production planning. *Construction Management and Economics,* Volume 14, pp. 213-225.

Goftar, V. N., Asmar, M. E. & Bingham, E., 2014. *A Meta-Analysis of Literature Comparing Project Performance between Design-Build(DB) and Design-Bid-Build(DBB) Delivery Systems.* Atlanta, Georgia, American Society of Civil Engineers, pp. 1389-1398.

Gransberg, D. D., Koch, J. A. & Molenaar, K. R., 2006. *Preparing for design-build projects: a primer for owners, engineers, and contractors.* 1st ed. Virginia: American Society of Civil Engineers.

Gransberg, D. D. & Villareal, M. E., 2002. *Construction Project Performance Metrics.* Portland Oregon, AACE International.

Habtamu, G., 2017. *Comparison Between Design Bid Build and Design-Build Delivery System in Federal Road projects,* Addis Ababa: Unpublished M.Sc. Thesis.

Hale, D. R., Shrestha, P. P., Gibson, E. & Miglicaccio, G. C., 2009. Empirical Comparison of Design-build and Design-bid-build Project Delivery Method. *Construction Engineering and Management,* Volume 135, pp. 579-587.

Harrison, H., Birks, M. & Franklin, R. &. M. J., 2017. Case Study Research: Foundations and Methodological Orientations (34 Paragraphs). *Forum Qualitative Sozialforschung / Forum: Qualitative Social Research,* 18(1).

Hosseini, A. et al., 2016. *Selection Criteria for Delivery Methods for infrastructure Projects.* Norway: Elsevier.

Ibbs, C. W., Kwak, Y. H., Odabasi, A. M. & Ng, T., 2003. Project Delivery Systems and Project Change: Quantitative Analysis. *Journal of Construction Engineering and Management,* 129(4), pp. 382-387.

Johannessen, B. A., 2017. Pavement. In: *Building Rural Roads.* Thailand: ILO, pp. 282-386.

Jonker, J. & Pennink, B., 2010. *The Essence of Research Methodology: A Concise Guide for Master and Ph.D. Students in Management Science.* 1st ed. Berlin: Springer.

Kirk, J. & Miller, M. K., 1986. *Reliability and Validity in Qualitative Research.* 1st ed. USA: SAGE Publications Ltd.

Konchar, M., 1997. *A Comparison of United States Project Delivery System,* U.S.A: Pennslyvania State University.

Konchar, M. & Sanvido, V., 1998. Comparison of U.S. Project Delivery Systems. *Journal of Construction Engineering and Management,* 124(6), pp. 435-444.

Kothari, C. R., 2004. *Research Methodology, Methods, and Techniques.* 2nd ed. New Delhi: New Age International Publishers.

Lahdenperä, P., 2001. *Design-build Procedures: Introduction, illustration, and Comparison of U.S. Modes,* Finland: VTT.

Lim, C. S. & Mohamed, M. Z., 1999. Criteria of Project Success: an Exploratory re-examination. *International Journal of Project Management,* 17(4), pp. 243-248.

Lincoln, Y. S., Lynham, S. A. & Guba, E. G., 2011. *Paradigmatic controversies, contradictions, and emerging confluences revisited.* 4th ed. Thousand Oaks, CA: SAGE.

Mahamid, I., 2013. Effects of the project's physical Characteristics on cost deviation in road construction. *Journal of King Saud University,* Volume 25, pp. 81-88.

Marczyle, G., DeMatteo, D. & Festinger, D., 2005. *Essentials of Research Design and Methodology.* 1st ed. New Jersey: John Wiley & Sons Inc.

Mathew, T. V., 2009. *Introduction to Pavement Design,* India: Indian Institute of Technology.

McWhirt, D. D., 2007. *A comparison of design-bid-build and design-build project delivery methods on military construction projects,* Iowa: Iowa State University.

Mekonnen, A., 2013. *Assessment on the Effectiveness of Design-Build versus Design-Bid-Build Project Delivery Method in Federal Road Construction Projects.* Addis Ababa: Addis Ababa University.

Merriam, S. B., 2009. *Qualitative research: A guide to design and implementation.* 2nd ed. San Francisco, CA: Jossey-Bass.

Miller, K., 2007. In: *Communication theories: perspectives, processes, and contexts (2nd ed.).* Beijing: Peking University Press, pp. 35-45.

Mills, A. J., Eurepos, G. & Wiebe, E., 2010. *Encyclopedia of Case Study Research.* 1st ed. USA: SAGE.

Minchin, R. E., Li, X., Issa, R. R. & Vargas, G. G., 2013. Comparison of Cost and Time Performance of Design-Build and Design-Bid-Build Delivery Systems in Florida. *Journal of Construction Engineering and Management,* 139(10), pp. 1-5.

