RELATIONSHIPS OF CONSTRUCTION TIME AND COST FOR RAILWAY PROJECTS IN ETHIOPIA

BY

ANTENEH BIRHANE

ADVISOR: DR. ING. WUBISHET JEKALE MENGESHA

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
(Railway Engineering)

July, 2015

Addis Ababa, Ethiopia

ADDIS ABABA UNIVERSITY
SCHOOL OF GRADUATE STUDIES
FACULTY OF TECHNOLOGY
DEPARTMENT OF CIVIL ENGINEERING

Relationships of Construction Time and Cost for Railway Projects in Ethiopia

By

Anteneh Birhane EShetu

Approved by Board of Examiners

1. Dr. Wubishet Jekale (Advisor)	_________ Signature	________ Date
2. Eng.Yibeltal Zewude (Internal Examiner)	__________ Signature	________ Date
3. Dr.Girmay Kahsay (External Examiner)	_________ Signature	_______ Date
4. Dr.Birhanu Beshah (Chairman)	_________ Signature	_______ Date

ACKNOWLEDGEMENTS

I would like to offer my sincerest thanks to my advisor Dr. Ing. Wubishet Jekale Mengesha for his dedication, motivation, support and valuable comments he has provided me to work my thesis on this title, Relationships of Construction Time and Cost for Railway Projects in Ethiopia. He has been exceptional role model and I know my work and my future have been positively influenced by him.

I am deeply grateful to all who have given me assistance in obtaining the information and data related to this work. Special thank goes to engineer Iskinder Mohammed for his help while collecting data. Particular thanks also go to the Ethiopian Railway Corporation (ERC) for sponsoring and helping me to succeed my dreams in collaboration with AAiT.

Many friends and acquaintances have been made throughout my study. The students, faculty, and staff of the Civil Engineering Department are some of the greatest I've known and have made my time at Addis Ababa University a pleasure. I appreciate my Company Sina Construction PLC for the positive attitude they have towards education and made me felt like their family member.

Finally, all my family deserves the greatest acknowledgement next to God. My Mother, my brothers Gulilat Birhane Eshetu including his family and Lule Kassegn Eshetu constantly encouraged me to pursue my dreams; they have paid much sacrifice throughout my entire education carrier. This is why I have dedicated this work to them.

TABLE OF CONTENTS

Pages

LIST OF TABLES

LIST OF FIGURES

ABBREVATIONS

AAiT	Addis Ababa Institute of Technology
AALRT	Addis Ababa Light Rail Transit
BCSC	Building Construction Duration Calculator
BCIS	Building Cost Information Service
BTC	Bromilow's Time-Cost Model
CPM	Critical Path Methods
COM	Composite Equation
CUB	Cubic Equation
ERC	Ethiopia Railway Corporation
EXP	Exponential
LIN	Linear
INV	Inverse
LOG	Logarithmic
LRT	Light Rail Transit
MLR	Multiple Linear Regression
PERT	Program Evaluation and Review Techniques
POW	Power
QUA	Quadratic
S	S-Curve
SLR	Simple Linear Regression
SQRT	Square Root
SRA	State Road Association
USD	USA Dollar

GLOSSARY

AALRT Project: - Addis Ababa Light Rail transit project is a **475,000,000 USD** project. It is a **32** month turnkey contract project according to the agreement signed between the client ERC and the contractor. It contains two main routes; the first route is laid from East to west while the second route is laid from North to South of Addis Ababa city. Now in May 2015 more than 85% of the work is executed and the train is already commenced its trial.

Sebeta Mieso project: - It is part of Addis Ababa Djibouti Railway project, that links Addis Ababa (Sebeta), Adama and Mieso and is under construction by a total amount of **1,841,470,000** USD. It is a **42** month turnkey contract and now in May 2015 the project is executed more than 70% according to the owner ERC’s report.

Mieso Dewanle project: - It is part of Addis Ababa Djibouti Railway project, that links Mieso,Diredawa, and Dewanle and is under construction by a total amount of **1,401,800,000** USD. It is a **42** month turnkey contract and now in May 2015 the project is executed more than 75% according to reports from ERC.

ABSTRACT

The principal objectives of this research are to develop a model to project duration based on actual executed amount and to check the validity of Bromilow's principle for Ethiopia Railway Corporation (ERC) projects. This study mainly focuses on ERC projects that are under construction and that have a better progress. Addis Ababa Light Rail Transit (AALRT), Sebeta- Miesso and Miesso –Dewnale projects have a better progress than other projects that are recently commenced. So, the data for this research is mainly conducted from these projects.

Statistical regression models and correlations are developed using real data of three projects. The collected data was tested for correlation by SPSS tools after the data was transformed in to different functions and obtained result showed that the transformed data was in better correlations and then the regression model has been developed by the help of SPSS software. So, Regression-Correlation was the method used in this research.

The obtained result from the analysis indicates that the Bromilow's principle expressed in the form of $T=KC^B$, where T is the actual construction time, K is the constant characteristics of the performance, and B is a constant indicative of the sensitivity of time performance to cost level is valid to ERC projects and different regression models have been developed as shown on the analysis part of this research. The model result can be used by project managers in the planning phase to validate the schedule critical path time and project budget and can be used by ERC to predict duration of the project while bidding new project. This regression model for repeated projects could be more precise if more independent variables were considered and if data were larger better models could be provided.

Key words: Time - Cost relationship; Bromilow's Principle; BTC Model, Regression Analysis.

CHAPTER ONE

1. INTRODUCTION

1.1. Background

Contract duration is the time allotted to the contractor, by the owner, for the performance of all duties within a contract. On the other hand, Construction duration is the number of days needed to perform the work required in the contract. This duration permits the contractor to perform his work as he sees fit, even finishing early, while guarding the owner against damages suffered due to late completion Fourie (2003). Duration estimations in different stages of construction projects, according to the projects data availability and time constraints, are very important for the planning phase of construction. For example, in pre-design stages, forecasting of construction duration is very difficult with minimum design information. The feasibility of construction is a very important step in construction. Client wants to know the approximate duration and cost of the project.

In construction projects, there is most common planning and controlling tools, these are; Bar charts, Critical Path Method (CPM), and Program Evaluation and Review Technique (PERT). Therefore, to form a reliable and practical estimation process without using these techniques depends on the planners' experiences and knowledge and planning process becomes an intuitive and subjective process. Models for estimating construction durations have been developed to get over this subjectivity approach. This study was initiated with the aim of developing a model that can be used to predict the construction duration of a railway project in a reliable and practical way. Contractors can thus use a project's characteristics, as given in the tender documents, to estimate the actual amount of time it would take them to complete the construction works.

A lot have been written about the importance for accurate and reliable duration estimates over the past decades. Accurate and realistic duration estimates are important to every aspect of the construction project. Unreasonably short contract durations raise the bid price, restrict qualified bidders from submitting bids, have potential to reduce the quality of the work, and increase the potential for legal disputes (FHWA 2002). Conversely, unreasonably long contract durations are a general inconvenience to the traveling public and encourage less qualified contractors to submit a bid (FHWA 2002). Construction duration estimation models that are based on statistical data are considered to be more representative of the true picture and, therefore, more reliable. For this reason, the Bromilow's Time-Cost Model (BTC), Building Cost Information Service (BCIS) Model also called the Building Construction Duration Calculator (BCDC), the Simple Linear Regression (SLR) Analysis and the Multiple Linear Regression (MLR) Analysis were chosen for this type of study.

Construction and contract duration estimation is performed by the construction owner or engineer. International huge construction companies take the responsibility for both design and construction of the railway projects in Ethiopia. The design includes many parts like over pass bridges, tunnels, sleepers, track etc. It is the responsibility of Ethiopian Railway Corporation (ERC) to hire such international contractors to design and build the rail line. To predict the time it takes to construct and finish it is better to have an empirical formula that shows a relationship between Time and Cost for Ethiopia railway projects. The existence of a relationship between construction time and cost has been considered obvious: the time-cost-performance triangle appears in practically all project management handbooks e.g. Kerzner (1984). However, it would be interesting to find out if this relationship could be described quantitatively, and if so, if it might find any practical application.

Ethiopia has planned to construct Railway by the three phases. The First phase is already started, especially the route from Addis Ababa -Djibouti and Addis Ababa light rail transit (AALRT) are rapidly under construction. The Addis Ababa –Djibouti Railway project is categorized in to two, the first category is from Sebeta –Mieso and second is from Mieso-Dewanle and are constructed by two separate contactors.

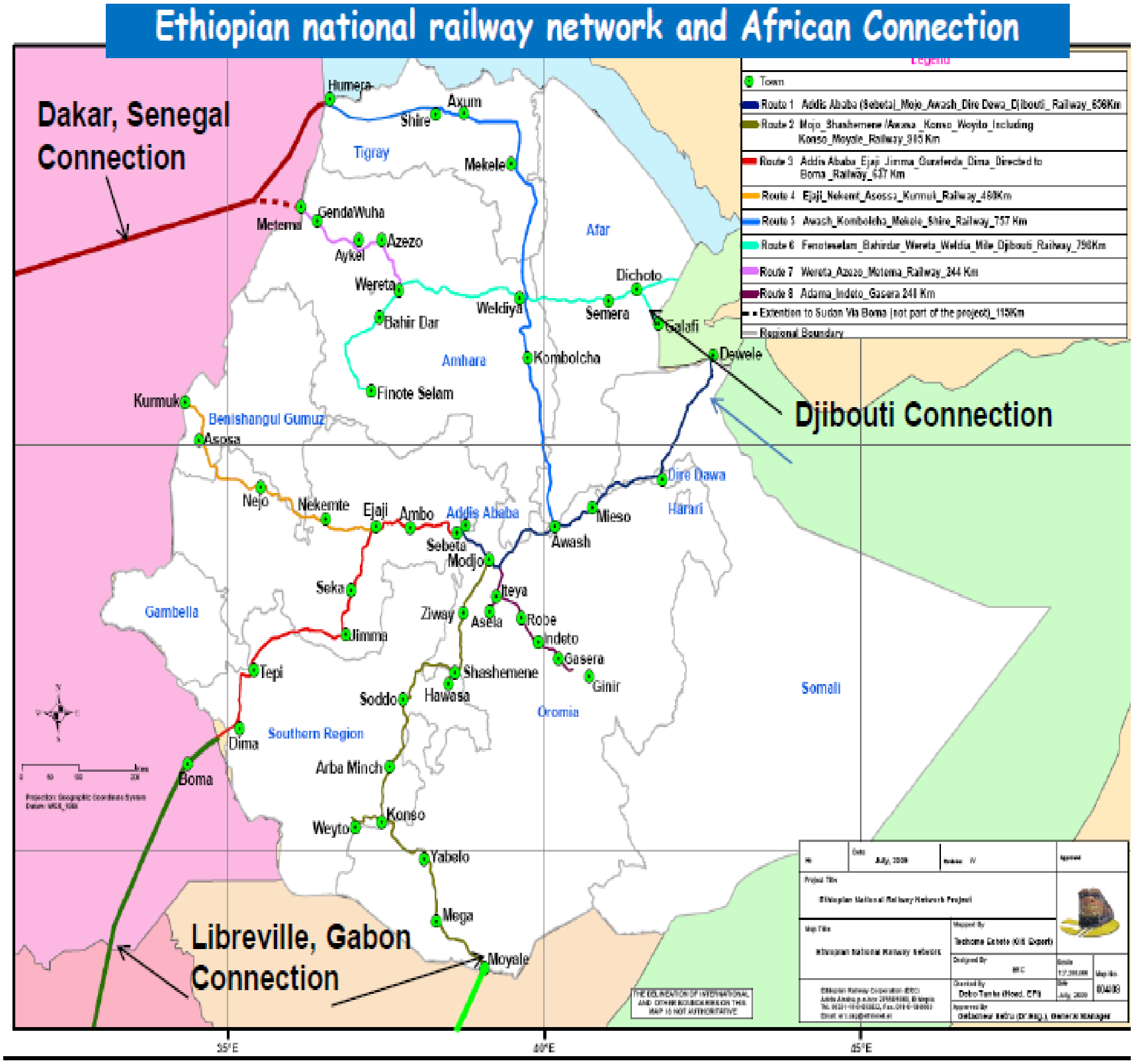


Fig.1.1 Ethiopian national railway network (ERC presentation July 2012)

The AALRT project is also categorized in two, the first category is from East-West and the second is from North-South.

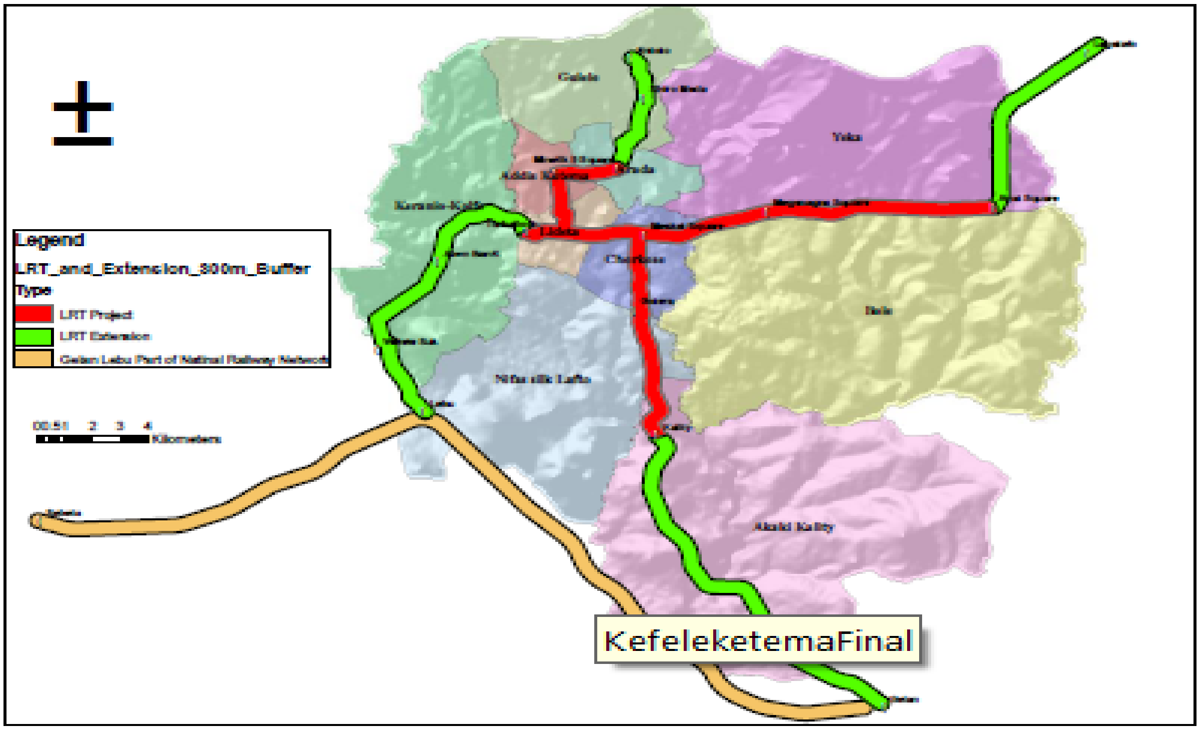


Fig 1.2 Addis Ababa LRT Project (ERC presentation July 2012)

1.2. Statement of the problem

Despite the importance of accurately and reliably estimating construction duration, early in the project development lifecycle, few tools, practices, and procedures exist for doing so. The building construction industry has explored this area and found results in statistical regression analysis. Such analysis has led to an understanding of the contract level components that influence construction duration and the relationships therein Bromilow (1980), Nkado (1992), Chan and Kumaraswamy (1995), Chan (1999), Skitmore and Ng (2001), Burrows et al. (2005).

The Railway construction industry has not demonstrated similar results. While most SRAs recognize a need for improved conceptual design level estimating practices, few have established processes, methods, or tools for preparing this estimate. Railway and Highway construction duration estimates are often prepared very early in project design and based on individual past experience on similar sized projects (Williams et al. 2008). Such practice has shown to be inaccurate and biased (Farqahl and Everett 1997). The alternative method employed by SRAs is using a more detailed scheduling tool and assuming pertinent project information such as material quantities and activity sequences (Williams et al. 2008). Such an estimate is time consuming and based on numerous assumptions. Regardless of the method used, these estimates are often left unrefined until completed project design where a more accurate duration estimate can be developed.

