ADDIS ABABA UNIVERSITY
SCHOOL OF GRADUATE STUDIES
ADDIS ABABA INSTITUTE OF TECHNOLOGY
SCHOOL OF CIVIL AND ENVIRONMENTAL ENGINEERING

A Study on the causes, cost effects and mitigation measures to design error induced variation on selected ERA's road projects

A Thesis Submitted to the School of Civil and Environmental Engineering
in partial fulfillment of the requirements for the Degree of Master of Science in
Civil Engineering (Construction Technology and Management Stream)

By: Ehyaudin Musema Ahmed

Advisor: Prof. (Dr. - Ing.) Abebe Dinku

July, 2020

Addis Ababa, Ethiopia

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Addis Ababa University
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School of Civil and Environmental Engineering
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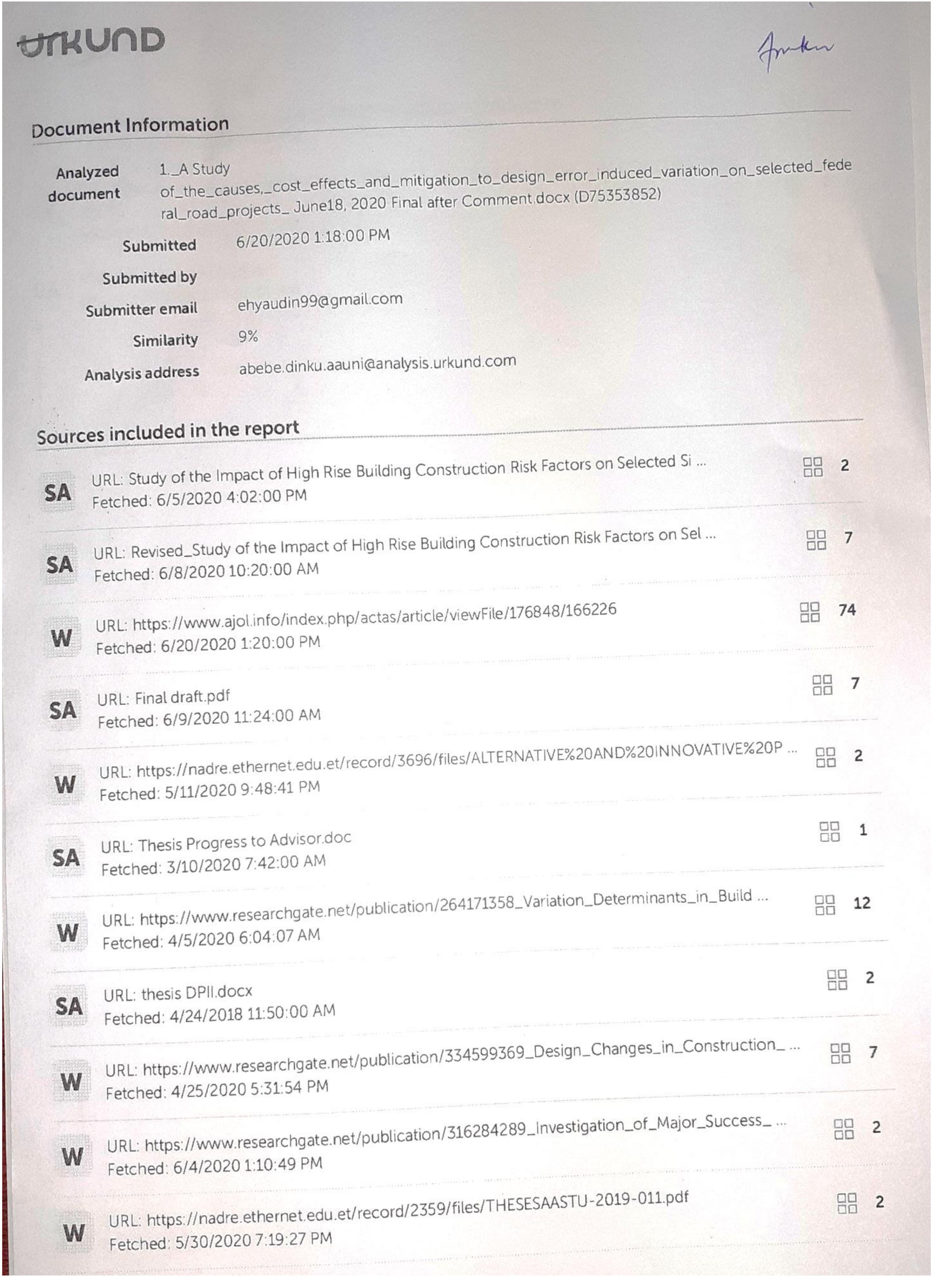
List of Abbreviation

AC	Asphalt Concrete
AfDB	Africa Development Bank
AAiT	Addis Ababa institute of Technology
BOQ	Bills of Quantity
CABE	Chartered Association of Building Engineers
CCCC	China Communication Construction Company
CSC	Construction Supervision consultant
DBB	Design Bid Build
DB	Design Build
DC	Design Class
DBST	Double Bitumen Surface Treatment
DS	Design Standard
ER	Employer's Representative
ETB	Ethiopian Birr
ERA	Ethiopian Roads Authority
ERAMS	Ethiopian Roads Authority Management System
GOE	Government of Ethiopia
HA	Horizontal Alignment
HHB	Hawassa – Hawassa Airport – Bishan Guracha
ICB	International Competitive Bidding
Km	Kilo Meter
MoUDHC	Ministry of Urban Development and Housing Construction
NCB	National Competitive Bidding
PPP	Public-Private-Partnership
RII	Relevance Importance Index
RSDP	Road Sector Development Program
SMEC	Snowy Mountains Engineering Corporation
SNNPR	South Nations Nationalities and Peoples Regional State
SPSS	Statistics and Probability for Social Studies
TOR	Terms of Reference
VO	Variation Order
VA	Vertical Alignment
VAT	Value Added Tax

Figure 1 URKUND Plagiarism Check Report



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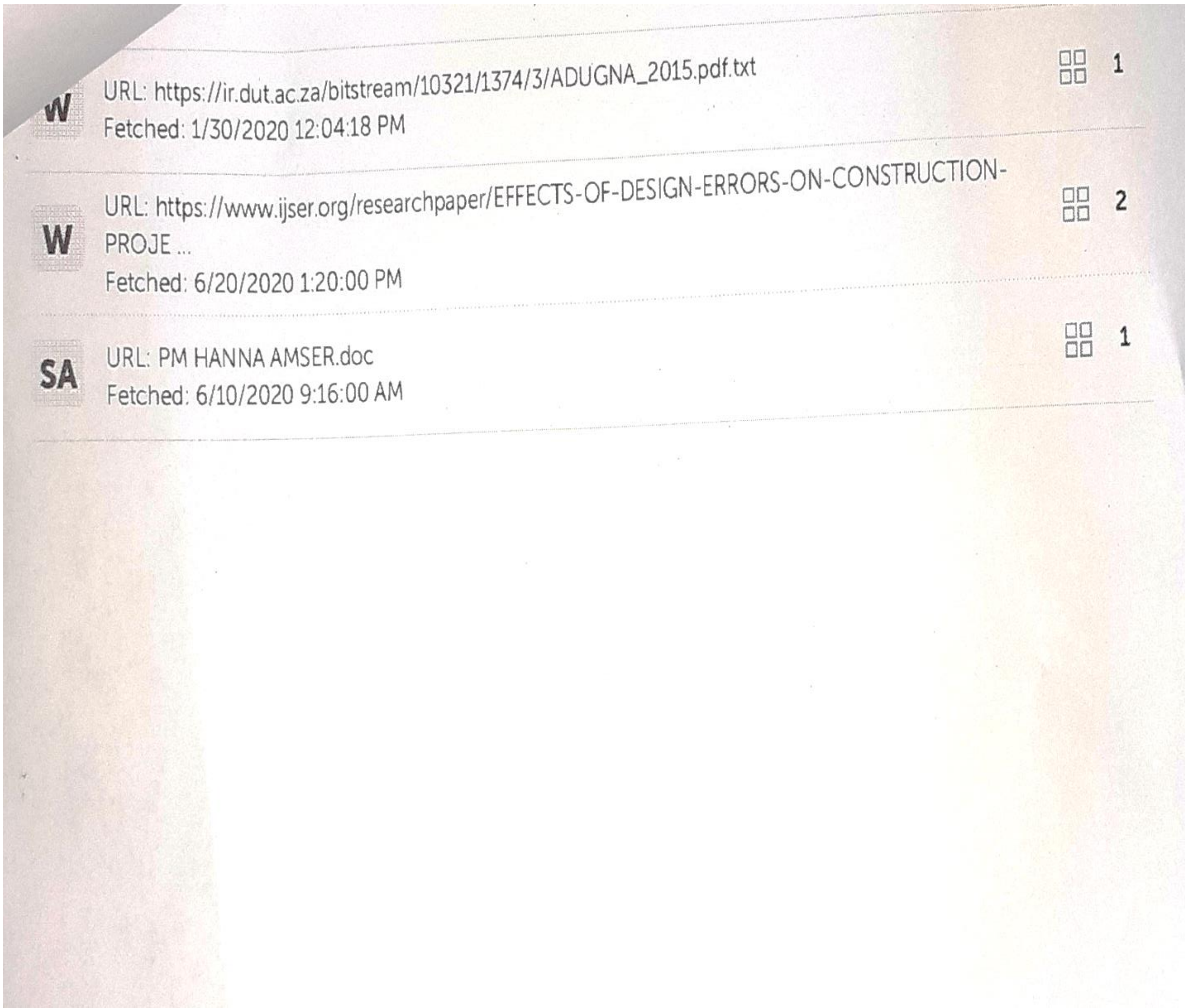

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Declaration

Following the appropriate regulations, I hereby submit my thesis titled "***A Study on the causes, cost effects and mitigation measures to design error induced variations on selected ERA's road projects*** and I declare that this thesis embodies the results of my own work and has been composed by myself. Where appropriate, I have made acknowledgment of the work of others and have referred to work carried out in collaboration with other persons. The thesis is the correct version of the thesis for submission. My thesis for the award referred to, deposited in the AAiT Library, should be made available for loan or photocopying, and subject to such conditions as the Librarian may require. I understand that as a student of the University I am required to abide by the Regulations of the University and to conform to its discipline and code of ethics.

Declared by Student:	Endorsed by Advisor:
Ehyaudin M.	Prof. (Dr. - Ing.) Abebe Dinku
Signature	Signature
_______________	_______________

Dedication

I dedicate my dissertation work to my new born baby girl Ayaarkha E. M. and my family. A special feeling of gratitude to my loving parents, Leyla J. and Musema A. whose words of encouragement and push for tenacity ring in my ears.

Ehyaudin M.

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My boundless gratitude will first go to my advisor (Prof. Dr. - Ing.) Abebe Dinku helping me to accomplish the research work by providing valuable comments and reinforcing the critical thinking approaches.

My gratitude also goes to the project engineers of all construction project management directorates of Ethiopia Roads Authority for providing me sufficient data for the research. It is also significant to thank my mother, father, and my spouse because their contribution is huge in terms of reinforcing to succeed in my life trials and tribulations.

ABSTRACT

In spite of the scarcity of study on the cost effect of design error induced variation on road projects, the study has investigated the very causes of design error induced variation, the frequent design errors that lead to variation, the cost effects of design error on the variation costs, and mitigations for design error induced variation in selected Ethiopian road projects. A two fold method of research (Questionnaire survey and Case study road projects) was applied in collecting the necessary data for the research through a purposive sampling technique. A specially designed survey questionnaire was distributed and collected from 25 project delegated respondents to fill out project-specific sections of the questionnaire as well as the industry generic questions for further analysis. The finding revealed that Inexperience of designers, Lack of knowledge, Lack of integration/coordination between designers of different disciplines, Design Cost, and Duration of Design are the top five causes of design error induced variation. The finding further ranks the frequency of occurrence of design errors based on design elements in the ordered as Vertical Alignment, Horizontal Alignment, Minor Drainage, and Pavement. Moreover, out of the total variation cost in road projects, 43% is influenced by design errors with major contributions of Horizontal Alignment and Minor Drainages Accounting 50% of the cases among others. Finally, based on the analysis of the results, recommendations have been proposed that enables to minimize design error which has the potential to result in variation costs.

Keywords: Cost Overrun, Design Error, Variation Cost, Valuation Documents

CHAPTER ONE

INTRODUCTION

1.1 General Introduction

The Construction industry, unlike other industries, passes through a process having the nature of demanding unique outputs while encountering complex and uncertain conditions. In contrary to other sectors of a state's economy, it usually encompasses a distinct function of design and construction activities.

Design works can significantly influence the project costs and sometimes unsatisfactory design performance (erroneous design) can lead to cost overrun (Barrie and Paulson, 1992). There have been few instances where engineering design is so complete that a project could be built to the exact specifications contained in the original design documents (Chang, 2002).

In a construction contract, the contracting parties may also have different desires that may lead the contract through conflicts of interest between the employer's want of saving money and the contractor's need for profit maximization. This push and pull interests among the parties typically lead to design error as a primary cradle of variation in construction projects (Asamaoh and Offei-Nyako, 2013).

According to the content analysis conducted on the above journal, although the conflict of interest between contracting parties seems to be presented in such a way that it usually causes design error resulting in variation, it does not demonstrate to convince the argument adequately and thoroughly that it can cause design error. For the reason that, at least it should describe the preconditions to be fulfilled as a parameters that design error can be occurred due to conflict of interest in the following criteria but not limited to, in which delivery method? , at which phase of the project cycle? and when in the contract clock? Should be elaborated.

Most often, the Construction industry encounters design errors and their consequential aggregate effect on the cost of organization and projects (Lopez, 2010). In addition to this, according to Yunus (2007), modifying design error directly increases the original contract price to execute the works as a result of the need for additional deployment of personnel and related overhead costs for the execution.

Moreover, Woldesenbet, Hyung Seok and Kirk (2012) reinforces this by stating that the nature and complexity of a project type could be able to result in design errors and changes which open the door to contractual problems regarding time delays and variation of preliminary engineering costs which was predetermined before the inception.

A desk study conducted by Turkey (2011) also identified that Variations, Right of way, Claims, Design problems (design error), and scope change are identified as major factors leading to cost overrun among the 8 potential factors.

Furthermore, Ayalew (2009) mentioned from the raw data of his study finding that the second most important cause of variation for Ethiopian road construction projects identified in his research is the change in defined scope, which includes addition, omissions or modifications of the original scope/design.

The study by Demeke (2015) ranks the five most common causes of change order from the overall point of view and mentions design error in the third place. The overall ranking of the top five causes of change are as follows:

1. Change of plans by the owner.
2. Change in design.
3. Errors and omissions in design.
4. Right of way issue
5. Lack of data for design and experience in predicting underground conditions.

He further implies that lack of data for design, experience in predicting underground conditions, error, and omission in the design are among the frequent causes of change orders initiated by design consultants. From overall design change in ERA, asphalt concrete road projects 76% by design consultant and 24% were by supervision consultant.

Reliability of road design has become a usual problem and continual concern that initiated researchers and stakeholders to study in Ethiopian construction industry (Etefa, 2016).

Critically considering the above facts, this study was managed to be achieved while considering a deficit of relevant empirical study in the area scrutinizing the very causes, cost effects and relevant specific mitigation measures for design error induced variation and accompanied by taking into account of the following particular objectives;

- ✓ investigating the frequent design errors that lead to variation,
- ✓ investigating the cost effects of a design error in variation cost,

- ✓ finding a Solution to design error induced variation in design elements,
- ✓ to enlighten the concerned parties on the susceptible areas that lead to design error besides bringing strategic mitigating solutions.

1.2 Statement of the problem

According to the Ethiopian construction development policy report, even though the construction industry is growing, it is seized with many problems. One of the critical problems of the country is the lack of capacity in the design work of road, building, water supply, irrigation, and all other construction sub-sectors (MoUDHC, 2014). Several pieces of kinds of literature also reflect this, for instance, Eliyas (2016) shows that Design problems directly affect construction works, which is a lack of constructability. The second most important causes of variation for Ethiopian road construction projects identified as design error Ayalew (2009), among the Effects Design problems (design error) and scope changes contribute to cost over-run of the federal road projects (Turkey , 2011).

Thus plenty of literature confirms that design error induced variation remains to be among the front lines over which several kinds of contractual complications arise from it including contract price variation leading to claim, quantity changes, and other related disputes between the parties.

Moreover, Muhammad, et al. (2015) identified that the three prominent sources of variation: design error and omission account for 65% of variation; design changes account for 30% of the variation, and other conditions account for only 5% of the variation.

To this end, early collaboration on projects between designers and contractors usually enhances their relationship and often results in change order minimization because the process encourages the contractor to point out problems in the design or constructability issues early in the bidding or design process (Asaminew, 2013).

Asaminew (2013) also states that a critical element for controlling the cost, schedule, and scope of a project is gaining and maintaining control of the design process. Failure to control and manage this process will result in delays and increased construction costs.

Similarly, Madelsohn (1997) also emphasized on design process because of that many problems are encountered during construction can be traced back to it. These problems can be as high as 75% of the total problems encountered during construction.

So that, this study has conducted a detail investigation of design error induced variation for the projects in the organization, to differentiate what are the root causes and effects of design error on the cost of variation and finally generating possible mitigations.

The subsequent questions are the key emphasis of interest addressed in this research: what are the primary causes that need manipulation to reduce design error induced variation to minimize the considerable cost of variations?, what about the effects of design error induced variation contribution on the total variation cost?, and finally what should be followed in the project cycle (from inception through Contract Administration to Closeout) to diminish design error based variations to every possible level.

1.3 Objective of the Study

1.3.1. General Objective

The primary aim of this thesis is to study the causes, cost effects, and mitigations for design error induced variation in Ethiopian Roads Authority projects.

1.3.2. Specific Objectives

In the road to hit the above mentioned main objective, this study simultaneously embraces but not limited to the following specific objectives.

- ✓ To investigate the frequent design errors that lead to variation
- ✓ To investigate the cost effects of design error in variation cost.
- ✓ To devise recommendations for the respective contractual parties.

1.4 Scope and Limitation of the study

1.4.1. Scope of the Study

The very domain of this study is;

i. The assessment of the causes cost effects and mitigation for the design error induced variation in selected ERA's projects.
ii. Projects that are under construction in the recent five years.
iii. Using the approach to achieve objectives using the close case study on valuation documents of design error induced variations of any delivery methods in ERA for representative sample projects.

iv. Project types of Construction, rehabilitation, and upgrading Projects, other than maintenance and gravel wearing course projects are among the study concern.

1.4.2. Limitation

In data collected from the secondary source it was not easy to get it readily because it is crucial to convince the project engineers administering the projects to provide the necessary data however, finally managed to access to the sufficient extent.

The detail about the history of the project that can be retrieved from head office archive exclusively valuation of variation documents were encountered some effort approach to get the details. However, sufficient data gets in to hand afterwards by convincing the officers accordingly to retrieve the data as per the requirement of the study.

1.5 Contribution of the research

Owing to Ethiopia's nationwide road penetration to its population size is very trifling in comparison with the world average according to the report Focus Africa (2016), as a result the road sector needs improvement and expected to do a lot in the way forward. In contrary, the road sector remains to encounter different hindrances holding back the countries Road Sector Development Programs (RSDP) against to the required level of excellence that it should be improved.

As mentioned in several studies reviewed it has been found that design error is the very most common cause of variation order in construction and civil work projects. This study intended to assist towards the improvement of the road penetration by reducing the occurrence of hindering contractual factors via providing the construction management concerned solutions to the problem, subsequently assessing the very causes of design error inducing variation; in particular, this has been achieved through scrutinizing the recurring design errors that need close attention in the project cycle.

Besides, their consequential effects on the variation costs, and pointing towards possible mitigation measures that are actionable on behalf of the contractual parties in reducing the impact of the captioned problems has been discussed.

To this end, Ethiopian road authority has projects to be administered under the current and upcoming RSDPs that need better project's contract administering and handling practices, as a result, this work has a contribution through an investigative approach with which one can analyze both factual and expert-opinion data to draft enhanced approach towards achieving the objectives of the current and upcoming RSDP's under the custody of the mentioned regulatory body (ERA) and provide the best road for a prosperous nation.

1.6 Research Questions

The research questions which have been addressed by the final findings are:-

i. What are the frequent design errors that lead to variation?
ii. What are the cost impacts of a design error in the variation cost of road projects?
iii. What will be the solution to diminish design error induced variations throughout the project life cycle?

CHAPTER TWO

LITERATURE REVIEW

The literature review has been divided into the following main areas for ease of presentation; Introduction, Definition of Concepts, Parties/stakeholders in road projects, Who Does Design, Selection Problem, Why Design fail, Good Design Vs. Bad Design, Consequences of Design Default, Variation Order Vs. Design, Causes of Design error induced variation, Effects of Design error induced variation in variation costs, Schemes in solving Design error induced variation, Current situation, Design Process for Designers, Summery of literature, and Knowledge Gap.

2.1. Introduction

The literature reviewed shows both past and current studies under the theme, while summarizing known causes and effects of variations particularly design induced variation orders and outline current methods for reducing impacts. It also identifies research areas that require further study and justify the need for this thesis.

Literature sources were academic journals, articles, institutional publications, industry websites, expertized reports, books, and other publications. Literature sourced from journal articles and institutional publications provided a good representation of research achievements to date and highlighted areas that require further study. Journal articles were sourced from online publication index databases. All literature was published in English.

2.2.Definition of Concepts

Road design by definition relies more on selecting the dimensions of the road and its components, e.g., the width of the carriageway, road profile, and type of road equipment. The process of road planning and design is complicated due to the numerous components the road consists of and the different aspects that have to be considered for an optimal solution (Karim & Magnusson, 2008). However, there are lots of other definitions meant for design, but deliberately for the use of this study, it keeps using the definition mentioned therein above.

Furthermore, when it comes to defining error, it is an event of unintended deviations from correct and acceptable practice that is avoidable Dosumu and Adenuga (2013); they further referred errors may involve different meanings and usages based on how they are conceptualized. Based on this concept, design error can be defined as avoidable deviations from acceptable standards of practice during the design of construction projects (Dosumu & Clinton, 2018).

While variation is any deviation from an agreed well-defined scope and schedule of construction projects after issuance of Variation order (Alaryan, et al. 2014). Moreover, Oluwaseun and Clinton (2017) define variation as a change or any modification to the contractual guidance provided to the contractor by the owner or consultants.

Variation in construction means the modification of the design, changes in quality, a quantity of work including the alteration of the standard of materials or goods to be used in the work and the removal from the site any kind of material not in accordance in the contract (Asamaoh & Offei-Nyako, 2013).

Those changes arise afterward to the signing of the initial contract and/or next to the commencement of works and encompass of changes to plans, specifications, or any other contract documents. The changes may be due to various reasons such as poor design, change in design, and misinterpretation of drawings leading to a construction error.

2.3.Stakeholders in road projects

This section intends to present the stakeholders that enforce the project an effective, efficient and successful implementation of stakeholder management from the project management body of knowledge in the respective stages of their involvement in the project cycle from inception through design and implementation until close out of projects.

The figure - 1 shown below depicts several kinds of project stakeholders that will involve in a typical construction project at various stages of the project cycle.

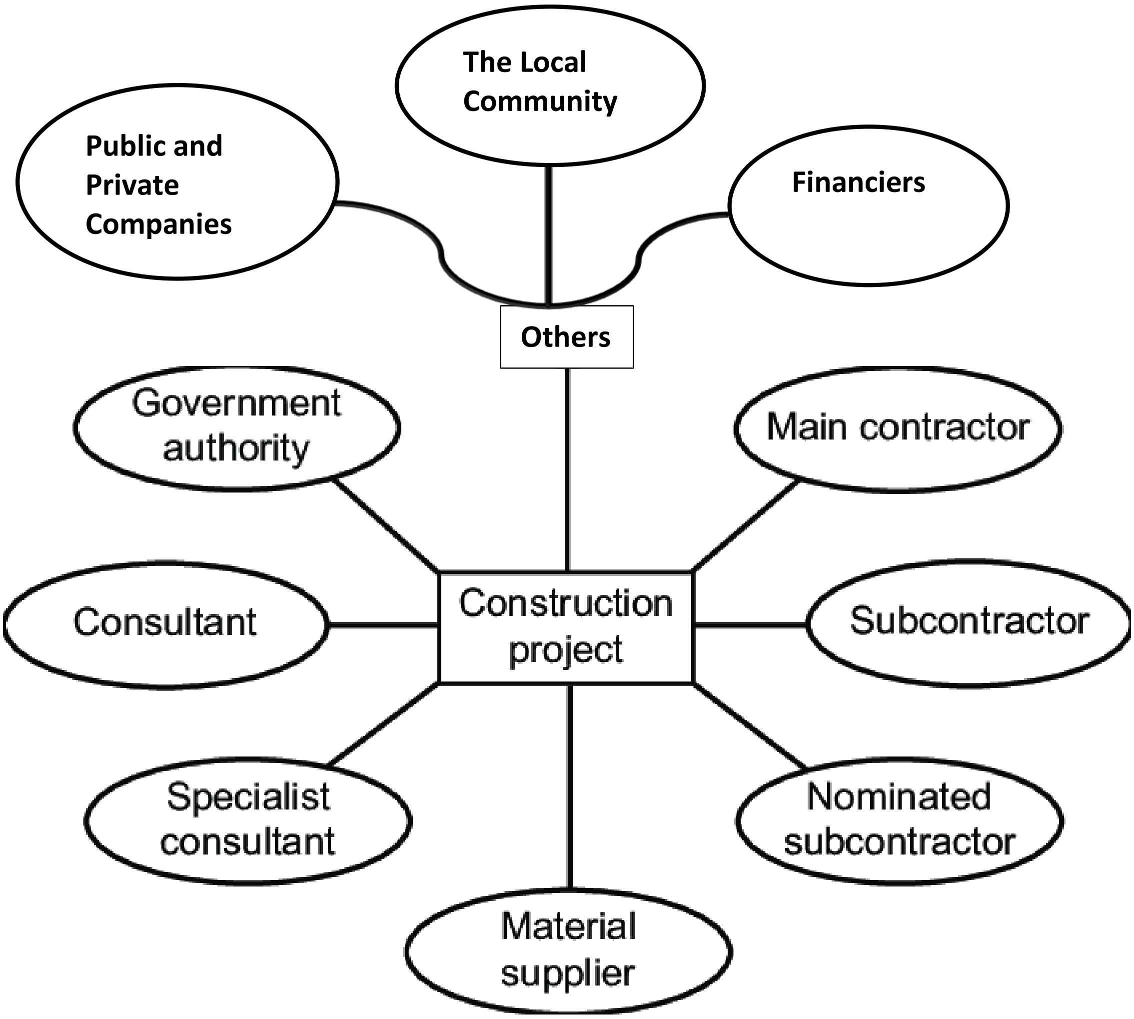

Figure 2: Participants in Road Construction Project **(Banaitis & NG., 2017)**

- Financiers

Finance for the construction industry, plays a crucial role. The financiers are the parties which provides for funds to finance the project and share in the risk of the project by negotiating with all the other parties (Hoffman, 2001). This may involve international funds for development, continent based development banks, grantors, partnerships, donors and debtors.

- Government

Since the government is the major driver of countries economy and infrastructures to lead a nation towards a certain vision, has a role to play and took the lead from some of the large multinational corporations.

The construction Industry is very vital for implementing all construction policy objectives of governments. Usually a substantial percentage of the economic resources laid out by a government in the form of budget proposals will be devoted to the provision of infrastructural facilities and bases for other developmental objectives and these resources will have to be expended in and by the construction industry (Aniekwu, 2003).

- Employer

Employer is an organization that initiates and finances the construction management, design, and construction of a project. Typical Employer's/Clients are federal, state and local governments, public corporations, community groups, and individuals. Without an employer a project would never get off the ground. The employer identifies a need for the project and sets in motion the requisite studies, investigations and designs, and arranges the finance. When the details of the project have been finalized, the employer engages a contractor to execute the works, ensures the land is available for the works to be constructed, and makes payments to the contractor at regular intervals or on achieving specified milestones, depending on how the contract sets out payment is to be made (The SMEC Group, 2019).

- Design and Supervision Consultants

Design consultant is contracted by the client to design, produce documentation, and provide technical services for the construction of the project. The role and responsibilities of the consultant may differ between projects and countries. Consultants may include architects, engineers of different disciplines, designers, surveyors and scientists. Typical responsibilities of the consultant include feasibility studies, design and documentation, cost-estimates, investigations, and coordination of designs. (UKessays, 2014). The consultant is expected to act impartial for both the client and contractor through his deliverable of the design service until the tender document preparation during design phase and even during construction contract administration phase.

While Construction Supervision consultancy (CSC) service contracts are contracts entered by ERA with an engineering consulting firm to provide supervision services on behalf of the Employer. The services to be provided are specified in the terms of reference that forms part of the CSC contract. The powers of the CSC on the Contractor are normally defined in the Conditions of the Works Contract. The other role of the Engineer is to serve as a mediator between the Employer and the Contractor on matters of dispute. He is expected to work independently as the supervisor and act impartially when mediating between the parties (Ethiopian Roads Authority, 2014).

- Contractor

Contractor is a party nominated by the client to construct the project using their own resources as per then project scope and size. They are responsible for completing the project in accordance with the design consultants design documentation and completing the project on program. Contractors can be companies capable of providing specialized construction methods, own specialized equipment or have skilled workers (UKessays, 2014).

2.4. Who does design

The design consultant is assigned by the employer to design, yield documentation, and provide technical engineering services before the construction phase of the project. The role and responsibilities of the consultant may differ between projects and countries. Consultants may include architects, engineers of different disciplines, designers, surveyors, and scientists. Typical responsibilities of the consultant include feasibility studies, design, and documentation, cost-estimates, investigations, and coordination of designs (Benjamin, 2014).

2.5. Selection strategies and bidding philosophies

The applicable parameters for selecting a designer are not always suitable. In most cases selection of design, consultants focused more on the least price quotations instead of considering the required level of service and expertise necessary for a successful design output (Engineers Australia , 2005).

In our countries context, the least bidder syndrome is also applicable in similar notions in such a way that a low price equals value for money. Selection of consultants purely based on price can lead to greater financial consequences in later stages of a project particularly during the implementation phase, Current marketplace conditions have pushed consultants to assess and cost projects based on minimalistic principles (Benjamin, 2014). As consequence tensions between contractual parties develop when project objectives and desired outcomes fall short of expectations. The report publicized by Engineers Australia (2005) drawn a strategy for selecting consulting services that are based on value, competency, and price. Listed below are bidding and selection objectives.

Employer's will:

I. have a better understanding of the term "value" which will incorporate:
   - Capability to deliver the required service within the project constraints (time and budget) and expectation (quality);
   - Reliability and capability to perform in a no adversarial manner;
   - Ensure sustainable project; and
   - Keep in mind the life cycle cost effects.

II. Understand the links and trade-offs between time, cost and quality;

III. Appreciate that with professional services, equivalent pay for equivalent efforts;

IV. Appreciate that many designs are prototypes so that procuring design and documentation services for infrastructure facilities differs from purchasing a commodity due to projects unique features;

V. Understand Partnership for sustainable growth;

VI. Encourage innovations and value engineering aspects through an incentive package;

VII. Recognize reputations in the industry and demonstrable evidence of innovation;

VIII. Understand the risk profile / risk allocation being between the parties;
   - Acknowledge the skills required for the project and the capabilities required of design teams proposed by prospective designers;
   - Have access to reliable and proven techniques for bid evaluation and contractual performance measurement.

The above are among other objectives which will increase competition, innovation, and quality, as well as reduce the impact of variations caused by the improper selection of consultants.

2.6. Why design fails

According to the literatures reviewed, poor coordination of the design process, Design salary (Cost), Design Duration, Documentation issue, Design verifications and interface coordination, Inexperience of designers, knowledge gap, flaws in selection strategy of designers and unforeseen events are among the factors identified from the content analyzed which can be able to result in the design to be erroneous. Moreover, it has been attempted to discuss the factors in detail hereunder.

2.6.1. Poor coordination of design management

Poor coordination of design management practice directly results in erroneous design causing complicated contractual issues. Design errors and variations are inherently part of many construction projects and require deliberate effort to combat (Oluwaseun & Clinton , 2018). Furthermore, the client's design approving and management has a great impact on the quality of the end design as it has the authority to guide the designer to the scope that the employer/client wants the project to be in compliance with other basic design parameters. Design submittals have been checked by junior engineers undertaking an inadequate review of design submittals as a way to have poor design output (Merima H, 2018).

2.6.2. Designer Cost and Duration

The designer's contract price in another language the design cost accordingly influences the motivation and effectiveness of the design team. The motivation and effectiveness of the design team influence the flow of information and as a result the number of errors generated while producing the construction documents (Rukn Eldeen , 2007).

In analogy, according to a study on the Impact of design cost on project performance by Nirajan (2011) depicts a flow chart showing the effects of design cost on construction projects as shown in figure-3 below.

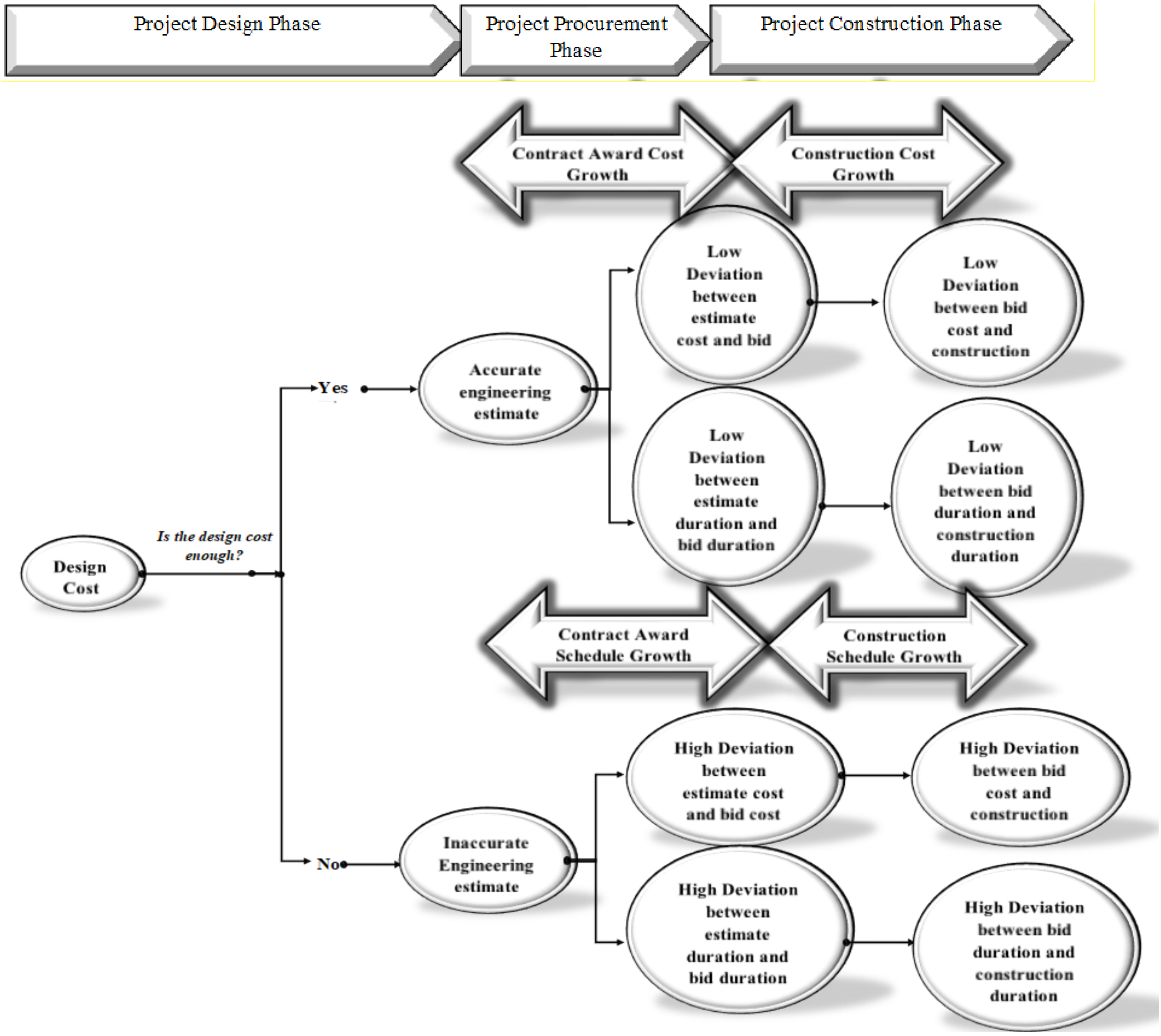

Figure 3 Design cost Vs. Project deliverability **(Nirajan, 2011)**

As shown in the figure 2 above enough design cost may or may not result in accurate engineering estimate which as a tendency of low deviation between estimate cost and duration against the bid similarly between bid and construction phases too. But the model is only to show simply a trend of negative relationships.