Mishra, G., 2018. *The Constructor Civil Engineering Home.* [Online]
Available at: https://theconstructor.org/construction/cost-estimation-factors/9316/
[Accessed 25 February 2019].

Mochtar, K. & Arditi, D., 2000. Alternate Pricing Strategies in Construction. *DIMENSI TEKNIK SIPIL,* 2(1), pp. 56-64.

Molenaar, K. R., Songer, A. D. & Barash, M., 1999. Public-Sector Design/Build Evolution and Performance. *Journal of Management in Engineering,* 15(2), pp. 54-62.

Moselhi, O., Gong, D. & El-Rayes, K., 1997. Estimating weather impact on the duration of construction activities. *Canadian Journal of Civil Engineering,* 24(3), pp. 359-366.

Mosly, I., 2016. Construction Project Delivery System Selection Framework: Professional Service Firm's Perspective. *Journal of Civil Engineering and Architecture,* Volume 10, pp. 368-378.

NBE, 2015/16. *National bank of Ethiopia Annual Report,* Addis Ababa: DEAPD.

Ndekugri, I. & Turner, A., 1994. Building Procurement by Design-build and Design-bid-build Approach. *Journal of Construction Engineering and Management,* 120(2), pp. 243-256.

Plusquellec, T., Lehoux, N. & Cimon, Y., 2017. *Design-Build and Design-Bid-build in Construction - A Comparative Review.* Greece, Heraklion, pp. 35-43.

PMI, 2016. *A Guide to the Project Management Body of Knowledge.* USA: Project Management Institute, Inc.

Pocock, J. B., Hyun, C. T., Liu, L. Y. & Kim, M. K., 1996. Relationship between Project Interaction and Performance Indicators. *Journal of Construction Engineering and Management,* 122(2), pp. 165-176.

Polenske, K. R. & Sivitanides, P., 1990. Linkages in the construction sector. *The Annals of Regional Science,* Volume 24, pp. 147-161.

Rahel, T., 2016. *Project delivery systems and their effects on cost and time overrun on ERA projects,* Addis Ababa: AAiT AAU.

Ranjan, R. & Hinge, G. A., 2015. Project Quarterback Rating to Assess Performance of Construction Project. *International Journal of Science and Research,* 4(5).

Rehman, A. A. & Alharthi, K., 2016. An Introduction to Research Paradigms. *International Journal of Educational Investigations,* 3(8), pp. 51-59.

Remington, K., Zolin, R. & Turner, R., 2009. *A model of project complexity: distinguishing dimensions of complexity from severity.* Berlin, QUT Digital Repository.

Robson, C., 2002. Real-World Research. A Resource for Social Scientists and Practitioner-Researchers (Second Edition). In: Malden: Blackwell, p. 624.

Roth, M. B., 1995. *An empirical analysis of United States Navy design/build contracts.* California: Dubbley Knox Library, Naval Postgraduate School.

Rowlinson, S., 1988. *An Analysis of Factors Affecting Project Performance in Industrial,* Hong Kong: The University of Hong Kong.

Saha, T. K., 2010. *Textbook on Legal Methods, Legal Systems and Research.* 2nd ed. India: Universal law Publishing.

Salkind, N. J., 2010. *Encyclopedia of Research Design.* 1st ed. Los Angeles: SAGE Publications, Inc.

Schmid, k. F., 2012. *Construction Estimating: A Step-by-step Guide to a Successful Estimate.* 1st ed. New York: Momentum Press.

Sertse, S., 2015. *The Management of the Construction Processes in Developing Countries: A Case Study of ERA,* Cape Town: Unpublished Ph.D. Thesis.

Shipley, D. D., 1981. Pricing Objectives in British Manufacturing Industry. *The Journal of Industrial Economics,* XXIX(4), pp. 429-443.

Shipman, M. D., 1997. *The Limitations of Social Research.* 4th ed. India: Longman.

Shrestha, P. P., Migliaccio, G. C., O'Conner, J. T. & Gibson, G. E., 2007. Benchmarking of Large Design-build HighwayProjects: One-to-one comparison and Comparison with DBB projects. *Journal of the Transportation Research Records,* pp. 17-25.

Shrestha, P. P., O’Connor, J. T. & Gibson Jr, G., 2012. Performance Comparison of Large Design-Build and Design-Bid-Build Highway Projects. *Journal of Construction Engineering and Management,* 138(1), pp. 1-13.

Sinclair, N., Artin, P. & Mulford, S., 2002. *Construction Cost Data Workbook.* Washington, D.C., World Bank.