Further, there is no consensus regarding the Railway and highway construction duration-influential parameters or factors. Authors have proposed such parameters and subjective evidence exists from experienced personnel. However, there has not been a study to determine the statistical significance of these factors. Additional research is also needed to quantify and model these relationships, the interactions between factors, and model the development of construction duration given this conceptual level project data.

1.3. Objective of the study:

Objective of the thesis;-

- To develop Time –cost relationship empirical formula for Ethiopia railway projects based on previous principles done for other constructions (Bromilow’s principle)
- To check the validity of Bromilow’s principle for ERC projects

1.4. Hypotheses

The hypothesis for this thesis is:

- To verify the validity and applicability of principles of Bromilow’s principles for Railway projects in Ethiopia.

1.5. Research Methods, Material and Procedures

1.5.1 Study area

This research is limited to Ethiopia railway projects

1.5.2. Study Design

This study is to be under taken based on past principles like Bromilow's principles and others for other constructions like Building and road.

1.5.3 Sample Size

This research was conducted by taking data from AALRT project, Sebeta Miesso and Miesso Dewanle projects as other projects are not progressed as the mentioned projects.

1.5.4. Method of Data Collection

The aim of research is to create an empirical formula of railway project construction duration based on relationships among the projects. The stage of the research will follow literature review, interviews with the construction clients, data collection and etc.

1.5.5. Plan of Data Analysis

After collecting the relevant data from the concerned body, data will be processed and Regression –Correlation analysis will be done (i.e Exploratory Analysis of Data and Test on Correlation and Developing Regression Models will be done)

CHAPTER TWO

2. LITERATURE REVIEW

2.1. INTRODUCTION

In order to develop a better understanding of the research objective, literature review has been conducted focusing on Time-Cost relationship in the construction industry. Moreover the literatures focusing on road projects are conducted because the road project has a better relation to railway project then other civil infrastructures. Time –Cost relationship For Road Projects, Bromilow principle, and Regression analysis have been discussed in this literature review.

Project duration delay or contract time delay occurs as a result of many factors all of which are associated with some different reasons. Identification and management of such reasons for repeated construction projects is a necessary step for the improvement of any given estimating system and can be used to locate areas where the greatest improvement can be obtained. As part of this process, chapter 2 provides a literature review on the aspects of Railway construction project Time-Cost Relationship that has a great effect on Duration of construction projects.

In order to finish on time, contract duration estimates based on actual data are critical to the initial decision-to-build process for the Railway construction projects. This decision-to-build point in a project's development is seen as the international standard for measuring any subsequent Time estimate inaccuracies involved with accuracy being defined as the difference between initial project estimate at the decision-to-build stage and the real, accounted project cost determined at the time of project completion.

Thus, it is a desire of all stakeholders that Projects to be completed within a speculated time frame. Unfortunately, many projects take longer to complete and cost more than originally estimated budget because of lack of professional skills in the area and other various factors directly and/or indirectly related with it. In most developing countries this problem is more aggravated; as a result many project-sponsoring organizations are discouraged to sponsor projects in these poor countries.

Since they involve human and non human factors as well as many other variables, construction projects are complex which require close cooperation and coordination among stakeholders Ahmed (2005) & Fetene (2008). This complexity together with the development status of developing country makes Time estimation a particularly difficult task in the construction industry of these country, often leading to considerable Time overruns that are explained by large uncertainties and uniqueness of projects Baker et al. (1999).

Prior to detailed design development Knowledge of construction duration is important to a number of project planning functions. Important project funding and financing decisions are made during the preliminary design stage using estimated construction duration. These decisions, such as the duration of financing, date of occupancy, and the beginning of positive cash flows arising from the construction investment, are crucial to project success. Resource allocation decisions are also critical to project, program, and organizational success. The construction owner must be able to adequately plan and allocate management and oversight personnel and funding. Further, resources must be allocated to multiple projects concurrently. This presents challenges to entire organization, and requires an understanding of construction duration early in project design.

The need for improved preliminary construction duration estimates has been noted by numerous authors and research has taken place in a number of construction industry sectors to support the development of these estimates Bromilow (1980), Nkado (1992), Chan and Kumaraswamy (1995), Chan (1999), Skitmore and Ng (2001), Burrows et al. (2005). However, industry research suggests that there is a noticeable lack of research in the ability to reliably and historically predict Rilaway construction duration using early-known project design details. Work has been performed in the residential and building construction areas internationally Bromilow (1980), Nkado (1992), Chan and Kumaraswamy (1995), Chan (1999), Skitmore and Ng (2001), Burrows et al. (2005). However, the railway construction industry has not seen the same level of attention.

2.2 Factors affecting Construction Duration

Starting from the early 1970s, there are many researches into the factors influencing construction durations across various categories of projects for many reasons Elvan odabasi (2009). Kumaraswamy and Chan (1995) investigated factors affecting construction duration in projects carried out in Hong Kong. Questionnaires were posted to 400 firms and 111 of them responded. Among these factors the most significant factors are selected and discussed for this literature. Elvan odabasi (2009)

1. Cost
2. Cash flow
3. Productivity of on-site
4. Procurement
5. Project Related Factors
6. Technology and Methodology of Construction
7. Experience
8. Coordination
9. Weather
10. Construction site
11. The degree of completeness of design project

2.2.1. Cost

Elvan odabasi (2009) stated that most of the sources, Chan and Kumaraswamy, (1995), BCIS (2004), Chen and Huang (2006) indicates that cost is an important factor for construction duration, The authors studied 126 Australian construction projects to examine the project time and cost relationship by using project scope factors (e.g. project type, procurement method, tender type, gross floor area (GFA) and number of storeys. The authors formed a Multiple Linear Regression Analysis and found that GFA and number of storey are key determinants of time performance in Building projects. Other important result is that cost is a poor indicator of time performance because it is not possible to know each cost before the work done. Although

Love et al. found the cost parameter as an insignificant factor; they found BTC to be applicable with reasonable results, especially early phases. Helvacı (2008) also states that the duration estimation models can be built without using the cost parameter.

2.2.2. Cash Flow

Clients make a yearly payment plan of the project by using cost and duration estimations. Payment for construction works is made to the contractor(s) at designated time intervals. Gören (1998) cited by Elvan odabasi (2009)

If there is any insufficiency of cash flow exists, it may cause long-term unfinished construction projects or changing of hands to finish the project. If contractor is financially strong, he can continue to finish the work in the contract period by using his own finance as much as possible until he receives payment. He tries to continue his work without any interruptions. It causes delays in the work schedule and lost time. Contractors aiming to make profit can even lose money. Gören (1998), Karslı (1998) stated that delays occur in more than the half of the projects that are run by housing cooperatives because of financial problems. Additionally, Gören (1998) explains the importance of right cost estimation on project duration. If cost estimation is wrong, investment will be insufficient and additional finance will be required. This unexpected financial problem can cause the interruptions or even stop the works.

2.2.3. Productivity of on-site

Productivity is important in all parts of the projects for all parties, for all employees. Especially on-site productivity affects the construction directly. Man-hours used in planning phases define the total construction duration. If the productivity of the workers decreases, it directly affects the speed of the construction works. Chan and Kumaraswamy (1995-1998), Gören (1998), Karslı (1998) and Nkado (1995) define productivity as overall construction (site) productivity, and labor productivity. Chan and Kumaraswamy (1995) analyzed productivity as micro factors (such as construction site productivity) besides macro factors (project-specific characteristics such as building construction costs, gross floor area, and number of levels). Chan and Kumaraswamy (1998) added that lowered productivity could contribute significantly to project delays.Chan and Kumaraswamy (1998) and Nkado (1995) listed factors affecting site productivity such as work space availability, attendance of operatives, learning curve, weather, labor relations, project complexity project buildability, foundation condition and effectiveness of supervision.

Karslı (1998) indicated that problems about productivity could be seen mostly in developing countries. The labors coming from rural areas have low salaries, which lowers productivity rates below expectations.

The solution is to find out the causes affecting productivity negatively and improve conditions to motivate employees such as: over-time pay, contribution for the special works, social activities, and to provide better living and working conditions Kumaraswamy and Chan, (1998), Karslı (1998) and Gören (1998).

2.2.4. Procurement

Gören and Karslı (1998) pointed out that the importance of procurement related factors on project duration. Either the owner or the contractor takes care of procurement. Not only the materials, but also workmanship should be provided on time for the continuation of works. The aim is that the right amount of material should be available in good condition at the right time and at the right place in order to achieve good work progress. It can be possible with a proper procurement plan. Dissanayaka and Kumaraswamy (1999) identified particular factors, which are significantly related to time and cost performance; to analyze the relationships of procurement and non-procurement related factors with time and cost performance; and to develop time and cost over-run models using critical factors influencing time and cost in Hong Kong. The authors grouped the factors affecting project performance into two main groups as procurement related factors (work packaging, functional grouping, payment modality, selection modality and conditions of contracts) and non-procurement related factors (factors related to project, factors related to client: client representative, factors related to designer, factors related to contractor, factors related to team performance and factors related to external conditions.) The authors found that although time over-runs affected by mainly non procurement related factors (on design and construction complexity and variation levels), cost over-runs were affected by both procurement and non-procurement related factors.

2.2.5. Project-Related Factors

Project related factors are building type (hotel, hospital, villa, housing project, industrial building, etc.), design aspects (form, uniqueness, complexity of projects, etc.), technical parameters (Area, No Floor, Structure, etc.)

Nkado (1995), Saraç (1998), Gören (1998), Karslı (1998), Bhokha and Ogunlana (1999), and Chan and Kumaraswamy (1999-2002) pointed out the importance of building size and the height of the building (number of floors) as important factors affecting project duration. When the building size (gross floor area) increases, the construction duration will be longer. The reason is being that the size of the building affects the system of construction, the choice of materials that will be used, procurement system and the technology that will be used. Larger building projects require good project and management teams. Nkado (1995), Sara (1998), Gören (1998), Karslı (1998), Bhokha and Ogunlana (1999), and Chan and Kumaraswamy, (1999, 2002) are agreed that complexity of project affects the duration also. If the level of complexity is low, the construction and the management will be easier. Actually, the complexity of the building is related with the project type Karslı (1998). For example, construction of a market building takes shorter time than a hospital building. It is also related with using similar details in projects, because of the standardization of project. Gören (1998) and Saraç (1998) Additionally, Love et al., (2005) state that there is no single agreed way for defining complexity. The authors explained two handling methods for measuring the complexity. First way is using measures such as constructability, inherent site conditions, quality of design coordination, quality management procedures, and site access. The second defines complexity to be a large project.

Gören (1998) and Nkado (1995) also pointed out the effect of design project characteristics on duration, e.g., form of the plan can cause more excavation, more workmanship.

2.2.6. Technology and Methodology of Construction

Gören (1998) stated that usage of new technology, machinery, and materials causes increase in production rates and high quality products by arranging times effectively and reducing lay-off times. There are three types of construction technique. First type is low-tech (manual technique) which is based on workmanship; most of the main works are constructed on site. Hence, labor productivity gains importance. Second type is medium-tech (mechanized technology) which is used to decrease construction durations or to increase the construction speed; for example, using sliding forms to reduce construction time.

Third type is high-tech (prefabricated building technique) where components of the building are produced beforehand and then erected on-site, thus, minimizing the duration.

2.2.7. Experience

Walker and Vines (2000), Saraç (1995), Gören (1998), (Karslı (1998) emphasize the importance of experience on duration. Experience on similar projects reduces errors and so decreases or even totally eliminate reworks, hence reducing the total construction duration.

Karslı (1998) described the importance of client experience. Especially clients of commercial projects know what their requirements are, so they can give their decisions quickly because of the repetitions of their works. The author also added the importance of contractor’s experience. If the contractor has executed similar projects before, he is familiar with the works and does not repeat mistakes. This leads to shortening of the duration.

Karslı and Gören, (1998) pointed out that the experience of team members with different parties for design, construction, or management group is valuable in reducing delays. Walker and Vines (2000) studied on factors affecting construction durations of multi-unit housing projects in Australia. The authors found experience as an important factor besides, management quality, environmental factors, and coordination.

2.2.8. Coordination

In every sector, communication between all parties has an important role for the progress of work. Especially in the construction sector, there are many parties coming together for the completion of the project, communication management is critically important between the design team, construction team of contractor subcontractor and consultant firms, suppliers, management teams, and the client’s agent. It also affects the motivation of all the employees. Nkado (1995), Chan and Kumaraswamy (1999-2002), Karslı (1998) and Walker and Vines (2000) emphasized the importance of the development of coordination between these various agencies involved in the construction for construction duration estimation.

2.2.9. Weather

Local weather conditions determine the duration also as working periods are defined according to seasonal conditions. For example, if a project starts in rainy season, the actual construction of this project will most probably start after 3 to 4 months. Saraç (1995), Kaming (1997), Karslı (1998), Gören (1998), Dissanayaka and Kumaraswamy (1999), Walker and Vines (2000), Chan and Kumaraswamy (2002) all agree that weather conditions affect construction duration.

Gören (1998) states that bad weather can interrupt or abort the works; cause decrease in production rate and quality of works, so the work has to be done again. This kind of delays cause increase in cost since labor and equipments lay idle. The Gören (1998) pointed out that if the weather effects are taken into consideration properly while preparing the working schedule, these losses can be prevented.

2.2.10. Construction Site

Chan and Kumaraswamy (1995), Saraç (1995), Gören (1998), Karslı (1998) and Bhokha and Ogunlana (1999) all state that the location of a building has a significant effect on construction duration, i.e. whether or not restrictions or easements exist, and if availability of services, supply of resources, use of major equipment and productivity on site, the accessibility to the site exists. Moreover, construction site conditions, e.g. topography, ground conditions, and the size of the construction site also affects the duration of construction. For example, according to the site conditions, different machinery will be required for either excavations or back fills; these additional steps can cause delays or the large size of the site can decrease the speed of constructions. Finally, no matter what size of construction the required construction site arrangement should be done in a logical way, i.e. site office, storage, shelter for labors, dining hall, etc. should be arranged to facilitate transportation (optimum duration for vertical and horizontal transportation between storage, site and supplier).

Karslı, (1998) and Saraç (1995) state that all the decisions are given according to the location of the project: whether a project is in the country or abroad. The condition at location requires a detailed analysis for executing the work; e.g. economic and commercial, such as, interest rate, exchange rate, personnel wages, material costs; social and cultural; legal-political, e.g., traditions, legal and religious holiday and working hours; and technical, etc and transportation between storage, site and supplier).

Karslı, (1998) and Saraç (1995) state that all the decisions are given according to the location of the project: whether a project is in the country or abroad. The condition at location requires a detailed analysis for executing the work; e.g. economic and commercial, such as, interest rate, exchange rate, personnel wages, material costs; social and cultural; legal-political, e.g., traditions, legal and religious holiday and working hours; and technical, etc.