He found that the correlation between design cost and cost growth is stronger in bridge projects than road projects, because bridge projects are more design-intensive than road projects. However, the correlation between basic design cost and total cost growth was found to be positive and significant in case of flood control projects. This finding is exactly opposite to the finding of the road projects. One of reasons for this correlation might be the very small sample size. On the other hand, due to the type of the projects the correlation was found to be exactly opposite. Therefore, it can be suggested that, while conducting these types of correlation analysis, the data should be separated depending upon the types of projects. It is recommended to conduct further study to validate these findings with large sample sizes.

Following the analogy of value for design vs. design deliverables, the author of this study attempts to create the relationship between Design duration and project deliverability as shown in the figure 3 below depicting that a relevant and enough duration for design will lead projects to have an adequate design documentations attributed to lesser inconsistencies which results projects to have a completed design prior of implementation phase besides having greater certainty in terms of project cost and durations and the vice versa.

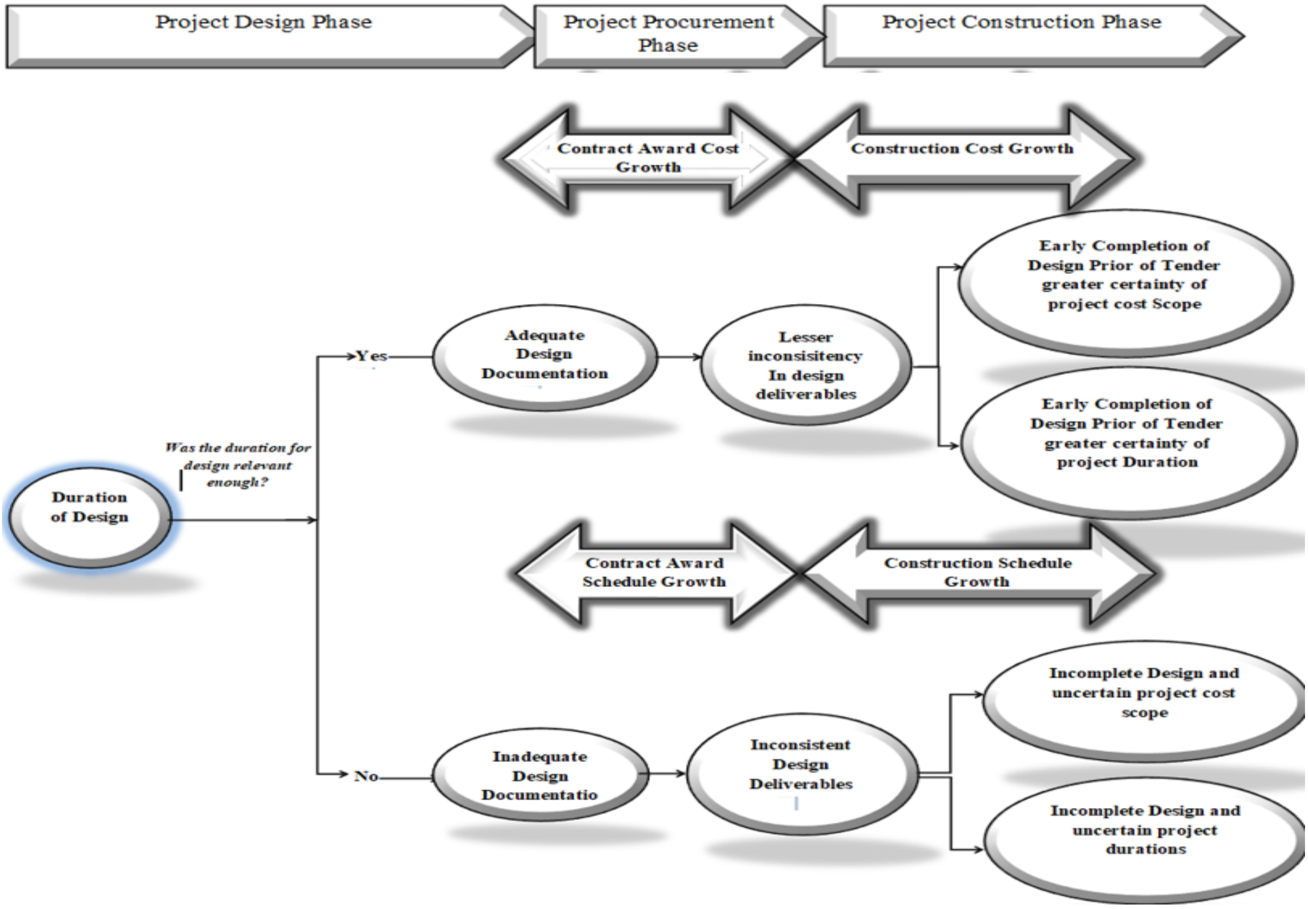

Figure 4 Design Duration vs. Project deliverability **(Nirajan, 2011)**

2.6.3. Design documentation

A proper review of final design documentations can prevent design changes (Benjamin, 2014). For contracts based on drawings and specification the design should be completed before tender. This will limit possible claims and disputes in later stages of a project. Coordination of design documentation between disciplines is important (Kagan, 1985). Design drawings and specifications should be reviewed by project participants to avoid conflicts and ambiguities. Trained professionals need to be actively involved in the design from conception to construction (Benjamin, 2014). In ERA's case, design submittals are checked by junior engineers who have insufficient exposure on the task during their career, such undertakings results in an inadequate review of design submittals as a way to have poor design output (Merima, 2018).

2.6.4. Lack of design verifications and interface coordination

Late discovery of a design error caused by multiple dysfunctional reasons such as unclear project leadership roles, lack of design verifications, and interface coordination are among the causes of design error induced variations. For such kinds of cases, this study makes the default designer responsible to pay for any error consequences arises due to such a design management gap.

2.6.5. Inexperience of designers and Project objectives

Among the major causes of design error induced variation as poor working drawings, lack of coordination during designs, change in scope of work by clients, omission in designs, inadequate project objectives, mistakes, the inexperience of designers, and owners' financial difficulties for building projects (Dosumu & Clinton , 2018).

On the other hand, if the design consultant is provided limited or insufficient project objectives the design will conflict with the client's expectations causing variations in later stages of the project (Keane, 2010).

2.6.6. Experience and knowledge of the design team

Once the design is complete, most designers leave the project regardless of transfering their encounterings to other new comers. Experienced designers have few mechanisms for passing their knowledge to newly hired personnel. Within the design community that a major issue with respect to facilitating the constructability process is the need of construction experience and knowledge among designers. This issue is resolved within most firms by assigning design review responsibilities to senior design personnel. It is apparent that this effort does not effectively bridge the gap between designers and contractors than the efficient constructability analysis on the other hand (Tsegaye, 2009).

2.6.7. Selection of Design Consultants

Selection of a consultant is often determined by price rather than the ability of the consultant to provide a high level of service required for successful outcomes (Engineers Australia, 2005).

2.6.8. Unforeseen

Design exceptions are defined as designs which do not conform to the minimum criteria as set forth in the standards, policies, and standard specifications. Common reasons for considering exceptions are impacts to the natural environment, social or right-of-way impacts, preservation of historic or cultural resources, sensitivity to context or accommodating community values, and construction or right-of-way costs (Tsegaye, 2009).

2.7. Good Design the Fundamentals

According to the definition of reliability-based design, the best design is one which performs as expected in the face of both expected and unexpected variations; and it does so because the design is inherently insensitive to changes in the design parameters and service environment (Wei Wang and J Wu, 1997). Furthermore, it is a philosophy a way of structuring professional activities so details are planned before actions (implementations) is taken place and problems are anticipated so they may be eliminated before occurring in the field or actual ground (Richard C Fries, 2016).

Richard Simmons, Chief executive, CABE, also attempted to show why design does matter – and what is the best way to achieve it? The essay presented why architecture and urban design are such important cultural assets, and why good design can be reached only if it has users in mind. Good design requires a good process, including a clear brief and adequate budget, along with strong leadership and the right regulation. He identified the following issues that make an organization fit for purpose to get reliable design after discussing with many design champions about their experiences and the environments in which they work.

These include:

Behavior:

- ✓ Leaders with vision who know that better design improves results,
- ✓ Effective partnership internally and with the right public bodies and private companies,
- ✓ Knowledgeable, skilled and trained decision-makers,

Resources:

- ✓ Design champions who can influence decisions,
- ✓ Strong public buy-in and appetite for design quality,
- ✓ In-house designers and/or a consultant design team with a brief to support the organization as a client or decision-maker,

Processes:

- ✓ Strong published policies and standards,
- ✓ Decision making that talks about and prioritizes good design,
- ✓ Robust procurement processes which set absolute minimum design requirements,
- ✓ Access to design review for key projects,
- ✓ Learning through the scrutiny of decision making, and
- ✓ Post-occupancy surveys of projects.

2.8.The Cost of Inadequate Design

Badly designed places impose costs on their occupiers, their neighbors, and society. There is a general truth that good design has financial and social value. Various publications presented an overwhelming set of arguments to justify the hypothesis that good design sometimes (but not always) costs more initially, but that it adds value. It can often create value in locations where quality has not been the norm. It certainly reduces whole-life costs.

In the construction industry as often known have problems regarding large slippage of calendar days of completion against the planned duration due to different inter-related causes and effect project contract variable controversies.

Among them design-related problem takes its own part, those variables resulting in projects to be completed through un-conducive performances creating public grievances here and there all around the country due to the project's influenced performance. For instance, from the desk study conducted by Turkey (2011) Variations, Right of way, Claims, Design problems (design risk), and scope change are identified as major factors leading to cost overrun among the 8 potential factors which have been identified.

Most claims result from the project designer's inability to fully provide for all eventualities, which means that changes will be made to the contract as it proceeds to the implementation and, where these involve additional work, adjusted payments will be necessary (Gibso, 2008). Due to the anticipated variations, the road agency cost (ERA's or financiers) will gradually increase against the budgeted level for that specific fiscal year budget secured for its implementation.

The construction design is a specialized and highly demanding form of problem-solving (Pressman, 1993; Lawson; 1997). It is where stakeholder's needs and requirements are conceptualized into a physical model of procedures, drawings, and technical specifications (Freire and Alarcon, 2000). It is a dynamic and complex multidisciplinary process, involving many parties and performed in a series of iterative steps to conceive, describe and justify increasingly detailed solutions to meet stakeholder needs (Sterman, 1992; Ogunlana et al, 1998; Baldwin et al, 1999).

Design process is claimed to be the key project process Morris, (1999); Cockshaw, (2001), defining up to 70% of the final product cost and adding value by delivering functionality, quality, enhanced services, reduced whole life costs, construction time and defects as well as delivering wider social and environmental benefits (Sileshi Ambachew, 2018).

2.9. Variation order vs. design

Al-Dubaisi A.H. (2000) in his study on Variation order in the construction industry of Saudi Arabia investigated that, change of plans by the owner, substitution of materials and procedures, error and omission in design, owner's financial problems and change in design by the consultant are the five topmost causes which contribute for variations.

Furthermore, among the five most important factors agreed by the clients, consultants and contractors as causing project cost overruns are; Schedule slippage, lack of project knowledge, underestimating of project costing and design errors followed in that order according to the Ghanaian construction industry (Nicholas & Berko, 2010).

While, Halwatura & Ranasinghe (2013) found that non-compliant design with government regulations, lack of coordination between consultant and contractor, conflicts between contract documents, lack of materials and equipment are the significant causes of variations that adversely affect construction projects in Sri Lanka cited as the potential causes of variations in construction phases while the same in Ghana. These kinds of literature are an implication that the subject is critical on a worldwide level.

Further, in a conference proceeding held in Malaysia, having the objectives to analyze the relationship of design changes and the consequent rework, to recognize their resulting project performance and to provide insights for directing further studies in the Malaysian context. The findings indicate that design changes as important causing factors to project delays and cost overruns. Similar results were found for studies done in both developed and developing countries around the world because construction projects commonly share key characteristics (Hamzah Abdul-Rahman, 2015).

When a variation order occurred, the contractor tends to charge higher rates for variation items. Then the client is affected in terms of cost (Halwatura & Ranasinghe, 2013).

In the Ethiopian construction industry particularly the road sector as often known have problems regarding large slippage of calendar days of completion against the planned duration and contract costs due to different inter-related causes and effect controversial project contract variables (Merima, 2018).

Unfortunately, the design-related problem is amongst those variables resulting in projects to be completed through un-conducive performances creating public grievances here and there in all around the country, Variations, Right of way Claims, Design problems (design risk) and Scope change are identified as major factors leading to cost overrun among the 8 potential factors which have been identified. Furthermore, the study also implies that Ethiopian Federal road construction projects 12.12 % cost overrun is come about due to design problems (Turkey , 2011).

On the other hand, Kassa (2018) finds that the fourth determinant of cost overrun in rail and road construction projects is inadequate specification/or bill of quantity and design of projects which confirms the theme discussed by other studies.

Most claims result from the project designer's inability to fully provide for all contingencies, which in turn raises a reliability question on the design; which mean that changes will be made to the contract as it proceeds to the implementation and, where these involve additional work enforces adjusted payments to be necessary. Due to the fact of anticipated variations which will gradually increase the road agency cost (in our case ERA's fund appraised either from GOE or Financiers) against the budgeted level for that specific fiscal year budget taken for implementation.

An Australian firm SMEC carrying out technical assistance for Modernization of the Ethiopian Roads Authority through Better Contract and Project Management Practices for the previous couples of years the firm analysed some gaps in the area of contract administration, their report reveals a high percentage of variation due to design problem as among the critical gaps observed in the organization contract administration practice so far. Mentioning design submittals has been checked by junior engineers undertaking an inadequate review of design submittals as a way to have poor design output (Merima, 2018).

In this regard, she also mentions some construction management perspective preventive solutions to reduce/avoid design errors/changes to mention some;

- ✓ There shall be a sufficient time (in ERA's practice it is assumed to be a for project definition, design and documentation;
- ✓ The Involvement of potential users, maintainers, and constructors in determining design shall be considered
- ✓ attempt to identify potential construction difficulties and make due allowance for them in determining the construction period;
- ✓ undertake robust project feasibility evaluation;

2.10. Variation Category

2.10.1 Beneficial variation orders

A beneficial variation order is one issued to improve the quality standard, reduce cost, schedule, or degree of difficulty in a project (Arain & Pheng, 2005b). However, all variation orders do not increase the costs of construction. Omissions in most cases reduce costs while additions increase costs (Ssegawa et al., 2002). Various studies have revealed that variation orders contribute to these cost overruns. While in practice the addition is treated by signed supplementary agreements between the parties on the above of the existing contract agreement.

Perhaps, the more the number of variation orders, the more they are likely to affect the overall construction delivery cost. A beneficial variation order eliminates unnecessary costs from a project. As a result, it optimizes the client's expenditures against the unnecessary costs. It is a variation order initiated for value analysis purposes to realize a balance between the cost, functionality, and durability aspects of a project to the satisfaction of clients (Zewdu, 2015).

2.10.2 Detrimental variation orders

A detrimental variation order is one that negatively influences the client's value or project performance (Arain and Pheng, 2005). For example, a client who is experiencing financial problems may require the substitution of quality standard expensive materials to substandard cheap materials (Zewdu, 2015).

2.11. Causes of Design error induced variation in construction projects

As referred from the above literature Design error has been adjudged to be the main source of variations in the construction industry. Concerning this, without identifying the design errors that have large contributions to variation cost, it may be tough to reduce the total cost of variation and invariably cost overrun of construction projects, (Dosumu & Clinton, 2018).

In the same analogy to this, without detecting the very causes of design discrepancy it will be challenging to harness and /or reduce the design error induced variation. Herein under are causes of design error induced variations are narrated in a glimpse from the literature reviewed.

The study by Dosumu & Clinton (2018) conferred that, wrong/inadequate descriptions in specifications, Errors in design calculations, and Omission of details in the specification are the top three causes of design error induced variations covering 33.3%, 30.3 %, and 15.2 % respectively.

They also indicate that specification-related errors contribute to 57.6% of the total errors leading to variation in construction projects. This entails many problems remain to be solved in the specifications of construction drawings. These problems include the provision of clear and detailed specifications for materials, and correct and adequate description of the specification, among others. Furthermore, errors in design calculations constituted 30.3% of the total errors leading to variation in construction documents.

On the other hand, in case of the Ghanaian construction industry the top three; which are design complexity, change in specification, and lack of knowledge are among the very primary reasons for design error that leads to variation as conferred by (Asamaoh & Offei-Nyako, 2013). In analogy, according to a descriptive study by Muhammad, et al. (2015) exposed that the impediment to prompt decision-making process, poor workmanship, lack of strategic planning, change in design, non-compliance of design with government regulation, aesthetics, cost, inadequate project objectives, mistake, and plan error as causes variation order initiated due to design error in building and civil engineering projects in the Nigerian construction industry.

On the other hand, Memon, Rahman and Abdul (2014) mention some causes for the design-related variations, among them inadequate working drawing details: To convey a complete concept of the project design, the working drawings must be clear and concise. Because of that Inadequate working drawing details can result in misinterpretation of the actual requirements for the project, at the end of the day causing variations in the project.

Sometimes, mistakenly considered assumptions against standard practices also led to a design error that might cause some serious problems including defects. However, this error can be detected subsequently before actual construction through a constructability review. But, once the bidding stage was already over and the contractor had already commenced some works, this error led to some formal variations and additional costs (Memon, Rahman & Abdul, 2014).

Besides, the owner must ensure that the program needs are conveyed to the design team. Since, the design of the facility must be buildable and design intent must be properly communicated, the owner requires that the design documents are constructible, complete, clear, and coordinated. The documents should properly incorporate unique features of the site to include subsurface conditions, interfaces with adjoining properties, access, and other characteristics. Owners must decide how much control they need to have over the design elements of a project (Asaminew, 2013).

An empirical study conducted by Dosumu and Clinton (2018) also reveals a consistent finding with the above kinds of literature by mentioning that the major causes of design error induced variation as poor working drawings, lack of coordination during designs, change in scope of work by clients, omission in designs, inadequate project objectives, mistakes, the inexperience of designers, and owners' financial difficulties for building projects. However, projects under the construction industry often share similar attributes from the perspective of the construction management body of knowledge.

All the major contributors of design error in the project contract environment is clearly shown by Jeffrey , Hamzah and Chen (2016) as depicted in the figure-5 below flow chart showing all the sub-factors from respective project environment influencers.

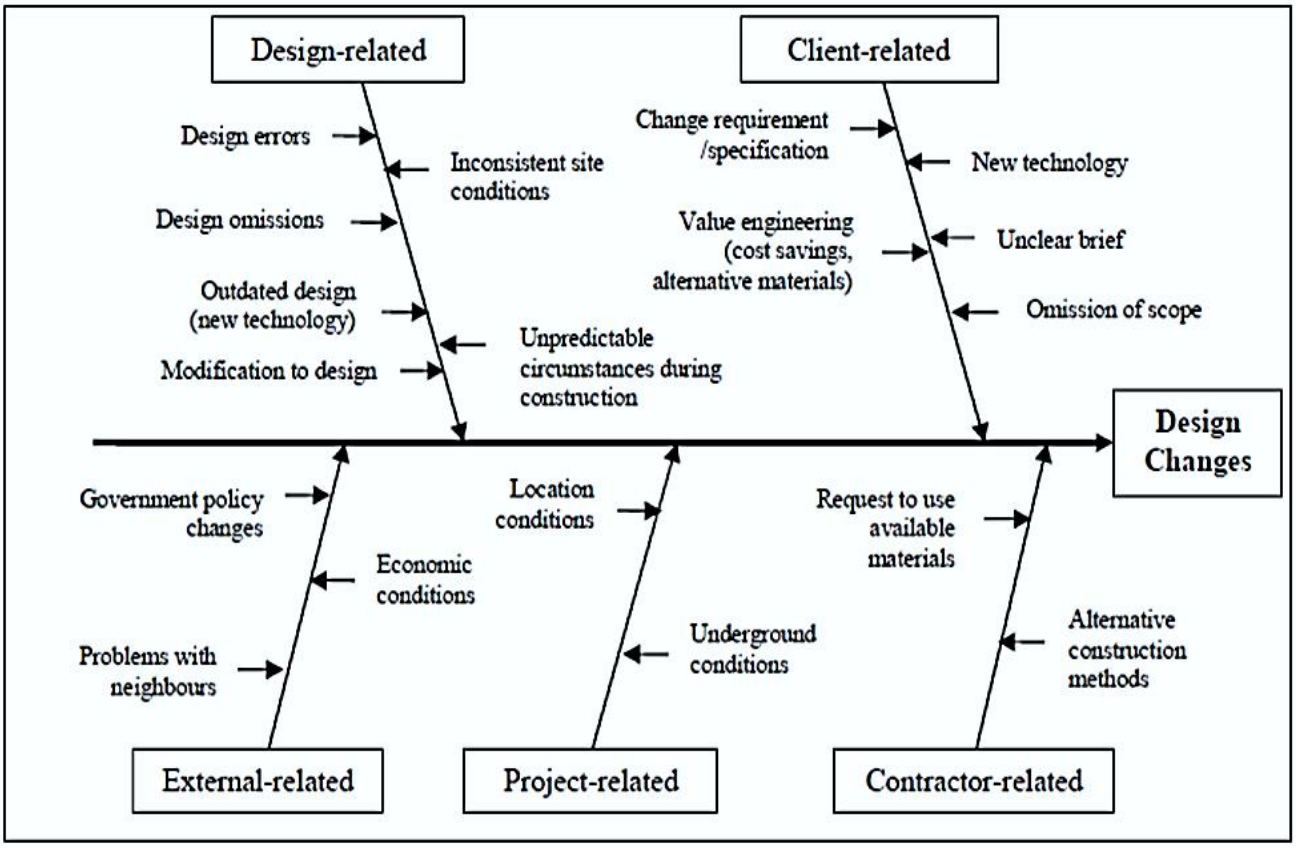

Figure 5: Generic cause-and-effect diagram of design changes **(Jeffrey , Hamzah , & Chen , 2016)**

2.12. Effects of Design error induced variation in variation costs

Dosumu and Clinton (2018) Emphasized that the probable effects of variation in all construction projects are resulting in the rise of the project cost followed by the additional payment due to the contractor, increase in overhead expenses, completion schedule delay, as well as rework and demolition. An increase in project cost and time are the two main effects of variation.

Moreover, analogical research done in building projects shows a result of a case study investigation that Errors in design calculations (53.5%) had the highest effect on the total cost of errors. This was followed by wrong/inadequate description in specifications (21.6%), the omission of details in specifications (13.2%), absence of specifications (9.5%), and others respectively (Dosumu & Clinton, 2018).

Dosumu and Clinton (2018) Concluded that here is the need to reduce errors in design calculations to the magnitude as minimized as possible, to reduce variation cost. There needs to be an improved specification-related issue that accounted for approximately 44.3% of the types of errors resulting in variation. This shows that specification-related issues and errors in the design calculation account for approximately 97.8% of the total design error cost leading to variation. Those figures show that specifications and calculations are the greatest issues of design errors and variation costs. Moreover, the total contribution of design errors to variation cost, according to the investigation in this study is 36%, which represents the probable net effect of design errors on variation cost of projects.

Moreover, in another publication by Oluwaseun & Clinton (2017) while studying the Impact of design errors on variation cost described that the contribution of design error to variation cost according to types of errors. Errors in design calculations have the highest contribution (53.5%) to the total cost of errors. This is followed by wrong inadequacy description in the specification (21.6%), the omission of details in specifications (13.2%), absence of specifications (9.5%), and dimensional error in drawing (2.2%).

A view encountered by SMEC in discussions with ERA staff was that price adjustment was the cause of large price escalations on some ERA contracts with the inference being that improvements to price adjustment procedures are needed to avoid the problem of large price escalation. SMEC reviewed 16 recent contracts to ascertain the severity and how widespread are the problems. Contract price escalation is the change in contract price compared with the original contract sum and includes price adjustment (rise and fall) and variations. In some cases, the variations were extensive changes in scope which naturally will result in a change in contract price as more work is being carried out. In two instances, there were very long extensions of time (three years and six years) as works were suspended while redesign was undertaken. This shows design error leads to redesign and finally might results in price escalation.

2.13. Schemes in solving Design error induced variation

2.13.1 Preventive step

Controls for variations and variation orders have been suggested by many researchers (Mokhtar et al., 2000; Ibbs et al., 2001). The controls were grouped under three categories: Design stage, Construction stage, and Design- Construction interface stage. These groups assisted in developing a comprehensive enumeration of potential controls for variation orders.

Among the design Stage Controls for Variation Orders as this thesis is more related on the design induced variation referring to Arian and Pheng (2005) the following design practice related mechanisms have been observed while citing other kinds of literature, to mention some;

Organizational Level

- Love, Lopez & Kim (2014) noted that people-related error management includes cognition, behavior, motivation and learning; organizational error management includes quality, culture and training,
- The involvement of professionals in design may assist in developing better designs by accommodating their creative and practical ideas (Arain et al., 2004). This practice would assist in developing a comprehensive design with minimum discrepancies (O'Brien, 1998).

Project Level

- Love, Lopez & Kim (2014) project-related error management includes the use of integrated procurement methods, implementations of smart technologies for instance Building Information Modeling (BIM), Computer-Aided Design (CAD) and as required.
- Value engineering at the conceptual stage can assist in clarifying project objectives and reducing design discrepancies (Dell' Isola, 1982).
- The provision of a large contingency sum may affect the participants' working approaches. This is because the designer may not develop a comprehensive design and would consequently carry out the rectifications in design as variation orders during the later stages of the construction project and much more.

Moreover, Koushki, et. al. (2005), revealed that clients who spent more time and money on the design phase issued fewer variation orders than those who allocated insufficient money and time to this phase. The more time spent on completing the contract documents before commencement of works, the more likely the avoidance of discrepancies between the contract documents, errors, and omissions into the design.

A proper review of the Terms of References (TOR) for design services in such a way that it will be more comprehensive, demanding sufficient key personnel inputs, with reasonable service period and with consideration of the use of specialized expert services for instance surveying work (Turkey, 2011).

2.13.2 Project Development Manual

Mary Ricard, (2014) provided guidance relative to the appropriate design year used for traffic forecasts for various project work types. The manual stated that the selection of the appropriate design year for traffic forecasts is a function of the project work type.

Purpose of Standardized Design Approval Document Formats Scoping and Design Approval Documents, New York State Department of Transportation,(2008), which mentioned that the design approval documents were required to be produced in the applicable standard formats to assure that all relevant issues have been considered and addressed, and to facilitate reviews by functional units, regional quality control units, advisory and regulatory agencies, the public and decision-makers.

Standardizing design approval of documents and formats is an important aspect to be adhered to it so that it will improve the quality management systems of designs (Etefa, 2016).

In essence, the design approval document serves as a checklist of issues considered during preliminary design and helps assure that the necessary studies and coordination have been completed or sufficiently advanced and evaluated before the granting of design approval. In our country context the Geometric Design Manual of ERA-2002 was prepared under the direction to establish basic design techniques for the economical design of highway geometric including typical sections, horizontal and vertical alignment, and design of junctions.

The procedures for the geometric design of roads presented in the manual have been applicable to trunk roads, link roads, main access roads, collector roads, feeder roads, and unclassified roads. The use of the procedures described in the manual helps in achieving reasonable uniformity in geometric design for a given set of Ethiopian conditions. Furthermore, ERA released the updated version of the manual in the year of 2013 based on local experiences and foreign expertise for the usage in the sector (ERA, 2013).

Geometric design was defined as a process whereby the layout of the road through the terrain is designed to meet the needs of the road users. The principal geometric features are road cross-section, horizontal, and vertical alignment.

Appropriate standards and combinations of geometric design elements are required to fulfill the under mentioned objectives (Etefa, 2016):

- ✓ Topography, land use, and physical features,
- ✓ Environmental considerations,
- ✓ Road safety considerations,
- ✓ Road function and control of access,
- ✓ Traffic volume and capacity,
- ✓ Design speed and other speed controls,

- ✓ Design vehicle and vehicle characteristics,
- ✓ Economic and Financial considerations, and
- ✓ Alternative construction technologies.

Notwithstanding the above, there may be circumstances where the designer will be obliged to deviate from these standards. For instance, the inclusion of a switchback and the use of a gradient greater than the desired value are considered as departures from the standard. In such cases and other departures, the designer requires obtaining written approval from ERA.

In general, quality management system of road projects' design has to be comprehended prior to the issuance of approval and further physical work commencement. Among the major quality management system, Control of nonconforming products/ services, and Guidance on the use of competency management system are mentioned by (Etefa, 2016).

2.13.3 Delivery method Vs. Design Risk

Under the common project development manual under the authority (ERA) for whatever delivery method to be applied for projects this section discusses the relation between the delivery method to be implemented and the very design error possibilities.

This study attempted to include both common kinds of delivery methods DB and DBB throughout its investigation, however a particular research could possibly be conducted for the future comparing them in relation to their contributions and susceptibility to design error induced variations.

The advantages of using Design-Build (DB) generate from: its single point of accountability for design and construction, fast track delivery because of construction begins before the design is the complete and early definition of the project cost in the process. But also the DB project has its drawbacks too; like quality problems, higher unit cost and it requires high professional skill to clearly and explicitly state employer requirement to eliminate changes after commencement to the work (Tariku, 2016).

On the other-hand according to Kassa (2018) a delivery method called Public-Private Partnership (PPP) have two main features; develop incentive system on-time and on-budget project delivery. First, they combine multiple aspects of project delivery, such as design, construction, operations, and maintenance into a single contract. This creates a level of integration within the integration of common purpose and related activities like designers, contractors, and operators of the project right from the planning stages of the project. There is a direct line of responsibility within the consortium for any design flaws or challenges during handovers between subcontractors on the job.

2.13.4 Developing a Project Culture

In developing an effective approach to the management of design, the strategies encompass communication, collaboration, technology clusters, location, and start-up meetings.

i. Communication

The most common problem is the need to understand the network of communication and how it must be facilitated at each level. Most organization charts are two-dimensional in that they concentrate on the hierarchal issues and assume that the horizontal network issues are understood. Alongside these thoughts are those of teamwork and the "design team".

The design team is a loose collective team to describe the fact that the design process requires considerable input from a whole range of contributors. Most of the contributions come from a loose network of different organizations selected because of their knowledge, skills, and capability (Sileshi Ambachew, 2018).

Sileshi Ambachew (2018) Further discussed that teamwork is assumed to be required and until a team is formed the group will not function adequately. The view taken here is that the group needs to be integrated to ensure that it exchanges its skills and knowledge, but that within a temporary multi-organization of loose contributions, teamwork in the conventional sense will not occur.

ii. Early Collaboration

Given the time constraints and the practice of developing teams, a realistic approach to the needs of modern design is to aim for a degree of collaboration that enhances the creative and decision-making process.

Halwatura & Ranasinghe (2013) suggested that; consultants should ensure that the design/specifications fall within the approved budget and the budget team should be appointed early and they should participate in the designing process. Further, all parties should forecast unforeseen situations. Closer consultant coordination is required at the design stage, and utilization of an experienced consultant to produce a concluding design, working drawings, and contract drawings should be done at the tender stage.

Specialization is the response to complexity Lawrence and Lorsch, (1967) and Scharge, (1990). Specialists cannot work in isolation, they need to be brought together to achieve a product that is the result of a combination of their skills. The task of management is to provide a collaborative environment to allow for the transfer of knowledge. Collaborators are constantly reacting and responding to each other and the frequency of contact becomes almost as important as the nature of the contact. In practice, collaboration is a far richer process than teamwork. But the issue is not communication or teamwork; it is the creation of value. This is at the heart of the modern design process (Sileshi Ambachew, 2018).

Collaboration requires people to work together freely to the maximum of their potential. This can only happen where there are mutual trust and respect for each other's capabilities. Management must provide this type of working environment for each collaborating group. Successful collaboration must allow the continual exchange of information and knowledge without any barriers being put in the way. There should be clear lines of authority but no restrictive boundaries so that the communication can flow freely between organizations.

iii. Technology Clusters

Another view of managing complex and technologically-driven environments is to bring together all contributors to the development of the components at the systems level and ensure that the value chain remains unbroken from start to finish (Gray, 1996). The object is to merge the group with the support function into an integrated task group called a technology cluster. "A cluster develops its expertise, expresses a strong customer orientation, pushes decision making towards the point of action, shares information broadly, and accepts accountability for results" (Mills,1991).

A. Nature of technology clusters

The technology cluster, by focusing on the specifics of the technology within the manufacturing process, enables constant evaluation of every aspect of the process to ensure that the overall aims are not compromised by the desire to optimize a component.

The aims of technology clusters are as follows.

- ✓ Group all contributors together, preferably in one location.
- ✓ Elicit solutions to technical, quality, and efficiency criteria to support innovative design solutions.
- ✓ Create a fully integrated system-level solution.
- ✓ Focus upon completion of the system as an integrated unit.

- ✓ Preservation of the value chain throughout the supply chain.

B. Skills

The people who are involved in a technology cluster need to be multi-skilled, mightier mastery of an area special competence. A technology cluster requires that only people with exceptional levels of skill are involved. They must be given the freedom to work, so their work must not be over-planned. However, management expertise, both for management of the group and management of its contribution to the project, it's always an integral part of the group. All member of the group must transmit their knowledge to other peoples and organizations in the group. This requires good communication skills and the ability to contribute freely to the group. (Sileshi Ambachew, 2018)

iv. Team Building and Location

All the characteristics of good team building must be available and used. All components of them must be present from the start. This requires an honest and open evaluation of the required knowledge and potential sources to be made at the start. A radical rethinking of purchasing of the contributors required, particularly the specialist contractors. They must be involved as early as possible if their capabilities are to be maximized, and ways must be found to achieve. These teams need to be adjacent to production; technology clusters require close physical presence to work for put teams together in a location be suited to making project focused decisions (Sileshi Ambachew, 2018).