Skitmore, M. & Smyth, H., 2007. Pricing construction work: a marketing viewpoint. *Construction Management and Economics,* 25(6), pp. 619-630.

Smith, M. E., Thorpe, R. & Jakson, P., 2015. *Management & Business research.* Los Angeles: SAGE Publications Ltd.

Solomon, S., 2006. *An Investigation into the Practice of the Project Management Office (PMO) concept in the German Developer, Contractor, and Project Management sectors.* Cape Town: University of Cape Town.

Speight, J. G., 2016. *Asphalt Materials Science and Technology.* USA: Elsevier.

Stake, R. E., 1995. *The art of case study research.* 1st ed. Thousand Oaks, CA: Sage.

Sue, V. M. & Ritter, L. A., 2012. *Conducting Online Surveys.* 2nd ed. Los Angeles: SAGE Publications Inc.

Surahyo, A., 2018. *Understanding Construction Contracts: Canadian and International Conventions.* 1st ed. Canada: Springer.

TCS, 2007. *Construction Project Delivery Systems and Procurement Practices,* Philadelphia: Trauner Consulting Services, Inc.

Tellis, G. J., 1986. Beyond the Many Faces of Price: An integration of Pricing Strategies. *Journal of Marketing,* Volume 50, pp. 146-160.

Tomas, S. R., Macken, C. L., Chung, T. H. & Kin, I., 2002. *Measuring the impact of the delivery system on project performance: Design-build and Design-bid-build,* Austin: CII.

Touran, A. et al., 2009. *Guide Book for Evaluation of Project Delivery Methods,* Washington DC: s.n.

Tran, D., Lampe, J. C., Bypaneni, S. & Molenaar, K., 2016. An Empirical Comparison of Cost Growth between Highway Design-Bid-Build and Design-Build Projects by Project Size. *Construction Research Congress,* pp. 2029-2038.

Turina, N., Radujkovic, M. & Car-Pusic, D., 2008. *Design And Build in Comparison With the Traditional Procurement Method and the Possibility of its Application in the Croatian Construction Industry.* Croatia, s.n.

Turochy, R., Hoel, L. & Lacy, L., 2001. *Highway Project Cost Estimating Methods Used in the Planning Stage of Project Development,* Virginia: Virginia Transportation Research Council.

Vaus, D. d., 2001. *Research design in social research.* 1st ed. London: SAGE Publications.

Walker, D. H., 1997. Choosing an appropriate research methodology. *Construction Management and Economics,* 15(2), pp. 149-159.

Warne, T. R., 2005. *Design-build contracting for highway projects: A performance.* South Jordan, UT: Tom Warne & Associates, LLC.

Wubishet, J., 2003. *Performance for Public Construction Projects in (least) developing countries: Road and Educational Building projects in Ethiopia,* Norway: Unpublished Ph.D. Thesis.

Wubishet, J., 2018. *Advanced Construction Procurement and Contract Management.* Addis Ababa: unpublished.

Yin, R. K., 2018. *Case Study Research Design and Methods.* 6th ed. United States of America: SAGE Inc.

Zimolong, W., 2012. *American Bar Association.* [Online]
Available at: aaps.americanbar.org
[Accessed 13 January 2019].

ANNEX

Bill of Quantity (BOQ) for Project-A & Project-D

Series	Description	Unit	Project-A (DBB)			Project-D (DB)		
			Quantity	Rate	Amount	Quantity	Rate	Amount
1000	Provision of educational materials	month	17.00	10,000.00	170,000.00	44.00	10,000.00	440,000.00
	Voluntary counseling and Testing services	month	17.00	10,000.00	170,000.00	44.00	10,000.00	440,000.00
	Providing at least 10 condoms per month	month	17.00	10,000.00	170,000.00	44.00	10,000.00	440,000.00
	Providing care and support for living with HIV AIDS	month	8.00	10,000.00	80,000.00	44.00	10,000.00	440,000.00
	Fees for a Sociologist, a nurse and an Animator	month	17.00	10,000.00	170,000.00	44.00	10,000.00	440,000.00
	Maintenance & Service for Office & Laboratories	month	19.50	50,000.00	975,000.00	44.00	50,000.00	2,200,000.00
	Type B Vehicle for Engineer and his staff	No	11.00	2,000,000.00	22,000,000.00	8.00	2,000,000.00	16,000,000.00
	Fuel, lubricants, maintenance, insurance for type B vehicle	veh-mon	304.31	25,000.00	7,607,650.00	352.00	25,000.00	8,800,000.00
	Driver for the Engineer's vehicles	man-month	304.31	10,000.00	3,043,060.00	352.00	10,000.00	3,520,000.00
	Chainmen	man-month	104.00	10,000.00	1,040,000.00	176.00	10,000.00	1,760,000.00
	Assistants for the Engineer's laboratory	man-month	54.00	10,000.00	540,000.00	88.00	10,000.00	880,000.00
	Type A Housing	No	8.00	2,500,000.00	20,000,000.00	8.00	2,500,000.00	20,000,000.00
	Type B Housing	No	1.00	3,750,000.00	3,750,000.00	1.00	3,750,000.00	3,750,000.00
	Type C Housing	No	1.00	2,000,000.00	2,000,000.00	1.00	2,000,000.00	2,000,000.00
	Type D Housing	No	1.00	2,500,000.00	2,500,000.00	1.00	2,500,000.00	2,500,000.00
	Temporary Office accommodation	month	2.00	50,000.00	100,000.00	4.00	50,000.00	200,000.00