2.2.11. The Degree of Completeness of Design Project

Nkado (1995), Gören (1998), Saraç (1995), and Karslı (1998) agreed that the degree of completeness and precision of project information is very important for project duration. Firstly, this can be affected from the design changes. Any changes in the original design may not be communicated to construction site. This affects construction resource program, cash flow, and material procurement program, therefore, uncertainty of projects can cause delays. Secondly, the details should be completed in project stage for the continuation of project. Finally, the project should meet with the requirement of client. Saraç (1995) explained the reasons of completion ahead of the schedule, although this situation exists rarely. These are summarized factors affecting construction duration also as follows:

1. The urgency from the client's side
2. The bonus announced by the client
3. Higher safety factor in the allocation of time
4. Procurement of material on or ahead of schedule
5. Previous experience in similar projects
6. Use of modern machinery
7. Employment of more than the estimated number of skilled workers
8. The number of workers employed was the same as that of estimated one, but the level of skill was higher than average.
9. The number of workers employed was less that of the estimated one,but the level of efficiency was much higher
10. The size of the project was reduced
11. The design and drawings were simplified before or during construction
12. Effective coordination of different activities
13. High motivation due to harmonious supervisor and worker relationship

2.3 Time-Cost Relationship:

Estimates of the construction time and cost are of key importance in the early phases of the project – they serve as a basis for the decision whether to commence with planning or not, and are used as input for budgets and programmes. The project's success depends on reliability of these estimates. It is thus crucial to answer the question: what do the project time and cost depend on? Or easier to answer: correlated with? The answer can be based only on experience – personal as well as recorded in databases or mathematical models. Tools facilitating construction project planning on the basis of past experience are the object of research for many years Agata Czarnigowska and Anna Sobotka (2012)

Construction time has always been seen as one of the benchmarks for assessing the performance of a project and the efficiency of the project organization. Timely completion of a construction project is one goal of the client and contractor because each party tends to incur additional costs and lose potential revenues when completion is delayed Thomas et al. (1995). Chan and Kumaraswamy (1996) opined that a project is usually regarded as successful if it is completed on time, within budget and to the level of quality standard specified by the client at the beginning of the project. However, severe criticisms of the industry are generated when projects take far longer than planned. The problem of project time overrun is of international concern. According to Chan and Kumaraswamy (1996), in Australia, it was found out that seven-eighths of building contracts surveyed in the late 1960s were completed after scheduled completion while in Hong Kong, 70% of building projects were delayed. In Saudi Arabia, Al-Khalil and Al-Ghafly, (1999) confirmed in a study carried out by them in 1995 that contractors agreed that 37% of all their projects were subject to delay while consultants admitted that delayed projects accounted for 84% of projects under their supervision. They further reported another study, which concluded that 70% of public projects in the same country experienced time overrun. All these have made construction projects one of the most visible 'failure modes', attracting criticisms on the industry's profile Kumaraswamy and Chan, (1999). A preliminary investigation prior to the main study of Odeyinka and Yusif, (1997) in Nigeria showed that seven out of ten housing projects surveyed suffered delays during their execution.

Dr. Ogunsemi and G.O.Jagboro (2006). A study on a road projects in Ethiopia by (Abraham A, 2008) showed that the road projects constructed by International contractors were subjected to 57% time overrun whereas, those constructed by Domestic Contractors incurred 77% time overrun.

This literature is surveyed for Time-Cost relationships in railway projects in Ethiopia. In fact it is difficult to get the literatures directly related to Time-Cost relation in railway projects but researches have been done on building and road projects both internationally and some researches have been done here in Ethiopia. The following will be discussed as literature in this research:-

1) Bromilow's Time-Cost model
2) S-curve
3) Parametric Regression Analysis to predict Duration

2.3.1 Bromilow's Time-Cost Model

Application of models using systematically recorded experience to planning and managing new project has been an object of interest of many researchers Lai , Lee et al., (2008), Kaplinski (1997). Among the models considered, regression-based ones are reported to provide a useful tool in cost planning e.g. Chou and Tseng (2011). Though project cost databases tend to be more popular than those of project schedules, there have been a number of attempts to construct models of project duration based on historical data. Agata Czarnigowska and Anna Sobotka (2012)

Attempts to predict construction duration represent a problem of continual concern and interest to both researchers and project managers. Skitmore and Ng (2003) identified the use of detailed analysis of work to be carried out and resources available as well as limited budget and time available to the client as the common methods of estimating construction time in practice. However, to reduce subjectivity according to them, serious interest in construction time performance commenced with a pioneering investigation by Bromilow in 1969 in

Australia Chan and Kumaraswamy (1999). His efforts yielded result in 1974 when he established a model for predicting project duration for building projects based on a time-cost relationship. Chan (1999) provided insight into the model and further studies carried out by other researchers in the same direction are now discussed. In a survey of 370 building projects in Australia, Bromilow (1974) produced a model, which predicted construction duration as follows: Agata Czarnigowska and Anna Sobotka (2012)

$T=KC^{B}$ …………………………………………………………………… Equation 2.1

Equation 2.1 – Bromilow's Time-Cost Model Bromilow (1969)

Where: T = actual construction time in working days,

C = final cost of building in millions of dollars,

K = constant characteristic of building time performance,

B = constant indicative of the sensitivity of time performance to cost level.

His model was summarized as

$T=313C^{0.3}$ ………………………………………………………………… Equation 2.2

He further made use of mathematical models to show the relationship between cost and time, variation and pre-construction time. He also analyzed overruns on time and cost, which provided a measure of the accuracy of the industry’s time and cost prediction.

Similar work was carried out by Ireland (1983) to predict the construction time of high-rise commercial projects in Australia. His model from the analysis of 25 high-rise buildings based on cost in millions indexed to June (1979) was

$T=219C^{0.47}$……………………………………………………….………… Equation 2.3

Since recent studies of time-cost relationships were concentrated on building works, Kaka and Price (1991) conducted a similar research on roadwork projects within the period 1984–89 in the United Kingdom and a similar empirical relationship was arrived at. They studied two types of sample projects; the first group included 661 building projects which include all types of commercial, industrial, residential and public projects and the second included 140 road projects within the period 1984- 89. Kaka and Price are one of the few ones to study civil engineering projects namely road projects. They have stated that building projects are more accurate to predict than civil engineering projects: roads, which are more badly affected by weather and ground conditions. A study of the time-cost relationship of 67 Australian public projects, 20 Australian private projects and 51 Malaysian public projects confirmed Bromilow's initial model at the 0.00 level of significance and came up with the following models Yeong (1994).

Australian private projects: $T=161C^{0.367}$ …………………………………… Equation 2.4

Australian public projects: $T=287C^{0.237}$ ……….……………………….… Equation 2.5

Australian all projects: $T=269C^{0.215}$ ……………………………………… Equation 2.6

Malaysian public projects: $T=518C^{0.352}$ …………………………..………. Equation 2.7

Furthermore, since most of the studies so far reported dealt with either building or civil engineering projects, Kumaraswamy and Chan (1995) surveyed a combination of building and civil engineering projects and confirmed that the time-cost relationship for both types of project can be modeled in the form of Equation 1. They suggested the inclusion of other project-characteristic macro variables such as construction cost, gross floor area, number of storeys and micro factors affecting productivity, as well as other significant factors that may influence project duration. The latest of the series of studies of time-cost relationship was carried by Chan (1999). His study of 110 building projects in Hong Kong resulted with the following models:

Public projects: $T=166C^{0.28}$…………………………………………………… Equation 2.8

Private projects: $T=120C^{0.34}$………………………………………………….. …Equation 2.9

All projects: $T=152C^{0.29}$…………………………………………………….....Equation 2.10

In more recent work, Love et al. (2005) postulated that while cost was a poor predictor of project time (since one cannot know the project cost before the completion of the project), they suggested gross floor area and number of floors as better determinants. They came out with the following model:

$\text{Log}(T) = 3.178 + 0.274 \log(GFA) + 0.142 \log(Floor)$……………………………....Equation 2.11

for Australian projects.

Andinet et al. (2006) collected data for 29 public educational building projects in Ethiopia and concluded that the time-cost relationship for the sample education sector construction projects in Ethiopia can be expressed using Bromilow's model as:

$TIME = 7.06 * COST^{0.47}$………………………………………………………….. Equation 2.12

Abraham (2008) collected data from many different road projects in Ethiopia and concluded that the time-cost relationship for the sample Road projects in Ethiopia can be expressed using Bromilow's model as follows:

<u>IC - AC Road Projects</u>

$\text{Log}(T) = -47.058 + 8.7640 \text{Log}(C) - 0.0394 (\text{Log}(C))^3$ …………………. Equation 2.13

<u>IC - DBST Road Projects</u>

$\text{Log}(T) = -32.759 + 6.1661 \text{Log}(C) - 0.0268 (\text{Log}(C))^3$ ………………....Equation 2.14

Where T – Time in calendar days and C – cost in Ethiopian Birr

IC – International Contractors

DC – Domestic Contractors

AC - Asphalt Concrete Surfaced Road Project

DBST- Double Surface Asphalt Treatment Road Project

Abraham (2008) has modeled for Domestic Contractors as well though; the relationship with final Time and cost was weak for DC projects the relationship between contract Time and length has been found to be strong enough to yield the result shown below:

<u>DC – GS Road Projects</u>

$(Tc) = 15.0615 + 20 .2224 (L) - 0 .2631(L)^2 + 0.0013(L)^3$ …… Equation 2.15

Where T – Time in calendar days and L –project length in km

DC – Domestic Contractors

GS – Gravel Surfaced Road Project

Other investigations into project duration included Kumaraswamy and Chan (1995), who examined a hierarchy of both qualitative and quantitative factors affecting the construction duration of a building project. Ashley et al. (1987) investigated the factors used to evaluate project success, while the impact of contractor selection method and performance on project outcome has been studied by Russell and Skibniewski, (1988). An overview of the reasons for delays based on bringing together the views of different practitioners involved in the industry in order to provide an improved understanding of the problems and subsequently, if addressed, result in improvements in time and cost performance in future construction projects has also been addressed.

2.3.2 A study on S – Curve

The study on Road projects In Ethiopia by Abraham (2008) shows that the S – curve theory is not valid for the case study Road Construction projects in Ethiopia. The conclusions from findings include:

A. The S – curve progress method is not applicable as the projects have not fulfilled the normal curve assumption of the S – curve concept.
B. The plans prepared lack detail and are not critical.
C. The contractors have been biased by schedule push and most of the work has been carried out in the last year of the project periods.
D. The schedule variances are almost always negative indicating a constant slippage in performance.
E. The schedule performance indexes indicated that proper categorization and scale for attitudinal measurement of the indexes needs to be developed.
F. The estimate at completion computed based on schedule in cost is not valid for the case study projects.

Cost, schedule, and quality are the three major indicators for construction project performance Jung and Kang (2007). Keeping the project on schedule and within budget is a primary objective in every project. This is one of the main functions of cost and schedule control and is vital to monitoring the progress of design and construction projects and keeping these projects on track Nassar et al. (2005). Large amounts of money are lost each year in the construction industry because of poor schedule and cost control. Few contractors specify and follow systematic schedule monitoring practices Nassar et al., (2005). Accordingly, integration of cost and schedule control systems has been an issue of great concern for researchers and practitioners as these two important control systems are closely interrelated, sharing numerous common data Rasdorf and Abudayyeh (1991); Jung and Gibson (1999), Jung and Woo (2004) cited by Jung and Kang (2007) in their controlling processes.

Though the progress of construction projects is most often used as a critical index for effective project management, the method, structure, data, and accuracy of detailed progress measurement may vary depending on specific characteristics of a project Jung and Kang, (2007). This situation can lead to misinterpretation of the project status, especially under a multi-project management environment. It is also a daunting task for the inexperienced engineers to formulate and monitor the project-specific work packages. At the same time, maintaining very detailed and highly accurate progress information requires excessive managerial efforts.

In recent efforts to systemize construction management processes, standard methods and procedures coupled with information technology have been widely adapted Jung and Woo, (2001) cited by Jung and Kang, (2007). S – Curves have been widely used in the industry for controlling projects throughout their execution stage Blyth and Kaka (2006). The shape of the S-curve budget against time is a quick way to judge whether the developed curve is logically constructed and makes sense when compared to available project resource Daneshmand and Khreich (2006). Miskawi (1989) cited by Blyth and Kaka, (2006) stated that though S – Curves are used in scheduling and planning, for reporting actual, earned and planned values and for resource loading various activities of a projects, their reliability and accuracy is still in question.

According to investigations by Singh and Lakanathan (1992) cited by Daneshmand and Khreich (2006), the application of “S curves” for cash flow projections can achieve an accuracy of approximately 88-97%.

The earned value management system (EVM), which integrates cost and schedule control is a good example Jung and Woo (2001) cited by Jung and Kang (2007). Two important features of EVM are the combination of two different construction business functions i.e., cost and schedule into a unified perspective and the provision of highly detailed standard methods and procedures so as to compulsorily maintain data integrity among many different project participants.

No previous research or professional practice has comprehensively addressed the issues of standard progress measurement methodology in terms of its practicability, accuracy, efficiency, and potentiality for automation in the Ethiopian Construction Industry. This is also true for other countries like South Korea Jung and Kang (2007). This research plans to use the earned value method using the earned and planned values. As stated above the S – Curves for the planned and earned values will be used to understand the projects progress and variances.

Abraham (2008) came across of two complete articles related to the S – Curve and methods on developing a model to forecast S – Curves. The results of the review are presented as follows.

Nassar et al, (2005) stated that here have been many attempts in the past to develop cash flow forecasting models. They were mainly part of more comprehensive models aimed at assisting contractors or clients forecast their cash flow on an individual project level Kaka and Price (1996), or on a company level Kaka (1994). The majority of these models were based on the idea of developing standard S-curves to represent the running value or cost of different types of construction projects. Typically this was achieved by collecting data relating to the monthly valuations and the projects' general characteristics. These projects would then be classified and distributed into groups and average S-curves would then be fitted on the individual groups Balkau (1975); Bromilow and Henderson (1977); Hudson (1978); Oliver (1984); Miskawi, (1989); Khosrowshahi (1991); Evans and Kaka (1998). Several mathematical models were used to fit the S-curves (e.g. alpha-beta cubic equation, Weibull function, DHSS model etc.). These models could be used, given that the total value and duration of the projects to be constructed are known, to forecast the cumulative monthly (or at any other time interval), value/cost of that project.

The accuracy of these previous models is in question Kaka and Price (1993) cited by Nassar et al (2005). Kenley and Wilson (1986), argued that the underlying principle of the idiographic approach is that the value curves are generally unique and that they should be modeled separately, hence a curve should be fitted for each project. Petros (1996) investigated the effect of having different works plans on the cost flow curve of one project. Four different planners attempted to schedule the construction activities of the same industrial project. Each of the four plans was analyzed and used to estimate a cost flow curve. Results showed the significant variability of the possible S-curves for the same project arising from planning differences. Kaka (1999), suggested that unless more accurate standard S-curves are produced (perhaps by the use of a more detailed classification criteria), contractors should resort to detailed calculations using the works plan and cost estimates. He also indicated that as construction projects are unique, future attempts to standardize the cost/value relationship were likely to fail. He instead used a stochastic model based on historical data, as it allowed users to incorporate variability and inaccuracy in their forecasts and decision making. Barraza (2004) used stochastic S – Curves to determine forecasted project estimates as an alternative to using S – Curves and traditional forecasting methods.

The two main findings of the literature search applicable to this research revealed that previous attempts to forecast S-curves have not been accurate. First, that cash flow forecasts are likely to be inaccurate due to the fact that construction projects are unique and the progress of work varies greatly from one project to another, and second, that the choice of project groupings in previous work has been poor.

2.3.3 Parametric Regression Analysis to Predict Duration

Collection of research relating to parametric regression analysis for predicting construction duration demonstrated a large detachment between the work taking place in the United States, and that being performed internationally in the United Kingdom, Australia, and Hong Kong. Robert C. Williams (2008)

Orczyk (1989) proposed identifying and modeling milestone dates for construction projects using conceptual design parameters. To do so, Orczyk (1989) first surveyed construction industry professionals to determine those project milestones and parameters most crucial to construction duration for a small office building (1 to 4 stories). The survey results indicated that the five most crucial factors to construction schedules were type of frame, owner’s schedule requirements, subsurface conditions, type of cladding, and number of floors Orczyk (1989). Orczyk (1989) next developed a survey requesting actual historical data on these parameters from across the United States. Through model development and schedule simulation, Orczyk (1989) was able to explain 72% of the variation in the parameters and the timing or occurrence of events. The total area of the building accounted for 45% of variation explained Orczyk (1989). Finally, Orczyk (1989) reviewed the results of surveys sent to highway and bridge constructors. While there was not a sufficient amount of data returned for analysis, Orczyk (1989) cites the most commonly reported influential parameters for railway, highway and bridge construction as weather and the volume of earthwork. Meanwhile, completion of sub-grade, paving, bridge substructure, and bridge superstructure as significant milestones in the construction process Orczyk (1989).

A study performed by the United States Army Corps of Engineers states describes the prevalence of underestimating construction duration within in military and civil works East et al. (1992):

“In fiscal year 1988, actual duration of military construction projects took an average of 17 percent longer than estimated. Similarly, actual duration of civil construction projects averaged 19 percent longer than estimated.”