A. Commitment

Each organization will have its way of working and its corporate objectives. These may be sympathetic to the project, but can often override it. Successful projects overcome those constraints and combine the contributor's identity with the project and its objectives. This can only be achieved by gaining the personal commitment of individuals (Sileshi Ambachew, 2018).

There is an assumption that because it is the originator of the design, there is an automatic commitment to the project by this group. In the concept stage, this is easily achieved, but as the project progress the number of people involved will grow and their association with the project will be different. Their acceptance of the same motivation as the originators of the design may take considerable time to achieve if it occurs at all. However, if the contribution is large and a lot of people are involved, considerable effort is needed to avoid any tail off in commitment (Gray and Hughes, 2001).

B. Co-location and Project Design Offices

A hurdle is in achieving integration is that most design professionals work in their own geographically separate offices. Physical communication barriers have to be overcome by a variety of means. To manage effectively such a diverse and dispersed organization, it is essential to focus the efforts of each involved in the needs of the project.

A co-location is a project approach to providing a site-based working environment where everyone is in the same building or space. The advantage is that integrated working is easier to achieve; communication is immediate and genuine team spirit, that embraces the whole project, can develop. When this enhanced by the presence of the designers from the key specialists and subcontractors, and a representative from the client's office (Counter Parts Engineers), considerable savings in time and effort can be achieved (Sileshi Ambachew, 2018).

To establish a more formal approach to co-location, the client may choose, as part of the organization strategy, to provide a central location, a project design office, which all contributes to the design process can work (Gray and Hughes, 2001).

v. Start-up Meetings

Even without a project design office, much can be achieved. It is important to identify each key stage in the process, the designers and the personnel in their teams, and to introduce them in a positive way to the objectives of the project. This is most effectively done at formal start-up meetings (Sileshi Ambachew, 2018).

A start-up meeting is a meeting initiated by the client or project manager and differs in purpose from all other forms of a project meeting.

A. The Timing of Start-up Meetings

The designer should also be involved in the start-up meetings at the beginning of construction and, on large projects, at the beginning of key stages of the project milestones that require their inputs.

B. The Briefing Stage

The object of the start-up meeting at the briefing stage is to initiate the preparation of "the statement of need". This is the key document required by the project manager to enable him or her to brief the design team properly.

The purpose of the meeting is to bring together the key contributors so that a mutual, in-depth understanding of the client's development objectives can be achieved.

vi. Defining the Tasks

The most important phase is the initiation of the project, as decisions made at this point will set the pattern for all subsequent activity. It is essential to provide a clear means for communicating the design and task objectives across the interfaces between one stage and the next. The task is divided into different stages. The first three stages are; getting started, statement of the need, and the business case. However, it is a vital design stage as a very large amount of information is assembled, evaluated, and integrated into a set of documents, which are crucial to the success of the project. Whoever is involved at this stage must appreciate the design issues implicit in the process.

vii. Getting Started

The briefing process is a series of stages of increasing detail as issues and specific requirements are refined and stated. The client and /or the project initiator should establish a working party to oversee the development of the brief. The report produced is used as the basis for either confirming or rejecting the need to proceed.

The designer may use a particular idea primarily as a route into the problem. This may be a constraint imposed by the designer in arriving at the solution and which can be so powerful that it may be retained through adversity and criticism until it either proves unsuitable or becomes dominant (Sileshi Ambachew, 2018).

In the early stages of the design phase, such as preparation, brief, concept design, etc., processes are creative, iterative, and innovative. These are processes that many solutions, thoughts, and ideas are shared between stakeholders. These processes need to be open and to enable the best solution to arrive (Hansen & Olsson, 2011). The process has an iterative form Kalsaas & Sacks (2011) and all iterations will hopefully contribute to the end value of a project. Once the functional brief had been established, estimated, and agreed, changes should be resisted at all costs.

A. Value Management

Value Engineering has a somewhat broader scope, and is generally applied as a basic design evaluation while a product is still in the design stage. Value Analysis, on the other hand, tends to concentrate on after-the-fact and review cost-value relationships in existing products. The distinction between the two is hardly clear cut since both require the same skills and approaches (Dawit, 2018).

Value management is a strategy of examining every aspect of the whole project to ensure that all of the expectations can be delivered most economically. A problem with traditional briefing documents is that they contain any judgment as to the relative priorities in the requirements. The assumption is that all needs must be satisfied irrespective of the costs or value attached to them. However, many developer clients are questioning this assumption (Sileshi Ambachew, 2018).

B. Standard briefing documents

The purpose of a standard briefing document is to avoid "reinventing the wheel" for every aspect of the design. It is particularly suitable for clients who have a continuous development program and who can benefit from carrying forward the experience gained from one project to the next. The advantage of this approach is that it avoids discarding valuable experience from earlier projects. The document can also contain experience and guidance gathered from recognized authorities in the industry.

Typically, alternative designs are evaluated on the following

- ✓ Value,
- ✓ Improved flexibility and performance of the road,
- ✓ Reduced costs of occupation,
- ✓ Improved speed of design or construction,
- ✓ Better quality and/or more reliability.

It is good practice to bind the statement of need together with the standard brief, suitably modified for a particular project, into all agreements and contracts for the project. As the functional brief is the culmination of the briefing process it is important that it covers all of the client's requirements and is totally accepted and agreed, and formally signed off by the client and the design team.

viii. Concept and scheme design

The development of the functional brief into a full scheme design is a substantial exercise that must be done carefully in conjunction with the client. However, for efficiency, once the basic concept and its feasibility are accepted, the various system designs can be developed in parallel, as long as the technical and physical interfaces between them are isolated and the boundaries defined (Sileshi Ambachew, 2018).

The completion of the scheme design is a crucial client's decision point in a project. It is also a key point in the management of the process. The client and the designers must agree on the complete scope of the work. It is usual at this stage for the design consultants to prepare a complete set of project information that is formally agreed upon by the client.

ix. Design Quality Assurance Plan

All design organizations are advised to establish quality control departments to verify all designs conducted by their firms and appropriate sanctions should be prescribed for defaulters (Dosumu & Clinton, 2018).

The design QA plan prepared by establishing level, frequency, and methods of the procedure or actions necessary to accomplish the following tasks while performing them with strict necessity under the theme of design operation.

Including but not limited to:

- The preparation of all the necessary drawings
- Checking math and engineering computations and other aspects of drawings
- Reviewing the technical accuracy of the plan
- Reviewing the specifications
- Ensuring that the plan conforms to contract requirements
- Checking the form, content, and spelling in plans
- Reviewing coordination with another design discipline
- Reviewing the sequence of construction
- Reviewing the design for the omission
- Ensuring there will be no utility conflicts
- Constructability reviews

2.14. Highway Design and Variation

According to a desk study conducted by Zewdu (2015); some of the major causes for the variation order in federal road projects were geometric design change (horizontal and vertical alignment changes) most of the case the change is made by the client due to new ground condition, revision of typical cross-section, additional works to the project (supplementary agreement), design change of at grade junctions to roundabout or underpass/overpass or interchange junctions, road width widening and realignment due to master plan modification, additional provisions of drainage facilities and bridge elevation modification due to change in grade. Although the study is claiming to obtain some of the major causes, it does not clearly order according to their severity and further not pined out particular root causes for those design changes through the research.

In analogy, Hamzah (2015) refers to some suggestions for future research among them are recognizing design changes as a major cause of delays and cost overruns in a construction project in Malaysia. This event doesn't imply the root causes of that design change captioned as the primary cause resulting in Malaysian's projects cost overrun at least by prioritizing the design discrepancies anticipated more habitually so that the concerned stakes of the project environment will easily be able to generate a solution to reduce the related problem prior from existing.

The design practice in the road sector has been assessed on road projects by involving those projects whose detailed design and construction activities are being carried out at different stages. Accordingly, a survey on the geometric, pavement, minor drainages, bridges, pavement, and departure elements of designs were taken to comprehend the current situation when compared with the original design. Among these components of the design aspect, road geometry plays a vital role in determining project cost, time, and quality of the completed road. On the other hand, the road development program has been expanding by practicing conventional ways of planning, designing, construction, operation, and maintenance.

However, this has to be supported by conducting exhaustive research activities to improve the development of the sector in the country for the future through the application of advanced technologies to mention some, automated and advanced data gathering, advanced site investigations, traffic forecasting techniques, mechanistic-empirical pavement design, usage of sophisticated highway design aids, advanced construction materials, pavement and bridge management systems, etc. need to be in place so that road development shall be supported and sustained accordingly in the long run. These advanced technologies will have their contribution to the input parameters that should be considered in advance and will ultimately improve the design philosophies to be adopted in the country too.

The geometric design of a road traverses through the topographical feature of the area to meet the needs of the road users by following standards and geometric elements. However, in some cases, exceptions to standards are usually accustomed to being entertained by the designers. Hence, most kinds of literature like manuals being used by most countries suggest practicing some standards to deviate from the provided values of parameters, provided that safety issues should not be compromised or sacrificed. The highway designers are expected to evaluate the existing geometric designs against the criteria. In case, the existing geometric design does not at least meet the lower criteria, the designer has to evaluate the practicality of improving the feature. Once the improvement of geometric design element was decided, the improvement level should be in line with the project purpose.

Many studies have been written about design changes, but few documents focus on the impacts of design changes on the project life cycle performance. Hence, future studies are requisite to capture the dynamics of design changes and systematically assess their impacts to facilitate effective construction project management.

Moreover, statistically determine the probability of occurrences of those design discrepancies to enlighten the concerned parties (project stakes) the susceptible area resulting in design error that can lead to variations. Nevertheless, changes and cost overruns are inevitable, particularly in construction projects. It should be reduced as possible as to the extent the project success level being achieved in terms of time, cost, and quality.

Nowadays, most of the federal roads are turned to design and build a delivery method that results in a need to educate an increasing number of people in design management techniques to equip them to manage today's fast-moving and demanding projects in particular of design and build delivery method. However, many current design management tools are insufficiently developed for industrial applications. Therefore, to improve design management in the industry, current techniques must be modified to align them with the needs of the modern design manager.

2.15. Design Process for Designers

In the early stages of the design phase, such as preparation, brief, concept design, etc., processes are creative, iterative, and innovative. These are processes that many solutions, thoughts, and ideas are shared between stakeholders. These processes need to be open and to enable the best solution to arrive (Hansen & Olsson, 2011). The process has an iterative form Kalsaas & Sacks (2011) and each of the iterations will hopefully contribute to the end value of a project. Once the functional brief had been established, estimated, and agreed, changes should be resisted at all costs. The use of value management or the discipline of quality function deployment techniques may help to control the need to revisit the earlier stages.

However, it is a vital design stage as a very large amount of information is assembled, evaluated, and integrated into a set of documents, which are crucial to the success of the project. Whoever is involved at this stage must appreciate the design issues implicit in the process.

Value engineering at the conceptual stage can assist in clarifying project objectives and reducing design discrepancies (Dell' Isola, 1982). Furthermore, insufficient information in the RFP document particularly for DB project delivery is among the reasons for controversial design outputs which are primarily observed in the procurement stage of ERA's project procuring. Thus, sufficient time for project definition, design, and documentation supposed to be in place; and the Involvement of potential users, maintainers, and constructors in determining design shall be considered as among the key steps in disseminating full information among the project parties (Merima H., 2018).

An alternative view is that the design process comprises stages of interpretation, generation, comparison, and choice which is performed through transforming client's requirement into a technically feasible terms while creating a prototypical output through the process for its evaluation against the client's requirement for his ultimate judgement. The process is one of making a selection at each stage, as illustrated by (Hickiling, 1982). However, the proposition that design is a linear sequence can be questioned. It is possible that the designer thinks freely across the boundaries of a problem and a complex cyclic model is more realistic and representative of the process.

This study reviewed literature such as journals, articles, documents from repository database, and authorized reports by the concerned public body, and conference proceedings in the construction industry. The objectives are to assess the relationship of design error and the consequent variations, to recognize their resulting impact on the variation cost, and to provide insights for directing further studies in ERA's context.

The findings indicated that design error/changes as an important causing factors to project cost overruns by influencing cost of variation order. Similar results were found for studies done in both developed and developing countries around the world because construction projects commonly share key characteristics. Therefore, suggestions for future research by several kinds of literature has recognized design changes as a major cause of Variation and/or cost overruns in the road construction project in Ethiopia, identifying causes stimulating design errors/changes and the ability to predict the resulting impacts on project performance in terms of the impact on variation cost prior of happening and raising the state of the art construction project management solution is the core purpose of the study.

2.16. Summary of Literature

It is a fact that all the Literatures reviewed confirmed that design error/change will result in a variation on road projects. Furthermore, they also better stratified, ranked and correlated some of other causes that results in variation order.

The literature review has also shows the problem under focus and has tried to explore the basic principles through cascaded conceptual and contextualized basis for the very objective of the study. First of all presenting the primary participants of road construction project which can have an influence in the design output defacto the differing contributions in various stages of project cycle as employer, Design and Supervision Consultants, Government through its varying policies and strategies from time to time, Financiers and Contractors particularly in case of design build delivery method.

Accordingly, this section also defined the keywords design, variation order and valuation documents in technical terms through which the study mainly focused in the study. Then attempts to discuss which party among the primary participants of road project conduct the design work and the contractual relations with his client and his typical responsibilities as feasibility studies, design, and documentation, cost-estimates, investigations, and coordination of designs according to (Benjamin, 2014).

In doing this, the content analysis also obtained the flaws in the selection strategy of design consultants criticizing the process mainly emphasized on the least bidder instead of considering the required level of service and expertise necessary for a successful design output agreeing with Engineers Australia (2005) which is the problem too in our context ERA projects.

later on, the literature has managed to identify the basic factors which initiate the design error as;

- poor coordination of design management,
- designer Salary (Design cost) and Duration by showing their correlations with design deliverables according to a study by (Nirajan, 2011),
- design documentation as the proper review of final design documentations can prevent design changes (Benjamin, 2014),
- lack of design verifications and interface coordination, Inexperience of designers and Project objectives, knowledge gap and others.

The Design Verification Process is depicted herein under in a glimpse according to (Guru, 2018);

i. Identification and preparation:

During the development stage of a specification, the identification of verification activity is done parallel. This enables the designer to make sure that the specification is verifiable. So a test engineer can start detailed test plan and procedures. Any changes in the specification should be communicated (Guru 2018).

Identifying the best approach to conduct verification, define measurement methods, required resources, tools, and facilities. The completed verification plan will be reviewed with the design team to identify issues before finalizing the plan.

ii. Planning:

Planning for verification is a concurrent activity with core and development teams. This occurs throughout the project life cycle. This will be updated as and when any changes are made to design inputs. During this phase, the software or system under test shall be documented in scope.

Preliminary test plan and test plan refinement are made at this stage. Test plan captures the critical milestone reducing the project risk. Tools, test environment, development strategy and identifying the requirements through inspection or analysis.

iii. Developing:

The test case development will coincide with the methodology implemented by a project team. A variety of test methods are identified during this stage. The design inputs must be developed including simplest verification activities which are unambiguous and verifiable.

Verification time shall be reduced when similar concepts are conducted in sequence. Even the output of one test can be used as input for subsequent tests. Tractability links are created between test cases and corresponding design inputs, to ensure that all the requirements are tested and the design output meets the design inputs.

iv. Execution:

The test procedures created during the development phase is executed in accordance with the test plan, strictly following them in verification activity. If any invalid results occur or if any procedures required modification, it is important to document the changes and get proper approval. Any issues are identified and logged as a defect at this stage.

Tractability matrix is created to verify that all the design input identified in the verification test plan has been tested and determine the pass ratio.

v. Reports:

This activity is performed at the end of each phase of verification execution. The design verification report gives the detailed summary of verification results which includes the configuration management, test results for each type of testing and issues found during the verification activity.

Design verification traceability report is created between requirements and corresponding test results to verify all the requirements have been tested and provided with appropriate results.

Any non-conformance will be documented and appropriately addressed. Reviews are done upon the completion of design verification activity and are approved respectively.

Moreover, the literature distinguish the fundamentals of Good Design and The Cost of Bad Design by refer to the best design as one which performs as expected in the face of both expected and unexpected variations.

While the bad one as undermining the key project process defining up to 70% of the final product cost and adding value by delivering functionality, quality, enhanced services, reduced whole life costs, construction time and defects as well as delivering wider social and environmental benefits citing (Sileshi Ambachew, 2018).

Consequently, it presents the relationships between variation order and design error prior of particular discussing about the causes, cost effects and remedial of design error induced variation. Through the review process and desk study on some selected projects, 20 potential project management state of the art related factors which are resulting in design error induced variations on road projects and 8 (Eight) major mitigation measures has then established the specially designed questionnaire survey.

In view of the fact that, the total contribution of design errors to variation cost, according to the investigation in this study by Dosumu & Clinton (2018) is 36%, which represents the probable net effect of design errors on variation cost of projects.

The literature approached the manner of closing the content review by establishing a detailed Schemes in solving Design error induced variation through the project cycle by involving preventive step, project development manual, choosing the best fit delivery method for corresponding design risk and finally developing a project culture besides establishing a comprehensive design process for designers to reduce the detriment of the problem on road projects through depicting the global experience and considering the current situations of Ethiopian road projects in particular.

2.17. Gap Identification

As we see from the relevant kinds of literature, however, there is plenty of researches conducted in the area of a design-related problem taking into account of cost and time overrun in road construction projects, the following points remain to be scrutinized;

- Detail investigation in order to avoid the problem from its source. Most kinds of literature confirm that design errors are among the primary causes of variation and/or cost overruns in road projects, to mention some, the research which was conducted by Turkey (2011), mentions design errors and/or change as among the primary causes in resulting in overall project cost overrun, regardless of enumerating the root causes and the frequent one of the design error and/or change among the design failures anticipated in the case of Ethiopian Roads Authority.
- The cost impact of design error induced variation on the variable costs which is the critical point over which the reviewed literature did not consider Ethiopian road projects in this quantitative parameter as far as an attempt have been appreciated to correlate design error and variation in different aspects.
- Construction Project Management State of the art mitigating measures for the captioned problem encountering in road projects, so that there should be a clear actionable procedure that a system shall implement and/or improve on the way of administering projects against the regular practices so that easily and better be able to handle (reduce) the design error induced variation.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Study Design

For the case of this study the design used is considered to be observational main group and involving both exploratory and descriptive of design sub-group, since the information known was little in the area under focus. The process of data overview is in such a way that the researcher has been standing apart from events taking place without any interventions that might change the outcome during the study. Impartially attempts to observe and record direct data in the population while evaluating the perception of the respondents as dispersed to the samples recognized as representative. Finally describes the distribution of the characteristics of the design error/change in the road projects causing contract price variations.

Once the problem has been discuss through a literature review then a mixed instrument has been used to generate primary data. The first one is a specially designed questionnaire which encompasses both project-specific as well as road sector generic questions created using Google forms open source web application that plays an ease in collecting different opinions and/or facts of professionals and projects in the sample bounded to be representing the whole population (i.e. assumed to be all currently ongoing rehabilitation and upgrading Road projects that encounter increase of the contract price due design error and/or change issues while using purposive sampling technique).

Secondly, projects were chosen once after the survey has been conducted based on non-probabilistic purposive sampling technique through Google forms, the responses then triangulated to check their reliability through sample case studies through reviewing the correspondences (valuation of variation documents, Engineer's quantification, and Employer's Approval) transacted between parties (ERA, Supervision Consultant, and Contractor) exceptionally considering constraints as mentioned in the limitation section. In general, the specific research tools that the author used in this research to gain a fuller understanding of phenomena are; Books, Journals, Literatures, TA Reports, ERA's correspondence with other Government regulatory bodies (Like FIIDCA) and ERA Guidelines.

After all, the systematically collected data on hand directly fed into the analysis stage after dismantling of some outliers, then transferred to the conclusion based on the correlation observed due to the analysis found. So that, recommendations and suggestions have been forwarded to solve and/or mitigate the problem stated in the problem statement section which was the final aim of the study.

3.2 Study Area

The main participants of the study are the Ethiopian Roads Authority (the Employer), Construction Contractors and Consulting firms engaged in the road construction industry. Particularly from the Employer side only head quarter offices all the Construction Project management directorates that are;

i. Southern Region Construction Project Management Directorate, (SRCPMD)
ii. Eastern Region Construction Project Management Directorate, (NRCPMD)
iii. Western Region Construction Project Management Directorate, (WRCPMD)
iv. Northern Region Construction Project Management Directorate, (NRCPMD) has been approached by the study to investigate projects for the very aim of this study.

3.3 Sampling Technique

The sampling technique the author used to adopt through screening representative sample size is non-probabilistic purposive sampling over which once the variable is supposed as the variation of the contract price of the road projects resulted due to design error, as project encountering those variables (Design error and/or change-induced VO) then approached for detail investigation.

Then once the sampling frame is arranged by this manner of convergence the sample population has been selected by having a prior purpose in mind.

- The criteria of the elements which are to include in the study are predefined (only projects encountering design error and/or change-induced VO).
- So we do not include all projects, rather only those included which meet the defined criteria, by using survey questionnaires to generate project-specific responses as well as road sector generic questions. Later on, a case study has been conducted to reinforce the expected output from the survey questionnaire.

Having the prior purpose in mind, the study participants as discussed in the study area section has been approached, once then the samples has been obtained from ERA's management system database and extracted reports from this vast data base has been readily took for the next course of action[1]. Having the ERA database management system (ERAMS) extraction on hand the regional directorate's was approached for detail data of the projects. After all a total population of 40 projects

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[1] The extracted sheet from ERAMS has been attached in the annex.

has been gets on hand out of the available CPM Directorates for final screening as shown in table-1 below.

Table 1 Population Sample from respective regional directorates

Sr. No.	Regional CPMD	No. of Projects Taken	%age
1	SRCPMD	10	25%
2	NRCPMD	11	28%
3	WRCPMD	10	25%
4	NRCPMD	9	23%
5	**Total**	**40**	**100%**

3.4 Sample size

Once following the above technique a total of 40 projects has been taken for further investigation and the data collection tools was disseminated to the corresponding project delegated professionals to fill Google forms generated survey questionnaire which is a web-based open source surveying approach. However, Out of them only 25 projects has been managed to have data provided or being responsive by respective project delegates among which 5 are of DB delivery projects and the rest 25 are DBB type. Laterally a total of 4 Projects has been chosen to discuss in the case study section for further triangulation of the scenario through detail overview of valuation of variation documents. According to Catherine Dawson (2009), the correct sample size in a study is dependent on the nature of the population and the purpose of the study.

$$n = \frac{n1}{1+\frac{n1}{N1}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{[Eq. 3.1]}$$

$$n1 = \frac{s2}{E2}\ , s2 = p(1-p)\ \ldots\ldots\ldots\ldots\ldots \text{[Eq. 3.2]}$$

Where:
N-Total population (no of projects) = 40
n = sample size from finite population
n1= sample size from infinite population
S2= the variance of the population elements

$$s2 = p(1-p)\ \ldots\ldots\ldots\ldots\ldots \text{[Eq. 3.3]}$$

P = Proportion of the population elements that belong to the defined category

E= Standard error of the sampling distribution

Assumptions:

- Confidence level = 95%
- Population proportion (P) = 0.31
- Margin of error (E) = ±5% = ±0.05
- Addition of samples by half to counter balance the non-response rate that may anticipate

Hence solving for n1;

$s2 = p(1-p)$ = 0.31 (1 - 0.31) = 0.21

E2 = 0.05^2 = 0.0025;

Thus, $n1 = \frac{s2}{E2}$ = 0.21/0.0025 = 85.7834 and,

$\boldsymbol{n = \frac{n1}{1+\frac{n1}{N1}}}$ = **26** therefore, n=26

The sample size formula used above provides the minimum number of responses to be obtained. Addition of half of the sample size has been made to compensate for anticipating non-response rate. Consequently, in this research a total of 40 questionnaires were distributed to 25 projects purposively.

Table 2 Sample size of the Study by Category

Category of respondents in terms of Organization	Sampling technique	Circulated Survey	Responded	The percentage of each party responses out of total circulation
Employer (ERA)	Purposive	25	17	43%
Supervision Consultant	Purposive	8	4	10%
Contractor	Purposive	7	4	10%
Total		40	25	63%

3.5 Rationalization of Method and Analysis Procedure

Each survey respondent was asked to provide details on the following for the project that they had mentioned: Design Standard (DC or DS), type of procurement method Delivery Method, original contract value, variation, and revised contract value. Besides, direct and indirect estimates of design error costs that occurred during the project were sought. Types of project, facility, and procurement methods were measured on a nominal scale; whereas, ratio scales were used to measure design error costs. Respondents were also asked to rate design error causes considering their selected projects in particular and the road sector in general. The quantitative data gathered were analyzed by using SPSS (statistical package for the social sciences) Version 25 software. The descriptive analysis provided a frame of reference examining the dataset.

The researcher uses the inferential statistics Likert scale approach to answering the research question to answer frequent root causes that make designs to be erroneous as the respondent's feedback was designed to be organized in the form of a Likert scale; the numbers assigned to the agreement or degree of influence (1, 2, 3, 4, 5) have been used, but which does not mean that the interval between scales is equal, nor do indicate absolute quantities. They are merely numerical labels. As indicated in herein below table 3:

Table 3 Scales that represent chances of occurrence of design error causes and important factors to reduce the occurrence of design error induced VO as discussed in the literature review and later on included in the questionnaire

Chances of occurrence	**Very Significant/ Very important**	**Significant/ Important**	**Neutral**	**Insignificant/ Unimportant**	**Very Significant/ Very Unimportant**
Scale	1	2	3	4	5

The procedure used in analyzing the results aimed at establishing a relevance importance index values for each cause and solution factors

$$\text{RII} = \sum \frac{W}{AN} * 100\ \% \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{[Eq. 3.4]}$$

$$\text{Relative importance index} = \frac{5n_5 + 4n_4 + 3n_3 + 2n_2 + 1n_1}{A * N}$$

$$= \frac{5n_5 + 4n_4 + 3n_3 + 2n_2 + 1n_1}{5 * N} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{[Eq. 3.5]}$$

$$(0 \leq \text{RII} \leq 1)$$

Where; n_5 = No. of respondents for Very Significant
n_4 = No. of respondents for Significant
n_3 = No. of respondents for Neutral
n_2 = No. of respondents for Insignificant
n_1 = No. of respondents for Very Insignificant
A (rating) = 5
N (number of respondents) = 25

Furthermore, responses, valuation, and variation documents for the study were related to cost and frequency, they were analyzed with sums, frequencies, and percentages. To interpret the findings, the following formula was used to calculate the cost effect of design error on variation (Dosumu & Clinton , 2018);

$$\text{Variation cost } (\%) = \left[\frac{(\text{Cost of Design error\&/or Change})}{\text{Total Variation Cost}}\right] \times 100\% \ldots\ldots\ldots \text{ [Eq. 3.3]}$$

Furthermore, SPSS Software has been adopted to increase the efficiency of the data analysis as required in the process.

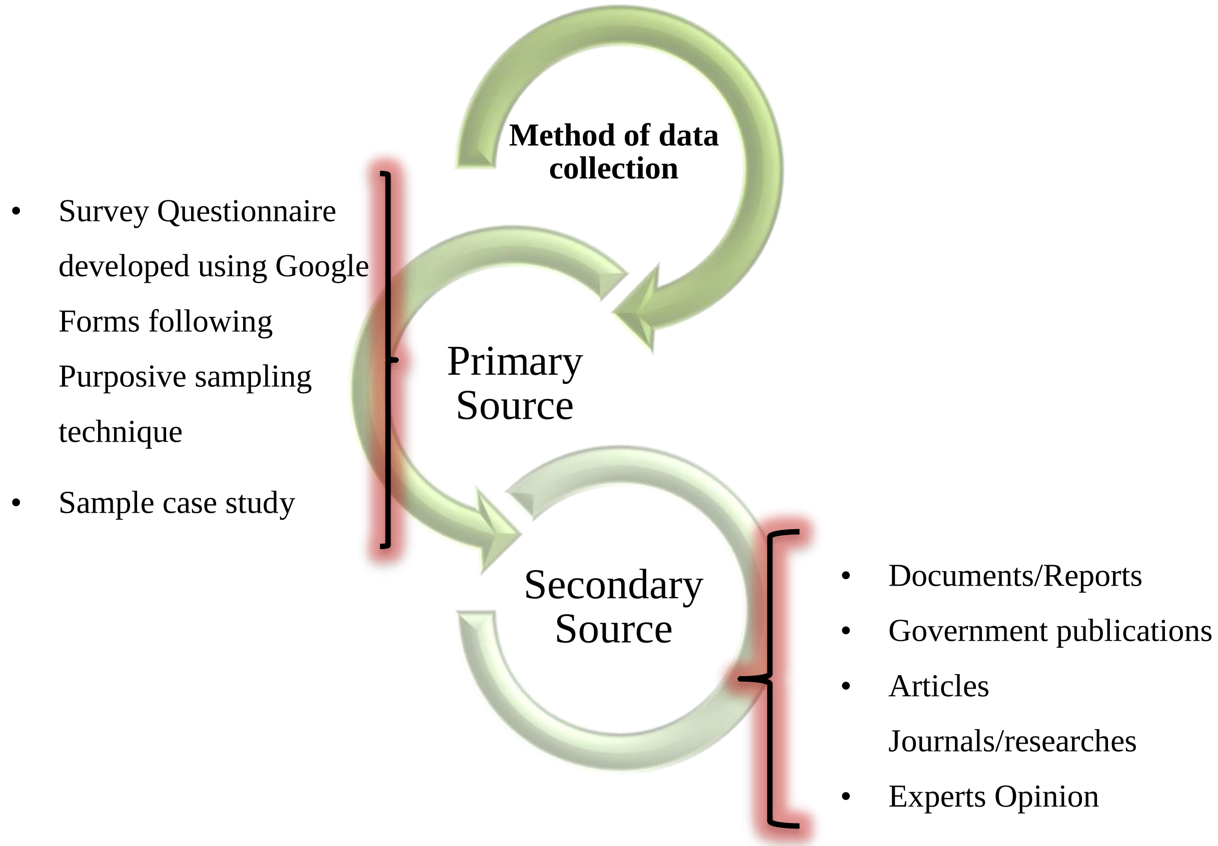

Figure 6 Method of Data Collection Flow Chart

CHAPTER FOUR

RESULTS AND DISCUSSIONS

4.1 Survey Results

The study sample was selected from the Ethiopian Roads Authority compiled database from its headquartered archive by using the purposive sampling technique. This technique increased the efficiency to gather data easily and was useful in enabling general statements on portions of the population to be made. Before the main study sample size was determined, a pilot study was undertaken with 3 selected projects through corresponding delegates to evaluate the data gathering performance of the questionnaire for this study, its comprehensiveness, and easy to understand by the respondents. The pilot study tested the likely response rate, comprehensibility, and suitability of the survey questionnaire. Respondents were asked to seriously review the design and structure of the questionnaire.

All the comments received were positive, and as a result, the questionnaire modified a little bit to mention some; questions that are in the project-specific section has been to include a cost field to be filled by the respondents that have been anticipated due to design error/change for each design elements of a road project.[2] After the modification, the main questionnaire then distributed to corresponding project delegates to collect the required information.

Each respondent was contacted and informed about the aim of the research by e-mail with the questionnaire developed and attached using Goggle forms web-based open source. In addition, telephone calls were made to each respondent to follow-up on each e-mail that had been distributed. A total of 25 valid survey questionnaires were received in the main survey through the open-source Google forms web-based application against the 40 questionnaires sent to corresponding delegates of the projects. This represents a combined response rate of 63%, the response rate is considered satisfactory for a survey aiming on attaining replies from industry practitioners (Edward-Gibson and Whittington 2010).

Figure 4 below provides a break-down of valid responses by respondent type. The main types of respondents were from the project delegates representing the Employer (ERA) 68%, Supervision Consultant 16%, and Contractor 16%.

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[2] See annex-1 to observe the referred questions as per the modified questionnaire.

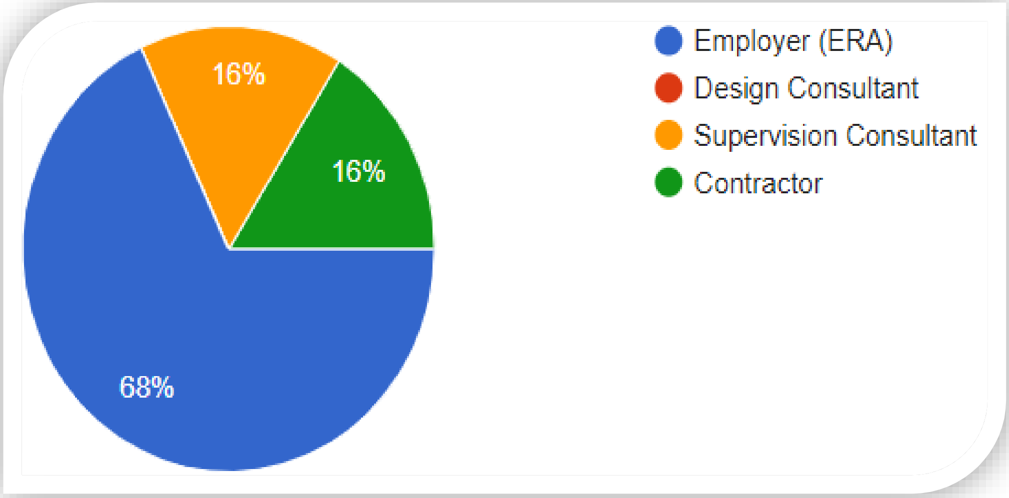

Figure 7 Respondents Characteristics in terms of Party

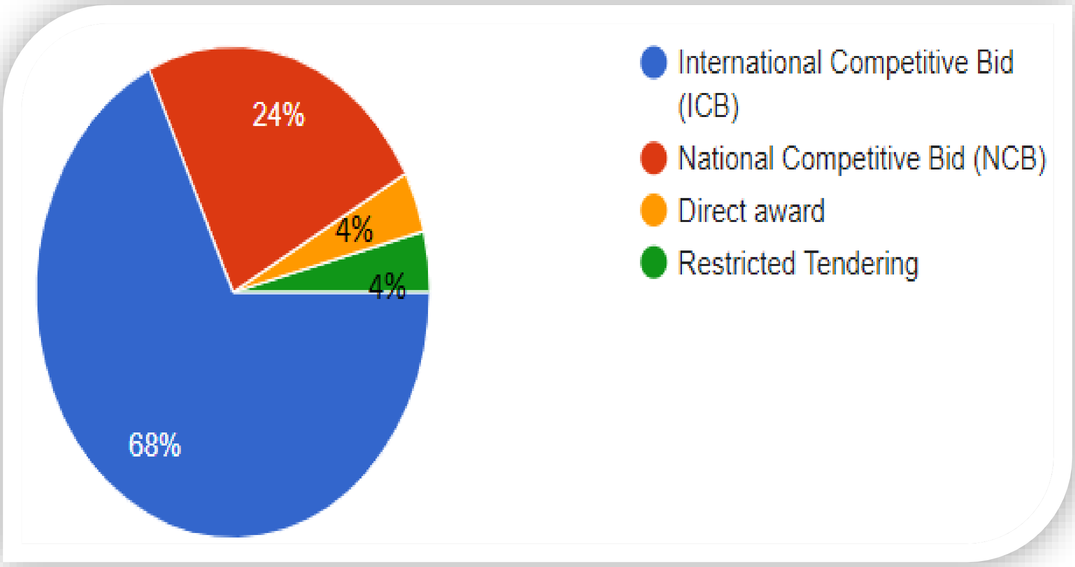

Figure 8 Procurement Methods of projects

The Procurement method/process as discussed in the literature influences the design output of the road projects as responded by the respondents their respective projects procurement process has been passed as stratified in the above pie chart. In Analogy, the delivery method of the projects as responded by the respective party delegates has been presented in the chart below.