	Temporary Laboratory accommodation	month	2.00	10,000.00	20,000.00	4.00	10,000.00	40,000.00
	Temporary Housing	month	2.00	100,000.00	200,000.00	4.00	100,000.00	400,000.00
	Temporary Type B vehicle	veh-mon	7.68	200,000.00	1,535,400.00	12.00	200,000.00	2,400,000.00
	Surveying Equipment	month	2.50	100,000.00	250,000.00	4.00	100,000.00	400,000.00
	Maintenance and services for Type B Housing	month	19.00	50,000.00	950,000.00	44.00	50,000.00	2,200,000.00
	Maintenance and services for Type C Housing	month	19.00	20,000.00	380,000.00	44.00	20,000.00	880,000.00
	Maintenance and services for Type D Housing	month	19.00	30,000.00	570,000.00	44.00	30,000.00	1,320,000.00
	Maintenance and services for Type E Housing	month	19.00	20,000.00	380,000.00	44.00	20,000.00	880,000.00
	Radio Service Provision and Maintenance	month	20.50	30,000.00	615,000.00	44.00	30,000.00	1,320,000.00
	Accommodating and maintaining temporary diversion	km	118.59	10,000.00	1,185,900.00	92.19	10,000.00	921,900.00
	Sub-total				**70,402,010.00**			**74,571,900.00**
2000	Clearing & grubbing	ha	355.60	30,000.00	10,668,000.00	351.90	30,000.00	10,557,000.00
	Sub-total				**10,668,000.00**			**10,557,000.00**
3000	Excavation of Soft material for Culverts	M^3	41,831.10	65.00	2,719,021.39	93,503.71	65.00	6,077,741.15
	Backfilling Using imported selected material (minor drainage)	M^3	62,847.56	110.00	6,913,231.95	36,312.78	110.00	3,994,405.36
	Concrete pipe culvert Nominal Diameter 1220mm (48")	LM	3,531.00	4,000.00	14,124,000.00	3,563.00	4,000.00	14,252,000.00
	Cast In-Situ Concrete and formwork (C- 25)	M^3	5,161.52	4,000.00	20,646,062.24	5,320.68	4,000.00	21,282,720.00
	Paved Waterway - Grouted stone pitching (minor drainage)	M^2	10,550.19	300.00	3,165,057.34	67,819.42	300.00	20,345,826.00
	Stone Masonry Walls	M^3	34,365.04	1,700.00	58,420,566.89	14,090.12	1,700.00	23,953,204.00

	Sub-total				**105,987,939.80**			**89,905,896.51**
4000	Removal of unsuitable material	m^3	1,127,996.24	65.00	73,319,755.60	546,384.21	65.00	35,514,973.65
	Cut to fill	m^3	300,575.93	110.00	33,063,352.30	1,940,501.26	110.00	213,455,138.60
	Cut to spoil	m^3	852,964.14	65.00	55,442,669.10	546,384.21	65.00	35,514,973.65
	Improved Sub-grade (Capping layer)	m^3	1,064,359.73	130.00	138,366,764.90	546,384.21	130.00	71,029,947.30
	Sub-total				**300,192,541.90**			**355,515,033.20**
5000	Gravel sub-base layer	m^3	286,149.18	200.00	57,229,836.00	389,382.20	200.00	77,876,440.00
	Crushed stone base layer	m^3	189,807.17	600.00	113,884,302.00	228,322.54	600.00	136,993,524.00
	Sub-total				**171,114,138.00**			**214,869,964.00**
6000	Prime coat	lt	963,745.73	40.00	38,549,829.20	890,099.60	40.00	35,603,984.00
	Asphalt Concrete (AC)	m^2	897,069.23	300.00	269,120,769.00	890,099.60	300.00	267,029,880.00
	Double Bitumen Surface Treatment (DBST)	m^2	66,901.10	100.00	6,690,110.00	322,560.00	100.00	32,256,000.00
	Sub-total				**314,360,708.20**			**334,889,864.00**
	Total				**972,725,337.90**			**1,080,309,657.71**