To remedy this problem, the study incorporates three factors found to unexpectedly extend construction activities: work delays, weather delays, and productivity delays. From this information, a contract scheduling system is developed that requires the input of project parameters and specific activity information and durations East et al. (1992). While this study was focused on building construction, a matrix of influential activity factors on building construction activities are useful to the study at hand. A number of factors found to affect building construction activity are also expected to impact highway construction.

Nkado (1992) found eight statistically significant building construction time variables: gross floor area, height, type of cladding, number of stories, location, predominant frame, storey height, and approximate building volume. To incorporate the large amount of variables into a model, Nkado (1992) developed regression models to predict durations of individual project components, and then modeled the relationship between the duration or size of those components and the lag time between successive component starts. Once developed, the models developed were tested against the estimates from nine planners from three separate project offices and found to be within the distribution of planner estimates Nkado (1992).

Next, Khosrowshahi and Kaka (1996) sought to determine regression models for both building project cost and duration. The authors considered such factors as the project type, operation, scope, form, structural properties, cost, ground condition, building height (in stories), site access, and build-ability Khosrowshahi and Kaka (1996). Regression analysis determined a duration estimation model that incorporates cost, access, build-ability, scope, operation, framing, start month, and building height Khosrowshahi and Kaka (1996). The authors note that a log transform of cost within the equation produces a better prediction of duration Khosrowshahi and Kaka (1996).

In the Hong Kong public housing sector, Chan and Kumaraswamy (1999a, 1999b) found that prediction equations typically included the number of stories, gross floor area, ratio of gross floor area to ground floor plan area, external cladding area, type of foundation, information exchange between architect/contractors, ground conditions, and labor productivity Chan and Kumaraswamy (1999a), Chan and Kumaraswamy (1999b). Notice several of these same factors exist in their earlier building industry prediction models.

Chan and Chan (2004) developed a benchmark model for project time performance in Hong Kong. Of particular interest to Chan and Chan (2004) was the identification of critical factors influencing construction durations of high-rise public housing buildings in Hong Kong. Through their analysis, Chan and Chan (2004) determined five statistically significant regression variables: (1) total construction cost, (2) type of housing scheme, (3) use of pre-cast facades, (4) building volume, and (5) ground floor area per floor.

Burrows et al. (2005) studied the relationship between project sector, procurement route, contractor selection method, client type, building function, and location to the building construction duration using data from more than 1,500 new building construction projects in the U.K. between 1998 and 2002. Each of these categories was subdivided into a number of more detailed classifications, each of which analyzed for their relationship to building construction duration Burrows et al. (2005). The results provided a number of important insights regarding the relationship between the aforementioned factors and the construction duration. First, there is a significant relationship between project cost and duration Burrows et al. (2005). This relationship is more pronounced as the cost increases (Burrows et al. 2005). The study also revealed that housing projects tend to take the longest to complete, all other parameters being equal Burrows et al. (2005). Finally trends between the location or region and the project duration were noticed. Small projects tended to have similar durations through the country while larger projects, on the other hand, tended to be completed in less time in urban regions as opposed to rural regions Burrows et al.(2005).

As seen, other construction industry sectors have investigated the relationships between early-known design parameters and project duration (both contract and construction duration). SRA is the most commonly cited method for identifying and quantifying the relationships between early-known project details and duration. It is expected that the highway construction industry would realize similar results.

2.3.4 The Criticism of the Models

Regression Models are related with mathematical values and very sensitive to data distribution. Therefore, if the variables are not clear, it is not possible to use regression models. Sezgin (2003)

Time-cost models and parametric models had close reasonably accurate estimations. The predictive accuracy of time-cost models was slightly better than parametric models. However, parametric estimations do not require cost estimation. Helvacı, (2008)

This study is limited to the validation of time-cost relationship developed by Bromilow et al. (1980) in Ethiopian construction industry, particularly with reference to the railway construction sector. It does not incorporate the implications of other factors that are likely to influence the total time required for the completion of a construction projects.

CHAPTER THREE

3. RESEARCH DESIGN AND METHODOLOGY

3.1. Introduction

Research Methodology deals with the methods for creating knowledge about the world and the interpretation of this knowledge in the light of ontological and epistemological position Reich (1994). Ontology deals with the nature of the things we know about the world or the nature of the world, while epistemology deals with the relation between humans and their knowledge. Typical epistemological questions are:

- What can we know?
- How do we know?
- What is truth?
- Is there a priori knowledge, and if so, of what?

The previous chapter presented reviewed literature on Time-Cost relationship developed previously for different construction projects. This chapter presents the methodology used to carry out the research presented in this thesis in order to address the defined study aim and objectives. The chapter highlights the various methodologies that can be adopted for research purposes. It further explains how the problem was investigated and describes the tools used to undertake the investigation. It also describes the characteristics of the research sample and the methods of data analysis employed.

3.2 Type of Research

Research can be classified from three perspectives: Kumar (1999), Dawson & Catherine (2002), and Kumar, Ranjit (2005)

1. Application of research study
2. Objectives in undertaking the research

3. inquiry mode employed

Application:

From the point of view of application, there are two broad categories of research:

- *Pure research and*
- *Applied research*.

Pure research involves developing and testing theories and hypotheses that are intellectually challenging to the researcher but may or may not have practical application at the present time or in the future. The knowledge produced through pure research is sought in order to add to the existing body of research methods.

Applied research is done to solve specific, practical questions; for policy formulation, administration and understanding of a phenomenon. It can be *exploratory,* but is usually *descriptive*. It is almost always done on the basis of basic research. Applied research can be carried out by academic or industrial institutions. Often, an academic institution such as a university will have a specific applied research program funded by an industrial partner interested in that program.

So this research is thus an ***Applied research*** as it can be used for policy formation, administration and to solve specific problems.

Objectives:

From the viewpoint of objectives, a research can be classified as

-*descriptive*
-*correlational*
-*explanatory*
-*exploratory*

Descriptive research attempts to describe systematically a situation, problem, phenomenon, service or programme, or provides information about , say, living condition of a community, or describes attitudes towards an issue.

Correlational research attempts to discover or establish the existence of a relationship/ interdependence between two or more aspects of a situation.

Explanatory research attempts to clarify why and how there is a relationship between two or more aspects of a situation or phenomenon.

Exploratory research is undertaken to explore an area where little is known or to investigate the possibilities of undertaking a particular research study (feasibility study/ pilot study).

So this research is thus a ***Descriptive research*** as it attempts to describe systematically a situation by viewing the problem and is a ***Correlational research*** as it establishes the existence of a relationship / interdependence between two or more aspects.

Inquiry Mode:

From the process adopted to find answer to research questions – the two approaches are:

- *Structured approach*
- *Unstructured approach*

*Structured approach**:*** The structured approach to inquiry is usually classified as ***quantitative research***.

e.g. how many people have a particular problem? How many people hold a particular attitude? Different opinions different people have about an issue, description of working condition in a particular industry.

So this research is thus a ***quantitative*** *structured approach:* The unstructured approach to inquiry is usually classified as ***qualitative research.***

e,g, description of an observed situation, the historical enumeration of events, an account of ***research*** as it attempts to quantify the relationship and develop parameters for future use. But sometimes both ***quantitative research*** and ***qualitative research*** can be used together.

3.3 The Research process

The research process is similar to undertaking a journey. For a research journey there are two important decisions to make-

1) What you want to find out about or what research questions (problems) you want to find answers to;

2) How to go about finding their answers.

This research agrees with the research process developed by Kumar (1999) based on the model by Festinger and Katz (1966). Thus this research process has eight steps.

Steps in Research Process:

1. Formulating the Research Problem
2. Extensive Literature Review
3. Developing the objectives
4. Preparing the Research Design including Sample Design
5. Collecting the Data
6. Analysis of Data
7. Generalization and Interpretation
8. Preparation of the Report or Presentation of Results-Formal write ups of conclusions reached.

Analysis can be categorized into descriptive, inferential, correlation and causal analyses. Analysis is a matter of giving meaning to first impressions as well as to final compilations (Stake (1995)).NIST (2008), three most popular quantitative data analysis approaches are:

1. Classical
2. Exploratory (EDA)
3. Bayesian

For this research both quantitative and graphical solutions are sought, thus both classical and exploratory data analysis was used. Thus this research has used the quantitative hypothesis testing by using regression techniques and also the exploratory scatter plot techniques.

3.4 Research Hypothesis

The hypothesis for this thesis is:

- To verify the validity and applicability of past principles like Bromilow's principles and others for Railway projects in Ethiopia.

3.5 Research objective

Objective of the thesis;-

- To develop Time –cost relationship empirical formula for Ethiopia railway projects based on previous principles done for other constructions (Bromilow's principle)
- To check the validity of Bromilow's principle for ERC projects

3.6 Statement of the problem

Despite the importance of accurately and reliably estimating construction duration, early in the project development lifecycle, few tools, practices, and procedures exist for doing so. The building construction industry has explored this area and found results in statistical regression analysis. Such analysis has led to an understanding of the contract level components that influence construction duration and the relationships therein Bromilow (1980), Nkado (1992), Chan and Kumaraswamy (1995, Chan (1999), Skitmore and Ng (2001), Burrows et al. (2005). The Railway construction industry has not demonstrated similar results. Railway and Highway construction duration estimates are often prepared very early in project design and based on individual past experience on similar sized projects Williams et al. (2008). Such practice has shown to be inaccurate and biased Farqahl and Everett (1997). The alternative method employed by SRAs is using a more detailed scheduling tool and assuming pertinent project information such as material quantities and activity sequences Williams et al. (2008). Such an estimate is time consuming and based on numerous assumptions. Regardless of the method used, these estimates are often left unrefined until completed project design where a more accurate duration estimate can be developed.

Further, there is no consensus regarding the Railway and highway construction duration-influential parameters or factors. Authors have proposed such parameters and anecdotal evidence exists from experienced personnel. However, there has not been a study to determine the statistical significance of these factors. Additional research is also needed to quantify and model these relationships, the interactions between factors, and model the development of construction duration given this conceptual level project data. The other difficulties in Ethiopia are as railway is new it will be difficult to get the appropriate data.

3.7 The research design

Research design is the conceptual structure within which research would be conducted. Research design is the conceptual structure within which research would be conducted. The preparation of research design, appropriate for a particular research problem, involves the consideration of the following:

- Objectives of the research study.
- Method of Data Collection to be adopted
- Source of information—Sample Design
- Tool for Data collection
- Data Analysis-- qualitative and quantitative

3.7.1 Methods of Data Collection

According to Kumar (1999), data sources can be divided into two Primary and Secondary. Primary data is collected from Primary sources like Observation, Interviewing and Questionnaire and Secondary data is collected from Secondary sources like documents: Government publications, earlier researches, census and personal records. The data sources used in this study are the contract documents, final completion reports, interim completion reports, and payment certificates. Since these data's have not been used for any other related research purpose, according to Kumar (1999) they are regarded as Primary Data for this research

3.7.2 Selection of Research Method

Accordingly Nick (2000) identified the following research approaches:

- Survey Research – based on questioner, historical data and asking people
- Experimental Research – based on conducting tests
- Action Research – based on actual study of causes and effects
- Case Study Research – based on looking in detail of number of instances or cases

This research use the two approaches mostly Survey research and Case study research

3.8 Research Validity and Reliability

Validity is defined as the degree to which the researcher has measured what he has set out to measure Smith (1991) cited by Kumar (1999). The concept of reliability to a research is based on if a research tool is consistent and stable, and hence, predictable and accurate Kumar (1999).

According to Fink (1998), reliability and validity can be tested by the following questions:

- Are the data collection methods adequately described?
- Is the measure valid?
- Is the measure reliable?

According to Kumar (1999) there are three type of validity: face and content, concurrent and predictive, and construct validity. Face validity is established when the instrument is judged to measure what it is primarily suppose to based on a logical link between the questions and the objectives of the study. And when it covers the full range of the issue or attitude, content validity is established. Predictive validity is judged by the degree to which an instrument can forecast an outcome. And concurrent validity is judged by how well an instrument compares with a second assessment concurrently done. Construct validity is based on statistical procedures and is determined by ascertaining the contribution of each construct to the total variance observed in a phenomenon. The researcher believes that the face and predictive validity has been maintained and that efforts have been made to have content validity for the first hypothesis by testing length as an independent variable.

CHAPTER FOUR

4. ANALYSIS OF FINDINGS AND DISCUSSION

4.1. Introduction

The cost of the project is the important independent variable for the regression model and detail processing is required for effects of price escalation, inflation and currency. This research has considered processing and analysis to be inclusive of one another even though Kothari (2004) considers them to be different, though Selltiz, Jahoda and others cited by Kothari consider them as the same. Kothari (2004) considers that processing include the following operations: editing, coding, classification and tabulation and considers analysis to mainly involved in testing a hypothesis for drawing references. Many of the literatures reviewed Choudhury & Rajan (2003), Love et al (2005), Kaka & Price (1991) and Endut et al (2006)) lacked clarity on the processing of their research data, mainly the data related to cost of projects

4.2 Analysis of Hypothesis

The hypothesis of this research is to test the applicability of the Bromilow's principle which states that the construction duration of projects can be determined by the following relationship：

$T=KC^B$ ……………………………………………………. Equation 2.1

Where T is construction time in months, C is cost in USD dollars, K is a constant characteristic of time performance, and B is a constant indicative of the sensitivity of time performance to cost level.

This research is focused on testing the above relationship for Ethiopian Railway Construction projects. The steps taken are summarized as follows:

1. Data Collection

2. Data Processing

3. Exploratory Analysis of Data and Test on Correlation of Data

4. Hypothesis Testing

5. Developing Regression Models

4.2.1 Data Collection

The data on projects was collected from the Ethiopia Railway Corporation, the client for all projects. The data collected consists of to date percentage executed, to date executed amount, each month paid amount and total contract price of the projects. The data sources were contract documents, enterim payment and reports.

4.2.2 Data Processing

The data is collected from ERC for ALRT, Sebeta Mieso , and Mieso Dewanle projects. There are other projects which are under construction but are not enough for this research as more payment is not collected by the Contractors. The summary of the data collected is presented on Table 4 – 1, Table 4-2 and Table 4-3 and later categorized in to two categories each by considering the S-Curve as shown on Table 4.4, Table 4.5, Table 4.6 and Table 4.7.

The data identified for this research includes 3 projects which are all from a single employer, ERC. The first Bromilow model was developed based on 370 projects Bromilow (1974). Kaka and Ireland (1994) used 140 road projects, Chan and Kumaraswamy (1995) used 15 road projects, and Andient et al (2006) used 29 projects. The size of the data used for this research is small compared to the data used by Bromilow's and other researchers but the railway route under construction is long kilometer and should be updated each year to get the accurate result.