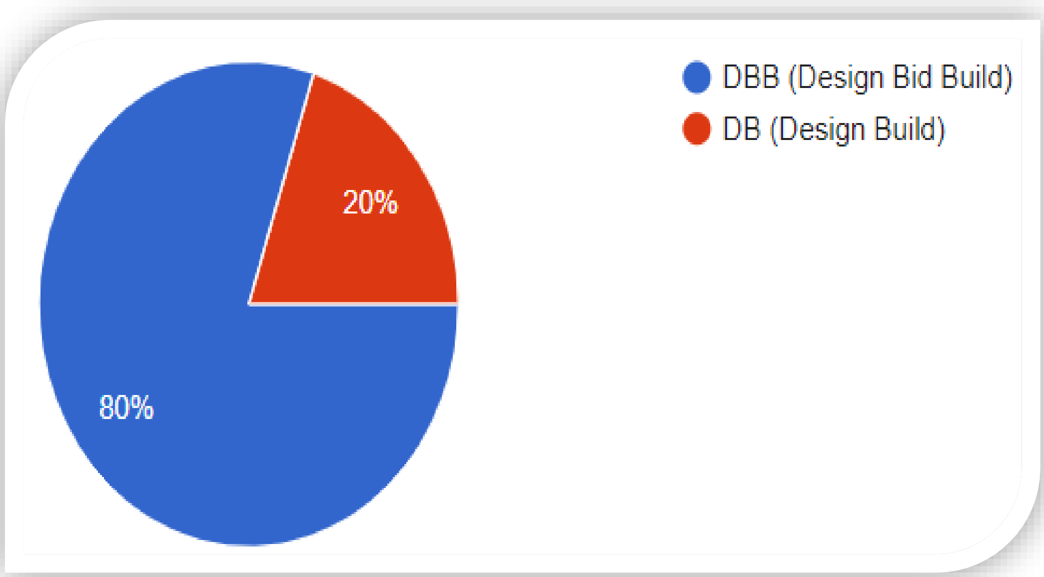

Figure 9 Projects by Delivery Methods

However, the study includes both common types of delivery methods DB and DBB the portions that they take out of the sample size is not in equivalent number this is because lots of the projects follows the traditional method of project delivery. This can be scrutinized in future researches by comparing or contrasting the issue based on delivery methods.

Table 4 Contract sum of Road projects

Contract Sum	**Frequency**	**Percentages**
Below 500 Million	6	24%
500 Million – 1 Billion	12	48%
Above 1 Billion	7	28%
Total	25	100%

Out of the total sample size approximately quarter of them are amounting of less than or equals to half billion Ethiopian birr of contract prices, while almost half out of the sample size are laid between half billion and one billion Ethiopian birr of contract prices and 28% of them amounts of more than or equal to one billion Ethiopian birr of contract prices which is a significant amounts out of the road fund project financing budgeted for the road sector.

4.1.1 Causes of design error induced variation in road projects with their respective level of significance indicated

The tables below indicates the result of the questionnaire conducted with professionals on the causes of variation in road projects concerning their corresponding level of significance. Once the contents of their response were analyzed, the Likert scale has been computed using the relative importance index to rank which cause has greater impacts for the design error induced variation to be encountered on road projects based on the formula presented below, the RII applied to measure the response related to the rating of each variable. Most of the studies used this method to determine the significance of variables. Generally, it has been applied in many similar types of surveys in Construction Management research (Bagies and Fortune, 2009; Enshassi, Arain, and Al-Raee, 2010). It is also well known as a noted technique for generating scores of variables (Akadiri, 2011).

In the case of the five-point Likert scale;

$$\textbf{RII} = \sum \frac{W}{AN} * 100\ \% \quad \text{……… [Eq. 4.1]}$$

$$\text{Relative importance index} \quad = \quad \frac{5\mathrm{n}_5 + 4\mathrm{n}_4 + 3\mathrm{n}_3 + 2\mathrm{n}_2 + 1\mathrm{n}_1}{\mathrm{A} * \mathrm{N}}$$

$$\underline{= 5n_5 + 4n_4 + 3n_3 + 2n_2 + 1n_1} \over 5 * N$$ ……… [Eq. 4.2]

$$(0 \leq \text{RII} \leq 1)$$

Where; n_5 = No. of respondents for Very Significant

n_4 = No. of respondents for Significant

n_3 = No. of respondents for Neutral

n_2 = No. of respondents for Insignificant

n_1 = No. of respondents for Very Insignificant

A (rating) = 5

N (number of respondents) = 25

According to the respondents of this study table -5 below presents the frequencies of 5-point likert scale measures for each cause of design error on the road projects, prior of applying the RII (Relative Importance index Formula) to show which factors has the prior significances among others by ranking them based on their RII as computed in table -6.

Table 5 Causes of Design error in road construction projects

Which of the following factors will cause design error/change resulting in a variation on cost? Indicate in the hereunder matrix based on their degree of significance?					
Factors	**Very Significant (5)**	**Significant (4)**	**Neutral (3)**	**Insignificant (2)**	**Very Insignificant (1)**
Inadequate application of Smart technologies	2	12	8	3	0
Change in specification	4	8	11	1	1
Inadequate Detailing of Specifications	5	13	5	2	0
Lack of knowledge	6	14	5	0	0
Inexperience of designers	8	11	6	0	0
Design Cost	5	15	4	1	0
Duration of Design	4	16	5		0
Design Complexity]	3	12	8	2	0
Inadequate project objectives	1	14	9	1	0
Lack of design verification and interface coordination	4	15	6	0	0
Owner's financial difficulties	2	12	8	3	0
Large Provisional Sums	2	9	10	4	0
Ineffective design review documents	4	15	6	0	0
Ineffective methods of programming (lack of proper project	4	12	9	0	0
Inadequate evaluation of information	3	15	7	0	0
Design submitting has been checked by Junior Engineers of the client/ERA	4	9	10	2	0
Poor TOR development	6	11	6	1	1
Method of contract administration	3	9	9	4	0
The duration interval to implement designed projects	5	10	10	0	0
Lack of integration/coordination between designers of different disciplines.	5	15	5	0	0

Table-5 above Shows that Lack of knowledge and Inexperience of designers accounting greater frequencies to be considered under the very significant scales followed by Design Cost, Poor TOR development, The duration interval to implement designed projects, Lack of integration/coordination between designers of different disciplines.

Table-6 presented herein under displayed that the detail computation of RII (relative importance index) values to prior of ranking the factors causing design error based on their level of significances. The table includes the columns containing values which are going to use as an input on the RII (relative importance index) formula as clearly depicted in Table-7 in detail.

Table 6 Computation Table of Relative Importance index for causes of design error

Factors	Very Significant (5)	Significant (4)	Neutral (3)	Insignificant (2)	Very Insignificant (1)	Total	Total No.(N)	A*N	RII	Rank
Smart technologies	10	48	24	6	0	88	25	125	0.70	16
Change in specification	20	32	33	2	1	88	25	125	0.70	16
Inadequate Detailing of Specifications	25	52	15	4	0	96	25	125	0.77	8
Lack of knowledge	30	56	15	0	0	101	25	125	0.81	2
Inexperience of designers	40	44	18	0	0	102	25	125	0.82	1
Design Cost	25	60	12	2	0	99	25	125	0.79	4
Duration of Design	20	64	15	0	0	99	25	125	0.79	4
Design Complexity]	15	48	24	4	0	91	25	125	0.73	13
Inadequate project objectives	5	56	27	2	0	90	25	125	0.72	14
Lack of design verification and interface coordination	20	60	18	0	0	98	25	125	0.78	6
Owners's financial difficulties	10	48	24	6	0	88	25	125	0.70	16
Large Provisional Sums	10	36	30	8	0	84	25	125	0.67	20
Ineffective design review documents	20	60	18	0	0	98	25	125	0.78	6
Ineffective methods of programming (lack of proper project planning)	20	48	27	0	0	95	25	125	0.76	10
Inadequate evaluation of information	15	60	21	0	0	96	25	125	0.77	8
Design submitting has been checked by Junior Engineers of the client/ERA	20	36	30	4	0	90	25	125	0.72	14
Poor TOR development	30	44	18	2	1	95	25	125	0.76	10
Method of contract administration	15	36	27	8	0	86	25	125	0.69	19
The duration interval to implement designed projects	25	40	30	0	0	95	25	125	0.76	10
Lack of integration/coordination between designers of different disciplines.	25	60	15	0	0	100	25	125	0.80	3

Table 7 Ranking of Causes of design error Based on Relative Importance Index to indicate their respective level of Significance

Factors	Relative Importance Index Value	Significance
Smart technologies	0.704	16
Change in specification	0.704	16
Inadequate Detailing of Specifications	0.768	8
Lack of knowledge	0.808	2
Inexperience of designers	0.816	1
Design Cost	0.792	4
Duration of Design	0.792	4
Design Complexity	0.728	13
Inadequate project objectives	0.720	14
Lack of design verification and interface coordination	0.784	6
Owners' financial difficulties	0.704	16
Large Provisional Sums	0.672	20
Ineffective design review documents	0.784	6
Ineffective methods of programming (lack of proper project planning)	0.760	10
Inadequate evaluation of information	0.768	8
Design submitting has been checked by Junior Engineers of the client/ERA	0.720	14
Poor TOR development	0.760	10
Method of contract administration	0.688	19
The duration interval to implement designed projects	0.760	10
Lack of integration/coordination between designers of different disciplines.	0.800	3

As shown in the table-7 above most of the factors laid in the range of high to significant level according to Akadiri's categorization of RII (relative importance index) values. However, some of them are laid in the first level category as per Akadiri's categorization which is the High level of of significances, among them Lack of knowledge, Inexperience of designers and Lack of integration/coordination between designers of different disciplines are the only three factors laid on the higher level of significance range.

On the other hand, among the lower ranked factors such as; Poor TOR development, Inadequate project objectives, ineffective methods of programming (lack of proper project planning), Design reviewed by Junior Engineers of the client, Design Complexity and The duration interval (time at large of the buffer period) to implement designed projects are among the primary ones. One can say the poor TOR development may not be a factor in case of ERA since the organization is known with a standardized TOR however inflexible standards have a probability of resulting the problem. Thus the two scenarios the ERA's standardized TOR and the respondent's reply of poor TOR development can be reconciled in such a way that the factor can cause the problem under the study, but with lower level of significance against other factors as shown in the RII computed table-7 above with a RII value of 0.76 which can be considered as a medium level of significance range according to Akadiri, (2011) catalog as shown in the table-8 below.

According to Akadiri (2011), importance levels are as follows for five-point Likert ranking;

Table 8 Significance level categories by **(Akadiri, 2011)**

RII Values	**Significance Level**
$0.8 \leq RII \leq 1$	High
$0.6 \leq RII \leq 0.8$	High – Medium
$0.4 \leq RII \leq 0.6$	Medium
$0.2 \leq RII \leq 0.4$	Medium - Low
$0 \leq RII \leq 0.2$	Low

Considering the above tables that the result of the questionnaire survey implies in figure-9 below that Designers experience (1st), Lack of knowledge (2nd), Lack of integration/coordination between designers of different disciplines (3rd), Design Cost & Duration of Design (4th each), (Lack of design verification and interface coordination) and (Ineffective design review documents) 6th each and Inadequate evaluation of information (8th) are among others that are significant results in design error to be encountered in road construction projects. From this, we can say a Lack of knowledge & experience are the main problem having a major push on projects to face design error. Moreover, poor integration of the design disciplines obviously could result in discrepancies in the design. On the other hand, the two major contractual themes Cost and Duration for the Design service have equal consequences resulting in poor design service contract deliverables.

All the significant causes of variation recognized in this study were directly associated with design; which is consistent with the content analysis made in the literature reviewed in this study. To elaborate on this finding, a summary of valuation/variation documents reflected through the project-specific section of the questionnaire survey by the respective project delegates from the road construction projects. Furthermore, these studies attempted to examine specific design errors that led to variation in the road construction projects.

It is important to mention that the causes identified during the literature review and later by the respondent's indication using the Likert scale may be taken as design errors, on the one hand, and they may, however, equally be regarded as causes of variation, on the other.

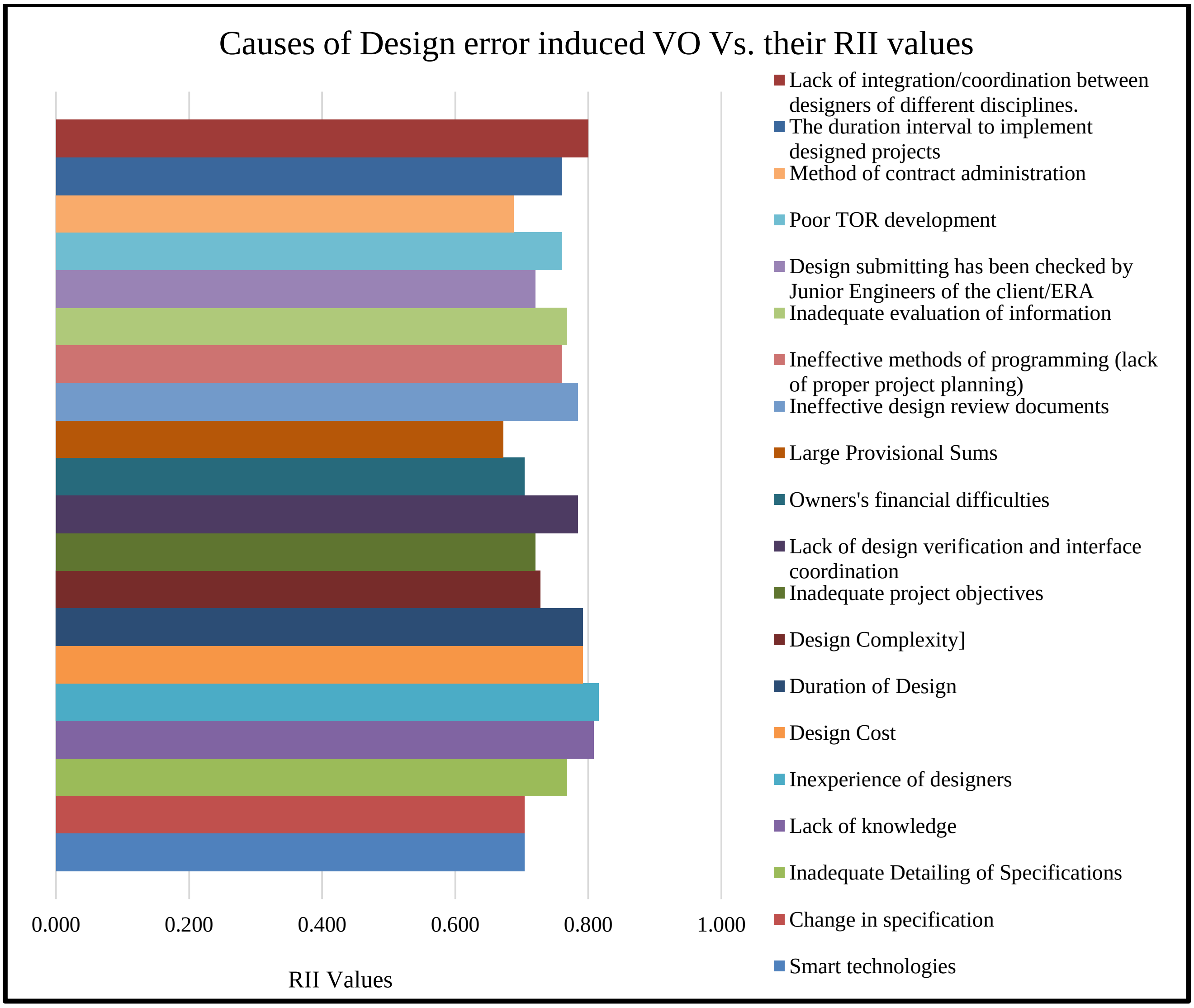

Figure 10 RII values of Causes of design error

Table 9 indicates the design errors that led to a variation on construction projects according to the project delegated respondents from the conducted questionnaire survey. The frequencies, types of design errors, and their descriptions were also obtained from the responses on hand from the respective project delegates. Due to space, the table presents only the frequencies of design error on construction projects and their corresponding percentages based on the design element and the total number of design errors identified.

Table 9 Design errors that led to variation based on the design element

Design Elements and respective Design Error/Change	Frequency	Total Error Per Design Element %age	Total Design Error %	Rank
Horizontal Alignment				
Error to achieve the best/economical route and environmental considerations	2	13%	3%	12
Error to traverse through additional control points	2	13%	3%	12
Error to maintain design parameters: min. radius, traffic volume, design speed, vehicle, etc.	4	27%	6%	7
Slope stability problems and/or land slide areas,	2	13%	3%	12
Underestimating soil type and climate,	1	7%	1%	17
Erroneous Drainage structures like bridges, culverts, retaining walls, etc.,	1	7%	1%	17
Not considering Town section extension and including of median due master plans	3	20%	4%	8
Total	**15**	**100%**	**21.7%**	
Vertical Alignment				
Error to maintain the design parameters: gradient, K value, etc.,	6	32%	9%	3
Due to Design error/change in horizontal alignment,	7	37%	10%	2
Slope stability problems and/or land slide areas,	2	11%	3%	12
Error to adapt with topographic features of the area,	3	16%	4%	8
Undermining Erosion protection on high fills	1	5%	1%	17
Total	**19**	**100%**	**27.5%**	
Minor Drainage				
Error in Nos. due hydrological Data	10	83%	14%	1
Size Error	2	17%	3%	12
Total	**12**	**100%**	**17.4%**	

Major Drainage				
Revision due error of structural elements,	3	27%	4%	8
Revision due error of hydrological information,	5	45%	7%	5
Revision due error of Geo-technical information	3	27%	4%	8
Total	**11**	**100%**	**15.9%**	
Pavement				
Undermining Traffic volume growth	5	42%	7%	5
Based on sub-grade material characteristics	6	50%	9%	3
Pavement omission	1	8%	1%	17
Total	**12**	**100%**	**17.4%**	
Total of Total	**69**	**100%**		

A total of 69 errors were found as clearly shown in the above table-9 classified based on design elements with the contribution of Horizontal Alignment 15, Vertical Alignment 19, Minor Drainage Structures 12, Major Drainage Structures 11, and Pavement 12, respectively. Those respective Contributions can be interpreted towards **21.7%**, **27.5%**, **17.4%**, **15.9% and 17.4%** respectively for the Design elements as shown in the web diagram in the hereunder figure - 10**.**

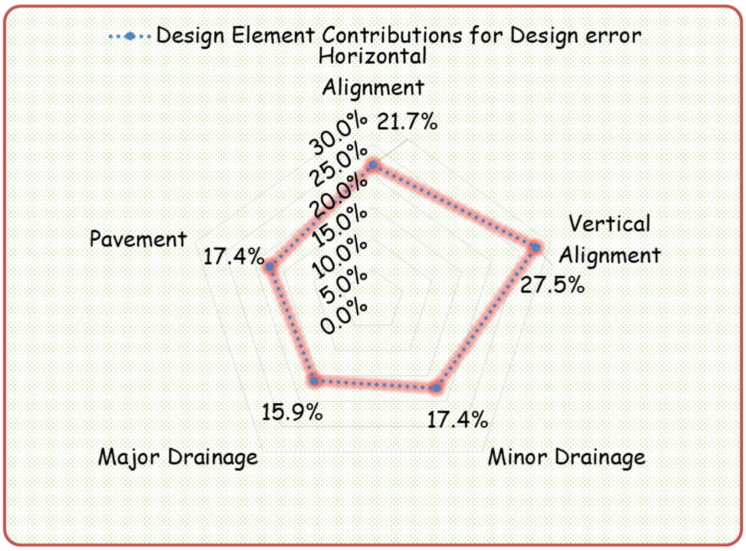

Figure 11 Web diagram of design error contribution based on Highway design elements

Table-9 further shows that the frequency of occurrence of design errors in the investigated projects based on highway design elements in the order of Vertical Alignment (27.5%), Horizontal Alignment (21.7%), Minor Drainage and Pavement (17.4%) each and Major Drainage (15.9%) respectively. This means that to reduce the Variation order that will be anticipated to the barely minimum, more concern shall be brought to the two alignments the Vertical and Horizontal alignment (49.2%) to reduce the frequency of error occurrence beginning from the project inception and during the design phase, since; they cover near 50% of the total impact on the Variation to be encountered due to design errors.

Besides the observation based on design elements, Error in Nos. of minor drainage structures due to hydrological Data (14%) happened to be the highest design error that led to variation, followed by Design error/change due to horizontal alignment that resulting the VA Design to be changed (10%), Based on sub-grade material characteristics and Error to maintain the design elements: gradient, K value, etc., (9% each), Revision due to an error of hydrological information and undermining growth in Traffic volume (7% each), Error to maintain design parameters of HA; min. radius, traffic volume, design speed, vehicle, etc. (6%).

On the other hand, Not considering Town section extension and including of median due master plans, Error to adapt with topographic features of the area, Revision due error of structural elements, Revision due to an error of Geotechnical information (4% each), Error to achieve the best/economical route and environmental considerations, Error to traverse through additional control points, Slope stability problems and/or landslide areas, Catchment Size Error and Slope stability problems and/or landslide areas (3% each), Underestimating soil type and climate, Erroneous Drainage structures like bridges, culverts, retaining walls, etc., Undermining Erosion protection on high fills, Pavement omission (1% each), are among others respectively.

Table-10 presented below shows the frequency of occurrence of design error according to the type of errors encompassed under the hierarchy of Design Element, Design operation, and respective Design Phase divisions' which has easily figured out the birthplace of corresponding design errors resulting in variation to occur.

Table 10 Design errors that led to variation in road construction projects based on the type of error and Design Operation

Design Phase Category	Sub Category	Design operation	Design Element	Type of Design error/change	Frequency	% age	Total Freq in Design Opr.	% age	Rank	Total Freq in Design phase sub-group	% age	Rank
Public Consultation	**Preliminary Consultation and Integration with concerned design stakeholders from the local community and Gov'tal Offices**	Road Corridor	Horizontal Alignment	Missing to consider Town section expansion and including of median	3	4%	3	4%	8	3	4%	**6**
TRAFFIC SURVEY AND ANALYSIS	**TRAFFIC SURVEY AND ANALYSIS**	TRAFFIC SURVEY	Pavement	Traffic volume	5	7%	5	7%	5	5	7%	**4**
Highway Engineering	**Route selection**	Route selection	Horizontal Alignment	Missing To achieve the best/economical route and environmental considerations	2	3%	4	6%	6	4	6%	**5**
				Missing To traverse through additional control points	2	3%						
	Preliminary Engineering Design	Topography of project area	Vertical Alignment	Improper Consideration of topographic features of the area	3	4%	3	4%	8	21	30%	**1**
		Geometric Design	Horizontal Alignment	Missing To maintain design parameters min. radius, traffic volume, design speed, vehicle, etc.	4	6%	18	26%	1			
			Vertical Alignment	error in maintaining the design parameters: gradient, K value, etc,	6	9%						
				Due to error/change in horizontal alignment,	7	10%						
				Erosion protection on high fills	1	1%						

Highway Engineering	**PRELIMINARY HYDROLOGICAL, HYDRAULICS AND STRUCTURAL DESIGN**	Hydrological Study	Minor Drainage Structures	Error in Nos. due hydrological Data	10	14%	17	25%	2	21	30%	**1**
				Size Error	2	3%						
			Major Drainage	Revision of hydrological information,	5	7%						
		Hydraulic Design		Revision of structural elements,	3	4%	4	6%	6			
			Horizontal Alignment	Design error in Drainage structures like bridges, culverts, retaining walls, etc..	1	1%						
	PRELIMINARY MATERIALS INVESTIGATION AND PAVEMENT DESIGN	Material and Site Investigation	Horizontal Alignment	Errornouse Soil type classification and climate consideration	1	1%	8	12%	3	15	22%	**3**
				Slope stability problems and/or land slide areas,	2	3%						
			Vertical Alignment		2	3%						
			Major Drainage	Revision of Geo-technical information	3	4%						
		Preliminary Pavement Design	Pavement	Based on sub-grade material characteristics	6	9%	7	10%	4			
				Pavement ommision	1	1%						
	TOTAL				**69**	**100%**	**69**	**100%**		**69**	**100%**	

As shown in the Table-10 above the design operations and their design error contributions are presented as 18 (26%) were due to Geometric Design, 17 (25%) were due to Hydrological Study, 8 (12%) were due to material and site investigation, 7 (10%) were due to Preliminary Pavement Design, 5 (7%) were due to Traffic Survey, 4 (6%) were due to Route Selection and Hydraulic Design each and 3 (4%) were due to Road Corridor and Topography of project area each. This implies that Design errors/changes that led to variation in road construction projects are ranked by their contribution as Geometric Design, Hydrological Study, Material and site investigation, Preliminary Pavement Design, Traffic Survey respectively.

Moreover, Preliminary hydrological, Hydraulics, and Structural design-related errors accounted for 31% of the total errors leading to variation in road construction projects. Which implies that a lot is expected to be done in the hydrology related subgroup during the design phase. This problem includes the provision of clear and an in-depth investigated hydrological data which must show all possible run-off streamlines, catchment requirements, and any need for flood control systems as required by the actual site condition by giving greater concern for the actual site conditions are among others.

On the other hand, out of the six (6) design phase sub-groups encompassing of the design errors of the road construction projects, 21(30%) were (Preliminary Engineering Design) & (Preliminary Hydrological, Hydraulics and Structural Design) each followed by Preliminary Materials Investigation And Pavement Design accounting for 15(22%), Traffic Survey And Analysis accounting 5(7%), Route selection 4(6%) and the last but not the least is Preliminary Consultation and Integration with concerned design stakeholders from the local community and Governmental Offices accounting 3(4%) respectively. Out of which 88% of the design errors were found on the Highway Engineering phase which covers the significant portion of all the design phases since it contains several sub-groups followed by Traffic Survey and Analysis the immediate design phase prior of the Highway Design Phase accounting 5(7%) alone out of the total design errors which directly affects the pavement design in five (5) projects out of the 25 projects investigated in this study.

In Ethiopia Roads Authority design and implementation practices are in such a way that the Design of projects conducted far early before the implementation phase only just considering the traffic growth with the design norms, while the Organization floats the projects for the implementation based on its procurement plan, budgetary constraints and various other factors undermining the anticipated traffic growth unlike that of assumed during the original design deliverables which can likely exceed the traffic estimation computed with ordinary design norms. In another language, the time gap between design and implementation is so large in ERA's practice resulting in the traffic to vary among each other resulting in related design elements to be under-designed not serving the anticipated traffic leading the contract to design revisions based on the newly anticipated traffic volume.

4.1.2 Cost-effect of design error on variation cost of the road projects

The tables 11 and 12 below show the cost effects of design errors on variation and total cost of road projects based on design elements and cumulative VO due to Design error/change for the respective investigated projects.

Table 11 Responded Contract Data of respective projects

Describe the name of the project (Optional)	Commencement Date of the Project (MM/DD/YYYY)	The mention Contract amount of the Project? (ETB)	Cumulative Variation Order up-to-date resulted due to design error/changes and modifications? (ETB)[3]
Sawla - Laska Road Project	10/11/2011	697,725,209.50	150,958,748.70
Construction Works of Sodo-Chida Road Project	8/9/2017	1,171,155,714.52	
sawla-kako lot 2	5/12/2017	293,026,395.94	
Hawassa- Hawassa Airport- Bishan Guracha/Tikur Wuha	11/17/2017	592,084,400.00	17,765,900.00
Ambo-Gedo Road Overlay Project	6/12/2017	438,546,135.51	
Tepi- Mizan RUP	1/25/2018	1,259,866,322.00	
x[4]	10/11/2019	942,565,236.12	
Hawassa-Hawassa Airport-Bishan Guracha Tikur Wuha Design-Build Road Project	11/17/2017	592,084,400.00	17,765,900.00
Mizan - Dima	9/23/2013	1,133,472,329.44	
Shambu - Bako road upgrading project	7/7/2016	993,280,400.04	
Chuko - Yirgachefe	4/24/2017	889,003,033.30	39,771,907.14
Hawassa-Chuko	1/27/2017	965,247,145.48	173,436,967.52

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[3] The amount of VO resulted due to design error has been obtained separately from ERA's progressive reporting Compilations refer the annex

[4] Some Projects are required by the Respondents to be excluded from being mentioned by name

Ageremariam-Yabelo road project	5/11/2011	740,685,321.21	46,204,419.14
Y[5]	6/20/2017	1,955,438,532.41	(234,274,410.00)
Kuch-Ayhu-Zigem-Chagni	12/27/2017	22,543,910.00	
Adaba - Angetu	11/18/2014	1,249,684,230.55	150,690,318.00
Z[6]	4/1/2013	834,554,046.64	-
Moricho- Dimtu- Bitena- Sodo Design and Build Road Project, Contract 2: Bitena- Mayo Kote- Zala Iyesus-Sodo and mayo Kote-Delbo Junction to Alaba Sodo Road Project (48.3Km)	12/15/2014	949,946,190.20	36,037,034.14
Nekemte Town Road Upgrading	7/25/2014	138,000,000.71	42,633,989.14
Dima - Road Bridge	3/15/2016	926,796,000.00	35,405,457.14
Kongi-Begondi-Wenbera	1/11/2013	400,000,000.60	424,000,000.00
Mekenajo - Ayra	10/7/2011	633,000,000.50	59,155,471.14
Mizan -Dima	9/23/2013	1,133,000,000.47	125,755,277.00
Irebti- Afdera	8/22/2008	7,696,068,218.05	111,417,021.14
Nehile Abala Road Project	1/26/2011	272,721,847.78	78,680,731.14
Total		**25,787,022,691.53**	**1,275,404,731.31**

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[5] & [4] Some Projects are required by the Respondents to be excluded from being mentioned by name

Table 12 Cost Effects of design errors on variation cost of projects based on design elements

Design Elements and respective Design Error/Change	*Cost of error*	*Effects on the total cost of an error on Design elements*	*Effects on the total cost of error*	*Effects on total VO*	*Rank*
Horizontal Alignment					
Error to achieve the best/economical route and environmental considerations	(147,521,539.02)	-40%	-11.57%		21
Error to traverse through additional control points	68,888,888.89	19%	5.40%		9
Error to maintain design parameters: min. radius, traffic volume, design speed, vehicle, etc.	99,084,300.28	27%	7.77%		7
Slope stability problems and/or land slide areas,	93,972,499.13	26%	7.37%		8
Erroneous classification of Soil type and climate,	-	0%	0.00%		18
Erroneous Drainage structures like bridges, culverts, retaining walls, etc.,	119,873,888.91	33%	9.40%		6
Not considering Town section extension and including of median	121,250,360.65	33%	9.51%		5
Poor and late cooperation with Design stakeholders	9,870,318.67	3%	0.77%		16
Total	**365,418,717.51**	**100%**	**29%**	**12%**	

Vertical Alignment					
Error to maintain the design parameters: gradient, K value, etc.,	67,588,825.42	36%	5.30%		10
Due to Design error/change in horizontal alignment,	121,604,874.99	66%	9.53%		4
Slope stability problems and/or land slide areas,	48,595,508.46	26%	3.81%		13
Error to adapt with topographic features of the area,	(65,865,270.01)	-36%	-5.16%		20
Undermining Erosion protection on high fills	13,405,552.65	7%	1.05%		15
Total	**185,329,491.50**	**100%**	**15%**	**6%**	
Minor Drainage					
Error in Nos. and types due hydrological Data	217,462,163.52	79%	17.05%		2
Size Error	56,917,674.80	21%	4.46%		11
Total	**274,379,838.31**	**100%**	**22%**	**9%**	
Major Drainage					
Revision due error of structural elements,	8,898,692.45	4%	0.70%		17
Revision due error of hydrological information,	51,962,914.71	26%	4.07%		12
Revision due error of Geo-technical information	139,251,510.00	70%	10.92%		3
Total	**200,113,117.15**	**100%**	**16%**	**7%**	
Pavement					
Undermining Traffic volume growth	235,413,438.22	94%	18.46%		1
Based on sub-grade material characteristics	19,569,731.11	8%	1.53%		14
Pavement omission	(4,819,602.50)	-2%	0%		19
Total	**250,163,566.83**	**100%**	**20%**	**8%**	

TOTAL of Total	**1,275,404,731.31**				
Total variation cost of investigated projects				**2,966,057,514.66**	
Impact of design error on variation cost (%)				**43%**	

According to design elements, Horizontal alignment had the greater cost-effective against the other elements on the total variable cost (29 %), preceding Minor Drainage (22 %), Pavement (20 %), Major Drainage (16 %) and the last but not the least Vertical Alignment (15 %), respectively.

Individually, however, Undermining Traffic volume growth (18.46 %) has been scored followed by Error in Nos. and types due to hydrological Data of minor drainages (17.05 %), Revision due to error of Geotechnical information of Major Drainage structures (10.92 %), Due to Design error/change in horizontal alignment (9.53 %), Not considering Town section extension and including of median (9.51 %), Erroneous Drainage structures like bridges, culverts, retaining walls, etc., (9.40 %), Error to maintain design parameters: min. radius, traffic volume, design speed, vehicle, etc. (7.77 %), Slope stability problems and/or landslide areas (7.37 %), Error to traverse through additional control points (5.40 %), Error to maintain the design parameters: gradient, K value, etc., (5.30 %), Catchment Size Error (4.46 %) respectively are among others.

The above table also shows that, when design error costs were compared with the total cost of Variation = (ETB **2,966,057,514.66),** Horizontal Alignment Contributed 12 % to the total Variation Cost, Minor Drainage Contributed 9 %, Pavement Contributed 8 %, Major Drainage Structures Contributed 7 %, and Vertical Alignment Contributed 6 % respectively to the total variable cost of the road projects scrutinized in this study as presented in the web-diagram here in figure -11 below.

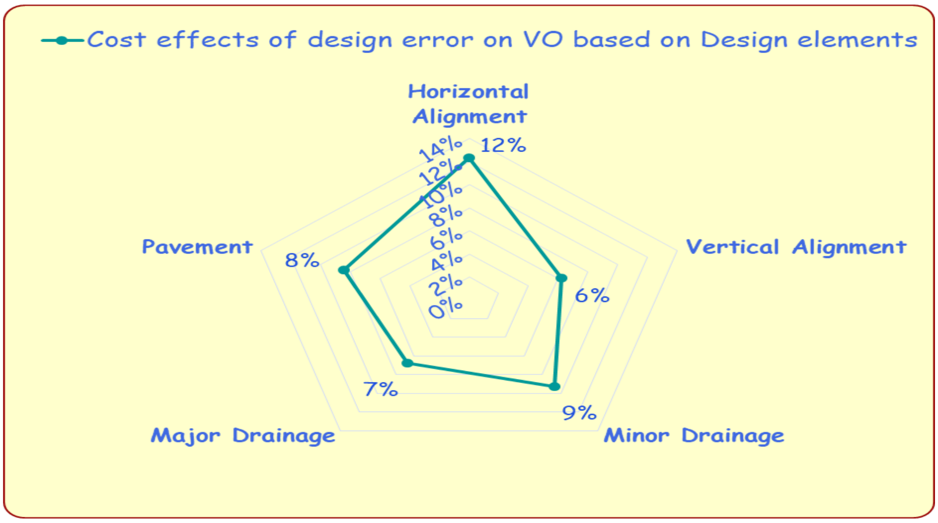

Figure 12 Web diagram of cost effect influence based on highway elements

In summary, if the design works of (highway engineers and hydraulic engineers) are correct and realistic enough, 21 % out of the 43 % variation cost could probably be saved which approximately around 50 % of the design error induced variation cost encountered.