Bill of Quantity (BOQ) for Project-A & Project-E

series	Description	Unit	Project-A (DBB)			Project-E (DB)		
			Quantity	Rate	Amount	Quantity	Rate	Amount
1000	Provision of educational materials	month	17.00	10,000.00	170,000.00	36.50	10,000.00	365,000.00
	Voluntary Counseling and Testing services	month	17.00	10,000.00	170,000.00	36.50	10,000.00	365,000.00
	Providing at least 10 condoms per month	month	17.00	10,000.00	170,000.00	36.50	10,000.00	365,000.00
	Providing care and support for living with HIV AIDS	month	8.00	10,000.00	80,000.00	36.50	10,000.00	365,000.00
	Fees for a Sociologist, a nurse and an Animator	month	17.00	10,000.00	170,000.00	36.50	10,000.00	365,000.00
	Maintenance & Service for Office & Laboratories	month	19.50	50,000.00	975,000.00	36.50	50,000.00	1,825,000.00
	Type B Vehicle for Engineer and his staff	No	11.00	2,000,000.00	22,000,000.00	8.00	2,000,000.00	16,000,000.00
	Fuel, lubricants, maintenance, insurance for type B vehicle	veh-mon	304.31	25,000.00	7,607,650.00	292.00	25,000.00	7,300,000.00
	Driver for the Engineer's vehicles	man-month	304.31	10,000.00	3,043,060.00	292.00	10,000.00	2,920,000.00
	Chainmen	man-month	104.00	10,000.00	1,040,000.00	146.00	10,000.00	1,460,000.00
	Assistants for the Engineer's laboratory	man-month	54.00	10,000.00	540,000.00	73.00	10,000.00	730,000.00
	Type A Housing	No	8.00	2,500,000.00	20,000,000.00	8.00	2,500,000.00	20,000,000.00
	Type B Housing	No	1.00	3,750,000.00	3,750,000.00	1.00	3,750,000.00	3,750,000.00

	Type C Housing	No	1.00	2,000,000.00	2,000,000.00	2.00	2,000,000.00	4,000,000.00
	Type D Housing	No	1.00	2,500,000.00	2,500,000.00	1.00	2,500,000.00	2,500,000.00
	Temporary Office accommodation	month	2.00	50,000.00	100,000.00	4.00	50,000.00	200,000.00
	Temporary Laboratory accommodation	month	2.00	10,000.00	20,000.00	4.00	10,000.00	40,000.00
	Temporary Housing	month	2.00	100,000.00	200,000.00	4.00	100,000.00	400,000.00
	Temporary Type B vehicle	veh-mon	7.68	200,000.00	1,535,400.00	12.00	200,000.00	2,400,000.00
	Surveying Equipment	month	2.50	100,000.00	250,000.00	4.00	100,000.00	400,000.00
	Maintenance and services for Type B Housing	month	19.00	50,000.00	950,000.00	36.50	50,000.00	1,825,000.00
	Maintenance and services for Type C Housing	month	19.00	20,000.00	380,000.00	36.50	20,000.00	730,000.00
	Maintenance and services for Type D Housing	month	19.00	30,000.00	570,000.00	36.50	30,000.00	1,095,000.00
	Maintenance and services for Type E Housing	month	19.00	20,000.00	380,000.00	36.50	20,000.00	730,000.00
	Radio Service Provision and Maintenance	month	20.50	30,000.00	615,000.00	36.50	30,000.00	1,095,000.00
	Accommodating and maintaining temporary diversion	km	118.59	10,000.00	1,185,900.00	92.00	10,000.00	920,000.00
Sub-total					**70,402,010.00**			**72,145,000.00**
2000	Clearing & grubbing	ha	355.60	30,000.00	10,668,000.00	276.00	30,000.00	8,280,000.00
Sub-total					**10,668,000.00**			**8,280,000.00**
4000	Removal of unsuitable material	m^3	1,127,996.24	65.00	73,319,755.60	780,479.00	65.00	50,731,135.16