Addis Ababa LRT Project data

Month	payment no	To date %age execute	Current paid Amount	Todate executed Amount	Grand total
1	IPC No 1	4.04	4,613,335.87	19,147,387.38	19,147,387.38
2	IPC No 2	4.26	1,949,611.16	20,192,387.38	20,192,387.38
3	IPC No 3	4.48	1,750,959.23	21,237,387.38	21,237,387.38
4	IPC No 4	4.70	1,316,387.38	22,282,387.38	22,282,387.38
5	IPC No 5	4.92	1,390,570.46	23,327,387.38	23,327,387.38
6	IPC No 6	5.14	1,396,573.94	24,372,387.38	24,372,387.38
7	IPC No 7	5.36	1,619,215.23	25,417,387.38	25,417,387.38
8	IPC No 8	5.58	1,312,568.08	26,462,387.38	26,462,387.38
9	IPC No 9	5.80	643,266.70	27,507,387.38	27,507,387.38
10	IPC No 10	6.02	1,678,686.46	28,552,387.38	28,552,387.38
11	IPC No 11	6.24	1,750,048.58	29,597,387.38	29,597,387.38
12	IPC No 12	6.34	1,632,768.12	30,072,387.38	30,072,387.38
13	IPC No 13	6.45	3,456,105.73	30,637,621.00	30,637,621.00
14	IPC No 14	7.51	4,011,953.76	35,652,563.37	35,652,563.37
15	IPC No 15	8.55	3,958,981.60	40,601,290.38	40,601,290.38
16	IPC No 16	9.75	4,584,978.75	46,332,513.82	46,332,513.82
17	IPC No 17	10.84	4,122,295.81	51,485,383.58	51,485,383.58
18	IPC No 18	11.56	2,731,690.96	54,899,997.27	54,899,997.27

19	IPC No 19	13.05	11,120,771.40	62,005,953.90	68,800,961.53
20	IPC No 20	14.04	3,747,897.73	66,690,826.07	73,485,833.70
21	IPC No 21	15.79	13,886,551.84	75,009,672.15	90,844,023.50
22	IPC No 22	18.31	12,868,030.16	86,995,206.62	115,968,404.91
23	IPC No 23	20.50	9,875,469.03	97,378,405.62	137,022,863.67
24	IPC No 24	23.76	10,654,819.81	112,861,225.22	161,012,648.20
25	IPC No 25	33.42	31,680,621.04	158,755,264.39	219,017,956.17
26	IPC No 26	36.48	8,109,213.04	173,288,016.71	238,212,854.12
27	IPC No 27	40.05	14,632,921.22	190,238,280.62	272,892,713.90
28	IPC No 28	43.12	16,925,572.26	204,834,652.16	307,572,573.70
29	IPC No 29	46.19	9,543,567.26	219,381,769.69	325,839,583.00
30	IPC No 30	46.66	2,014,871.19	221,653,125.22	344,106,592.25
31	IPC No 31	52.40	32,334,312.11	248,904,062.62	376,440,904.36
32	IPC No 32	62.21	62,252,329.78	295,478,569.73	446,888,974.35
33	IPC No 33	67.04	24,976,182.50	318,445,652.10	471,865,156.85
34	IPC No 34	69.20	10,264,169.61	328,709,821.71	482,129,333.46
35	IPC No 35	72.99	17,991,376.37	346,701,198.08	502,950,206.47
36	IPC No 36	78.79	21,172,361.40	374,240,690.01	530,489,698.40

Table 4.1 Addis Ababa LRT Project data

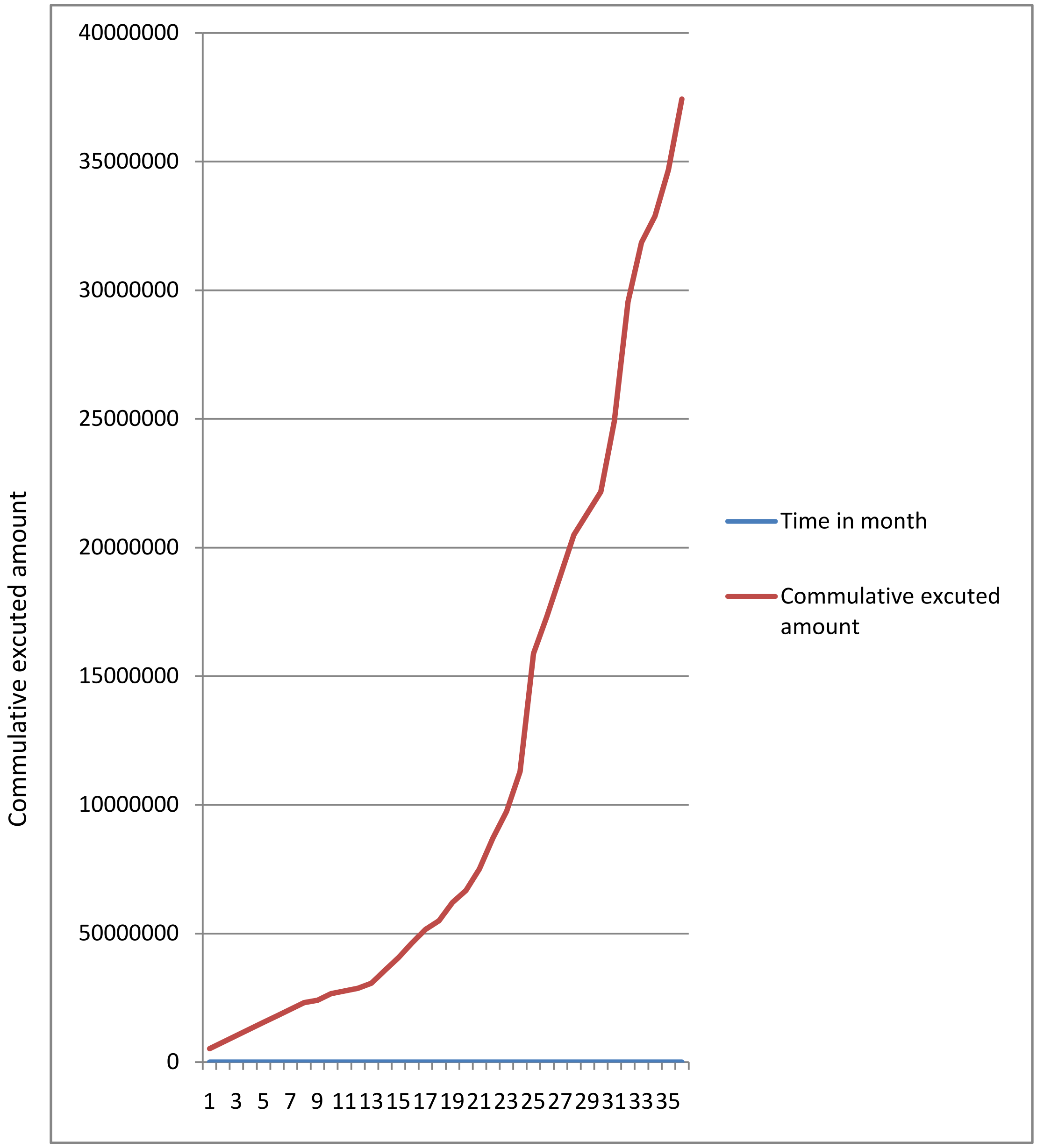


Fig 4.1 S-Curve for LRT

Time in month

The curve shows substantial change at month 22 or up to 18.31% so let separate the data in two that is the data from month 1 to month 22 should be sorted in to one category where as the data from month 23 to 36 should be sorted in to another group as follows

Category 1 from month 1 to month 22 (up to 18.31%)

Month	payment no	to date %age execute	Current payed Amount	Todate executed Amount	Grand total
1	IPC No 1	4.04	4,613,335.87	19,147,387.38	19,147,387.38
2	IPC No 2	4.26	1,949,611.16	20,192,387.38	20,192,387.38
3	IPC No 3	4.48	1,750,959.23	21,237,387.38	21,237,387.38
4	IPC No 4	4.70	1,316,387.38	22,282,387.38	22,282,387.38
5	IPC No 5	4.92	1,390,570.46	23,327,387.38	23,327,387.38
6	IPC No 6	5.14	1,396,573.94	24,372,387.38	24,372,387.38
7	IPC No 7	5.36	1,619,215.23	25,417,387.38	25,417,387.38
8	IPC No 8	5.58	1,312,568.08	26,462,387.38	26,462,387.38
9	IPC No 9	5.80	643,266.70	27,507,387.38	27,507,387.38
10	IPC No 10	6.02	1,678,686.46	28,552,387.38	28,552,387.38
11	IPC No 11	6.24	1,750,048.58	29,597,387.38	29,597,387.38
12	IPC No 12	6.34	1,632,768.12	30,072,387.38	30,072,387.38
13	IPC No 13	6.45	3,456,105.73	30,637,621.00	30,637,621.00
14	IPC No 14	7.51	4,011,953.76	35,652,563.37	35,652,563.37
15	IPC No 15	8.55	3,958,981.60	40,601,290.38	40,601,290.38
16	IPC No 16	9.75	4,584,978.75	46,332,513.82	46,332,513.82
17	IPC No 17	10.84	4,122,295.81	51,485,383.58	51,485,383.58
18	IPC No 18	11.56	2,731,690.96	54,899,997.27	54,899,997.27

19	IPC No 19	13.05	11,120,771.40	62,005,953.90	68,800,961.53
20	IPC No 20	14.04	3,747,897.73	66,690,826.07	73,485,833.70
21	IPC No 21	15.79	13,886,551.84	75,009,672.15	90,844,023.50
22	IPC No 22	18.31	12,868,030.16	86,995,206.62	115,968,404.91

Table 4.2 Category 1 LRT project (up to 18.31%)

Catagory 2 from month 23 to 36 (18.31% to 78.79%)

Month	payment no	to date %age execute	Current payed Amount	Todate executed Amount	Grand total
23	IPC No 23	20.50	9,875,469.03	97,378,405.62	137,022,863.67
24	IPC No 24	23.76	10,654,819.81	112,861,225.22	161,012,648.20
25	IPC No 25	33.42	31,680,621.04	158,755,264.39	219,017,956.17
26	IPC No 26	36.48	8,109,213.04	173,288,016.71	238,212,854.12
27	IPC No 27	40.05	14,632,921.22	190,238,280.62	272,892,713.90
28	IPC No 28	43.12	16,925,572.26	204,834,652.16	307,572,573.70
29	IPC No 29	46.19	9,543,567.26	219,381,769.69	325,839,583.00
30	IPC No 30	46.66	2,014,871.19	221,653,125.22	344,106,592.25
31	IPC No 31	52.40	32,334,312.11	248,904,062.62	376,440,904.36
32	IPC No 32	62.21	62,252,329.78	295,478,569.73	446,888,974.35
33	IPC No 33	67.04	24,976,182.50	318,445,652.10	471,865,156.85
34	IPC No 34	69.20	10,264,169.61	328,709,821.71	482,129,333.46

35	IPC No 35	72.99	17,991,376.37	346,701,198.08	502,950,206.47
36	IPC No 36	78.79	21,172,361.40	374,240,690.01	530,489,698.40

Table 4.3 Category 1 LRT project (18.31% to 78.79%)

Sebeta-Mieso Railway project data

Month	payment no	to date %age executed	Current payed Amount	Todate executed Amount	Grand total
1	IPC No 1	3.15	55,027,509.46	57,923,694.17	57,923,694.17
2	IPC No 2	3.44	5,206,190.31	63,374,845.41	63,374,845.41
3	IPC No 3	4.08	11,497,749.51	75,044,133.45	75,044,133.45
4	IPC No 4	9.00	95,306,608.70	170,783,955.22	170,783,955.22
5	IPC No 5	12.55	46,846,683.72	231,059,784.98	239,728,609.67
6	IPC No 6	14.23	21,623,062.47	262,090,613.32	271,746,999.46
7	IPC No 7	16.15	24,691,995.64	297,485,511.90	308,296,286.06
8	IPC No 8	22.19	78,544,267.37	408,612,043.09	424,067,941.62
9	IPC No 9	31.57	121,891,900.42	581,284,011.35	603,804,951.41
10	IPC No 10	39.71	106,932,751.89	731,193,519.38	106,932,751.89
11	IPC No 11	53.78	172,379,518.91	990,410,841.05	189,736,423.65

Table 4.4 Sebeta-Mieso Railway project data

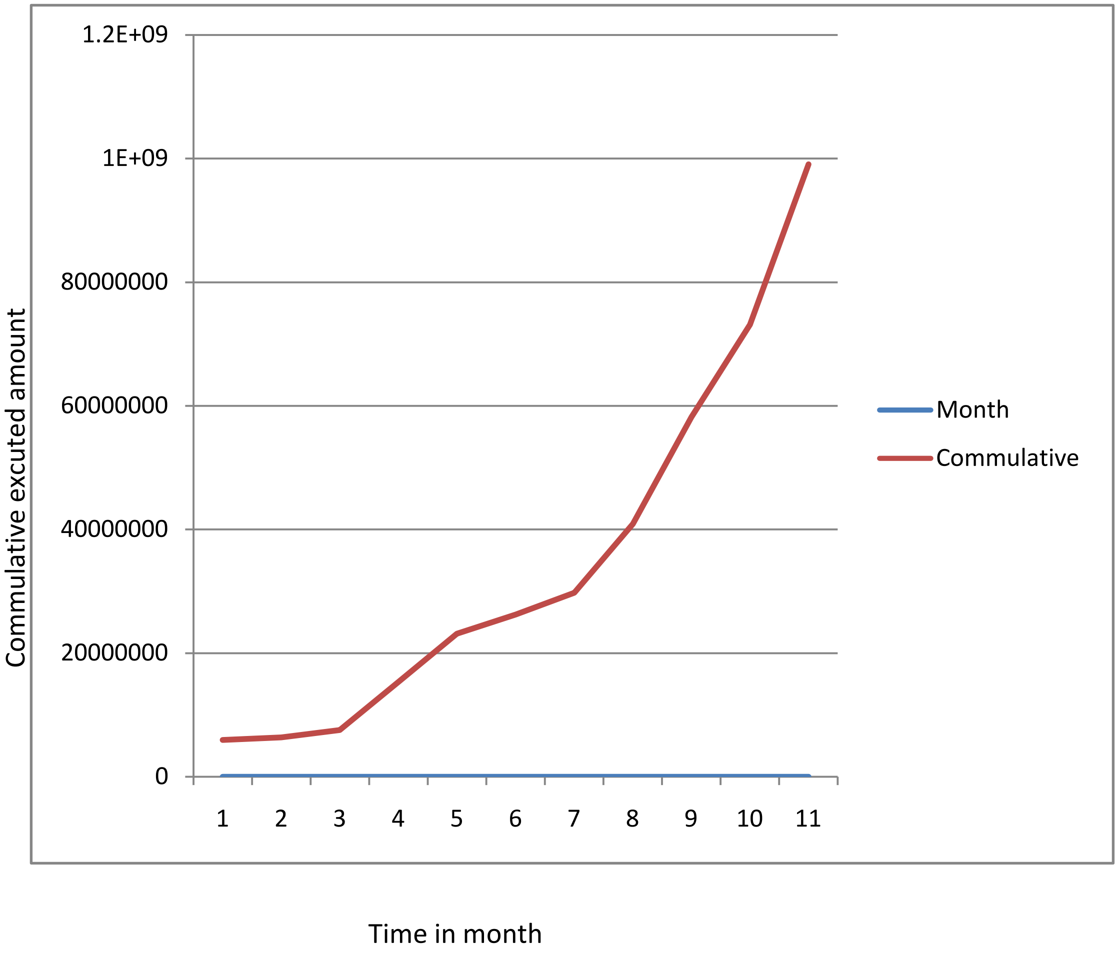


Fig 4.2 Sebeta Meiso S curve

The curve shows substantial change at month 7 (up to 16.15%) so let separate the data in two, that is the data from month 1 to month 7 should be sorted in to one category where as the data from month 8 to 11 should be sorted in to another group as follows

Category 1 Sebeta-Meiso (up to 16.15%)

Month	payment no	to date %age executed	Current payed Amount	Todate executed Amount	Grand total
1	IPC No 1	3.15	55,027,509.46	57,923,694.17	57,923,694.17
2	IPC No 2	3.44	5,206,190.31	63,374,845.41	63,374,845.41
3	IPC No 3	4.08	11,497,749.51	75,044,133.45	75,044,133.45
4	IPC No 4	9.00	95,306,608.70	170,783,955.22	170,783,955.22
5	IPC No 5	12.55	46,846,683.72	231,059,784.98	239,728,609.67
6	IPC No 6	14.23	21,623,062.47	262,090,613.32	271,746,999.46
7	IPC No 7	16.15	24,691,995.64	297,485,511.90	308,296,286.06

Table 4.5 Category 1 Sebeta-Meiso (up to 16.15%)

Month	payment no	to date %age executed	Current payed Amount	Todate executed Amount	Grand total
8	IPC No 8	22.19	78,544,267.37	408,612,043.09	424,067,941.62
9	IPC No 9	31.57	121,891,900.42	581,284,011.35	603,804,951.41
10	IPC No 10	39.71	106,932,751.89	731,193,519.38	106,932,751.89
11	IPC No 11	53.78	172,379,518.91	990,410,841.05	189,736,423.65

Table 4.6 Category 2 Sebeta Meiso (16.15 to 53.78%)