Table-13 presented below shows the cost effects of design errors on the VO based on the hierarchy of Design Element, Design operation and respective Design Phase divisions' one can be able to see the hierarchical effects.

Table 13 Cost effects of Design errors that led to variation in road construction projects based on Design Operation and Design sub-phase

Design Phase Category	Sub Category	Design operation	Design Element	Type of Design error/change	Total Cost of error (ETB)	Total Cost of error in design operation (ETB)	Effect on total Error cost (%)	Effect of error costs in design operation on total variation cost (%)	Rank	Total Cost of error in Design phase sub-group (ETB)	Effect on total Error cost (%)	Effect of error costs in Design phase sub-group on total variation cost (%)	Rank
Public Consultation	**Preliminary Consultation and Integration with concerned design stakeholders from the local community and Gov'tal Offices**	Road Corridor public consultation	Horizontal Alignment	Missing to consider Town section expansion and including of median	121,250,360.65	131,120,679.32	10.28%	4.42%	5	131,120,679.32	10.28%	4.42%	**5**
				Poor and late cooperations with Design stakeholders	9,870,318.67								
TRAFFIC SURVEY AND ANALYSIS	**TRAFFIC SURVEY AND ANALYSIS**	TRAFFIC SURVEY	Pavement	Traffic volume	235,413,438.22	235,413,438.22	18.5%	7.94%	4	235,413,438.22	18.46%	7.94%	**4**
Highway Engineering	**Route selection**	Route selection	Horizontal Alignment	Missing To achieve the best/economical route and environmental	(147,521,539.02)	(78,632,650.13)	-6.17%	-2.65%	9	(78,632,650.13)	-6.17%	-2.65%	**6**
				Missing To traverse through additional control points	68,888,888.89								
	Preliminary Engineering Design	Adapting with Topography of project area	Vertical Alignment	Improper Consideration of topographic features of the area	(65,865,270.01)	(65,865,270.01)	-5.16%	-2.22%	8	235,818,283.32	18.49%	7.95%	**3**
		Geometric Design	Horizontal Alignment	Missing To maintain design parameters min. radius, traffic volume, design speed, vehicle, etc.	99,084,300.28	301,683,553.33	23.65%	10.17%	2				
			Vertical Alignment	error in maintaining the design parameters: gradient, K value, etc,	67,588,825.42								
				Due to error/change in horizontal alignment,	121,604,874.99								
				Erosion protection on high fills	13,405,552.65								

Highway Engineering	**PRELIMINARY HYDROLOGICAL, HYDRAULICS AND STRUCTURAL DESIGN**	Hydrological Study	Minor Drainage Structures	Error in Nos. due hydrological Data	217,462,163.52	326,342,753.02	25.59%	11.00%	1	455,115,334.37	35.68%	15.34%	**1**
				Size Error	56,917,674.80								
			Major Drainage	Revision of hydrological information,	51,962,914.71								
		Hydraulic Design		Revision of structural elements,	8,898,692.45	128,772,581.36	10.10%	4.34%	6				
			Horizontal Alignment	Design error in Drainage structures like bridges, culverts, retaining walls, etc.,	119,873,888.91								
	PRELIMINARY MATERIALS INVESTIGATION AND PAVEMENT DESIGN	Material and Site Investigation	Horizontal Alignment	Errornouse Soil type classification and climate consideration	-	281,819,517.59	22.10%	9.50%	3	296,569,646.20	23.25%	10.00%	**2**
				Slope stability problems and/or land slide areas,	93,972,499.13								
			Vertical Alignment		48,595,508.46								
			Major Drainage	Revision of Geo-technical information	139,251,510.00								
		Preliminary Pavement Design	Pavement	Based on sub-grade material characteristics	19,569,731.11	14,750,128.61	1.16%	0.50%	7				
				Pavement ommision	(4,819,602.50)								
	TOTAL				**1,275,404,731.31**	**1,275,404,731.31**	**100.00%**	**43.00%**		**1,275,404,731.31**	**100.00%**	**43.00%**	
	TOTAL VO Cost of Investigated Projects (N=25)				**2,966,057,514.66**								

Hydrological Study (25.59 %) has the highest effect on the total cost of error; this was followed by Geometric Design (23.65 %), Material and Site Investigation (22.10 %), Traffic Survey (18.5 %), Road Corridor public consultation (10.28 %), Hydraulic Design (10.10 %), Preliminary Pavement Design (1.16 %), Adapting with Topography of project area (-5.16 %), Route selection (-6.17 %) respectively.

The Result shows that there is yet a lot that has to be done regarding Hydrological Study to reduce its error to the barest minimum, to reduce the variation cost with more than a quarter. There is also need to be improving (Preliminary Hydrological, Hydraulics, and Structural Design), (Preliminary Materials Investigation and Pavement Design) and (Preliminary Engineering Design) related issues that accounted for 35.68 %, 23.25 %, and 18.49 % respectively a total of 77.42 % of the Design errors under the corresponding design Sub-phase leading to Variation. This implies that the highway engineering phase of the design phase contributes almost 3/4th of the design errors and variation cost on road construction projects.

As the negative values indicate that their corresponding impact will be non-detrimental variations to the project cost since they will reduce the original cost by such amount though the percent seem smaller their cumulative impact should not be undermined. On the other horizon, those values, however, are negative (non-detrimental) errors on the total design error cost in particular and in the total variable cost, in general, it should be bear in mind that they are dynamic, so there may be some cases in the other side of the study that those errors or revisions may cause the error cost tending to be increasing and may contribute in total variation cost to show an increment.

On the above of this, errors in the hydrological study contributed approximately 25.6 % to the total cost of design error and error in Nos. and types of minor drainage structure design due to hydrological Data alone took 17.05 % (see table – 7). The problem with minor drainage structures in Ethiopia might be as a result of hydrological study design operations being conducted by hydrologist and/or hydraulic engineers who have hardly any (lack) or no enough knowledge and/or experience about the highway design process in a general and hydrological study in particular. Also, poor working (operational) methodology in some cases some design firms delegated professionals to conduct the study with no and/or insufficient actual site visits of the actual project location hydrological study affecting site features in consideration resulting in undermining natural runoff streamlines, water body buffer zones and related features of the project corridor.

Considering the above, Ethiopian federal roads regulatory authority ERA (Ethiopian Roads Authority) has been established recently its standalone Design Directorate which has the role to avoid the above-discussed discrepancies to improve the dynamic nature of highway design which is vulnerable to a various error that can anticipate variation and related contractual glitches. The own force is now building and strengthening its human capital, technology enhancements, and related resources necessary to conduct the design operation besides the outsourcing contractual design deliverables. This footstep is expected to result in market competitions in the road sector to prepare high-quality design outputs among the stakeholders involving in rendering the design service.

In addition, the above table shows the impact of design error costs on the total variation cost of road construction projects that has been investigated in this study based on the design operation and corresponding Design Sub-phase. Hydrological Study had (11 %), Geometric Design had (10.17 %), Material and Site Investigation had (9.5 %), Traffic Survey had (7.94 %), Road Corridor public consultation had (4.42 %), Hydraulic Design had (4.34 %), Preliminary Pavement Design had (0.5 %), Adapting with Topography of project area had (-2.22 %) and Route selection had (-2.65 %) respectively. The Total Contribution of design errors to variation cost, according to the investigation in this study, is **43.00 %.** That represents the probable net effect of design errors on the variation cost of road construction projects.

On the other hand, Preliminary Hydrological, Hydraulics and Structural Design Phase sub-group contributes with a higher portions (35.38 %, 15.34 %) of the total error cost and the total variation cost respectively, followed by Preliminary Materials Investigation And Pavement Design phase sub-group having (23.25 %, 10.00 %), Preliminary Engineering Design phase sub-group having (18.49 %, 7.95 %), Traffic Survey And Analysis having (18.46 %, 7.94 %), Preliminary Consultation and Integration with concerned design stakeholders from the local community and Governmental offices phase sub-group accounting (10.28 %, 4.42 %) and Route selection phase design-sub-group accounting (-6.17 %, -2.65 %) respectively for the total error cost and of the total variation cost.

From the above paragraph, one can construe that if a design firm or team happened to manage Preliminary Hydrological, Hydraulics and Structural Design Phase sub-group and Preliminary Materials Investigation and Pavement Design phase sub-group there will be no doubt that the firm can, on the other hand, avoid 58.23 % of total design error costs and 25.34 % of the total variable cost which have a very significant impact in minimizing the anticipating Variation cost as much as by a parcel of a quarter.

4.1.3 Solutions to design-error-induced variation in road projects

Content analysis method has been adopted after receiving the respondents by directly questing to suggest mitigation measures or important factors that could positively impact the dynamic nature of highway design operation that can be applied at any phase of the project cycle as effective as possible so that the mitigation measure could reduce the anticipating VO to be reduced to the bare minimum possible. Besides a Likert scale rating questions for some possible solutions have also been served to be indicated to measure their importance rank to be analyzed using the relevance importance index.

Table 14 Frequency Table of Likert scale measure for each solution indicated

Which of the following factors will help in the dynamic nature of highway design? Indicate in the hereunder table based on their degree of importance.					
Factors	**Very Important (5)**	**Important (4)**	**Neutral (3)**	**Un-Important (2)**	**Very Un-Important (1)**
Special Training to the Approving staff	8	**11**	**6**	**3**	**0**
Application of Smart technologies[7]	9	**10**	**6**	**0**	**0**
Design Quality Control	10	**13**	**2**	**0**	**0**
Constructability Review	10	**12**	**3**	**0**	**0**
Avoiding the frequent Change of specification	3	**10**	**12**	**0**	**0**
Design Reliability Analysis	7	**16**	**2**	**0**	**0**
Standardizing design approval	5	**16**	**4**	**0**	**0**

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[7] Smart technologies refers to the use of computer programs, software's, and applications that are available across different disciplines in the built environment should be used for the design process wisely, reasonably and compatibly with each other. Furthermore Tech such as. Drone technologies to have detailed site features, Virtual and augmented realities and etc.

documents and formats					
Guidance on the use of competency management systems	3	**19**	**3**	**0**	**0**

Table 15 Relevance Importance Index Computation for the solution of design error induced variations

Factors	Very Important (5)	Important (4)	Neutral (3)	Un-Important (2)	Very Un-Important (1)	Total	Total No.(N)	A*N	RII	Rank
Special Training to the Approving staff	40	44	18	6	0	108	25	125	0.864	1
Application of Smart	45	40	18	0	0	103	25	125	0.824	5
Design Quality Control	50	52	6	0	0	108	25	125	0.864	1
Constructability Review	50	48	9	0	0	107	25	125	0.856	3
Avoiding the frequent Change of specification	15	40	36	0	0	91	25	125	0.728	8
Design Reliability Analysis	35	64	6	0	0	105	25	125	0.840	4
Standardizing design	25	64	12	0	0	101	25	125	0.808	6
Guidance on the use of competency management systems	15	76	9	0	0	100	25	125	0.800	7

Table 16 Summary table of RII Obtained

Factors	**Relative Importance Index Value**	**Importance**
Special Training to the Approving staff	0.864	1
Application of Smart technologies	0.824	5
Design Quality Control	0.864	1
Constructability Review	0.856	3
Avoiding the frequent Change of specification	0.728	8
Design Reliability Analysis	0.840	4
Standardizing design approval documents and formats	0.808	6
Guidance on the use of competency management systems	0.800	7

According to Akadiri (2011), importance levels are as follows for five-point Likert ranking;

Table 17 Importance level categories by **(Akadiri, 2011)**

RII Values	**Importance Level**
$0.8 \leq RII \leq 1$	High
$0.6 \leq RII \leq 0.8$	High - Medium
$0.4 \leq RII \leq 0.6$	Medium
$0.2 \leq RII \leq 0.4$	Medium - Low
$0 \leq RII \leq 0.2$	Low

As we see from the RII computation table almost all factors are laid on the highly important strata considering them as very important factors to reduce design error induced variation to the barest minimum. Special training to the Employer's personnel and Design Quality Control accounting RII values of equal 0.864 each are indicated as the most important mitigating factor to reduce design errors prior of their existence in the design service contract deliverables by equipping the Employer's human resource equipped to detect and simulate the reliability of the design outputs. Followed by the most important process called Constructability review accounting 0.856, Design reliability Analysis accounting 0.840, Involvement of Smart technologies accounting for 0.824, Standardizing design approval documents and formats 0.808 and Guidance on the use of competency management systems having 0.8 as shown in the figure – 12 below.

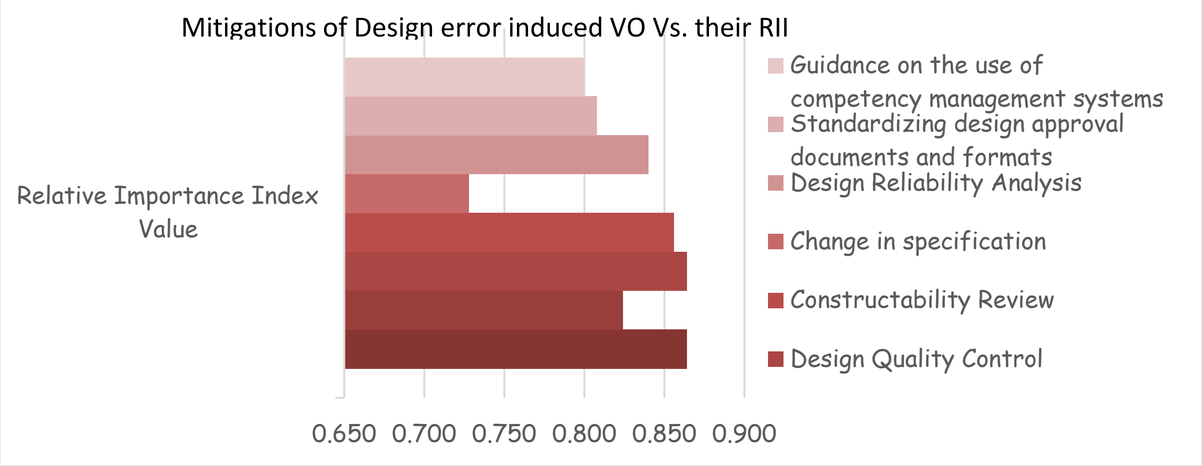


Figure 13 RII values for mitigating factors

Other solutions mentioned by the project delegates;

- To **compress the time gap** between design and implementation periods so that the varying site conditions and design parameters that are vulnerable to vary from season to season.
- Hiring **Experienced designers** that have enough experience for the respective complexity level of the projects based on their experience.
- **The cost of the Design work** shall be amended by the Employer since it affects the quality of the design at large discouraging design firms' motives.
- **Proper Public Consultations** and **Detailed justifications of alternative routes** during route selection considering the socio, economic and environmental aspects.
- **Serious follow-up** shall be done by the Employer. Nowadays, most of the Design works have been conducted in the Consultants head office without visiting the actual site scenario.
- **Accountability penalties** on defaulter designers
- Involving all design stakeholders including local interdisciplinary authorities mat help in getting sufficient information for the execution of the project.

Table 18 Measures and explanations for minimizing design-error induced variation in road projects

Category	Suggestions	Mechanism
Design Error/Omissions	Constructability review	Many designs are produced on the assumption that construction sites are of leveled topography and, as such, designs are produced based on that assumption. This unethical practice should be avoided, as it has caused a lot of design problems leading to litigations, delays, cost overrun, and wastages, among others. So one can conduct constructability reviews by conducting sufficient site visits to reconcile the gap between desk assumptions and actual ground.
	Design Quality control	Design management is a critical process at project development phase. While designs can be carried out according to codes and set procedures, the management of design process is not standardized.
	Accountability penalties	The implementation of this measure commences immediately after it is endorsed by the Management of ERA. To this effect, all Regional Offices will send to the Engineering Procurement Directorate with a copy to the Director General and Deputy Director General of Engineering Operations when they encounter such errors and deficiencies while administering the projects. Engineering procurement Directorate in consultation with the Engineering Operations Deputy Director General will take the recommended measures by way of excluding the firms from being shortlisted for upcoming service contracts for the specified period. In relation to the action to be taken on the individual professional staff the Engineering procurement or the DDG for Engineering Operation will notify the names and durations of ban to all concerned units of ERA from time to time.

	Application of Smart technologies	It was suggested that the use of computer programs, software, and applications that are available across different disciplines in the built environment should be used for the design process wisely, reasonably and compatibly with each other. Eg. Drone technologies to have detailed site features, Virtual and augmented realities etc.
Design Change	Special Training to the Approving staff	Design submittals are prone to be checked by Juniors/inadequate review of design submittals that have no or insufficient experience so that training can cement that gap.
	Guidance on the use of competency management systems	This suggestion is like that of knowledge sharing. However, the difference is that, in this case, there is a recognized co-ordination point where other designers can furnish themselves with relevant information concerning the type of project to be executed.

4.2 Case Studies

4.2.1 Overview

To address development constraints caused by restricted access and, owing to the importance of road transport in supporting social and economic growth and in meeting poverty reduction objectives, the Federal Democratic Republic of Ethiopia has placed an increased emphasis on improving the quality and size of the road infrastructure. Thus, the government formulated a ten year Road Sector Development Program (RSDP) in 1996 to increase the overall efficiency of the road transport system in general and bringing about an increase in Ethiopia access to the port, farm products to markets and delivery of the necessary service to the community in particular. To this end, the government has made a huge amount of investment towards the improvement of the road network; both qualitatively and quantitatively. This investment outlays cover the rehabilitation or upgrading of the main trunk, link, and rural roads and construction of new roads to expand the network.

As has been the case in the past, the Government continues its commitment to give the road sector the highest priority and is preparing more projects for funding by donors and from the national budget. Individual road projects are selected for inclusion in the RSDP based on needs assessment and taking into account the level of traffic, road condition, and access problem, etc.

Therefore, herein under this section shows some case studies studied by the author to understand the case under the study in close up.

4.2.2 Case Project-I: - Hawassa-Hawassa Airport-Bishan Guracha (Tikur Wuha) Design and build road project

One of the challenging issues that arise in such a construction project is the occurrence of a variation order in the due performance of the project; this issue even becomes more demanding when the project delivery type is Design and Build.

A. <u>Narratives of Correspondences about the Variation Issue</u>

In presenting the issue related to this, the author thought it is worthwhile to incorporate the fundamental timeline of the case for ease of see of the case from the root;

i. The contractor after the commencement of the project requested clarification on the Bishan Guracha Town Administration request to shift the whole alignment of section II: Km 0+000- Km 12+461 to the North direction around 308 meters (as shown in the figure below).

ii. He then informed the client's representative that he had received a letter from the Ethiopian Airports Enterprise which requests the contractor to connect the road to the new gate and the same will increase the project road to a minimum of 2.6 km.

iii. After a while, the contractor submitted a reminder for the client's representative to confirm the shift of section II road to the North direction around 308 meters and the request of the Ethiopian Airport's Enterprise's to connect the end of the road to the new gate.

iv. Again, the contractor requested confirmation and clarification for both cases.

v. In the meantime, the contractor submitted a Final Route selection report for the ER after incorporating the comments of the client's representative.

vi. Then, the contractor in his letter filed a notice to claim for an extension of time and additional costs for idling and demobilization resources due to deprivation of the final decision.

vii. The contractor filed a second notice to claim and requests the confirmation of the changing of the end control point of the project and the shifting of the alignment to the North Direction.

viii. After some time the contractor respectively submitted a reminder and notice to claim letters.

ix. Following the Employer's approval of the route selection, the client's representative approved the route selection report.

x. Consequently, the contractor requested for formal variation order and submit BOQ for the Employer's Representative review and approval, based on his assessment, the contractor had requested an additional cost of ETB 37,924,734.56 (Thirty-Seven Million Nine Hundred Twenty Four Thousand Seven Hundred Thirty-Four and 56/100).

xi. Following this, the Employer's Representative requested the contractor to further clarify and substantiate his request for an additional cost.

xii. The contractor, accordingly, submitted his clarification on his proposal for the additional cost for the alignment change.

B. Analysis of the Case

The contractor requests for the variation instruction and the subsequent determination of additional cost for Section II of the project road. Section II of the project road is located predominately in the Oromia Region. The Road as stated on the concept design and the project summary on the Employer's Requirement starts at a junction from Addis Ababa – Hawassa Truck Road just before 800m from the Northern tip of Hawassa City locally known as Tikur Wuha area and traverses west circumventing the lake in North-western direction towards the new airport terminal.

Being the preliminary information presented on the contract as above during the route selection, design and construction of the project road significant changes had come into existence and the contractor requests for variation order and the same has been discussed in detail hereunder;

The request of the Woreda Administration and Military to Shift the Alignment

It is known that the contractor is required to design and construct the project road using the control points given to him on the contract with reasonable adjustment as required. The control point of the start of the project road shown on the contract is (E=443075.700 and N=784729.946) which shows that the project was envisaged to take the last grid towards the lake. However, the Bishan Guracha Town Administration and the residents had requested the contractor to shift the whole alignment to the North Direction with around 308meters, which takes the road to the second grid line on the Master Plan from the Lake.

The road could be designed and constructed on the last grid as shown on the Master Plan, the contractor during the bidding process from the initial control point could only anticipate designing and constructing the road on the last grid since taking the road to the north direction increases at least the volume of the earthwork. Therefore, it is of the ER's view that it is very difficult for the contractor to anticipate the change made on the original control point that shifts the road to the second gird line to the Northern Direction (which is about 300m away from originally intended start point). The change emanates from the town administration strategy to utilize the land near the lake for other purpose and they claimed that they want to preserve the land for the investors to invest in the resort and hoteling market around the lake.

After shifting the road to the second line, the road traverses smoothly on the second grid, however starting from Km 6+100 to Km 8+ 600 the road would cross the military camp, on the other hand, the military forces refuse to grant the land for the construction of the road, which forces the contractor to return to the first original grid (where the concept design passes) with making local realignments, then after it returned to the second grid up to Km 11+100 after passing the military camp as per the town administration request until it crosses the Oromia Regional State.

The road could be designed and constructed with fulfilling all the requirements of the contract by taking the first grid of the master plan of Bishan Guracha Administration as the initial control point dictates and it would be very difficult to conclude that the contractor should anticipate the town administration's new demand to shift the road to the second line with their new intention to utilize the land near the lake for investment during the bidding process and on the other hand the military forces also refuse to grant possession of the site for the construction of the road as per the master plan due to this the contractor forced to push back the design and return to the first grid line until it traverses the military camp.

Generally, from the above discussion, the ER came to know that the contractor was forced to design and construct the road on the new alignment and it should be considered as a variation work starting from 0+000 to 11+100 (using the actual alignment). As the case study is observed from the valuation document the client's representative determination is relevant to the contractual provisions and the actual scenario changed on project site due to the anticipated need of project stakeholders (the airport enterprise and the military camp)

To clarify the road alignment, the ER has presented the sketch of the alignments on the concept design and finally designed and constructed alignment as shown below.

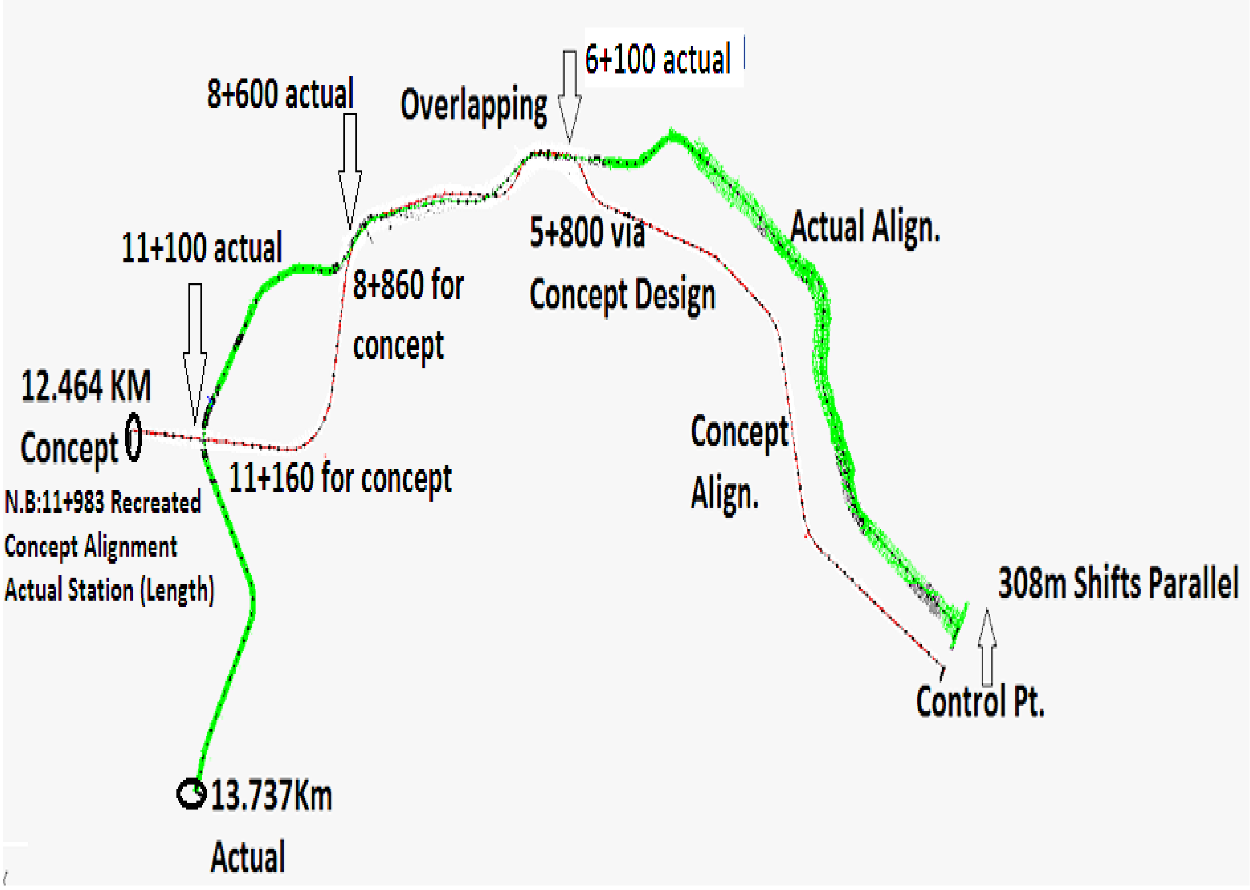


Figure 14: The alignment of the concept and actual design of HHB

The request of the Ethiopian Airport Enterprises

The contractor during the consultation for the alternative route assessment learned that the Ethiopian Airport Enterprises requires the road to be designed to their new gate, and it varies from the end control point stipulated on Item 6.1.1.2 [*Location*] Table 6-4, hence the contractor requests for variation order for this change either.

However, the Client's representative is not convinced with the contractor's argument that the request of the Ethiopian Airport Enterprise is a variation to the original contract because of the following core reasons;

1. Item 6.1.1.5 [*Scope of the service*] of the Employer's Requirement requires that the contractor to determine the full scope of the project through an examination of the contract and the Project site, or as may be reasonably inferred from such examination, as per this requirement.

   Had the contractor determine the full scope of the project as required on the contract by discussing with the Ethiopian Airport Enterprise, which is the major stakeholder for the project; he would have had information about the actual gate of the Airport.

   It is evident that the airport is constructed with the design and from the information gathered from the airport clearly shows that the end control point which was stipulated on the contract for indicative purpose only is connected to the runway. It in no way be possible to connect the roadway to the airplane run, rather the enterprises prefer to abandon the project.

2. Addendum No. 2 Item No. 4 of the works contract document states that

   "***The coordinates and stations of the end of Section II on the side of the airport are specified for indicative purpose**. As a result, the contractor shall bring consent from **Ethiopian Airport Enterprise and other relevant regarding the end coordinates of section II**. Besides, the contractor shall consider **the Master Plan and the future expansion of the Airport** while selecting the route and the terminal point. Besides, the proposed end of the project shall ensure safe, efficient, reliable operation of the envisaged road. Accordingly, the proposed endpoint shall be reviewed and approved by the Employer's representative subject to the fulfillment of the above characteristics. If there is any disagreement between the employer's representative and the Contractor, the Employer's decision will be final."*

From the above notion, it is crystal clear that the end control point is shown on the contract is indicative only, the contractor, should not take the end control point as final and binding. Rather, the contractor should consult the Airport Enterprise, which is the major stakeholder during the bidding process and should have had a prior knowledge regarding the Master Plan of the Airport as required under the contract, it is unlikely, that the airport changes their master plan and also the contractor did not present any evidence that illuminates that there is a change of plan by the Airport after the bidding process during the implementation process.

In addition, as responded by the Ethiopian Airports Enterprise, the coordinates shown on the contract ends at the end of the runway edge of the airport and it does not join with the gate of the airport, however, the contract requires the contractor to select the end of the project as the gate of the airport considering the Master plan and future expansion of the airport. Thus, the contractor's argument that declares that the end control point is changed after the contract signing becomes short and contractually unjustifiable.

Notwithstanding the above, the Terminal building being under construction and access road (which is the extension of Section I road) that was under construction also tells that the contractor had sufficient prior information on the possible gate of the project.

3. Clause 4- [*The Contractor General Obligation*], 4.1 states that;

"***The Works as completed by the Contractor shall be wholly in accordance with the Contract and fit for the purpose for which they are intended****, as defined in the contract. The Works shall include any work which is necessary to satisfy the Employer's Requirements, Contractor's Proposal and Schedules, or* **is implied by the Contract, or arises from any obligation** *of the Contractor, and all works not mentioned in the Contract but which may be inferred to be necessary for stability or completion or the safe, reliable and efficient operation of the Works…"*

The main purpose for the construction of the project road is to provide access to the airport, if the road is constructed with the preliminary end control point, which is the runway of the Airport, it would in no way be usable for the intended purpose, and thus it does not fit the purpose it is intended for.

Further, it also states that the works shall **include any work** that is implied by the contract, the contract not only with the implied term but also addresses that the name of the End Control Point as "*New Airport Terminal Gate*" not the New Airport Runway as claimed by the contractor.

Thus, changing the control point to the main gate of the Airport is the contractor's responsibility as required under the contract and it does not construe as a variation under clause 14 [*Variations*] of the General Condition of the Contract.

Due to the above reasons, the Employer's representative concluded that the contractor's request for variation order to connect the end of the project with the gate of the Airport is found to unacceptable and technically unjustified. Therefore, the contractor work executed starting from km 11+100 to 13+737 is part of his obligation and responsibility under the contract and does not require a variation instruction.

C. Conclusion of the VO Claim

In effect, the contractor assessed his overall entitlement to additional costs due to the critical adjustment causes. As shown on the contractor's assessment presented in the appendix to this proposal, the contractor requests an additional cost of ETB 37,924,734.56 (Thirty-Seven Million Nine Hundred Twenty Four Thousand Five Hundred Thirty-Four and 56/100, excluding VAT) and it is ETB 43,613,444.74 (Forty Thirty Million Six Hundred Thirteen Thousand Four Hundred Forty-Four and 74/100, Including VAT).

The Employer's Representative with the limitation stipulated above as shown in detail on the attachment, computed the value of the varied work, it amounts to ETB 17,765,900.40 (Seventeen Million Seven Hundred Sixty-Five Thousand Nine Hundred and 40/100 inclusive of VAT).

4.2.3 Case Project-II: - Konso - Yabelo Road Project

A. Narratives of the Case

Once the contract has been commenced in line with the supervision consultant's parallel design review the Engineer detected that substantial design scope of drainage structures has been found omitted from consideration by the original designer's deliverables. Following this, the supervision consultant swiftly recommends the Employer to add under detailed recommendations as a Variation Order:-

- ✓ Additional culverts (75Pipe Culverts and 2Slab Culverts /Box Culverts)
- ✓ Enlarging 44 Pipe Culverts and 41 Slab Culverts/Box Culverts of the original design
- ✓ Upgrading of the 800mm culverts to 900mm pipe culverts

Following this, due to the scope of the recommended variation is substantial, the Employer organized a meeting with Designer and Supervision Consultant in the presence of the respective two hydrologists to discuss the recommendations and reach to an agreement on the newly proposed findings.

However, giving due regards to the major deviation between Designer and Supervision Consultant, all parties agreed and scheduled a date to have a joint site visit by the two hydrologists to reach an agreement on the major part and finalize the same. However, the supervision consultant's hydrologist could not attend the scheduled site visit due to personal reasons which might result in still inconvenience among the cooperating the two firms as a project stakeholder, while the design hydrologist went to the project site and submitted his findings.

Accordingly, the design hydrologist has submitted his findings after having the site visit and still, there was a major deviation from the proposal submitted by supervising Consultant and the same is detailed under:-

- ➢ Out of 75 proposed additional pipe culverts, only 17 are required to be added as a relief structures
- ➢ No justification is found to change the 27 pipe culverts to slab culverts and it is unnecessary

- The 7-meter bridge added adjacent to an existing bridge to add opening at the bridge is not required at all
- The change/ modification made on slab culverts are not required

Generally, the designer hydrologist has accepted that he has missed considering the following 17 pipe culvert modifications during design and recommended that the same should be considered now.

B. Analysis

Having reviewed the above design error case and respective correspondences among the parties, it is sound that the Engineer's proposal was crucial to accommodating the water safely to ensure the service life of the road that may be otherwise jeopardized. Regarding the major difference and disagreement between Designer and Supervision Consultant in the introduction of the substantial number of drainage structures, the employer immediately engaged an independent Consultants to assess and give us his independent view to reconciling the design discrepancies. As a matter of priority due to critical activity sequence and has a significant effect in the progress of the works as the Contractor is working on such events, it is well expected that variation order might also be reinforced with some extension of time that will result in an additional claim from the Contractor.

C. Conclusion of the VO claim

Regarding the cost implication, the Employer after assessing the case then issued an approval for the proposed variations of the additional drainage structures to properly accommodate the flood in accordance with Conditions of the Contract with an additional cost of ETB: 26,161,547.36 (ETB: Twenty Six Million, One Hundred Sixty One Thousand, Five Hundred Forty-Seven and Cents Thirty Six) including 15% VAT and advise you to forward the said variations to the contractor to proceed with construction works of the same resulting in approximately 3% of the Contract Price due to the Design error.