	Road bed preparation	m^3	204,991.00	80.00	16,399,280.00	116,713.36	80.00	9,337,068.70
	Cut to fill	m^3	300,575.93	110.00	33,063,352.30	901,042.48	110.00	99,114,672.35
	Cut to spoil	m^3	852,964.14	65.00	55,442,669.10	780,479.00	65.00	50,731,135.16
	Hard rock to spoil	m^3	52,095.09	220.00	11,460,919.80	75,934.41	220.00	16,705,570.20
	Improved Sub-grade (Capping layer)	m^3	1,064,359.73	130.00	138,366,764.90	901,042.48	130.00	117,135,521.87
Sub-total					**328,052,741.70**			**343,755,103.45**
5000	Gravel sub-base layer	m^3	286,149.18	200.00	57,229,836.00	288,542.71	200.00	57,708,541.20
	Crushed stone base layer	m^3	189,807.17	600.00	113,884,302.00	161,022.98	600.00	96,613,788.00
	Gravel wearing course for shoulders	m^3	222,785.26	130.00	28,962,083.80	31,740.00	130.00	4,126,200.00
Sub-total					**200,076,221.80**			**158,448,529.20**
6000	Prime coat	lt	963,745.73	40.00	38,549,829.20	735,318.96	40.00	29,412,758.40
	Asphalt Concrete (AC)	m^2	897,069.23	300.00	269,120,769.00	735,316.56	300.00	220,594,968.00
Sub-total					**307,670,598.20**			**250,007,726.40**
Grand Total					**916,869,571.70**			**832,636,359.05**

Bill of Quantity (BOQ) for Project-B & Project-F

Series	Description	Unit	Project-B (DBB)			Project-F (DB)		
			Quantity	Rate	Amount	Quantity	Rate	Amount
1000	Provision of educational materials	month	19.00	5,760.00	109,440.00	32.00	5,760.00	184,320.00
	Voluntary Counseling and Testing services	month	19.00	7,200.00	136,800.00	32.00	7,200.00	230,400.00
	Providing at least 10 condoms per month	month	19.00	28,800.00	547,200.00	32.00	28,800.00	921,600.00
	Providing care and support for living with HIV AIDS	month	7.00	7,200.00	50,400.00	32.00	7,200.00	230,400.00
	Fees for a Sociologist, a nurse and an Animator	month	19.00	7,200.00	136,800.00	32.00	7,200.00	230,400.00
	Maintenance & Service for Office & Laboratories	month	37.00	60,480.00	2,237,760.00	32.00	60,480.00	1,935,360.00
	Type B Vehicle for Engineer and his staff	No	9.00	1,524,096.00	13,716,864.00	8.00	1,524,096.00	12,192,768.00
	Fuel, lubricants, maintenance, insurance for type B vehicle	veh-mon	349.23	30,240.00	10,560,715.20	256.00	30,240.00	7,741,440.00
	Driver for the Engineer's vehicles	man-month	349.23	3,780.00	1,320,089.40	256.00	3,780.00	967,680.00
	Chainmen	man-month	440.00	2,268.00	997,920.00	256.00	2,268.00	580,608.00
	Type B Housing	No	6.80	1,440,000.00	9,792,000.00	8.00	1,440,000.00	11,520,000.00
	Type C Housing	No	1.70	2,592,000.00	4,406,400.00	1.00	2,592,000.00	2,592,000.00
	Type D Housing	No	0.85	1,872,000.00	1,591,200.00	1.00	1,872,000.00	1,872,000.00
	Type E Housing	No	0.85	1,440,000.00	1,224,000.00	1.00	1,440,000.00	1,440,000.00
	Services and maintenance for residential accommodation	month	39.00	163,080.00	6,360,120.00	32.00	163,080.00	5,218,560.00
	Temporary Surveying Equipment	month	2.00	16,632.00	33,264.00	4.00	16,632.00	66,528.00

	Temporary Laboratory Accommodation	month	2.00	57,600.00	115,200.00	4.00	57,600.00	230,400.00
	Provision of service and maintenance of all equipment	month	35.00	1,800.00	63,000.00	32.00	1,800.00	57,600.00
	Sub-total				**53,399,172.60**			**48,212,064.00**
2000	Clearing & grubbing	ha	195.75	10,139.83	1,984,893.88	232.08	10,139.83	2,353,251.75
	Sub-total				**1,984,893.88**			**2,353,251.75**
4000	Removal of unsuitable material/undercut	m^3	317,448.00	34.61	10,986,875.23	70,137.50	34.61	2,427,458.88
	Roadbed preparation and compaction	m^3	104,606.27	43.56	4,556,649.14	165,751.26	43.56	7,220,124.89
	Cut to fill material (Compacted to 95% of modified AASHTO density)	m^3	2,037,078.19	53.38	108,739,233.86	1,973,942.06	53.38	105,369,027.40
	Rock fill obtained from cut	m^3	15,131.53	134.44	2,034,282.89	14,662.55	134.44	1,971,233.40
	Cut to spoil (Common/Normal/Soft) excavation	m^3	731,346.85	26.02	19,029,645.16	2,644,845.95	26.02	68,818,891.62
	Embankment construction	m^3	585,639.61	48.78	28,567,499.98	548,475.45	48.78	26,754,632.45
	Capping Construction	m^3	74,734.84	50.87	3,801,761.17	70,126.04	50.87	3,567,311.65
	Sub-total				**177,715,947.44**			**216,128,680.28**
5000	Crushed stone (specify compacted layer thickness) compacted to 97% of modified AASHTO density compacted Layer thickness of not more than 200mm	m^3	244,454.96	94.70	23,149,884.74	72,663.15	94.70	6,881,200.31
	Base layer construction (100% of modified AASHTO density Layer thickness of not more than 200mm)	m^3	143,532.32	286.61	41,137,799.65	117,145.33	286.61	33,575,023.03
	Gravel shoulder sub-base	m^3	34,471.80	94.70	3,264,479.46	31,414.35	94.70	2,974,938.95