Mieso –Dewanle Ralway project data

Month	payment no	to date %age executed	Current paid Amount	Todate executed Amount	Grand total
1	IPC No 1	3.00	34,625,230.63	36,318,158.64	36,318,158.64
2	IPC No 2	4.00	18,047,242.03	54,460,736.78	54,460,736.78
3	IPC No 3	8.00	49,914,663.38	105,839,723.30	105,839,723.30
4	IPC No 4	10.00	37,590,822.15	146,049,885.56	146,049,885.56
5	IPC No 5	12.65	22,296,529.15	177,322,423.16	182,627,099.11
6	IPC No 6	21.21	84,680,661.34	297,340,228.99	307,513,725.40
7	IPC No 7	30.00	87,650,595.50	420,531,088.71	436,433,258.90
8	IPC No 8	38.03	80,157,212.79	533,061,709.11	554,288,229.52
9	IPC No 9	44.00	57,475,234.11	613,263,449.49	614,820,271.10
10	IPC No 10	46.23	25,048,687.96	648,106,966.04	675,352,312.66
11	IPC No 11	49.24	28,040,428.72	690,273,024.27	720,181,572.65

Table 4.7 Mieso –Dewanle Ralway project

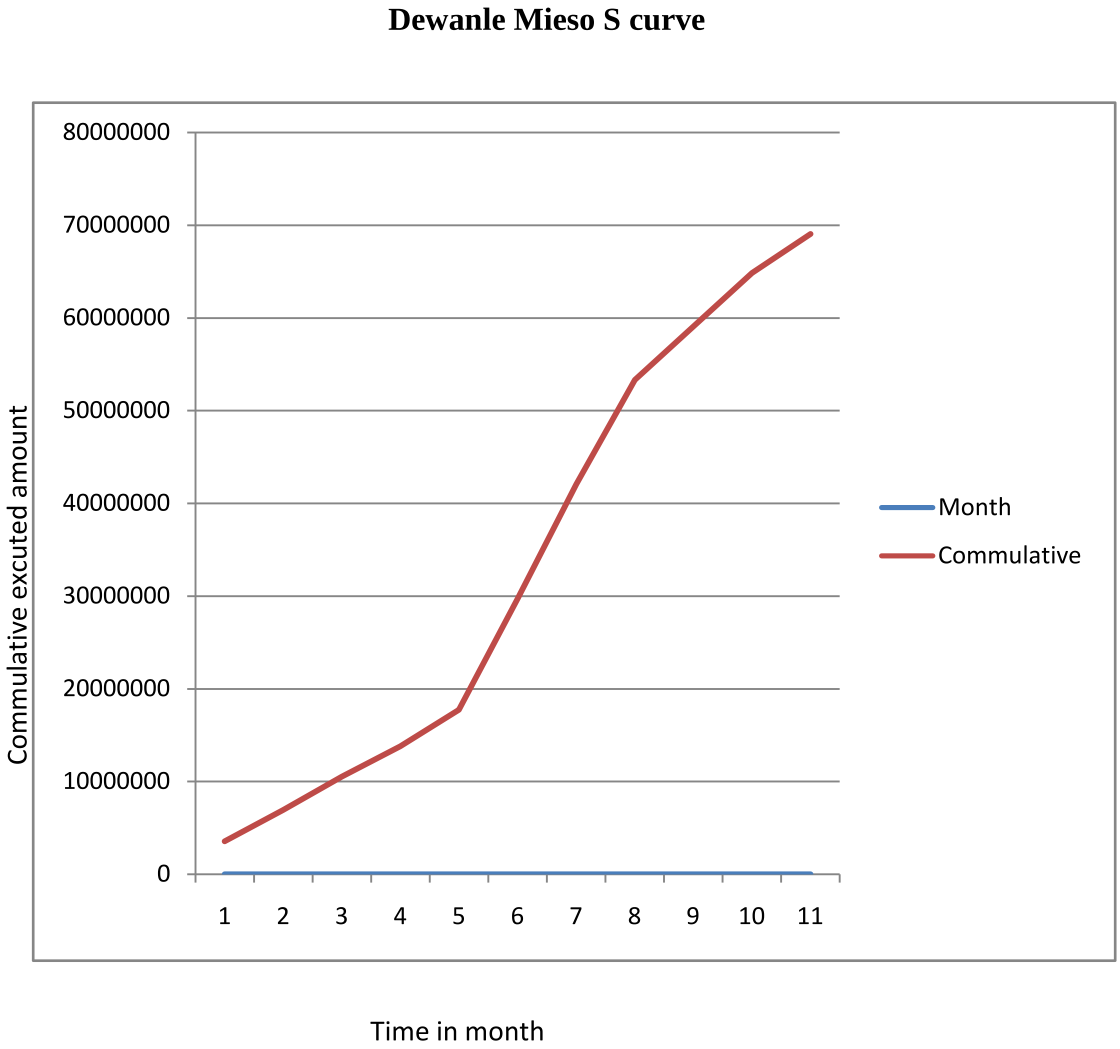


Fig4.3 Meiso Dewanle S curve

The curve shows substantial change at month 5 (12.65%) so let separate the data in to two, that is the data from month 1 to month 5 (up to 12.65%) should be sorted in to one category where as the data from month 6 to 11 (12.65% to 49.24%) should be sorted in to another group as follows

Category 1 Meiso dewanle (up to 12.65%)

Month	payment no	to date %age executed	Current payed Amount	Todate executed Amount	Grand total
1	IPC No 1	3.00	34,625,230.63	36,318,158.64	36,318,158.64
2	IPC No 2	4.00	18,047,242.03	54,460,736.78	54,460,736.78
3	IPC No 3	8.00	49,914,663.38	105,839,723.30	105,839,723.30
4	IPC No 4	10.00	37,590,822.15	146,049,885.56	146,049,885.56
5	IPC No 5	12.65	22,296,529.15	177,322,423.16	182,627,099.11

Table 4.8 Category 1 Meiso Dewanle (up to 12.65%)

Month	payment no	to date %age executed	Current payed Amount	Todate executed Amount	Grand total
6	IPC No 6	21.21	84,680,661.34	297,340,228.99	307,513,725.40
7	IPC No 7	30.00	87,650,595.50	420,531,088.71	436,433,258.90
8	IPC No 8	38.03	80,157,212.79	533,061,709.11	554,288,229.52
9	IPC No 9	44.00	57,475,234.11	613,263,449.49	614,820,271.10
10	IPC No 10	46.23	25,048,687.96	648,106,966.04	675,352,312.66
11	IPC No 11	49.24	28,040,428.72	690,273,024.27	720,181,572.65

Table 4.9 Category 2 Meiso Dewanle (12.65 to 49.24%)

Sebeta –Dewanle Ralway project (Addis Abab-Djibouti)

Month	payment no	to date %age executed	Current payed Amount	Todate executed Amount	Grand total
1	IPC No 1	3.08	17,312,615.32	47,120,926.41	47,120,926.41
2	IPC No 2	3.72	9,023,621.02	58,917,791.10	58,917,791.10
3	IPC No 3	6.04	24,957,331.69	90,441,928.38	90,661,689.63
4	IPC No 4	9.50	18,795,411.08	158,416,920.39	158,416,920.39
5	IPC No 5	12.60	11,148,264.58	204,191,104.07	211,177,854.39
6	IPC No 6	17.72	42,340,330.67	279,715,421.16	289,630,362.43
7	IPC No 7	23.08	43,825,297.75	359,008,300.31	372,364,772.48
8	IPC No 8	30.11	40,078,606.40	470,836,876.10	489,178,085.57
9	IPC No 9	37.78	28,737,617.06	597,273,730.42	609,312,611.26
10	IPC No 10	42.97	12,524,343.98	689,650,242.71	391,142,532.28
11	IPC No 11	51.51	14,020,214.36	840,341,932.66	454,958,998.15

Table 4.10 Sebeta –Dewanle Ralway project (Addis Abab-Djibouti)

Sebteta-Dewanle S Curve (Addis Ababa-Djibouti)

It is a curve created by combining the two projects, that is sebeta-Meiso and Meiso –Dewanle projects

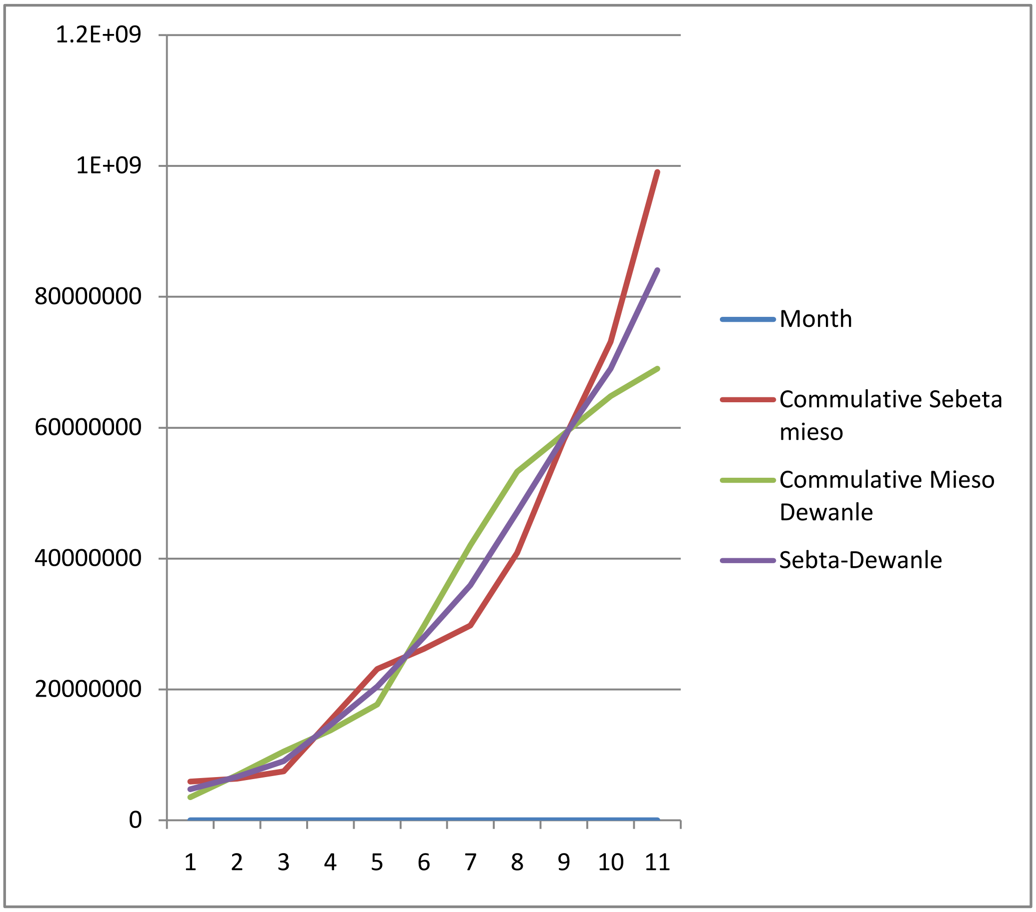


Fig 4.4 Sebeta Dewanle S Curve

The curve shows substantial change at month 6 (17.72%) so let separate the data in two, that is the data from month 1 to month 5 (up to 17.72%) should be sorted in to one category where as the data from month 7 to 11 (17.72 to 51.51%) should be sorted in to another group as follows

Category 1 Sebeta Dewanle

Month	payment no	to date %age executed	Current payed Amount	Todate executed Amount	Grand total
1	IPC No 1	3.08	17,312,615.32	47,120,926.41	47,120,926.41
2	IPC No 2	3.72	9,023,621.02	58,917,791.10	58,917,791.10
3	IPC No 3	6.04	24,957,331.69	90,441,928.38	90,661,689.63
4	IPC No 4	9.50	18,795,411.08	158,416,920.39	158,416,920.39
5	IPC No 5	12.60	11,148,264.58	204,191,104.07	211,177,854.39
6	IPC No 6	17.72	42,340,330.67	279,715,421.16	289,630,362.43

Table 4.11 Category 1 Sebeta Dewanle (up to 17.72%)

Month	payment no	to date %age executed	Current payed Amount	Todate executed Amount	Grand total
7	IPC No 7	23.08	43,825,297.75	359,008,300.31	372,364,772.48
8	IPC No 8	30.11	40,078,606.40	470,836,876.10	489,178,085.57
9	IPC No 9	37.78	28,737,617.06	597,273,730.42	609,312,611.26
10	IPC No 10	42.97	12,524,343.98	689,650,242.71	391,142,532.28
11	IPC No 11	51.51	14,020,214.36	840,341,932.66	454,958,998.15

Table 4.12 Category 2 Sebeta Dewanle (17.72 to 51.51%)

4.2.3 Exploratory Analysis of Data and Test on Correlation of Data

Correlation coefficients of variables of projects

Category	Variable	
	Time	Cost
LRT	1	0.908
Sebeta-Meiso	1	0.938
Meiso-dewanle	1	0.983
Sebata-dewanle (AA-Djibouti)	1	0.975

Table 4.13 Pearson's correlation coefficient

The transformation of a data by using SQRT, LOG or INVERSE functions yields better results for correlation models NIST (2008)). Thus the data has been transformed by using SQRT and LOG functions only as INVERSE functions will reduce the significance figure of the cost.

Time and cost	LRT Project			Sebta Mieso project			Mieso dewanle Project			Sebeta dewanle Project		
Correlation	Observed	LOG	SQRT	Observed	LOG	SQRT	Observed	LOG	SQRT	Observed	LOG	SQRT
T-C correlation.	0.908	**0.984**	0.954	0.938	**0.987**	0.982	0.983	0.971	**0.989**	0.975	0.988	**0.997**

Table 4.14 Correlation coefficient for transformed data

The results shown in Table 4.13 clearly indicate that LOG transformations result is in a better correlation for LRT and sebeta mieso projects where as SQRT transformation is in a better correlation for Mieso dewanle and Sebeta meiso projects.

The existence of a relationship was also checked by using exploratory methods; mainly scatter plots for observed and transformed data's respectively. The results shown in Figures below indicate that there is a relationship between time and cost for all Projects.