4.2.4 Case Project-III: - Salayish-Omo Road Project

A. Narratives of the Case

It has been noted that in the Hydrology and Hydraulics review section of the design review report, major design changes are recommended regarding minor drainage structures. The recommended changes can be grouped as follows;

- Group A -14 pipe culverts are changed to slab/box culverts due to low capacity of catchment against the anticipating discharge.
- Group B- 8 new slab/box culverts are introduced which were not considered in the Original Design due to the gap in hydrological data.
- Group C - 3 slabs/box culverts are changed to new locations due to an unconsidered streamline of flow.
- Group D -92 new pipe culverts are introduced.
- Group E -sizes of 18 pipes, culverts are changed (either reduced or increased).
- Group F -18 pipe culverts are changed to new locations.

B. Analysis

It has been noted that the original design considers only a total of 7 slab/box culverts and 87 pipe culverts were provided. However, in the revised design a total of 25 slab/box culverts and 153 pipe culverts of different sizes are recommended. As a result, an additional 18 slabs/box culverts and 66 pipe culverts are recommended which are overlooked during the original design.

C. Conclusion of the VO claim

Having thoroughly reviewed the variation proposal for the construction of additional 18 slabs/box culverts and 66 pipe culverts in the project, the Employer (ERA) then has decided that it is necessary to adopt the recommended design changes for the safety and Serviceable life of the road.

Therefore, considering all the specified clarifications and the reasons for the variation, the Employer approves for the inclusion of 18 additional slab/box culverts and 66 pipe culverts with an additional cost of ETB 23,084,431.89 (Ethiopian Birr Twenty Three Million Eighty-Four Thousand Four Hundred Thirty-One and 89/100).

4.2.5 Case Project IV: - Diredawa-Melka Jebdu Design and Build Road Project

A. Narratives of the Case

- The Contractor (MELCON Constriction Plc.) after the commencement of the project advised by the Employer (ERA) to amend the referenced Project's road width from 30m (with dual carriageway of three lanes (3.65m each), 3m Walkway on both sides and 2.1m Median) to 50m in line with the request of Dire Dawa City Administration by providing 20m median to accommodate the future expected massive traffic owing to the industrial park development along the project area.
- In Consultation with the Employer and the Contractor, Dire Dawa City Administration regarding the subject matter and the Dire Dawa City Administration has also requested the provision of Bicycle Lane and Green Area considering the future development of the city and the representatives from the Employer (ERA) have pledged to assess the possibility of providing both Bicycle Lane and Green Area.
- The Contractor has submitted the revised design considering the 50m road width with dual carriageway of three Lanes (3.65m each), 3m Walkway, 2m Bicycle Lane, 1.5m Green Area on both sides and 15.1m Median to the Employer's Approval.
- The Employer's Representative then submitted the revised design of the subject project following the Contractor's submission of the additional cost proposal for the same along with estimated revised quantities and the respective cost implication for the Employer's review and approval.

B. Analysis

After having reviewed the chronology of the above project history observing through the valuation of variation for the Design error/change encountered impacts most of the Bill item in the Contract price;

1. Drainage

For the computation of the volume of the varied work under the category of Drainage, it has been considered the following points;

- As per the original design (30m road width), 42" and 48" longitudinal pipes have been considered in right and left side of the roadway including at junctions, and these longitudinal pipes remain unchanged in the 50m design.

- In addition to the longitudinal pipes, it has been proposed 12 box culverts due to the widening of the road width from 30m to 50m. However, due to the ground that the outlets of the three culverts, at Km 0+572, Km 2+090 and Km 6+239, will not drain into the natural channel and will pose flooding threat to the nearby community, a joint meeting has been held with all parties to resolve the problem and the following was agreed;

- Box Culvert at Km 0+572 was agreed to be omitted as its outlet will not drain into the natural channel and will pose flooding to a nearby community, and as an alternative, it is recommended to raise the fill height at least 1m, which increase the Embankment and help in controlling surface drainage.
- Box culvert at Km2+090 was agreed to be omitted as its outlet causing the flood to the nearby Dire Dawa – Dawele project and also the availability of well-defined natural crossing structure just 50m ahead of the proposed location.
- Box Culvert Km 6+239 was also agreed to omit in consideration of raising the grade for crossing will create access inconvenience for Melka Jebdu Residents. Instead, it is proposed to direct them an outlet to the natural stream just 500m ahead of the proposed location.

Then the Employer's Representative computed the quantities of both Slab and Box culverts which has resulted in increment of cost amounting ETB 28,388,587.06 excluding VAT.

2. Earthwork

The earthwork volume has shown a significant increase from the original design due to the increase in median width (which has been changed from 2.1m to 15.1m with a net increase of 13m), the introduction of the Bicycle lane (4m) and Green area (3m). To minimize the earthwork, the ER was proposed a depressed fill in the median with cross fall of 1:10, which reduces the volume of earthwork for 50m road width by 35,000 cubic meters resulted in increment of cost amounting **ETB 33,484,143.62** excluding VAT.

3. Sub-base and Road base

The sub-base and bituminous base course for carriageway, walkway, junctions, and bus lane have shown a slight increase in volume due to an increase in width of Median U-turns. It is considered that ten (10) U-turns with an average cross-section width of 20m and as a result, The volume of bituminous base and sub base has increased by 500 and 460 cubic meters respectively. In addition, following the introduction of 2m bicycle lane (both sides) with a pavement layer consisting of 40mm AC, 150mm crushed base course, and 150mm sub-base, the volume of crushed base course and sub base has increased by 4300 cubic meters resulted in an extra cost of **ETB 6,416,919.64** excluding VAT.

4. Bituminous Surfacing

The bituminous surfacing for carriageway, junctions, and bus lane, similar to the base and sub-base, has shown a slight increase in volume due to an increase in width of the median, which intern increases the width of each U-turn the cost of bituminous surfacing has increased by **ETB 10,928,450.44** excluding VAT.

5. Structures

To fit the requirement of the road width, an extension of width (in addition to protection works) for the existing two bridges has been proposed in the original design of the subject project. An existing bridge crossing collapsed after the signing of the subject Contract and the Construction works of the same are under construction by Dire Dawa City Administration. Hence, the ER has omitted the extension works of the bridge.

In addition, because of the widening of the median from 2.1m to 15.1m, the existing bridge falls on the median and there is no extension at this location. Instead, a new bridge is recommended at both sides, which accommodate the main carriageway, walkway, and bicycle lane resulted in a cost-saving of **ETB 3,214,104.14 excluding VAT.**

C. Conclusion of the VO claim

Having reviewed the ER's recommendation of the cost proposal, ERA then displayed its assessment using the documents furnished by the Employer's Representative and considering the discussion that has been held among the project parties in different occasions, the original Project Cost of **ETB 470,000,000.00** is revised to be **ETB 578,540,045.88** including VAT with a total cost increment of **ETB 108,540,045.88** including VAT to the existing Contract on the revised design (**amendment of Road Width from 30m to 50m a complete scope change). C**onsidering that 5% of contingency has been taken from similar Design and Build road projects in the country instead of 11.77%, which was assumed by both the Contractor and the ER.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusions

This study investigated the causes of variation, design errors that lead to variation, their respective cost effects, and solutions to a design-error-induced variation on road construction projects.

5.1.1 Causes of Design Error Induced variation

The findings of the study show that the main causes of design-error induced variation are Inexperience of designers, Lack of knowledge, Lack of integration/coordination between designers of different disciplines. Design Cost and Duration of Design, change in scope of work by clients are among the front lines. Which seems in alignment with the existing body of knowledge as discussed in the literature review section.

The result in advance specifies that the probability of occurrence of design error in the investigated projects based on highway design elements is in the order of Vertical Alignment (27.5%), Horizontal Alignment (21.7%), Minor Drainage and Pavement (17.4%) each and Major Drainage (15.9%) respectively.

In addition to this, Error in Nos. due hydrological Data (14%), Due to error/change in horizontal alignment (10%) and Error on sub-grade material characteristics (9%) are the top three recurring errors that lead the corresponding design elements minor drainage structures, Vertical Alignment and pavement respectively to encounter design error induced variation.

On the Other hand, the Geometric design operation (26%) is in aggregate affected by the following errors joint responsibilities to mention some; (Missing To maintain design parameters of HA min. radius, traffic volume, design speed, vehicle, etc.,) (error in maintaining the design parameters of VA: gradient, K value, etc.,) and (Due to error/change in horizontal alignment).

Error in Nos. due hydrological Data and Size in minor drainages and revisions of hydrological data are the design errors that make the hydrological study operation the 2nd design operation which is mostly encountering Design error accounting for 25%.

In consideration of the above one can certainly say that the deliberate improvements on the geometric and hydrological study design operation could lead to a reduction of over half of the total design error leading to variation in road construction projects.

Furthermore, missing to consider Town section expansion and including of median during the preliminary consultations of design stakeholders (mostly local administration) alone drives the horizontal alignment to face a variation order during implementation due new anticipations of town section expansion requests, the inclusion of medians against the profile as stipulated in the original design output as reinforced by the 1st and 4th case studies narrated accordingly from the valuation documents of the projects.

5.1.2 Cost-effect of design error on variation cost of Road projects

As reviewed in the literature it is rare to see the effects of design error on the variation in terms of quantitative terms rather lots of them dictate in terms of qualitative, so that this may make comparison with the body of knowledge challenging in some sort. In contrasting the findings of this study with the content analyzed in the literature review in such a way that in case of the content analysis we can obtain that majority of the literatures attempt to convince the effect of the design error in terms of qualitative terms simply arguing their impact on the contribution of a cost overrun in construction project.

The unique attribute of this study in comparing to the content analyzed literatures is it clearly discusses the cost effect in quantitative terms beyond the qualitative manner as in the literatures reviewed, even categorizing the design error initiated design elements and their corresponding design operation under the hierarchy of the design phase sub-groups.

The Cost effect analysis in this study has implied that Horizontal alignment and Minor Drainage alone constitute 51 % of the total cost of error in Highway Design Elements and approximately 21 % of the variation cost of road projects. This shows that however Vertical alignment and Pavement encompass the most number of errors in highway design, those of Horizontal alignment and Minor Drainage have the most cost effects on a variation when compared with other highway design elements. This will alert any contracting parties a crucial concern should be brought to Geometric design and hydrological study design operations if a considerable reduction of design error and variation costs are targeted to be achieved.

In Ethiopia, for example, Highway designers and hydraulic engineers/hydrologists are still capable of being assigned in each other's interchangeably in the name of being an engineer undermining specializations beyond the convict of the inadequate experiences in the respective fields and this could be a major cause of the problem with the interdisciplinary nature of highway design. Therefore, new practitioners should be encouraged by involving in the knowledge and technology transfer hierarchy of the industry's crucial attribute.

5.1.3 Solutions to design-error-induced variation in building projects

Later on, as the respondents replied in the web-based questionnaire their aggregate responses exposed that design error induced variations can be reduced importantly to the bare minimum through the implementations of Special Training to the Approving staff (to the Employer), implementation of Design Quality Control, Constructability Review, Design Reliability Analysis, Application of Smart technologies (e.g. web-based design management practices, drone technologies to investigate site features, etc.), Standardizing design approval documents and formats, Guidance on the use of competency management systems. Furthermore, under the other open-ended questions, they have responded that to compress the time gap between the time of design and implementation, the amending Cost of the Design work and implementing Accountability penalties are among other's strategic way outs for design errors before being encountered resulting in variation in road projects.

In consideration of the above, it is apparently observed that comparing these suggestions with previous studies indicates that they agree with (Love et al. 2014) in respect of the learning and use of technology enhancements. Furthermore, an error can be detected subsequently before actual construction through a constructability review as (Memon, Rahman , & Abdul, 2014) have found in their study aligns with the findings of this study too.

In amending the design cost the study justifies there could result in improved design deliverables which comply with the study conducted by (Nirajan, 2011) on the Impact of design cost on project performance.

5.1.4 Summary of Survey finding

Based on the findings of this study, it was concluded that Inexperience of designers, Lack of knowledge, Lack of integration/coordination between designers of different disciplines. Design Cost and Duration of Design, change in scope of work by clients are among the front lines. Due to error/change in horizontal alignment and Error on sub-grade material characteristics are the top three recurring errors that lead the corresponding design elements minor drainage structures, Vertical Alignment, and pavement respectively. The highest numbers of errors in highway design elements are Vertical Alignment, Horizontal Alignment, and Minor Drainage respectively. In these elements (Vertical Alignment, Horizontal Alignment, and Minor Drainage), to maintain the design elements: gradient, K value, etc., to maintain design elements: min. radius, traffic volume, design speed, vehicle, etc. and Error in Nos. due hydrological Data were the most concerned.

Moreover, Vertical alignment and Pavement encompasses the most number of errors in highway design, those of Horizontal alignment and Minor Drainage have the most cost effects on a variation when compared with other highway design elements. The most implicated errors in those elements are error in Traffic volume analysis, Town section extension and including of median, Error in Nos. and types due to hydrological Data and Revision of Geotechnical information.

The last but not the least is approaches in minimizing design-error-induced variation are adequate training to the Approving staff (to the Employer), implementation of Design Quality Control, Constructability Review, Design Reliability Analysis, Application of Smart technologies (e.g. web-based design management practices, drone technologies to investigate site features, etc.), Standardizing design approval documents and formats, Guidance on the use of competency management systems, amending Cost of the Design work and implementing Accountability penalties are among others strategic way outs for design errors prior of being encountered resulting in variation in road projects.

5.1.5 Summary of Case study Conclusions

The findings from the case study section reveals that poor integration during the public Consultation and Integration stage with concerned design stakeholders from the local community and other Governmental Offices results in the original design to be conducted in such a way that it will not acknowledge or consider the very interests of those design stakeholders as a result the design will be susceptible to changes that can lead to variation costs during the implementation period.

On the other hand, the case study also implies that Hydrology and Hydraulics section of the original design in most cases are prone to major design changes recommended for minor drainage structures. In this regard, as the case as it may hydrological study needs greater focuses as lots of design error are arise from it resulting in variation orders to implement the remedies recommended during the design review of supervision consultants. This kinds of failing to get the actual stream line, the sufficient catchment capacity of structures and adequate number of inlet and outlet point for drainage structures affects the safety and serviceable life of the road which in turn needs to be handled as early as possible to maintain the sustainability of the road at whatever cost feasible in the face of the Employer which is variation to the works contract.

Moreover, the widening of the road width as per the town seats of local governments request after the commencement of construction in most cases inclusion of median is among the variation generating factors which can be considered as design error resulted owing to poor public consultation during the design phase. Such design error in road width results variation not only on the drainage structures but also the corresponding earth work quantity against the original design quantity, quantity of sub-base, base course as well as bituminous application. Moreover, any structures which was evaluated to be suitable during original design will now be no longer go with the new design. Consequently, some crucial modification, addition and/or omission with new realignment may be required to fit with the changed design. Thus results in significant variation of contract price against the originally signed one.

5.1.6 Comparison of the Case Study vs. Survey findings

As per the discussion that has been made in the previous sections one can easily extract a contrasting points out of the two methods applied the survey finding and case study section as follows;

i. Both methods finds out that hydrological study has the greater frequency of design error while missing streamlines, catchment capacity (size), location and numbers of the drainage structures.
ii. Poor integration with design stakeholders during the design phase results in inadequate consideration of the stakeholders needs resulting in design change with variation costs.
iii. The Frequent design change in town section width which results in the horizontal alignment change is reinforced by the case study finding in similar way which even

has a dominos effect influencing the quantity of other activities of the road construction such as; earth work, sub-base, road base, pavement and drainage works.

iv. Unlike the case study findings the survey method clearly depicts that Vertical alignment and Pavement encompasses the most number of errors in highway design which is not shown in the case study.

v. In both methods the major drainage structures encounter design error less frequently in the investigated projects, ranking last in case of the survey having a 15 % probability of occurrence. In analogy the case study contends also that the major drainage structure is rare to have design error and corresponding variation costs by themselves in most cases, until unless and other wise affected by the dominos effect of other design errors.

vi. In general, however the survey method details each and every aspects under the theme the case study in most cases also confirmed similar findings supporting the findings in the former method.

5.2 Recommendations

5.2.1 General

- The life-cycle costs of road projects should be given the utmost attention while designing and introducing variations to a contract.
- Professional associations should establish an organized web-based open source for knowledge sharing for the sustainability of optimum design outputs in the industry.

5.2.2 To The Government Regulatory Bodies (ERA)

- Developing appropriate guidelines for Design work Accountability penalty schemes (Appropriate sanctions should be prescribed for defaulters) beyond the indemnity insurance scope of service contract securities to be applied directly to design firms resulting in a significant level of design error for their service rendering.
- Establishing a standalone infrastructures design reviewing institute/agency.
- The concerned government authority ERA has to take the lion-share in stimulating the design market competition by modernizing its own force design team in every aspect.
- Preparing a sustainable and adequate knowledge-sharing platform to be transferred through the public domain for the free access of various design-related experiences

encountered in the projects administered at various points in time. This will prevent the perennial problem of over-and-under designing that could result in recurring variation costs in road projects.

- Improving the price of Design contracts and Duration respectively to some reasonable extent for the very motivation of the design market to have design outputs with a reduced level of error.
- Encouraging value engineering aspects of design to counterbalance the cost expenditure of the project are among the prior suggestions of the author.
- Compress the Duration between design and implementations.
- Implement an alternative contract delivery method that is relevant to the design complexity of the project.

5.2.3 Design Consultants

- Developing lessons learned archival to avoid encountering analogous design errors at different times.
- Establishing a team among the design team closely evaluating the design by conducting constructability reviews and its implementation road maps thoroughly with the theme of the firm's mission.
- Managing the design through a web-based open-source tool for better coordination and alignments among the design team interdisciplinary congregation.
- Conduct sufficient site visits prior and simultaneously with the design operation and triangulate desk work with the realistic site location.
- All design organizations should be advised to establish quality control departments to verify all designs.
- Implement Advanced Technologies Virtual and augmented realities in office works as necessary to comply with the image of the site feature and train the design team for its implementations are among other suggestions forwarded with the Design firms.

5.2.4 Supervision Firms

- An early review of design
- Design calculations should be verified by a dedicated supervision firm before proceeding to the site for construction supervision service.

5.3 Future Research

The findings and recommendations of this thesis possible could consider by future associated studies as input and citations. Particularly, future researchers may consider;

1. Developing a generic conceptual process flow model showing the design error induced variation order, its cost effects, and effective mitigation measure of design error/change-induced variations in public infrastructure projects as a whole and the road sector in particular. The model as a tool should help policymakers, academicians, professionals, and contracting parties of the construction industry to confine construction variations that may happen due design error.
2. The same study further by considering of comparing the subject under various delivery methods that are applicable in the federal roads.
3. Assessing the true cost of design variation.
4. Investigating design variations from designers and clients perspective.
5. Investigating the impact of technology in the quality of design deliverables.

Bibliography

Akadiri O P Development Of A Multi Criterea Approach For The Selection Of Susutainable Materiald For Building Projects, [Conference] // Phd Thesis. - Wolverhampton, Uk : University Of Wolverhampton, 2011.

Alaryan Alia [Et Al.] Causes And Effects Of Change Orders On Construction Projects In Kuwait [Article]. - Kuwait : Issn : 2248-9622, July 2014. - 7 : Vol. 4. - Pp. 01-08.

Al-Dubaisi A.H. Change Orders In Construction Projects In Saudi Arabia [Journal] // Msc. Thesis, King Fahd University Of Petroleum & Minerals, Dhahran, Saudi Arabia.. - 2000. - P. Cited By Tadesse Ayalew.

Aniekwu A.N Government Role In Developing The Construction Industry In Nigeria [Report]. - Benin City, Nigeria : University Of Benin, 2003.

Asamaoh Richard Oduro And Offei-Nyako Kofi Variation Determinants In Building Construction: Ghanaian Professionals Perspective [Journal] // Kicem Journal Of Construction Engineering And Project Management . - 2013.

Asaminew Mekonnen Assessment On The Effectivness Of Design Build Vs. Design Bid Build Project Delivery Method In Federal Road Construction Projects [Journal] // A Thesis Submitted To The School Of Graduate Studies Of Addis Ababa University In Partial Fulfillment Of The Requirements For The Degree Of Master Of Science In Civil Engineering Construction Technology And Manageme. - 2013.

Ayalew Tadesse Causes And Effects Of Variation In Ethiopian Road Projects [Journal] // A Thesis Submitted To School Of Graduate Studies Of Addis Ababa University In Partial F ulfillment Of The Requirements Of The Degree Of Master Of Science In Civil Engineering (Construction Technology And Management Major) . - 2009. - P. 82.

Banaitis Audrius And Ng. Pl. Construction Mediation And Its Hybridization: The Case Of The Hong Kong Construction Industry [Journal]. - Hong Kong : Organization, Technology And Management In Construction: An International Journal, 2017. - Vol. 9.

Benjamin Liddell Steven Assessing The True Cost Of Design Variations [Report]. - Queensland : University Of Southern Queensland Faculty Of Health, Engineering & Sciences, 2014, Page 21.

Demeke Fikreyesus Analyzing Change Orders In Selected Ethiopian Roads Authority Asphalt Concrete Road Projects Constructed By Foreign Contractors [Journal] // Analyzing Change Orders In Selected Ethiopian Road Authority Asphalt Concrete Road Projects Constructed By Foreign Contractors . Addis Ababa : Addis Ababa University, 2015. - Vol. I.

Dosumu Oluwaseun And Clinton Aigbavboa An Assessment Of The Causes, Cost Effects And Solutions To Design-Errorinduced Variations On Selected Building Projects In Nigeria [Journal] // Navorsingsartikels • Research Articles. - 2018. - P. 40.

Dosumu Oluwaseun Sunday And Adenuga Olumide Afolarin Causes, Effects And Remedies Of Errors In Nigerian Construction Documents [Journal] // Organization, Technology And Management In Construction · An International Journal · 5(1)2013686. - 2013. - Pp. 676-686.

Eliyas Sahle Review On Lack Of Integration In Design And Construction Phases Of Building Projects And The Effect Of Constructability (A Case Study On Selected Public Buildings In Addis Ababa) [Journal] // Aau, Aait, School Of Civil And Environmental Engineering Msc Thesis. - 2016.

Engineers Australia Getting It Right The First Time [Report]. - Queensland : Engineers Australia, 2005.

Ethiopian Roads Authority, Manuals on Geometric Design, Ethiopia, 2002 and 2013.

Ethiopian Roads Authority, Works Contract Administeration Manual, Ethiopia, 2014.

Etefa Deribachew Mezgebu Road Design Projects In Ethiopia [Report]. - Addis Ababa : Era, 2016.

Focus Africa Focus Africa [Report]. - Johanes Busg : Focus Africa, 2016.

Guru99 [Blog], United Kingdom; www.guru99.com, 2018

Halwatura, R. U., And Ranasinghe, N. P. Causes Of Variation Orders In Road Construction Projects In Sri Lanka. Isrn Construction Engineering, [Journal] // International Journal Of Construction Engineering And Management. - 2013.

Hamzah Abdul-Rahman Impacts Of Design Changes On Construction Project Performance: Insights From A Literature Review [Conference] // Construction Management In Construction Research Association Conference And Annual General Meeting. - Kuala Lumpur, Malaysia : Micra, 2015. - P. 1.

Jeffrey Boon Hui Yap, Hamzah Abdul-Rahman And Chen Wang A Conceptual Framework For Managing Design Changes In Building Construction [Journal] // Conference Paper In Matec Web Of Conferences . - 2016.

Karim Hawzheen And Magnusson Rolf Road Design For Future Maintenance Problems [Journal] // Journal Of Transportation Engineering ©Asce. - 2008. - P. 523.

Kassa Yenealem Fentahun Determinants Of Infrastructure Project Delays And Cost Escalations. The Case Of Road And Rail Construction Projects In Ethiopia [Journal] // College Of Business And Economics Department Of Public Administration And Development Management, Addis Ababa University. - 2018.

Koushki P A, Al-Rashid K And Kartam N. Delays And Cost Increases In The Construction Of Private Residential Projects In Kuwait' . [Book Section] // Construction Management And Economics / Book Auth. Koushki P.A. Al-Rashid K & Kartam, N. - Kuwait : Kuwait, 2005.

Memon A. H., Rahman I.A. And Abdul Hassan M.F .Signifcant Causes Of Effects Of Variation Orders In Construction Projects. [Journal] // Journal Of Applied Sciences, Engineering And Technology. - 2014. - Pp. 4494-4502.

Merima H. Technical Assistance For Modernisation Of The Ethiopian Roads Authority Through Better Contract And Project Management Practices [Report] / Era. - Addis Ababa, Ethiopia : Smec, 2018.

Muhammad Nasiru Zakari [Et Al.] Causes Of Variation Order In Building And Civil Engineering Projects In Nigeria [Journal] // Journal Technology. - 2015.

Nicholas Chileshe And Berko Paul Danso Causes Of Project Cost Overruns Within The Ghanaian Road Construction Sector [Conference] // Proceedings 5th Built Environment Conference. - Durban, South Africa : Isbn: 978-0-620-46703-2, 2010. - P. 72.

Nirajan Mani Impact Of Design Cost On Project Performance Of Design Bid Build Projects [Journal] // Master Of Science In Construction Management, University Of Nevada, Las Vegas. - 2011. - P. 4.

Oluwaseun Dosumu And Clinton Aigbavboa Impact Of Design Errors On Variation Cost Of Selected Building Project In Nigeria [Journal] // Creative Construction Conference. - 2017.

Oluwaseun Dosumu And Clinton Aigbavboa An Assessment Of The Causes, Cost Effects And Solutions To Design-Errorinduced Variations On Selected Building Projects In Nigeria [Journal] // Navorsingsartikels • Research Articles. - 2018. - P. 40.

Richard C Fries Reliability Design Of Medical Devices [Book]. - Baco Raton : Crc Press, 2016.

Rukn Eldeen Mohammed An Exploratory System Dynamics Model To Investigate The Relationships Between Errors That Occur In Construction Documents In Saudi Arabia And Their Possible Causes [Journal] // Submitted For The Degree Of Doctor Of Philosophy, Heriot-Watt University School Of The Built Environment. - 2007.

Sileshi Ambachew Assessment On Design Managment Practices Of National Consultant [Journal] // Msc. Thesis In Construction Tech. & Management, Addis Ababa University. - 2018. - P. 1.

Tadesse Ayalew Causes And Effects Of Variations In Ethiopian Federal Road Projects [Journal] // Msc. Thesis, Addis Ababa University School Of Civil And Environmental Engineering, Ethiopia. - 2009.

Tariku Rahel Project Delivery Systems And Their Effects On Cost And Time Overrun On Ethiopian Road Authority Projects [Journal] // Thesis Submitted To The School Of Graduate Studies Of Addis Ababa University, Faculty Of Technology. - 2016. - P. 65.

Tsegaye Getachew, Design Risk management in Ethiopian Federal Road Projects [Report]. Addis Ababa : Addis Ababa University, 2009.

Turkey Wakjira Risk Factors Leading To Cost Overrun In Ethiopian Federal Road Construction Projects And Its Consequences [Journal] // A Thesis Submitted To The School Of Graduate Studies Of Addis Ababa University In Partial Fulfillment Of The Requirements For The Degree Of Master Of Science In Civil Engineering (Construction Technology And Management). - Addis Ababa : Aau, 2011. - P. 92.

Ukessays The-Participants-Ofconstruction-Projects-Construction [Report]. - [S.L.] : Online, 2014.

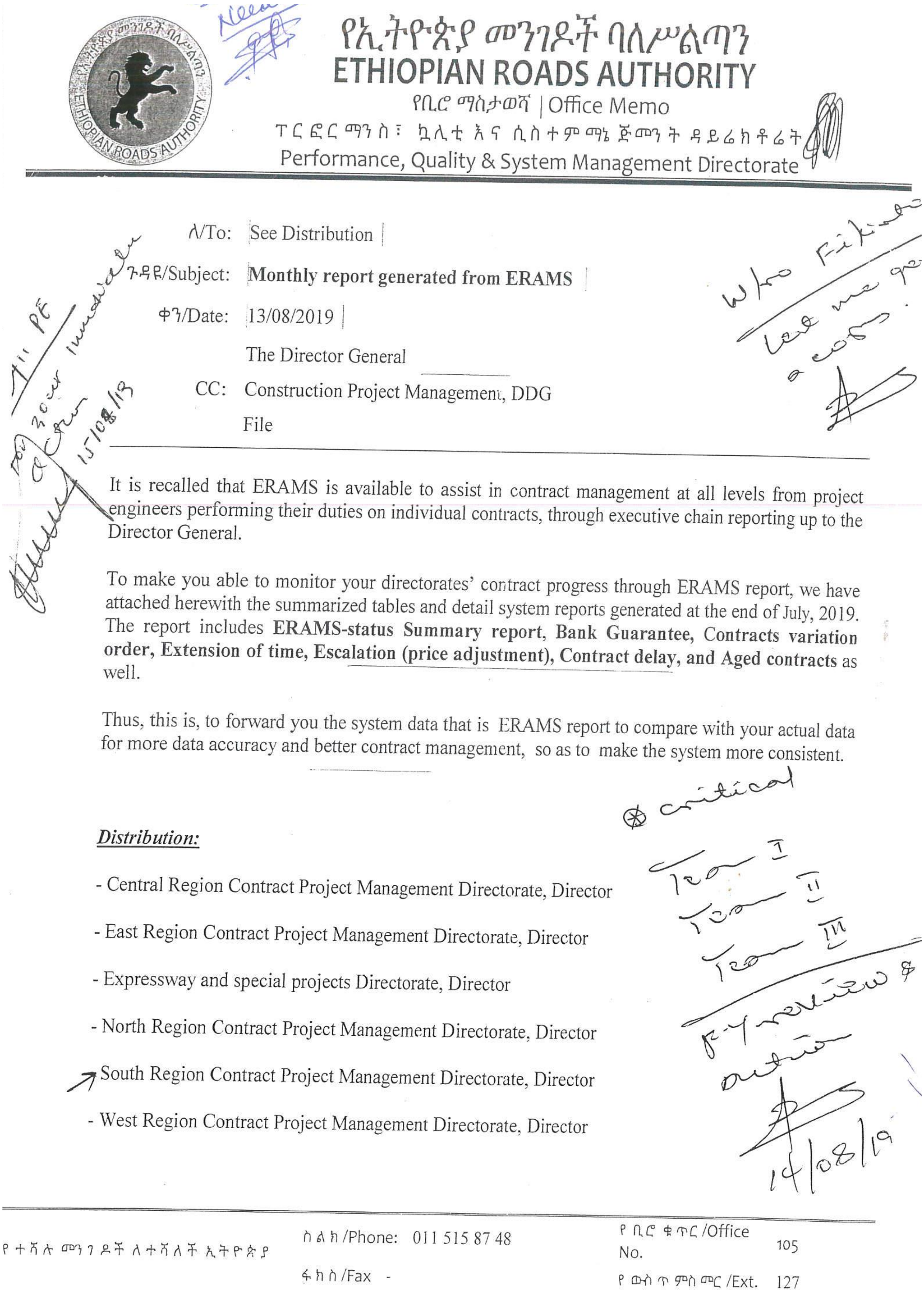
Woldesenbet Asregedew , Hyung Seok Jeong And Kirk Goins Procedure And Models For Estimating Preconstruction Costs Of Highway [Report]. - Oklahoma : School Of Civil & Environmental Engineering Oklahoma State University, 2012.

Yunus Nurul Uyun Bt Mohd Variation Control Affecteing Construction Works For Felda, [Journal] // Thesis. - 2007.

Zewdu Tewodros Causes And Effects Of Variation Orders In Road Construction Projects: The Case Of National Works Contract Administered By Addis Ababa City Roads Authority. [Journal] // Partial Fulfillment Of The Requirements For The Degree Of Master Of Science In Construction Technology And Management.. - 2015. - P. 43.

Annex - I

Ethiopian Roads Authority Management System (ERAMS) Database Extraction for the population and study area in the sampling frame



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ETHIOPIAN ROADS AUTHORITY

የቢሮ ማስታወሻ | Office Memo

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Performance, Quality & System Management Directorate

ለ/To: See Distribution

ጉዳዩ/Subject: **Monthly report generated from ERAMS**

ቀን/Date: 13/08/2019

The Director General

CC: Construction Project Management, DDG

File

W/ro Filimon
let me get a copy.

All PE
for your immediate action
15/08/13

It is recalled that ERAMS is available to assist in contract management at all levels from project engineers performing their duties on individual contracts, through executive chain reporting up to the Director General.

To make you able to monitor your directorates' contract progress through ERAMS report, we have attached herewith the summarized tables and detail system reports generated at the end of July, 2019. The report includes **ERAMS-status Summary report, Bank Guarantee, Contracts variation order, Extension of time, Escalation (price adjustment), Contract delay, and Aged contracts** as well.

Thus, this is, to forward you the system data that is ERAMS report to compare with your actual data for more data accuracy and better contract management, so as to make the system more consistent.