	Gravel shoulder base course	m^3	42,462.31	94.70	4,021,181.00	36,419.25	94.70	3,448,902.98
	Sub-total				**71,573,344.85**			**46,880,065.26**
6000	Prime coat (MC-30 cutback bitumen)	lit	793,830.94	15.52	12,320,256.23	640,160.00	15.52	9,935,283.20
	MC-30 cutback bitumen	lit	793,830.94	16.52	13,114,087.17	640,160.00	16.52	10,575,443.20
	Asphaltic Surfacing (a) Continuously graded (medium)	m^2	720,099.74	133.89	96,414,154.53	720,099.74	133.89	96,414,154.53
	Binder variations (80/100 penetration grade)	ton	1,404.68	133.89	188,072.61	1,404.68	133.89	188,072.61
	Sub-total				**122,036,570.54**			**117,112,953.54**
Grand Total					**426,709,929.31**			**430,687,014.82**

Bill of Quantity (BOQ) for Project-C & Project-G

Series	Description	Unit	Project-C (DBB)			Project-G (DB)		
			Quantity	Rate	Amount	Quantity	Rate	Amount
1000	Provision of educational materials	month	35.55	5,760.00	204,768.00	36.50	5,760.00	210,240.00
	Voluntary Counseling and Testing services	month	35.55	7,200.00	255,960.00	36.50	7,200.00	262,800.00
	Providing at least 10 condoms per month	month	35.55	28,800.00	1,023,840.00	36.50	28,800.00	1,051,200.00
	Providing care and support for living with HIV AIDS	month	29.60	7,200.00	213,120.00	36.50	7,200.00	262,800.00
	Fees for a Sociologist, a nurse and an Animator	month	35.55	7,200.00	255,960.00	36.50	7,200.00	262,800.00
	Maintenance & Service for Office & Laboratories	month	31.85	60,480.00	1,926,288.00	36.50	60,480.00	2,207,520.00
	Type B Vehicle for Engineer and his staff	No	7.00	1,524,096.00	10,668,672.00	8.00	1,524,096.00	12,192,768.00
	Fuel, lubricants, maintenance, insurance for type B vehicle	veh-mon	255.59	30,240.00	7,729,041.60	256.00	30,240.00	7,741,440.00
	Driver for the Engineer's vehicles	man-month	255.59	3,780.00	966,130.20	256.00	3,780.00	967,680.00
	Chainmen	man-month	90.49	2,268.00	205,231.32	128.00	2,268.00	290,304.00
	Type B Housing	No	7.20	1,440,000.00	10,368,000.00	7.00	1,440,000.00	10,080,000.00
	Type C Housing	No	0.90	2,592,000.00	2,332,800.00	2.00	2,592,000.00	5,184,000.00
	Type D Housing	No	0.90	1,872,000.00	1,684,800.00	1.00	1,872,000.00	1,872,000.00
	Type E Housing	No	0.90	1,440,000.00	1,296,000.00	1.00	1,440,000.00	1,440,000.00