Scatter Plot for LRT Project

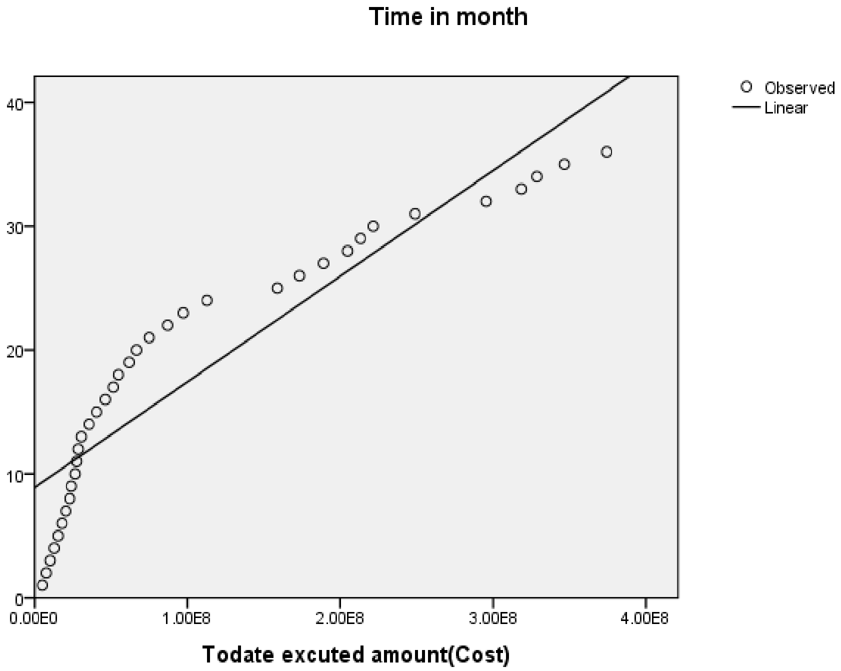


Fig 4.5 Scatter plot for observed data for LRT

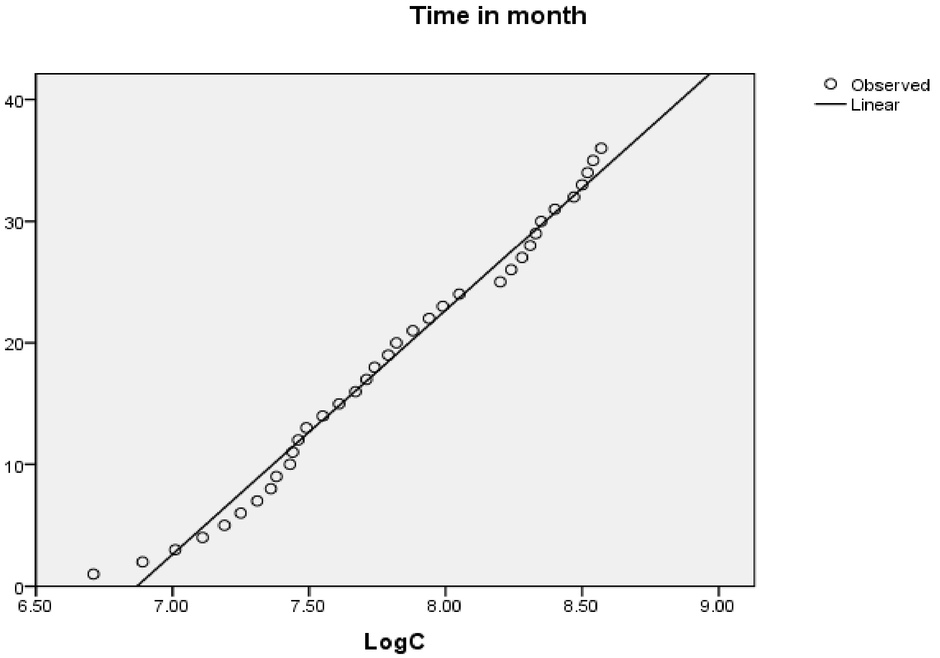


Fig 4.6 Scatter plot for LOG transformed data for LRT

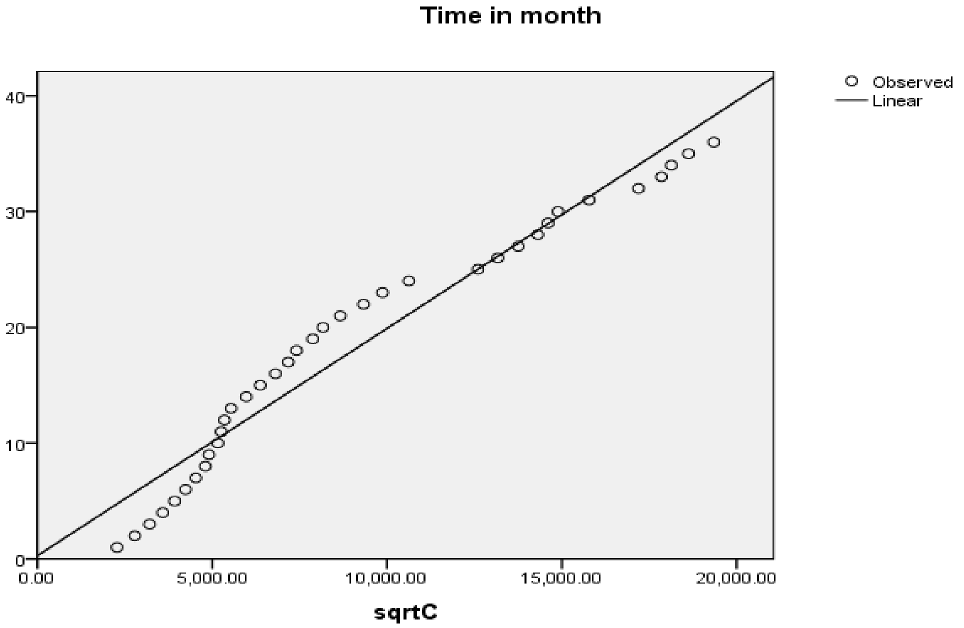


Fig 4.7 Scatter plot for SQRT transformed data for LRT

Scatter Plot for Sebeta Mieso Project

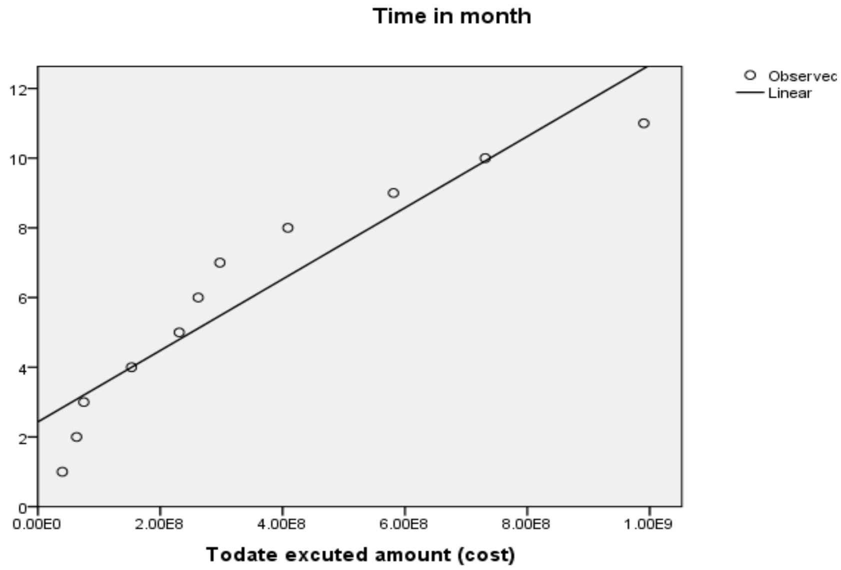
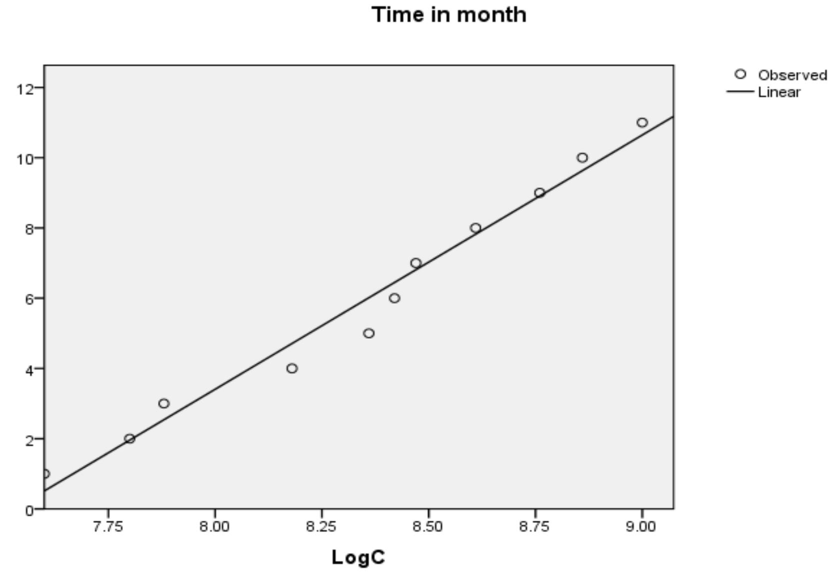