*critical

Distribution:

- Central Region Contract Project Management Directorate, Director
- East Region Contract Project Management Directorate, Director
- Expressway and special projects Directorate, Director
- North Region Contract Project Management Directorate, Director
- South Region Contract Project Management Directorate, Director
- West Region Contract Project Management Directorate, Director

Team I
Team II
Team III
For review &
action
14/08/19

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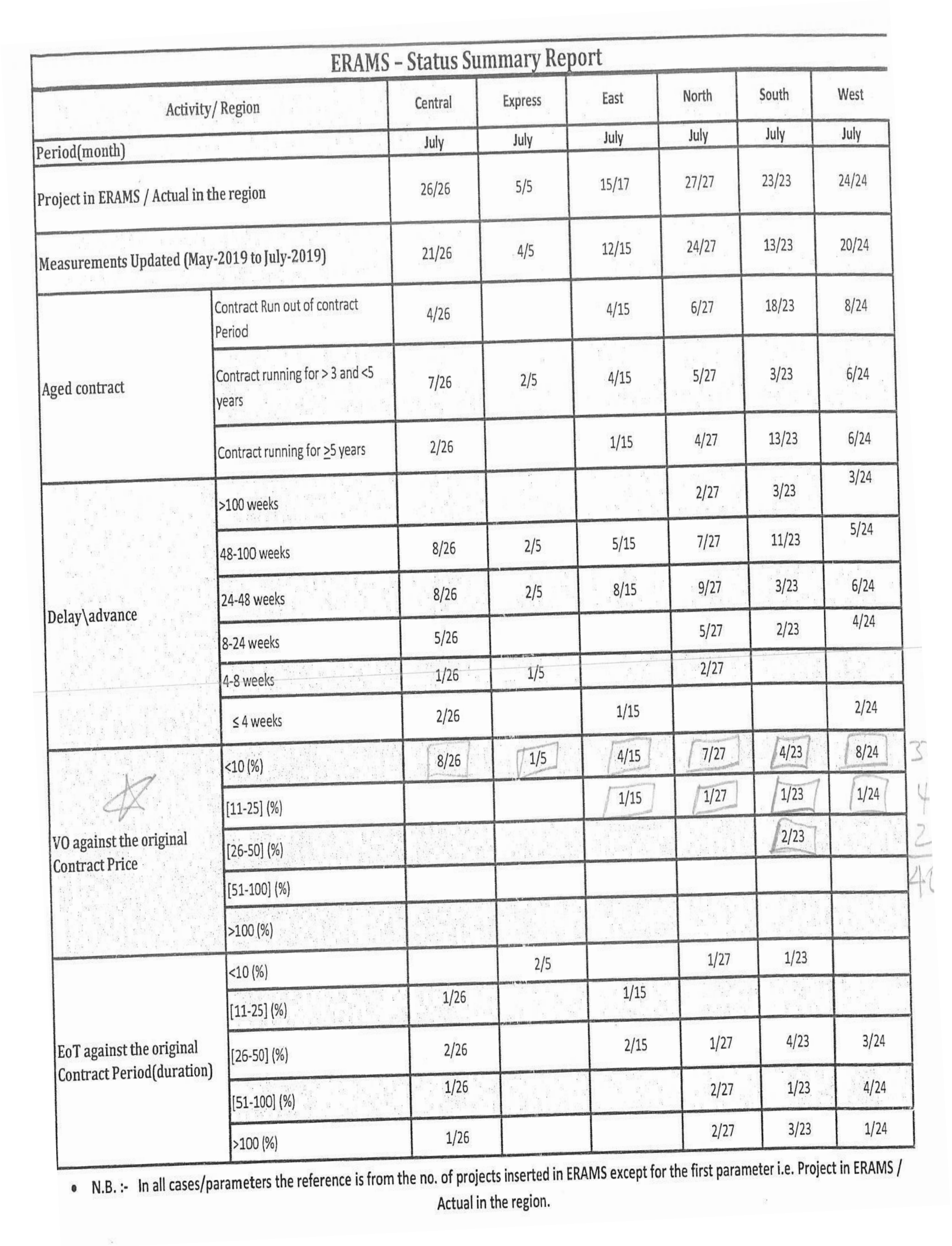


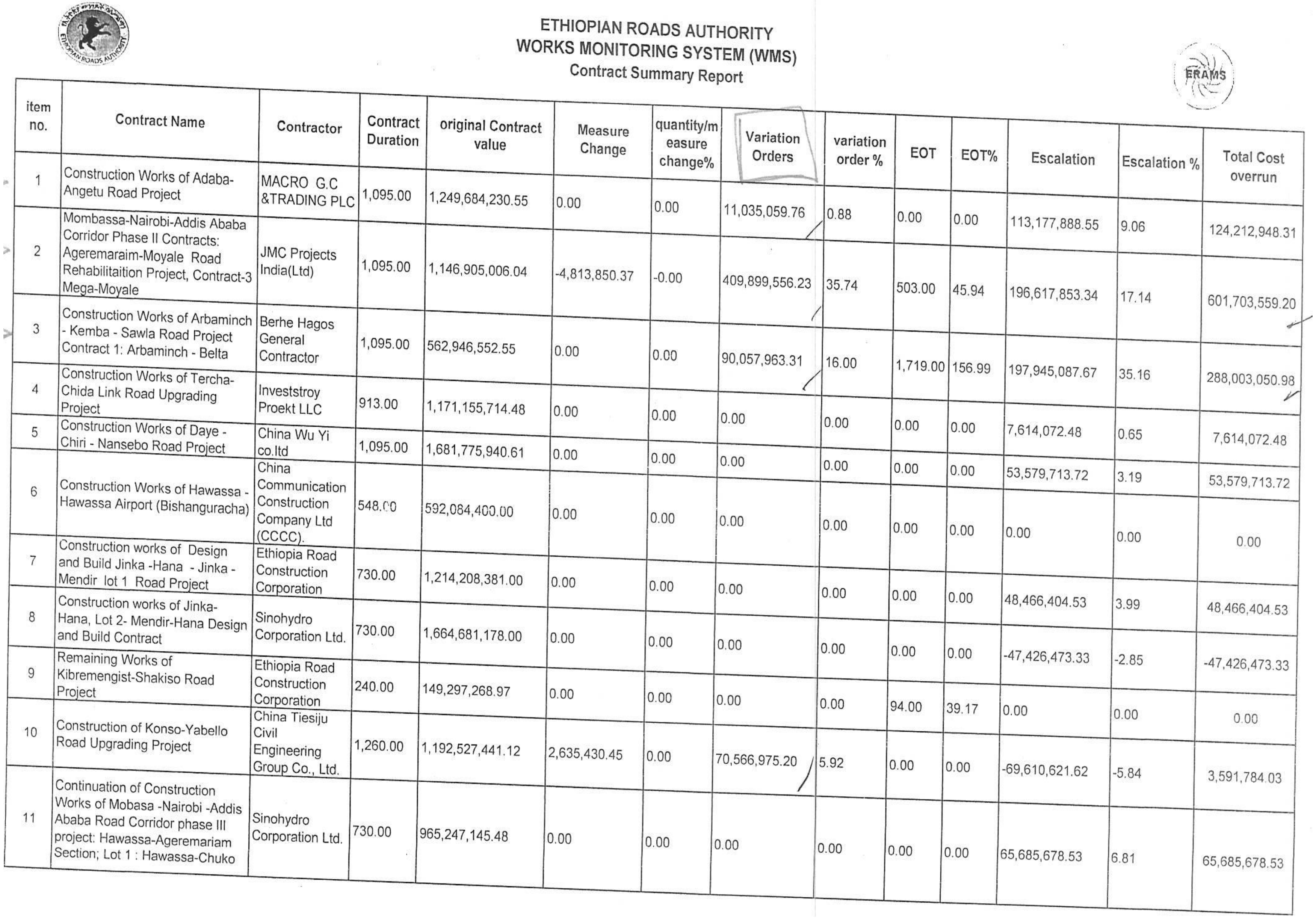
ERAMS – Status Summary Report

Activity/ Region		Central	Express	East	North	South	West	
Period(month)		July	July	July	July	July	July	
Project in ERAMS / Actual in the region		26/26	5/5	15/17	27/27	23/23	24/24	
Measurements Updated (May-2019 to July-2019)		21/26	4/5	12/15	24/27	13/23	20/24	
Aged contract	Contract Run out of contract Period	4/26		4/15	6/27	18/23	8/24	
	Contract running for > 3 and <5 years	7/26	2/5	4/15	5/27	3/23	6/24	
	Contract running for ≥5 years	2/26		1/15	4/27	13/23	6/24	
Delay\advance	>100 weeks				2/27	3/23	3/24	
	48-100 weeks	8/26	2/5	5/15	7/27	11/23	5/24	
	24-48 weeks	8/26	2/5	8/15	9/27	3/23	6/24	
	8-24 weeks	5/26			5/27	2/23	4/24	
	4-8 weeks	1/26	1/5		2/27			
	≤ 4 weeks	2/26		1/15			2/24	
VO against the original Contract Price	<10 (%)	8/26	1/5	4/15	7/27	4/23	8/24	3
	[11-25] (%)			1/15	1/27	1/23	1/24	4
	[26-50] (%)					2/23		2
	[51-100] (%)							4
	>100 (%)							
EoT against the original Contract Period(duration)	<10 (%)		2/5		1/27	1/23		
	[11-25] (%)	1/26		1/15				
	[26-50] (%)	2/26		2/15	1/27	4/23	3/24	
	[51-100] (%)	1/26			2/27	1/23	4/24	
	>100 (%)	1/26			2/27	3/23	1/24	

- N.B. :- In all cases/parameters the reference is from the no. of projects inserted in ERAMS except for the first parameter i.e. Project in ERAMS / Actual in the region.

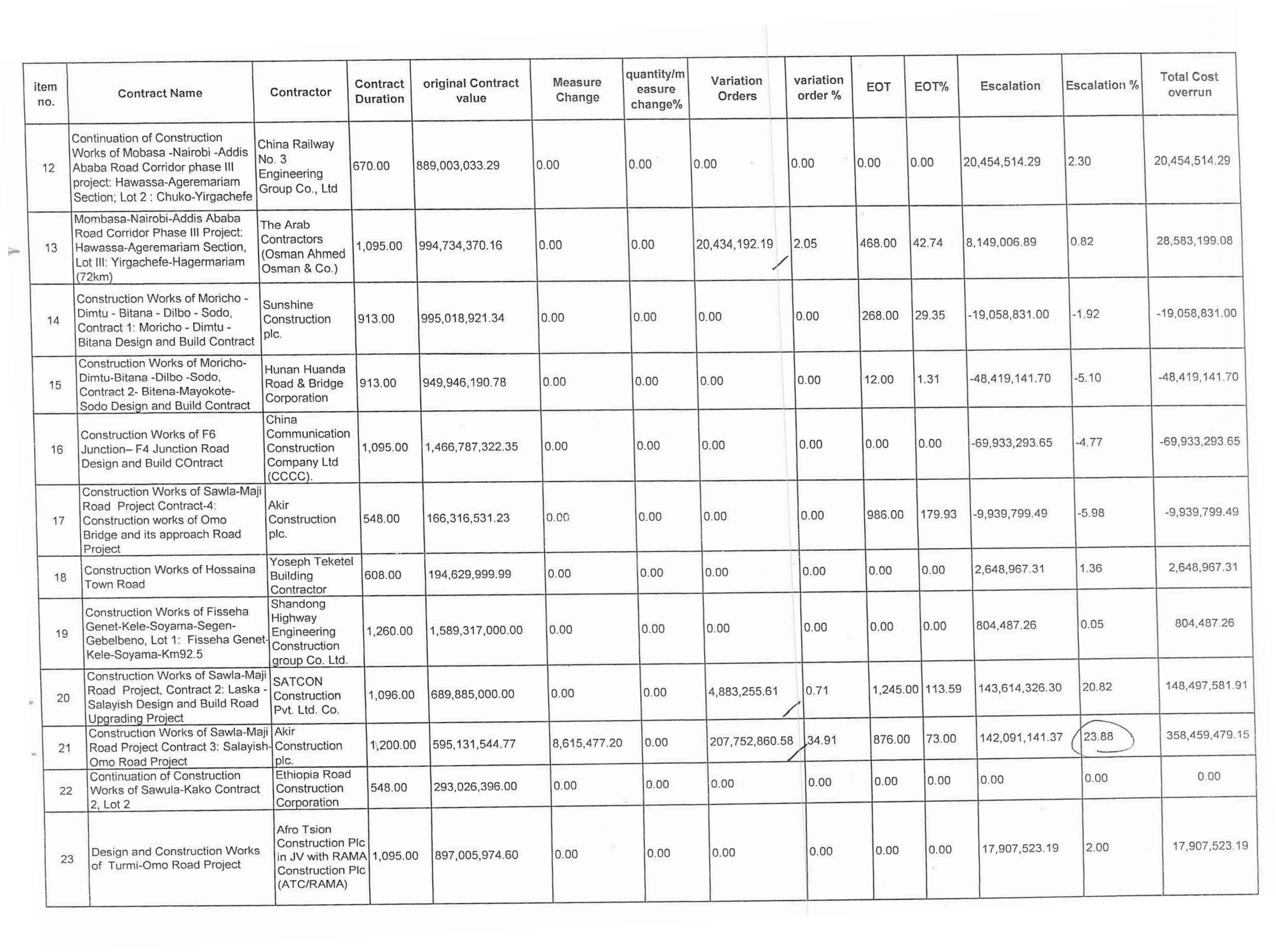
ETHIOPIAN ROADS AUTHORITY
Guarantee Status Information
Contracts with Guarantees Report

Directorate	Contract Name	Provider	Type	Start Date	End Date	Amount	Days left	Remark
South	Construction Works of Arbaminch - Kemba - Sawla Road Project Contract 1: Arbaminch - Belta	NIB Insurance Company	Advance Payment Guarantee	05-Mar-10	04-Mar-13	101,310,753.4	-2319.49	
South	Construction Works of Arbaminch - Kemba - Sawla Road Project Contract 1: Arbaminch - Belta	NIB Insurance Company	Advance Payment Guarantee	05-Nov-12	04-Jun-13	36,403,848.0	-2227.49	
South	Construction Works of Arbaminch - Kemba - Sawla Road Project Contract 1: Arbaminch - Belta	NIB Insurance Company	Performance Bond/Guarantee	19-Feb-10	09-Feb-14	56,294,655.3	-1977.49	
South	Construction Works of Arbaminch - Kemba - Sawla Road Project Contract 1: Arbaminch - Belta	Dashen Bank S.C	Retention Money Guarantee	18-Jul-13	17-Jul-15	10,758,177.6	-1454.49	
South	Mombasa-Nairobi-Addis Ababa Road Corridor Phase III Project: Hawassa-Ageremariam Section, Lot III: Yirgachefe-Hagermariam (72km)	Commercial Bank of Ethiopia	Advance Payment Guarantee	17-Jan-13	31-Aug-15	185,418,461.0	-1409.49	
South	Construction Works of Arbaminch - Kemba - Sawla Road Project Contract 1: Arbaminch - Belta	NIB Insurance Company	Advance Payment Guarantee	10-Oct-14	10-Oct-15	38,427,172.9	-1369.49	
South	Construction works of Jinka-Hana, Lot 2- Mendir-Hana Design and Build Contract	NIB Insurance Company	Professional Indemnity	07-Jul-15	04-Jan-16	66,587,247.0	-1283.49	
South	Construction Works of Sawla-Maji Road Project Contract 1: Sawla -Laska	Commercial Bank of Ethiopia	Advance Payment Guarantee	24-Jan-15	23-Jan-16	16,220,000.0	-1264.49	
South	Construction Works of Arbaminch - Kemba - Sawla Road Project Contract 1: Arbaminch - Belta	Abay Bank	Retention Money Guarantee	04-Feb-15	04-Feb-16	6,266,010.8	-1252.49	
South	Construction Works of Arbaminch - Kemba - Sawla Road Project Contract 1: Arbaminch - Belta	NIB Insurance Company	Advance Payment Guarantee	20-Jan-15	12-Feb-16	24,000,000.0	-1244.49	
South	Construction Works of Arbaminch - Kemba - Sawla Road Project Contract 1: Arbaminch - Belta	NIB Insurance Company	Advance Payment Guarantee	20-Jan-15	12-Feb-16	24,000,000.0	-1244.49	
South	Consultancy Services for Construction Supervision of Arbaminch-Kemba-Sawla lot III: Otolo-Sawla	Abay Bank	Retention Money Guarantee	14-Mar-16	14-Jun-16	4,000,000.0	-1121.49	
South	Construction Works of Arbaminch - Kemba - Sawla Road Project Contract 1: Arbaminch - Belta	Debub Global Bank S.C	Retention Money Guarantee	12-Jan-16	19-Jun-16	10,758,177.6	-1116.49	
South	Construction works of Jinka-Hana, Lot 2- Mendir-Hana Design and Build Contract	Lion Insurance Company S.C	Contractor's Plant and Machinery	17-Jul-15	16-Jul-16	180,781,036.0	-1089.49	
South	Construction Works of Sawla-Maji Road Project Contract 1: Sawla -Laska	The United Insurance Company S.C	Advance Payment Guarantee	27-Feb-15	26-Aug-16	20,000,000.0	-1048.49	
South	Mombasa-Nairobi-Addis Ababa Road Corridor Phase III Project: Hawassa-Ageremariam Section, Lot III: Yirgachefe-Hagermariam (72km)	Commercial Bank of Ethiopia	Advance Payment Guarantee	06-Aug-15	31-Aug-16	185,418,461.0	-1043.49	
South	Mombasa-Nairobi-Addis Ababa Road Corridor Phase III Project: Hawassa-Ageremariam Section, Lot III: Yirgachefe-Hagermariam (72km)	Commercial Bank of Ethiopia	Advance Payment Guarantee	06-Aug-15	31-Aug-16	185,418,461.0	-1043.49	
South	Construction works of Jinka-Hana, Lot 2- Mendir-Hana Design and Build Contract	Lion Insurance Company S.C	Contractor's Workmen Compensation	27-Jun-15	04-Jan-17	26,100,000.0	-917.49	
South	Construction works of Jinka-Hana, Lot 2- Mendir-Hana Design and Build Contract	NIB Insurance Company	Contractor's All Risk Policy	07-Jul-15	04-Jan-17	1,831,149,295.8	-917.49	Expired
South	Construction Works of Arbaminch - Kemba - Sawla Road Project Contract 1: Arbaminch - Belta	NIB Insurance Company	Performance Bond/Guarantee	27-Jan-15	25-Feb-17	56,294,655.3	-865.49	
South	Construction Works of Arbaminch - Kemba - Sawla Road Project Contract 1: Arbaminch - Belta	Abay Bank	Retention Money Guarantee	09-Mar-16	09-Mar-17	6,266,010.8	-853.49	
South	Mombassa-Nairobi-Addis Ababa Corridor Phase II Contracts: Ageremaraim-Moyale Road Rehabilitaition Project, Contract-3 Mega-Moyale	Commercial Bank of Ethiopia	Performance Bond/Guarantee	23-Feb-13	19-Mar-17	84,469,553.7	-843.49	
South	Mombassa-Nairobi-Addis Ababa Corridor Phase II Contracts: Ageremaraim-Moyale Road Rehabilitaition Project, Contract-3 Mega-Moyale	Commercial Bank of Ethiopia	Performance Bond/Guarantee	27-Feb-13	23-Mar-17	30,220,947.0	-839.49	
South	Construction Works of Moricho - Dimtu - Bitana - Dilbo - Sodo, Contract 1: Moricho - Dimtu - Bitana Design and Build Contract	United Bank S.C	Performance Bond/Guarantee	25-Sep-14	24-Mar-17	99,501,892.1	-838.49	
South	Construction Works of Sawla-Maji Road Project Contract-4: Construction works of Omo Bridge and its approach Road Project	Lion Insurance Company S.C	Advance Payment Guarantee	23-Oct-14	22-Apr-17	29,819,632.9	-809.49	
South	Construction Works of Sawla-Maji Road Project Contract-4: Construction works of Omo Bridge and its approach Road Project	Lion Insurance Company S.C	Performance Bond/Guarantee	23-Apr-15	22-Apr-17	16,631,653.1	-809.49	
South	Mombasa-Nairobi-Addis Ababa Road Corridor Phase III Project: Hawassa-Ageremariam Section, Lot III: Yirgachefe-Hagermariam (72km)	Commercial Bank of Ethiopia	Performance Bond/Guarantee	30-Nov-12	22-Apr-17	99,478,710.4	-809.49	
South	Construction Works of Moricho-Dimtu-Bitana -Dilbo -Sodo, Contract 2- Bitena-Mayokote-Sodo Design and Build Contract	Africa Insurance S.C	Contractor's Workmen Compensation	03-Feb-15	25-May-17	3,445,200.0	-776.49	
South	Construction Works of Sawla-Maji Road Project, Contract 2: Laska - Salayish Design and Build Road Upgrading Project	United Bank S.C	Advance Payment Guarantee	31-Jul-15	01-Aug-17	21,000,000.0	-708.49	
South	Construction Works of Sawla-Maji Road Project, Contract 2: Laska - Salayish Design and Build Road Upgrading Project	United Bank S.C	Performance Bond/Guarantee	21-Jun-11	01-Aug-17	68,988,500.0	-708.49	
South	Continuation of Construction Supervision of Consultancy Service for construction supervision of Sawla-Maji Road Project Contract 3 : Salayish-Omo Road Project	Abay Bank	Retention Money Guarantee	16-Aug-16	17-Aug-17	334,451,283.7	-692.49	
South	Construction Works of F6 Junction– F4 Junction Road Design and Build COntract	Ethiopian Insurance Corporation	Professional Indemnity	02-Sep-15	30-Aug-17	29,335,746.5	-679.49	
South	Construction Works of F6 Junction– F4 Junction Road Design and Build COntract	Commercial Bank of Ethiopia	Performance Bond/Guarantee	23-Jun-14	31-Aug-17	146,654,582.2	-678.49	
South	Construction Works of F6 Junction– F4 Junction Road Design and Build COntract	Commercial Bank of Ethiopia	Advance Payment Guarantee	23-Jun-14	31-Aug-17	293,309,164.5	-678.49	
South	Consultancy Service for Construction Supervision of Tercha-Chida Link Road Upgrading Project	Abay Bank	Advance Payment Guarantee	12-May-17	21-Dec-17	1,833,152.7	-566.49	
South	Consultancy Services for the Construction Supervision of Adaba-Angetu Road Project	Tsehay Insurance S.C.	Advance Payment Guarantee	30-Dec-14	29-Dec-17	1,994,790.0	-558.49	
South	Construction Works of F6 Junction– F4 Junction Road Design and Build COntract	Ethiopian Insurance Corporation	Contractor's All Risk Policy	15-Jul-15	30-Dec-17	1,466,787,322.4	557.49	

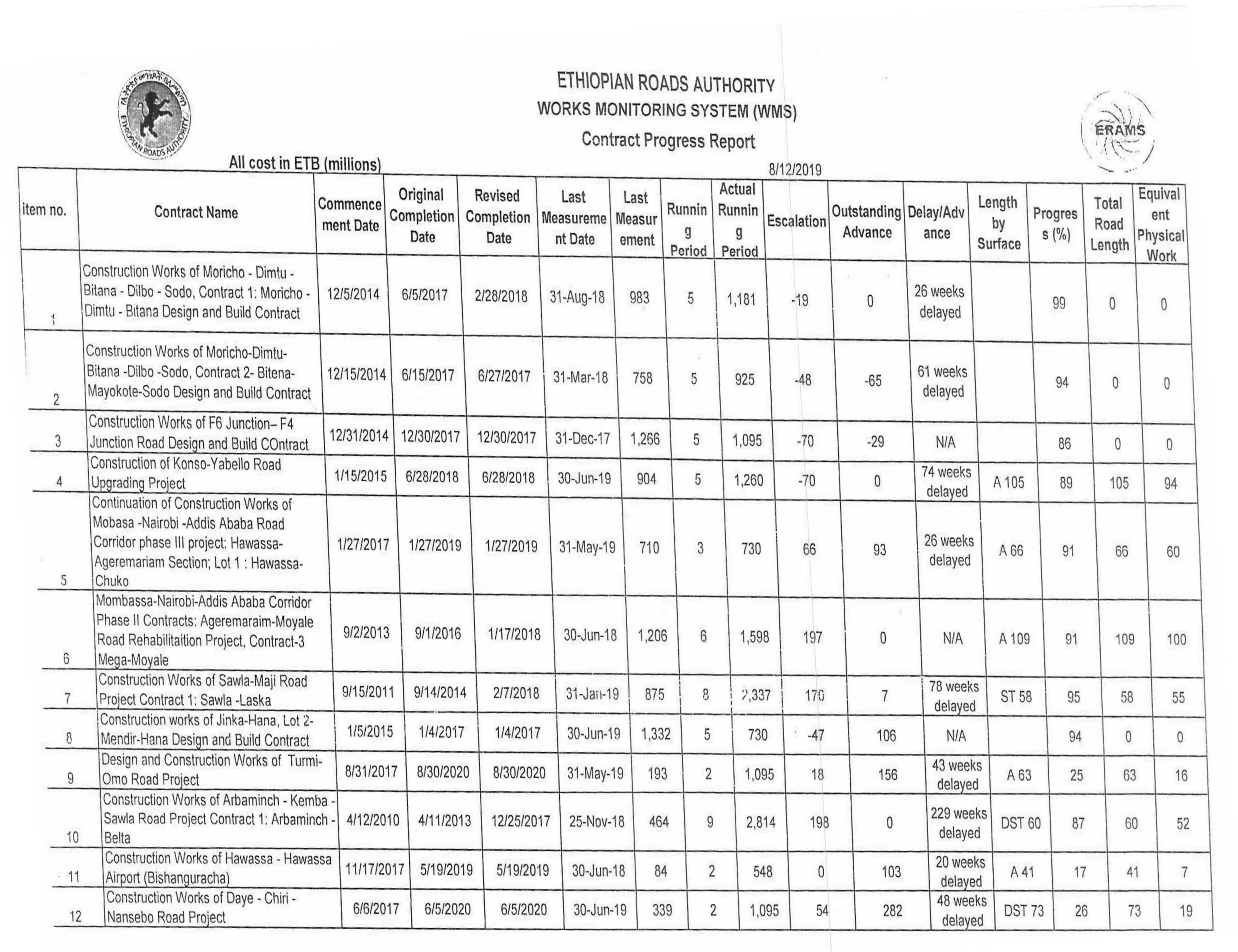


ETHIOPIAN ROADS AUTHORITY
WORKS MONITORING SYSTEM (WMS)
Contract Summary Report

item no.	Contract Name	Contractor	Contract Duration	original Contract value	Measure Change	quantity/measure change%	Variation Orders	variation order %	EOT	EOT%	Escalation	Escalation %	Total Cost overrun
1	Construction Works of Adaba-Angetu Road Project	MACRO G.C &TRADING PLC	1,095.00	1,249,684,230.55	0.00	0.00	11,035,059.76	0.88	0.00	0.00	113,177,888.55	9.06	124,212,948.31
2	Mombassa-Nairobi-Addis Ababa Corridor Phase II Contracts: Ageremaraim-Moyale Road Rehabilitaition Project, Contract-3 Mega-Moyale	JMC Projects India(Ltd)	1,095.00	1,146,905,006.04	-4,813,850.37	-0.00	409,899,556.23	35.74	503.00	45.94	196,617,853.34	17.14	601,703,559.20
3	Construction Works of Arbaminch - Kemba - Sawla Road Project Contract 1: Arbaminch - Belta	Berhe Hagos General Contractor	1,095.00	562,946,552.55	0.00	0.00	90,057,963.31	16.00	1,719.00	156.99	197,945,087.67	35.16	288,003,050.98
4	Construction Works of Tercha-Chida Link Road Upgrading Project	Investstroy Proekt LLC	913.00	1,171,155,714.48	0.00	0.00	0.00	0.00	0.00	0.00	7,614,072.48	0.65	7,614,072.48
5	Construction Works of Daye - Chiri - Nansebo Road Project	China Wu Yi co.ltd	1,095.00	1,681,775,940.61	0.00	0.00	0.00	0.00	0.00	0.00	53,579,713.72	3.19	53,579,713.72
6	Construction Works of Hawassa - Hawassa Airport (Bishanguracha)	China Communication Construction Company Ltd (CCCC).	548.00	592,084,400.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7	Construction works of Design and Build Jinka -Hana - Jinka - Mendir lot 1 Road Project	Ethiopia Road Construction Corporation	730.00	1,214,208,381.00	0.00	0.00	0.00	0.00	0.00	0.00	48,466,404.53	3.99	48,466,404.53
8	Construction works of Jinka-Hana, Lot 2- Mendir-Hana Design and Build Contract	Sinohydro Corporation Ltd.	730.00	1,664,681,178.00	0.00	0.00	0.00	0.00	0.00	0.00	-47,426,473.33	-2.85	-47,426,473.33
9	Remaining Works of Kibremengist-Shakiso Road Project	Ethiopia Road Construction Corporation	240.00	149,297,268.97	0.00	0.00	0.00	0.00	94.00	39.17	0.00	0.00	0.00
10	Construction of Konso-Yabello Road Upgrading Project	China Tiesiju Civil Engineering Group Co., Ltd.	1,260.00	1,192,527,441.12	2,635,430.45	0.00	70,566,975.20	5.92	0.00	0.00	-69,610,621.62	-5.84	3,591,784.03
11	Continuation of Construction Works of Mobasa -Nairobi -Addis Ababa Road Corridor phase III project: Hawassa-Ageremariam Section; Lot 1 : Hawassa-Chuko	Sinohydro Corporation Ltd.	730.00	965,247,145.48	0.00	0.00	0.00	0.00	0.00	0.00	65,685,678.53	6.81	65,685,678.53



item no.	Contract Name	Contractor	Contract Duration	original Contract value	Measure Change	quantity/measure change%	Variation Orders	variation order %	EOT	EOT%	Escalation	Escalation %	Total Cost overrun
12	Continuation of Construction Works of Mobasa -Nairobi -Addis Ababa Road Corridor phase III project: Hawassa-Ageremariam Section; Lot 2 : Chuko-Yirgachefe	China Railway No. 3 Engineering Group Co., Ltd	670.00	889,003,033.29	0.00	0.00	0.00	0.00	0.00	0.00	20,454,514.29	2.30	20,454,514.29
13	Mombasa-Nairobi-Addis Ababa Road Corridor Phase III Project: Hawassa-Ageremariam Section, Lot III: Yirgachefe-Hagermariam (72km)	The Arab Contractors (Osman Ahmed Osman & Co.)	1,095.00	994,734,370.16	0.00	0.00	20,434,192.19	2.05	468.00	42.74	8,149,006.89	0.82	28,583,199.08
14	Construction Works of Moricho - Dimtu - Bitana - Dilbo - Sodo, Contract 1: Moricho - Dimtu - Bitana Design and Build Contract	Sunshine Construction plc.	913.00	995,018,921.34	0.00	0.00	0.00	0.00	268.00	29.35	-19,058,831.00	-1.92	-19,058,831.00
15	Construction Works of Moricho-Dimtu-Bitana -Dilbo -Sodo, Contract 2- Bitena-Mayokote-Sodo Design and Build Contract	Hunan Huanda Road & Bridge Corporation	913.00	949,946,190.78	0.00	0.00	0.00	0.00	12.00	1.31	-48,419,141.70	-5.10	-48,419,141.70
16	Construction Works of F6 Junction– F4 Junction Road Design and Build COntract	China Communication Construction Company Ltd (CCCC).	1,095.00	1,466,787,322.35	0.00	0.00	0.00	0.00	0.00	0.00	-69,933,293.65	-4.77	-69,933,293.65
17	Construction Works of Sawla-Maji Road Project Contract-4: Construction works of Omo Bridge and its approach Road Project	Akir Construction plc.	548.00	166,316,531.23	0.00	0.00	0.00	0.00	986.00	179.93	-9,939,799.49	-5.98	-9,939,799.49
18	Construction Works of Hossaina Town Road	Yoseph Teketel Building Contractor	608.00	194,629,999.99	0.00	0.00	0.00	0.00	0.00	0.00	2,648,967.31	1.36	2,648,967.31
19	Construction Works of Fisseha Genet-Kele-Soyama-Segen-Gebelbeno, Lot 1: Fisseha Genet-Kele-Soyama-Km92.5	Shandong Highway Engineering Construction group Co. Ltd.	1,260.00	1,589,317,000.00	0.00	0.00	0.00	0.00	0.00	0.00	804,487.26	0.05	804,487.26
20	Construction Works of Sawla-Maji Road Project, Contract 2: Laska - Salayish Design and Build Road Upgrading Project	SATCON Construction Pvt. Ltd. Co.	1,096.00	689,885,000.00	0.00	0.00	4,883,255.61	0.71	1,245.00	113.59	143,614,326.30	20.82	148,497,581.91
21	Construction Works of Sawla-Maji Road Project Contract 3: Salayish-Omo Road Project	Akir Construction plc.	1,200.00	595,131,544.77	8,615,477.20	0.00	207,752,860.58	34.91	876.00	73.00	142,091,141.37	23.88	358,459,479.15
22	Continuation of Construction Works of Sawula-Kako Contract 2, Lot 2	Ethiopia Road Construction Corporation	548.00	293,026,396.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
23	Design and Construction Works of Turmi-Omo Road Project	Afro Tsion Construction Plc in JV with RAMA Construction Plc (ATC/RAMA)	1,095.00	897,005,974.60	0.00	0.00	0.00	0.00	0.00	0.00	17,907,523.19	2.00	17,907,523.19



ETHIOPIAN ROADS AUTHORITY

WORKS MONITORING SYSTEM (WMS)

Contract Progress Report

All cost in ETB (millions)

8/12/2019

item no.	Contract Name	Commencement Date	Original Completion Date	Revised Completion Date	Last Measurement Date	Last Measurement	Running Period	Actual Running Period	Escalation	Outstanding Advance	Delay/Advance	Length by Surface	Progress (%)	Total Road Length	Equivalent Physical Work
1	Construction Works of Moricho - Dimtu - Bitana - Dilbo - Sodo, Contract 1: Moricho - Dimtu - Bitana Design and Build Contract	12/5/2014	6/5/2017	2/28/2018	31-Aug-18	983	5	1,181	-19	0	26 weeks delayed		99	0	0
2	Construction Works of Moricho-Dimtu-Bitana -Dilbo -Sodo, Contract 2- Bitena-Mayokote-Sodo Design and Build Contract	12/15/2014	6/15/2017	6/27/2017	31-Mar-18	758	5	925	-48	-65	61 weeks delayed		94	0	0
3	Construction Works of F6 Junction– F4 Junction Road Design and Build COntract	12/31/2014	12/30/2017	12/30/2017	31-Dec-17	1,266	5	1,095	-70	-29	N/A		86	0	0
4	Construction of Konso-Yabello Road Upgrading Project	1/15/2015	6/28/2018	6/28/2018	30-Jun-19	904	5	1,260	-70	0	74 weeks delayed	A 105	89	105	94
5	Continuation of Construction Works of Mobasa -Nairobi -Addis Ababa Road Corridor phase III project: Hawassa-Ageremariam Section; Lot 1 : Hawassa-Chuko	1/27/2017	1/27/2019	1/27/2019	31-May-19	710	3	730	66	93	26 weeks delayed	A 66	91	66	60
6	Mombassa-Nairobi-Addis Ababa Corridor Phase II Contracts: Ageremaraim-Moyale Road Rehabilitaition Project, Contract-3 Mega-Moyale	9/2/2013	9/1/2016	1/17/2018	30-Jun-18	1,206	6	1,598	197	0	N/A	A 109	91	109	100
7	Construction Works of Sawla-Maji Road Project Contract 1: Sawla -Laska	9/15/2011	9/14/2014	2/7/2018	31-Jan-19	875	8	2,337	170	7	78 weeks delayed	ST 58	95	58	55
8	Construction works of Jinka-Hana, Lot 2-Mendir-Hana Design and Build Contract	1/5/2015	1/4/2017	1/4/2017	30-Jun-19	1,332	5	730	-47	106	N/A		94	0	0
9	Design and Construction Works of Turmi-Omo Road Project	8/31/2017	8/30/2020	8/30/2020	31-May-19	193	2	1,095	18	156	43 weeks delayed	A 63	25	63	16
10	Construction Works of Arbaminch - Kemba - Sawla Road Project Contract 1: Arbaminch - Belta	4/12/2010	4/11/2013	12/25/2017	25-Nov-18	464	9	2,814	198	0	229 weeks delayed	DST 60	87	60	52
11	Construction Works of Hawassa - Hawassa Airport (Bishanguracha)	11/17/2017	5/19/2019	5/19/2019	30-Jun-18	84	2	548	0	103	20 weeks delayed	A 41	17	41	7
12	Construction Works of Daye - Chiri - Nansebo Road Project	6/6/2017	6/5/2020	6/5/2020	30-Jun-19	339	2	1,095	54	282	48 weeks delayed	DST 73	26	73	19

item no.	Contract Name	Commencement Date	Original Completion Date	Revised Completion Date	Last Measurement Date	Last Measurement	Running Period	Actual Running Period	Escalation	Outstanding Advance	Delay/Advance	Length by Surface	Progress (%)	Total Road Length	Equivalent Physical Work
13	Construction Works of Adaba-Angetu Road Project	11/18/2014	11/17/2017	11/17/2017	31-May-19	613	5	1,095	113	33	117 weeks delayed	DST 102	62	102	63
14	Construction Works of Sawla-Maji Road Project Contract-4: Construction works of Omo Bridge and its approach Road Project	6/15/2012	12/15/2013	8/27/2016	05-Jun-17	93	7	1,534	-10	2	66 weeks delayed	DST 1	71	1	0
15	Construction works of Design and Build Jinka -Hana - Jinka - Mendir lot 1 Road Project	2/3/2016	2/2/2018	2/2/2018	31-May-19	476	4	730	48	159	96 weeks delayed		46	0	0
16	Mombasa-Nairobi-Addis Ababa Road Corridor Phase III Project: Hawassa-Ageremariam Section, Lot III: Yirgachefe-Hagermariam (72km)	4/1/2013	3/31/2016	7/12/2017	30-Sep-18	609	6	1,563	8	93	165 weeks delayed	A 72	74	72	53
17	Continuation of Construction Works of Mobasa -Nairobi -Addis Ababa Road Corridor phase III project: Hawassa-Ageremariam Section; Lot 2 : Chuko-Yirgachefe	4/24/2017	2/23/2019	2/23/2019	31-Jan-19	183	2	670	20	142	52 weeks delayed	A 60	26	60	15
18	Construction Works of Sawla-Maji Road Project Contract 3: Salayish-Omo Road Project	1/18/2012	5/2/2015	9/24/2017	31-Jul-18	655	8	2,076	142	8	57 weeks delayed	DST 79	92	79	76
19	Construction Works of Fisseha Genet-Kele-Soyama-Segen-Gebelbeno, Lot 1: Fisseha Genet-Kele-Soyama-Km92.5	10/19/2017	4/1/2021	4/1/2021	31-Mar-19	41	2	1,260	1	276	52 weeks delayed	A 93	3	93	3
20	Continuation of Construction Works of Sawula-Kako Contract 2, Lot 2	5/12/2017	11/11/2018	11/11/2018	25-Feb-19	39	2	548	0	44	10 weeks delayed	G 30	18	30	5
21	Construction Works of Hossaina Town Road	6/19/2017	2/17/2019	2/17/2019	31-May-19	28	2	608	3	34	52 weeks delayed	A 5	17	5	1
22	Construction Works of Tercha-Chida Link Road Upgrading Project	9/8/2017	3/9/2020	3/9/2020	31-May-19	70	2	913	8	182	71 weeks delayed	A 58	8	58	4
23	Remaining Works of Kibremengist-Shakiso Road Project	7/18/2016	3/15/2017	6/17/2017	30-Jun-19	66	3	334	0	9	126 weeks delayed	DST 19	56	19	11
24	Construction Works of Sawla-Maji Road Project, Contract 2: Laska - Salayish Design and Build Road Upgrading Project	8/5/2011	8/5/2014	1/1/2018	31-Oct-17	637	8	2,341	144	21	187 weeks delayed		108	0	0

Annex-2 Case study detail information

A. Contract Data and Project Description

1. CONSTRUCTION CONTRACT DATA	
Contract Name	Hawassa – Hawassa Airport – Bishan Guracha (Tikur Wuha) Road Project; Section I: Km 0+000 - Km 21+048 and Section II: Km 0+000 – Km 12+464 Design and Build Road Project
Funding	Federal Government of Ethiopia
Employer	Ethiopian Roads Authority
Length (km)	33.51 Km
Type of Contract	Lump-Sum
Construction Type	DC5 Asphalt Concrete (AC) standard
Contractor	China Communications Construction Company Ltd (CCCC)
Contract Signing Date	August 15, 2017
Project Cost	**ETB 592,084,400.00** (ETB: Five Hundred Ninety-Two Million Eighty-Four Thousand Four Hundred and cents Zero-Zero only) including 15% VAT and it is to be paid 80% in Ethiopian Birr and 20% in US Dollars
Consultant	Ethiopian Construction Design and Supervision Works Corporation - Transport Design and Supervision Works Sector
Consultancy Service Contract Price	ETB 18,770,190.75 (Ethiopian Birr: Eighteen Million Seven Hundred Seventy Thousands One Hundred Ninety and Cents Seventy-five only) including 15% VAT.