	Services and maintenance for residential accommodation	month	31.85	163,080.00	5,194,098.00	36.50	163,080.00	5,952,420.00
	Temporary Office accommodation	month	3.16	87,840.00	277,574.40	4.00	87,840.00	351,360.00
	Temporary Housing	month	17.51	41,400.00	724,914.00	4.00	41,400.00	165,600.00
	Temporary Type B vehicle	veh-mon	10.93	77,760.00	849,916.80	4.00	77,760.00	311,040.00
	Surveying Equipment	month	3.00	16,632.00	49,896.00	4.00	16,632.00	66,528.00
	GPS Equipment	month	0.50	57,600.00	28,800.00	4.00	57,600.00	230,400.00
	Provision of service and maintenance of all equipment	month	31.85	1,800.00	57,330.00	36.50	1,800.00	65,700.00
	Accommodating and maintaining temporary diversion	km	90.69	250,000.00	22,672,500.00	63.35	250,000.00	15,838,500.00
	Sub-total				**68,985,640.32**			**67,007,100.00**
2000	Clearing & grubbing	ha	173.86	50,000.00	8,693,000.00	190.05	50,000.00	9,502,500.00
	Sub-total				**8,693,000.00**			**9,502,500.00**
3000	Excavation for open drains (0 to 1.5m)	m^3	8,424.50	49.59	417,770.96	6,216.63	49.59	308,282.83
	Excavation in soft material for Culverts and Appurtenant Structures	m^3	8,089.72	49.59	401,169.21	5,969.59	49.59	296,032.02
	Backfilling using imported selected material	m^3	8,383.89	120.64	1,011,432.49	6,186.67	120.64	746,359.37
	Concrete pipe culverts (On class B bedding, 1060mm diameter R.C. pipe (including reinforcement))	m	2,943.00	5,199.53	15,302,216.79	2,171.71	5,199.53	11,291,858.90
	Concrete curbing Precast Class 25/20	m	1,400.00	582.88	816,032.00	1,033.09	582.88	602,168.84

	Concrete curbing-channeling, road side Gutter Inlet across sidewalk, U type reinforced Concrete C25/20 opening size 0.85m x 0.15m [wxh]	m	1,400.00	751.53	1,052,142.00	1,033.09	751.53	776,399.86
	Cast in situ concrete lining class 20/20, (0.1m x0.60m) [wxh] for U -drain type stone masonry	m^3	367.01	4,857.18	1,782,633.63	270.83	4,857.18	1,315,446.49
	Grouted pitching (200mm nominal thickness)	m^2	4,975.42	251.53	1,251,467.39	3,671.48	251.53	923,486.67
	Concrete pitching	m^3	3,988.99	1,746.86	6,968,207.07	2,943.57	1,746.86	5,142,000.80
	Sub-total				**29,003,071.55**			**21,402,035.79**
4000	Roadbed preparation and compaction	m^3	228,796.53	85.60	19,584,982.97	165,648.69	85.60	14,179,527.67
	Cut to fill material (Compacted to 95% of modified AASHTO density)	m^3	1,680,657.65	102.24	171,830,438.14	1,240,196.06	102.24	126,797,645.62
	Rock fill obtained from cut	m^3	600.44	340.10	204,209.64	430.54	340.10	146,426.17
	Cut to spoil (Common/Normal/Soft) excavation	m^3	36,396.30	53.78	1,957,393.01	27,617.79	53.78	1,485,284.88
	Side fills or Fill-flattening	m^3	124,287.54	151.57	18,838,262.44	87,388.48	151.57	13,245,472.14
	Sub-total				**212,415,286.20**			**155,854,356.47**
5000	Crushed stone (specify compacted layer thickness) compacted to 97% of modified AASHTO density compacted Layer thickness of not more than 200mm	m^3	145,371.51	423.27	61,531,399.04	114,357.06	423.27	48,403,911.71

	Base layer construction (100% of modified AASHTO density Layer thickness of not more than 200mm)	m^3	128,408.33	473.56	60,809,048.75	92,967.63	473.56	44,025,751.30
	Sub-total				**122,340,447.79**			**92,429,663.01**
6000	Prime coat (MC-30 cutback bitumen)	lit	642,278.85	44.48	28,568,563.25	482,894.88	44.48	21,479,164.40
	Sub-total				**28,568,563.25**			**21,479,164.40**
8000	Excavation for Structures (Soft material irrespective of depth (0m up to 2m))	m^3	8,344.96	49.59	413,826.57	6,448.41	49.59	319,776.52
	Backfill to excavations utilizing Imported material	m^3	6,876.15	120.64	829,538.74	5,217.68	120.64	629,460.37
	Formwork, Class F1 surface finish	m^2	4,998.09	84.85	424,087.94	4,001.36	84.85	339,515.02
	High yield strength deformed Steel bars of Grade 46	ton	138.50	43,939.76	6,085,656.76	99.31	43,939.76	4,363,649.96
	Cast in-situ Concrete (C-30)	m^3	1,926.42	5,233.49	10,081,899.81	1,595.89	5,233.49	8,352,078.46
	Cement-mortared stone masonry walls (Class 'B')	m^3	1,536.42	1,746.86	2,683,910.64	1,219.33	1,746.86	2,129,992.78
	Sub-total				**20,518,920.45**			**16,134,473.11**
	Grand Total				**490,524,929.55**			**383,809,292.78**