The project road surrounds Hawassa Lake and destined to be major access to the new Hawassa Airport from Hawassa and Bishan Guracha (Tikur Wuha) towns. It is divided into two sections, namely, Section I (from Hawassa town to Hawassa airport) with 21.1 km length and, Section II (from Bishan Guracha/Tikur Wuha/ to Hawassa Airport) having 12.4 km length. Section I is entirely located in Sidama Zone, South Nations and Nationalities People Regional State, and section II predominantly in West Arsi Zone of Oromia Regional State and ends up in SNNPR Regional State.

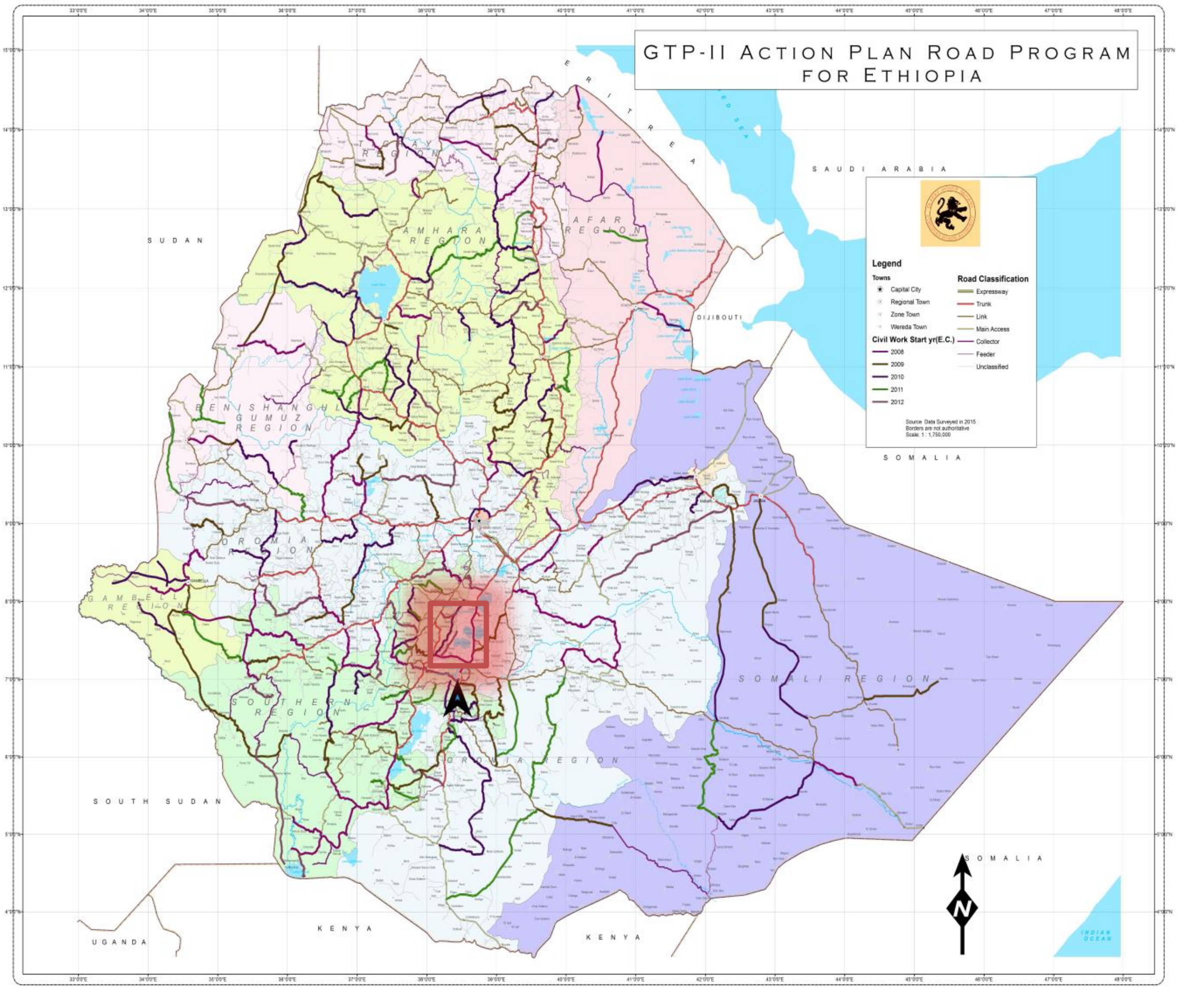


Figure 15: HHB Project Location

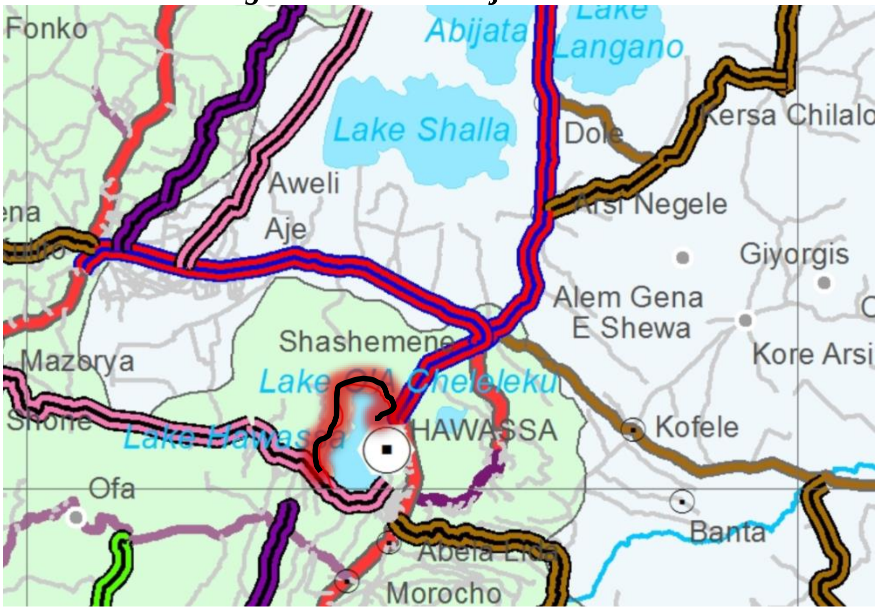


Figure 16: HHB (Hawassa -Hawassa Airport-Bishan Guracha) Road Project location in close up

B. Contract Data and Project Description

2. CONSTRUCTION CONTRACT DATA	
Contract Name	Konso – Yabelo road upgrading project
Funding	Federal Government of Ethiopia
Employer	Ethiopian Roads Authority
Length (km)	105 Km
Type of Contract	Lump-Sum
Pavement Type	Asphalt Concrete
Contractor	China Tiesiju Civil Engineering Group
Commencement Date	15-Jan-15
Project Cost	1,191,296,596.13 including 15% VAT
Consultant	Prome Omega Consulting Engineers

The Konso - Yabelo road project starts at about 1.5 km away from the Konso town and heads towards the southeast to reach Yabelo town located in the Oromia Regional State. However, in the meantime, about 2.5km of the road at Yabelo town has been asphalted. This has reduced the total length of the project road by 2.5km as compared to the project's original plan. On the other hand, the starting point of the road is 1.5 km away from the Konso town has created a negative feeling among the authorities of the Konso special woreda. During the discussion with local authorities, they requested concerned bodies to reconsider the starting point of the project road and they suggest that the road should start at the center of Konso town.

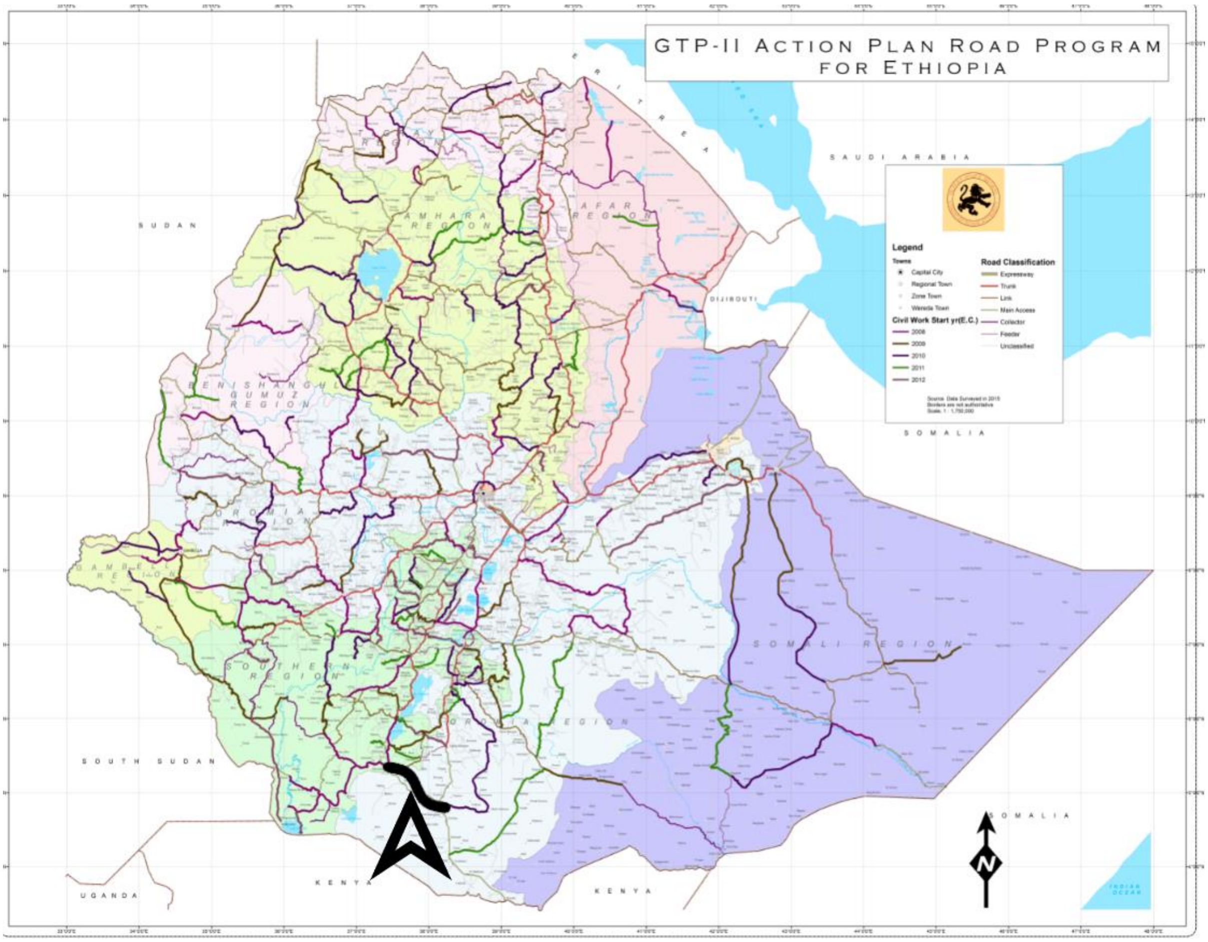


Figure 17: Location of Konso-Yabelo road project

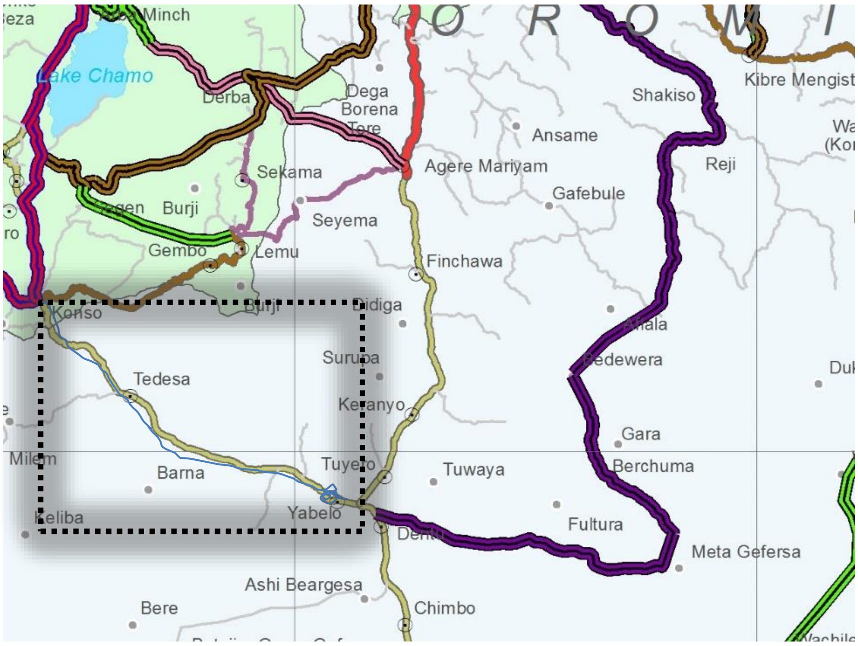


Figure 18: The Location Konso-Yabelo Road Project in Close up

C. Contract Data and Project Description

3. CONSTRUCTION CONTRACT DATA	
Contract Name	Sawla – Maji, Contract III: Salayish – Omo Road Project
Funding	AfDB
Employer	Ethiopian Roads Authority
Length (km)	79 Km
Type of Contract	Admeasurement
Pavement Type	Asphalt Concrete
Contractor	Akir Construction P.L.C.
Commencement Date	18-Jan-12
Project Cost	855,612,334.62 including 15% VAT
Consultant	CORE Consulting Engineers

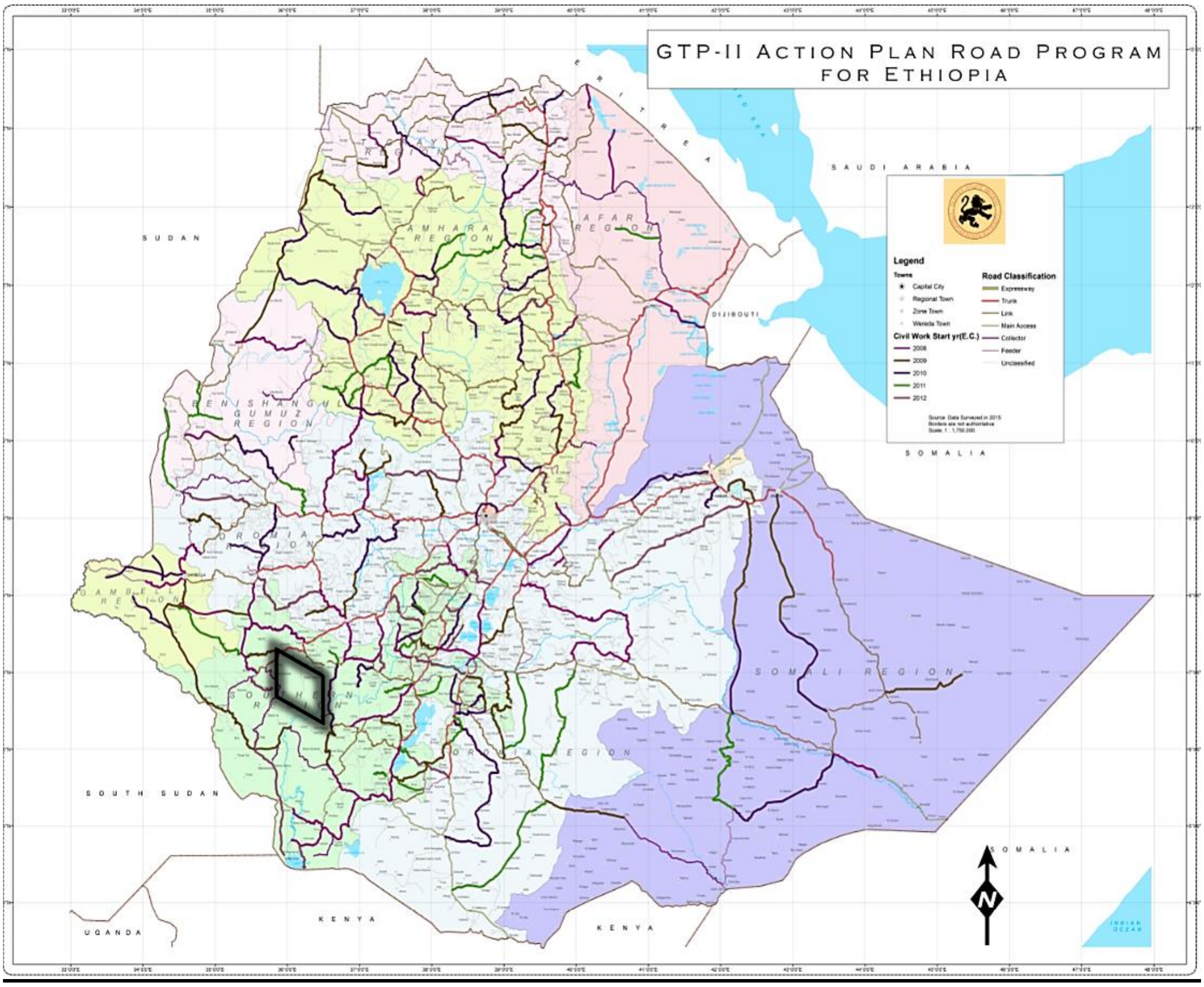


Figure 19 Location of Salayish - Omo

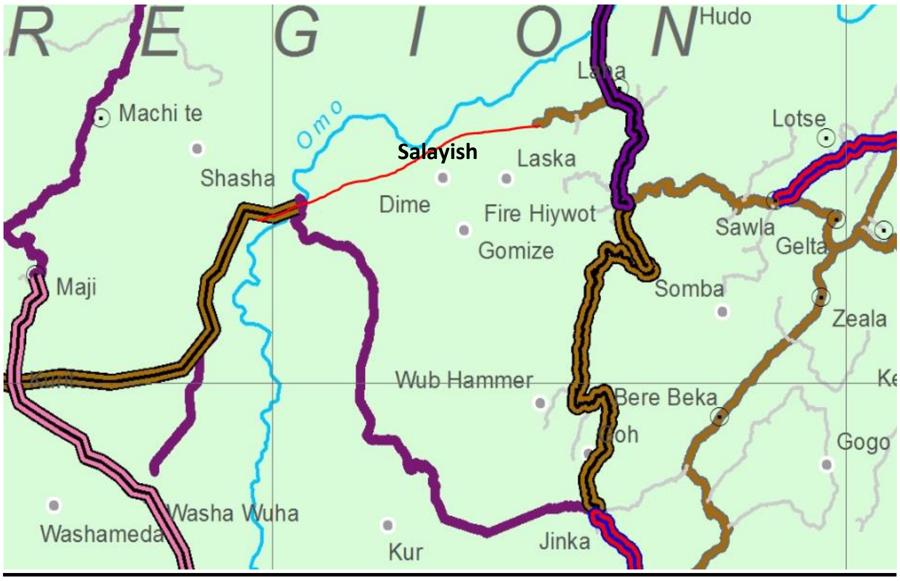


Figure 20 Salayish- OMO road project Location in Close Up

D. Contract Data and Project Description

4. CONSTRUCTION CONTRACT DATA	
Contract Name	Diredawa-Melka Jebdu Design and Build Road Project
Funding	GOE
Employer	Ethiopian Roads Authority
Length (km)	10 Km
Type of Contract	Lump sum
Pavement Type	Asphalt Concrete
Contractor	MELCON Construction Plc.
Commencement Date	January, 2016
Project Cost	855,612,334.62 including 15% VAT
Consultant	SEG Consulting Engineers P.L.C.

The road project is located in the eastern part of Ethiopia enclosed by the state of Dire Dawa administration which shares boundaries with Somali national regional states in the west, north and east and with the Oromia national regional state in the southern part of the country. The road project starts on the approach road (towards, kebele-02) 80m away from a bridge located on Oda river in the Dire Dawa town which is located about 560 km from Addis Ababa and traverses in west on Dire Dawa- Melka Jebdu existing gravel road till it reaches kebele 01 (Melka Jebdu) on the Dire Dawa town which is the project end. The works under this contract include design and construction of the road DC-7, flexible pavement standard. The road shall have a cross- section width of 22m and 2.1 m- wide median. The work also includes the design and construction of minor and major drainage structures.

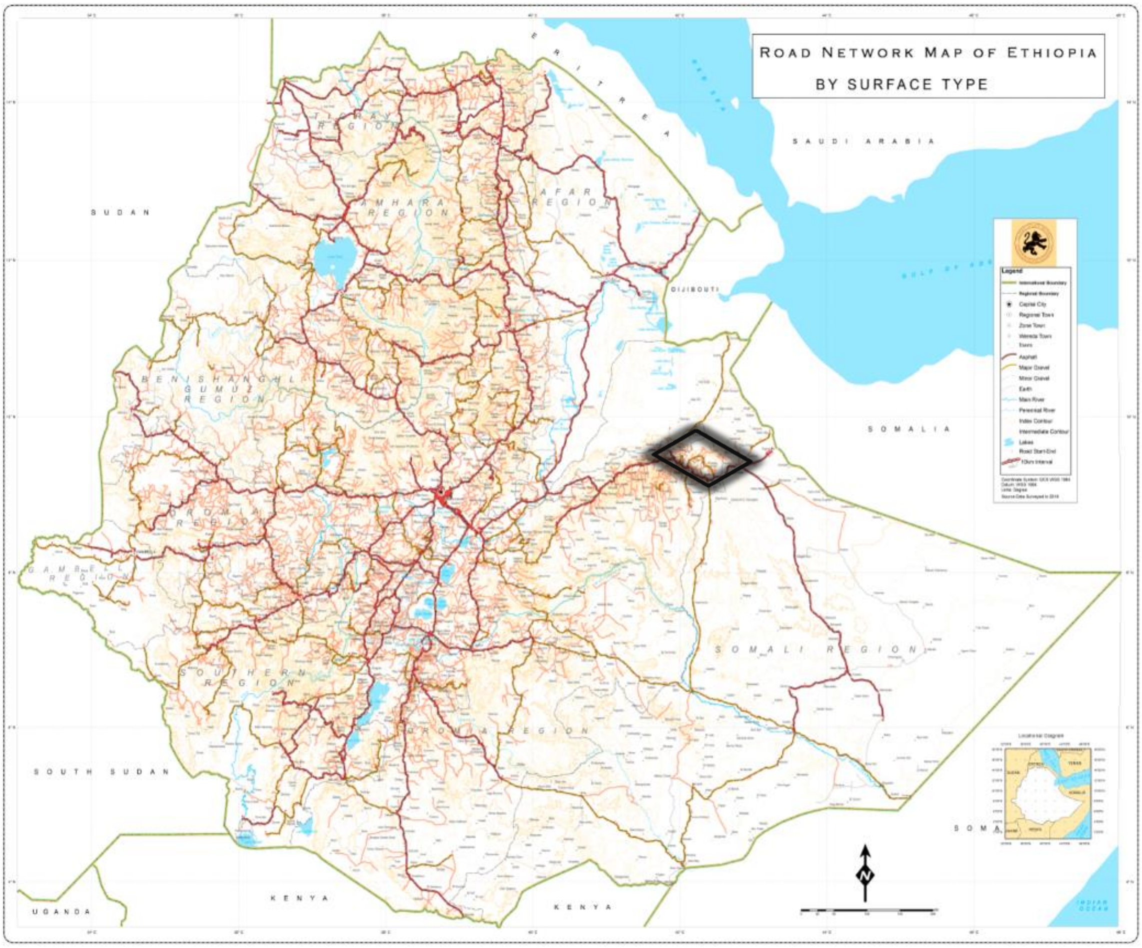


Figure 21: Location of Diredawa-Melka Jebdu Road Project

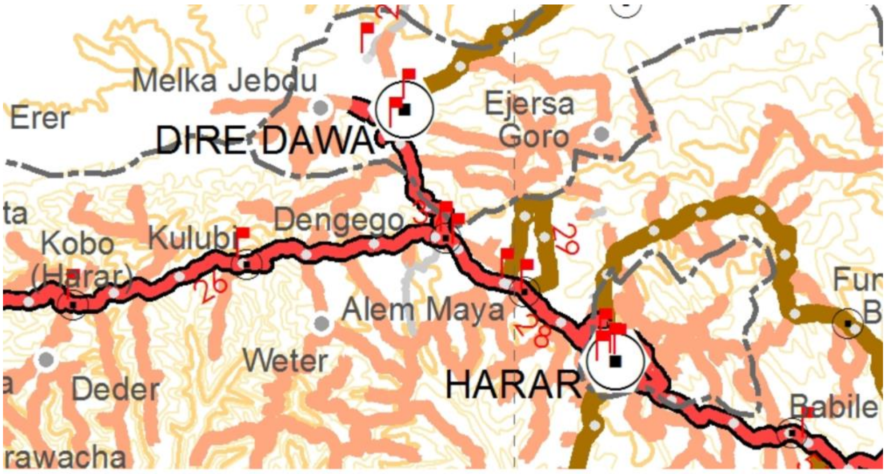


Figure 22: Diredawa-Melka Jebdu DB Road Project Location in Close up

Annexe-3 Questionnaire Survey Developed by Google Forms web-based open-source application

AAiT, School of Civil and Environmental Engineering

Dear Participant,
As part of fulfilling the requirements for MSc. Degree in Construction technology and management, I am carrying out the research on the topic “An Assessment of causes, effects and mitigation measures of design error induced variation: in ERA’s selected Road Projects” at Addis Ababa Institute of technology (AAiT), School of Civil and Environmental Engineering.

It is well known that the Ethiopian Roads Authority Often facing cost over runs (variation of contract price) and related claims resulting in extra funding requirement other than the budgeted cost for a certain project, among the front-line causes for such contractual complications is more of design related (design error&/or change).
Hence, the main objective of this thesis is to assess the causes, effects and mitigation measures of design error induced variation throughout the projects life cycle, consequently that might necessitate changes to happen during implementation of the road projects and offer suggestions for its improvement while maintaining modernized procedures tightening the gap to the future.
Therefore, enclosed herewith please find the questionnaires to collect understandings and opinions of professionals currently working in the road sector organizations and any concerned individuals the researcher believed that they can provide relevant data for the sole purpose of this academic research.
Please, be informed that all the data included in this questionnaire will be used exclusively for dissertation and will be confidential.
If you have any suggestion and comments, it is possible to put at the end of the pages.
Finally, I would like to thank you for your valuable time and cooperation.

Sincerely Yours,
Contact address: Ehyaudin musema
Mobile: +251929303257
Email: Ehyaudin99@gmail.com
* Required

1. Email address *

____

Section One: Basic Information of the Works Project

2. Describe the name of the project

____

3. Commencement Date of the Project

____

Example: January 7, 2019

4. Indicate which of the following parties you are representing for the project?

Mark only one oval.

○ Employer (ERA)
○ Design Consultant
○ Supervision Consultant
○ Contractor
○ Other: ____

5. Which type of the procurement is applicable to the works contract of the project?

Mark only one oval.

○ International Competitive Bid (ICB)
○ National Competitive Bid (NCB)
○ Other: ______________________

6. Applicable Design standard/Class (DS or DC)?

____

7. Which type of the delivery system is applicable to the works contract of the project?

Mark only one oval.

○ DBB (Design Bid Build)
○ DB (Design Build)
○ Other: ______________________

8. Mention Contract amount of the Project?

____

9. Mention Amount of Cumulative Variation Order up-to-date?

____

10. Was the revised price of the project mainly affected by design error/changes and modifications?

Mark only one oval.

○ Strongly disagree
○ Disagree
○ Neutral
○ Agree
○ Strongly agree

11. If yes how much of the Cumulative Variation Order up-to-date resulted due to design error/changes and modifications?

____

Section Two: Design Related Issues of the Projects

12. How long did the duration/time of original detail design & document preparation services provide for the project?

____

13. Indicate adequacy scale for on the allotted time for the project.

Mark only one oval.

	1	2	3	4	5	
Very insufficient	○	○	○	○	○	Very Sufficient

14. Did the project practice design reviews during implementation stage?

Mark only one oval.

○ Yes
○ No
○ Maybe

15. How much is the variation order due to the change/revision of horizontal alignment?

Mark only one oval.

○ None
○ 0-8% of the contract price
○ 9-16% variation of the contract price
○ 16-25% of the contract price
○ >25% of the contract price

16. Please indicate reason for change in horizontal alignment.

Check all that apply.

☐ To achieve the best/economical route and environmental considerations
☐ To traverse through additional control points
☐ To maintain design elements: min. radius, traffic volume, design speed, vehicle, etc.
☐ Slope stability problems and/or land slide areas,
☐ Soil type and climate,
☐ To adapt with topographic features of the area
☐ Drainage structures like bridges, culverts, retaining walls, etc.,
☐ Due to wrong surveying control points (GPS, BMS, etc.),
Other: ☐ ____________________

17. How much is the variation order due to the change/revision of Vertical alignment?

Mark only one oval.

○ None
○ 0-8% of the contract price
○ 9-16% variation of the contract price
○ 16-25% of the contract price
○ >25% of the contract price

18. Please indicate reason for change in Vertical alignment.

Check all that apply.

☐ To maintain the design elements: gradient, K value, etc,
☐ Due to change in horizontal alignment,
☐ Slope stability problems and/or land slide areas,
☐ Soil type and climate,
☐ To adapt with topographic features of the area,
☐ Drainage structures like bridges, culverts, retaining walls etc
☐ Due to wrong surveying control points (GPS, BMS, etc),
Other: ☐ ____________________

19. Was updating of culverts (box, slab and pipe) schedule practiced for the project?

Mark only one oval.

○ Yes
○ No
○ Maybe

20. Inclusion of some cross drainage structures implemented, which were not considered in the original design. How much cost is the variation order due to the change/revision of those minor drainage structures (please mention amounts or percentage of contract price)?

____

21. Was the number and/or design revision of bridges practiced for the project? ? If the answer is yes, indicate which of the following is/ are applicable to this revision?

Mark only one oval.

○ Revision of structural elements,
○ Revision of hydrological information,
○ Revision of Geo-technical information
○ Other: ____________________

22. Was pavement design revision practiced for the project? if yes, indicate which of the following initiated such revisions?

Check all that apply.

☐ Traffic volume
☐ Based on sub-grade material characteristics
Other: ☐ ____________________

23. How much cost is the variation order due to the change/revision of the pavement? (Please mention amounts or percentage of contract price)?

____

24. Which of the following factors will cause in design error/change resulting in variation on cost? Indicate in the here under matrix based on their degree of significance?

Mark only one oval per row.

	Very Significant	Significant	Neutral	Not Significant	Not very Significant
Smart technologies	○	○	○	○	○
Change in specification	○	○	○	○	○
Inadequate Detailing of Specifications	○	○	○	○	○
Lack of knowledge	○	○	○	○	○
Inexperience of designers	○	○	○	○	○
Design Cost	○	○	○	○	○
Duration of Design	○	○	○	○	○
Design Complexity	○	○	○	○	○
Inadequate project objectives	○	○	○	○	○
Lack of design verification and interface coordination	○	○	○	○	○
Owners’ financial difficulties	○	○	○	○	○
Large Provisional Sums	○	○	○	○	○
Ineffective design review documents	○	○	○	○	○
Ineffective methods of programming (lack	○	○	○	○	○

of proper project planning)					
Inadequate evaluation of information	○	○	○	○	○
Design submitting has been checked by Junior Engineers of the client/ERA	○	○	○	○	○
Poor TOR development	○	○	○	○	○
Method of contract administration	○	○	○	○	○
The duration interval to implement designed projects	○	○	○	○	○
Lack of integration/coordination between designers of different disciplines.	○	○	○	○	○

25. Which of the following factors will help in dynamic nature of highway design? Indicate in the here under table based on their degree of importance.

Mark only one oval per row.

	Very Important	Important	Neutral	Not Important	Not very Important
Special Training to the Approving staff	○	○	○	○	○
Smart technologies	○	○	○	○	○
Design Quality Control	○	○	○	○	○
Constructability Review	○	○	○	○	○
Change in specification	○	○	○	○	○
Design Reliability Analysis	○	○	○	○	○
Standardizing design approval documents and formats	○	○	○	○	○
Guidance on the use of competency management systems	○	○	○	○	○

26. if any other factors that will help in dynamic nature of highway design please mention?