Fig 4.8 scatter plot for observed data for Sebeta Mieso



`

Fig 4.9 Scatter plot for LOG transformed data for Sebeta Mieso

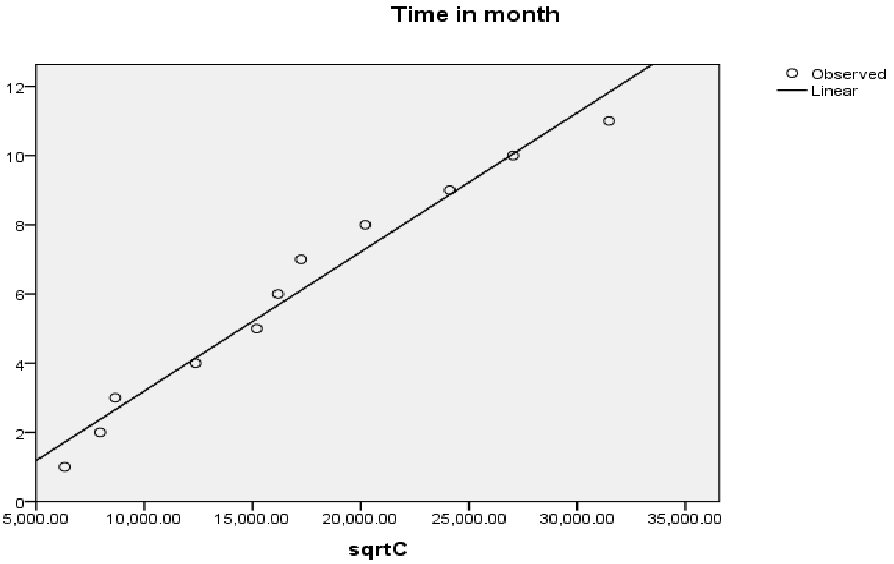


Fig 4.10 Scatter plot for SQRT transformed data for Sebeta Mieso

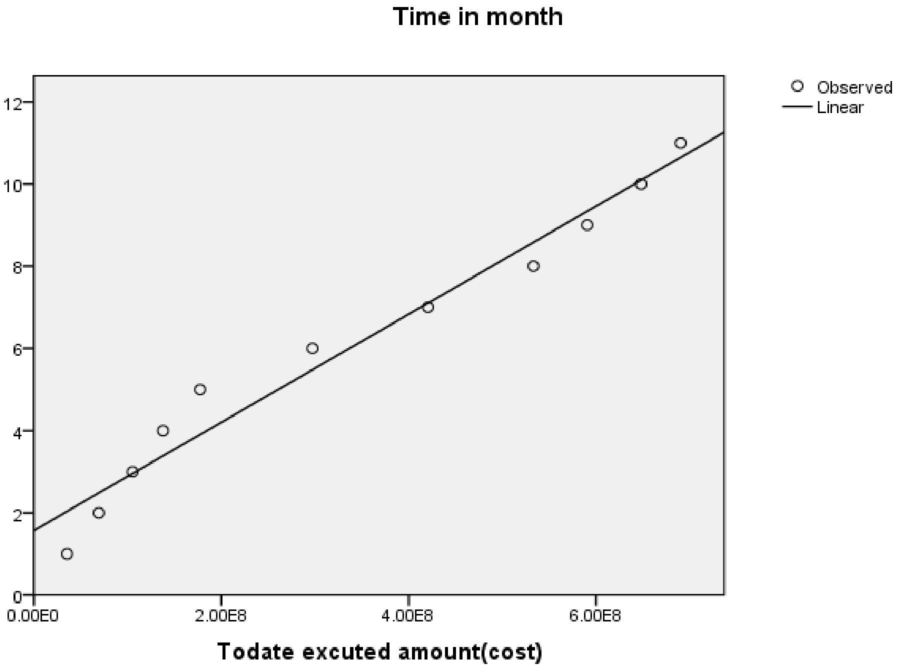


Fig 4.11 Scatter plot for observed data for Meiso dewanle

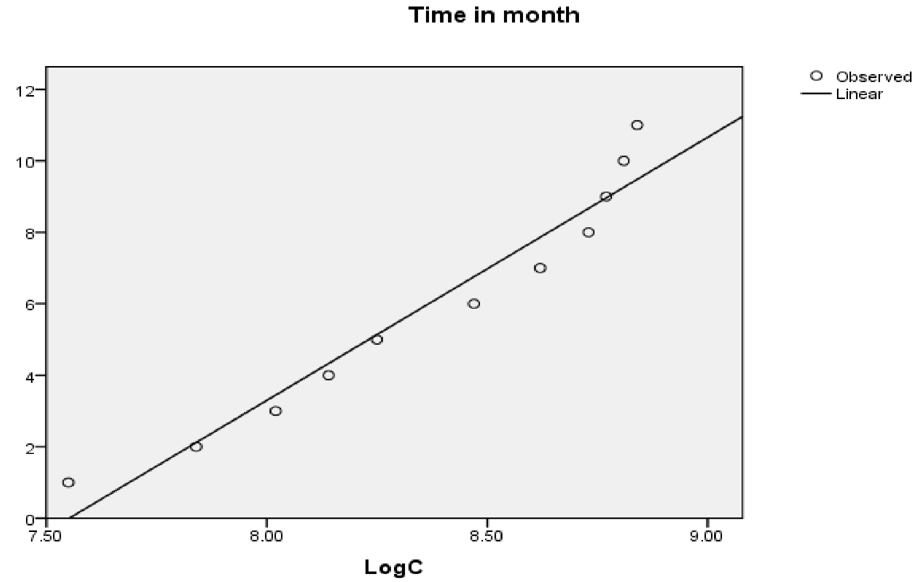


Fig 4.12 Scatter plot for LOG transformed data for Meiso dewanle

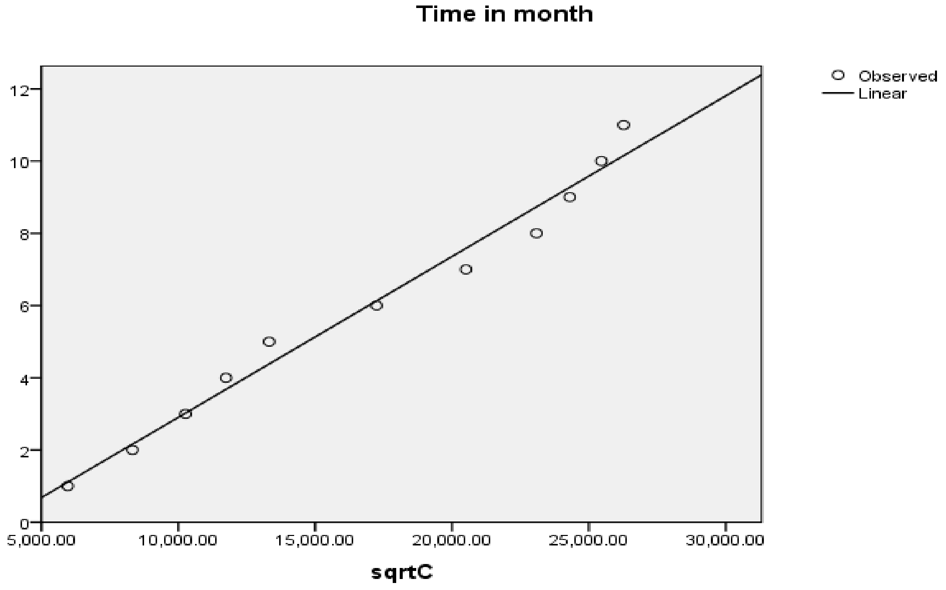


Fig 4.13 Scatter plot for SQRT transformed data for Mieso dewanle

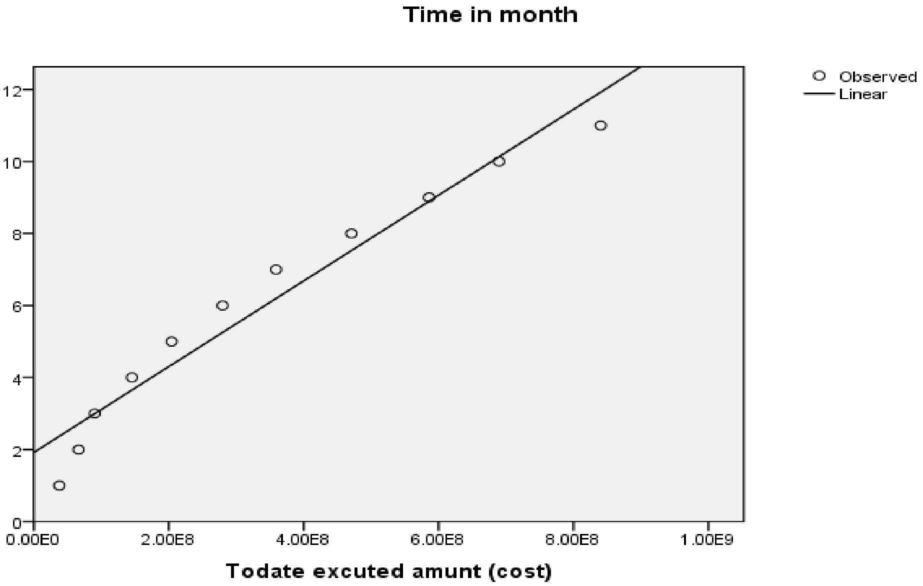


Fig 4.14 Scatter plot for observed data for Sebeta dewanle

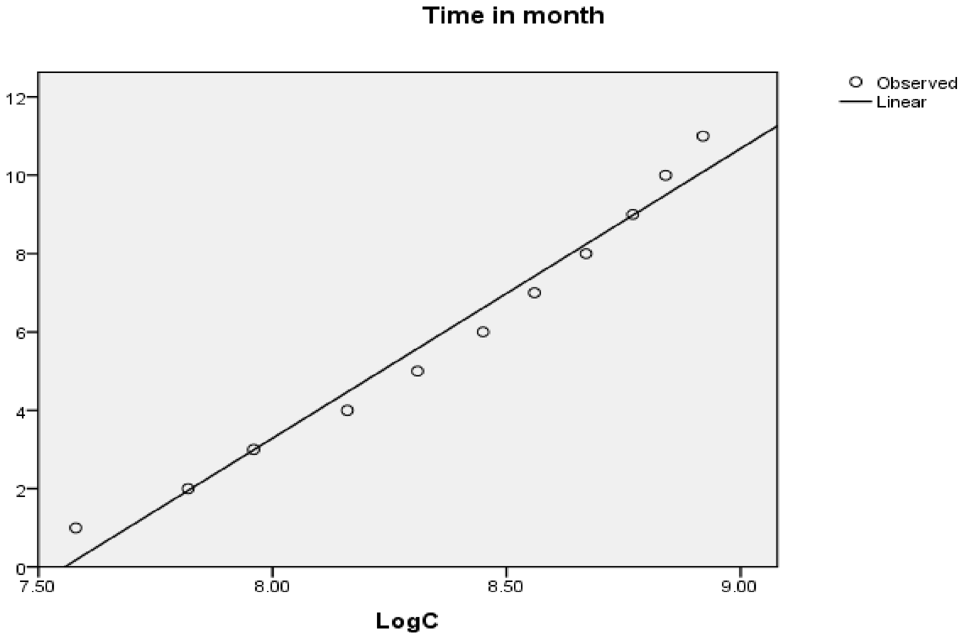


Fig 4.15 Scatter plot for LOG transformed data for Sebeta dewanle

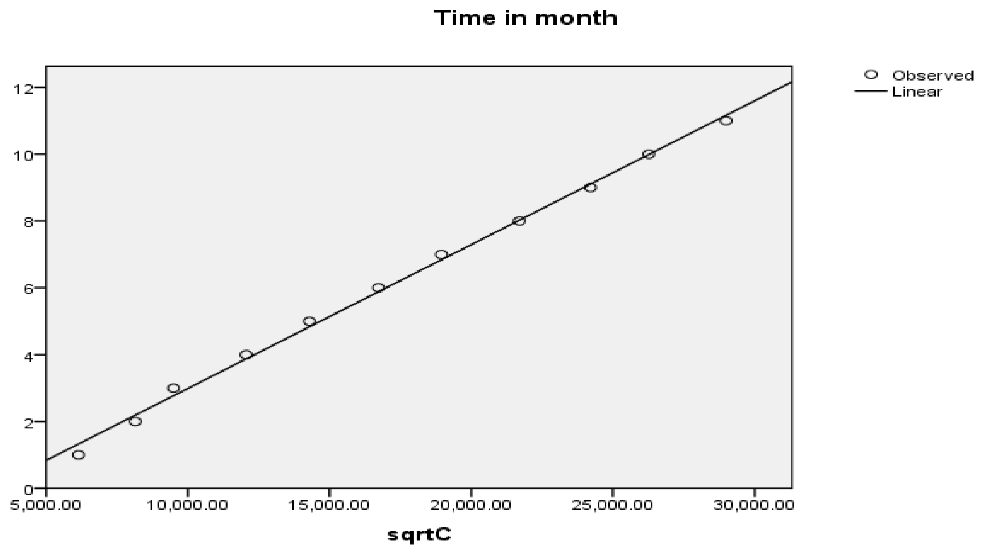


Fig 4.16 Scatter plot for SQRT transformed data for Sebeta dewanle

4.2.4 Hypothesis Testing

One of the objectives of this research is to test the applicability of Bromilow's model to Ethiopian Railway projects. According to Chen (2006) a correlation among variables shall be considered if the correlation coefficient is greater than 0.700. Thus correlation results shown in Table 4.12 are considered to be significant if their value is 0.700 or above. Null hypothesis was used to test the model by stating that there is no relationship between time (construction duration) and cost (construction cost) of railway projects. The F – test shall be used to test such relationships Chan (1999),Choudhury et al, (2003) and Endut et al, (2006). The relation will be tested at significance level of 5% ($\rho > 0.05$).

4.2.5 Test of Hypothesis for the railway projects

4.2.5.1 Test of hypothesis for LRT project

Figure 4.5, 4.6 and 4.7 shows the relationship between time and cost for LRT projects .and Table 4.14 shows the coefficient and linear regression results of the relationship.

Table : LRT project: Regression Analysis of the Time – Cost relationship	
Regression Results	Time and LOG C
R	0.993
R2	0.986
Adjusted R2	0.986
F	14.65
Significance	0.000

Table 4.15 LRT project: Regression Analysis of the Time-Cost relationship

Conclusion: The F – test result of the linear regression for Time and cost has a significance level of 0.000. The results is below the assumed 5% significance level and thus the LRT projects have been found to be accepted for Time – Cost relationship according to Bromilow's principle.

4.2.5.2 Test of hypothesis for Sebeta Mieso project

Figure 4.8, 4.9 and 4.10 shows the relationship between time and cost for Sebeta Mieso projects and Table 4.15 shows the coefficient and linear regression results of the relationship.

Table : Sebeta Mieso projects: Regression Analysis of the Time – Cost relationship	
Regression Results	Time and LOG C
R	0.988
R2	0.977
Adjusted R2	0.975
F	387.77
Significance	0.000

Table 4.16 Sebeta Mieso project: Regression Analysis of the Time-Cost relationship

Conclusion: The F – test result of the linear regression for Time and cost has a significance level of 0.000 (as the SPSS tools shows). The result is below the assumed 5% significance level and thus the Sebeta Mieso project has been found to be accepted for Time – Cost relationship according to Bromilow's principle.

4.2.5.3 Test of hypothesis for Mieso dewanle project

Figure 4.11, 4.12 and 4.13 shows the relationship between time and cost for Sebeta Mieso projects .and Table 4.16 shows the coefficient and linear regression results of the relationship.

Table : Mieso dewanle project: Regression Analysis of the Time – Cost relationship	
Regression Results	Time and SQRT C
R	0.990
R2	0.979
Adjusted R2	0.0.977
F	429.797
Significance	0.000

Table 4.17 Mieso dewanle project: Regression Analysis of the Time-Cost relationship

Conclusion: The F – test result of the linear regression for Time and cost has a significance level of 0.000. The result is below the assumed 5% significance level and thus the Mieso dewanle project has been found to be accepted for Time – Cost relationship according to Bromilow's principle.

4.2.5.4 Test of hypothesis for Sebeta dewanle project

Figure 4.14, 4.15 and 4.16 shows the relationship between time and cost for Sebeta Mieso projects .and Table 4.17 shows the coefficient and linear regression results of the relationship.

Table : Sebeta dewanle project: Regression Analysis of the Time – Cost relationship	
Regression Results	Time and SQRT C
R	0.999
R2	0.997
Adjusted R2	0.997
F	30.60
Significance	0.000

Table 4.18 Sebeta dewanle project: Regression Analysis of the Time-Cost relationship

Conclusion: The F – test result of the linear regression for Time and cost has a significance level of 0.000. The result is below the assumed 5% significance level and thus the Sebeta dewanle project has been found to be accepted for Time – Cost relationship according to Bromilow's principle.

4.2.6 Developing Regression Models

The regression model results indicated that there is a relationship among time and cost. For developing the regression model, the following nine regression models were investigated to identify the best format for this research: linear equation (LIN), logarithmic equation (LOG), inverse equation (INV), quadric equation (QUA), cubic equation (CUB), composite equation (COM), power equation (POW), S-curve equation (S) and exponential equation (EXP). Table presents the basic forms of the equations for these regression models, where X denotes the independent variable; Y denotes the dependent variable, and b0, b1, b2 denote constants.

Regression Model	**Regression equation**
Linear regression (LIN)	$Y= b_o+b_1*X$
Logarithmic regression (LOG)	$Y=b_o+b_1*\ln X$
Inverse regression (INV)	$Y=b_o+b_1/X$
Quadratic regression (QUA)	$Y=b_o+b_1*X+b_2*X^2$
Cubic regression (CUB)	$Y=b_o+b_1*X+ b_2*X^2 + b_3*X^3$
Composite regression (COM)	$Y=b_o*b_1^X$
Power regression (POW)	$Y=b_o*X^{b1}$
S-Curve regression (S)	$Y=e^{(bo+b1/X)}$
Exponential regression (EXP)	$Y=bo*e^{(b1*X)}$

Where X denotes the independent variable; Y denotes the dependent variable, and b0, b1, b2 and b3 denote constants.

Table 4.19 Equation forms of regression models

The models for Time were developed for LRT, Sebeta-Mieso, Mieso-dewanle and Sebeta – dewanle for each category that is for category1 and category2 based on the obtained S-Curve for all projects. The results of the regression models shown in Table 4.19 indicates that Cubic (CUB) equation combined with logarithmic transformation for LRT, Quadratic (QUA) equations combined with logarithmic transformation for Sebeta-Mieso, Cubic (CUB) equation combined with SQRT transformation for Mieso-dewanle, and Sebeta,dewanle projects. Thus the equations for the different categories have been developed as follows:

R2 for all projects				
	Project Category			
Regression Model	LRT	Sebeta Mieso	Mieso Dewanle	Sebeta Dewanle
LIN	0.986	0.977	0.979	0.997
LOG	0.978	0.975	0.944	0.973
INV	0.974	0.965	0.836	0.869
QUA	0.989	**0.988**	0.980	0.999
CUB	**0.991**	0.889	**0.993**	**0.999**
COM	0.912	0.911	0.924	0.936
POW	0.921	0.898	0.896	0.972
S	0.898	0.923	0.843	0.941
EXP	0.902	0.946	0.931	0.898
F	14.65	387.77	429.797	30.60
P	0.000	0.000	0.000	0.000

Table 4.20 R2 of regression equations for time prediction

1) **Regression Model for Category 1 for LRT project (up to 18.31% of the project)**
    - The selected equation is Cubic (CUB) equation combined with logarithmic transformation as show on table 4.19 and 4.13
    - Cubic regression (CUB)…………………………$Y=b_o+b_1*X+ b_2*X^2 + b_3*X^3$

      Where,

      Y=T

      bo= -52658.453

      b1= 20431.653

      b2= -2644.186

      b3= 114.177

      X= Log C

      $T= b_o+b_1*\text{Log C}+ b_2*(\text{Log C})^2 + b_3*(\text{Log C})^3$

$T= -52658.453 + 20431.653*(\text{Log } C) - 2644.186* (\text{Log } C)^{2} + 114.177* (\text{Log } C)^{3}$ ……………………………………………………….equation 4.1

Example 1. if we take randomly as an example the 10th and 20th month, the cumulative executed amount is 28,552,387.38 and 66,690,826.07 respectively

T at 10th month= -52658.453 + 20431.653*(Log 28,552,387.38) - 2644.186* (Log 28,552,387.38) ^{2} + 114.177* (Log 28,552,387.38) ^{3} = 10.15 month, so the percentage error is -1.46% which is acceptable as it is below maximum average percentage error of 15.75% (Chen, 2006)

T at 20th month= -52658.453 + 20431.653*(Log 66,690,826.07) - 2644.186* (Log 66,690,826.07) ^{2} + 114.177* (Log 66,690,826.07) ^{3} = 19.64 month, so the percentage error is 1.79% which is acceptable as it is below maximum average percentage error of 15.75% (Chen, 2006).

2) Regression Model for Category 2 for LRT project (from 18.31% to 78.79%)

- The selected equation is Cubic (CUB) equation combined with logarithmic transformation as show on table 4.19 and 4.13
- Cubic regression (CUB)…………………………$Y=b_o+b_1*X+ b_2*X^2 + b_3*X^3$

Where,

Y=T
bo= 69618.152
b1= -25046.446
b2= 3001.125
b3= -119.717
X= Log C

$T= b_o+b_1*\text{Log } C+ b_2*(\text{Log } C)^2 + b_3*(\text{Log } C)^3$

$T= 69618.152 -25046.446*(\text{Log } C) + 3001.125 (\text{Log } C)^{2} – 119.717* (\text{Log } C)^{3}$ ………………………………………….equation 4.2

Example 2. if we take randomly as an example the 25th and 35th month, the cumulative executed amount is 158,755,264.39 and 346,701,198.08 respectively

T at 25th month = 69618.152 -25046.446*(Log 158,755,264.39) + 3001.125 (Log 158,755,264.39) ^{2} – 119.717* (Log 158,755,264.39) ^{3} = 24.83 month, so the percentage error is 0.67% which is acceptable as it is below maximum average percentage error of 15.75% (Chen, 2006).

T at 35th month = 69618.152 -25046.446*(Log 346,701,198.08) + 3001.125 (Log 346,701,198.08) ^{2} – 119.717* (Log 346,701,198.08) ^{3} = 34.31 month, so the percentage error is 1.97% which is acceptable as it is below maximum average percentage error of 15.75% (Chen, 2006).

Regression model for the whole project for LRT (up to 78.79%)

- The selected equation is Cubic (CUB) equation combined with logarithmic transformation as show on table 4.19 and 4.13
- Cubic regression (CUB)………………………… $Y=b_o+b_1*X+ b_2*X^2 + b_3*X^3$
  Where,

Y=T
bo= -18551.61
b1= 6939.213
b2= -865.76
b3= 36.073
X= Log C

$T= b_o+b_1*\text{Log C}+ b_2*(\text{Log C})^2 + b_3*(\text{Log C})^3$

$$\mathbf{T= -18551.61 + 6939.213*(Log\ C) - 865.76\ (Log\ C)^{2} + 36.073*\ (Log\ C)^{3}}$$

Example. If we take randomly as an example the 10th and 20th month, the cumulative executed amount is 28,552,387.38 and 66,690,826.07 respectively

T at 10^{th} month -18551.61 + 6939.213*(Log 28,552,387.38) - 865.76 (Log 28,552,387.38) 2 + 36.073* (Log 28,552,387.38) 3 = 9.89 month, so the percentage error is 1.05% which is acceptable as it is below maximum average percentage error of 15.75% (Chen, 2006).

T at 20th month= -18551.61 + 6939.213*(Log 66,690,826.07) - 865.76 (Log 66,690,826.07) 2 + 36.073* (Log 66,690,826.07) 3 = 20.33 month, so the percentage error is -1.67% which is acceptable as it is below maximum average percentage error of 15.75% (Chen, 2006).

3) Regression Model for Category 1 for Sebeta mieso project (up to 16.15%)

- The selected equation is Quadratic (QUA) equation combined with logarithmic transformation as show on table 4.19 and 4.13
- Quadratic (QUA)…………………………$Y=b_o+b_1*X+b_2*X^2$

Where,

Y=T
bo= 657.564
b1= -168.744
b2= 10.856
X= Log C

$T= b_o+b_1*\text{Log } C+ b_2*(\text{Log } C)^2$

$T= 657.564 - 168.744*(\text{Log } C) + 10.856*(\text{Log } C)^2$ ………………………………………………………………equation 4.3

Example 3. if we take randomly as an example the 2^{nd} and 6^{th} month, the cumulative executed amount is 63,374,845.41 and 262,090,613.32 respectively

T at 2^{nd} month= 657.564 – 168.744*(Log 63,374,845.41) + 10.856* (Log 63,374,845.41) ^{2} =1.84 month, so the percentage error is 7.95% which is acceptable as it is below maximum average percentage error of 15.75% (Chen, 2006).

T at 6th month= 657.564 – 168.744*(Log 262,090,613.32) + 10.856* (Log 262,090,613.32)^2 = 6.37 month, so the percentage error is -6.15% which is acceptable as it is below maximum average percentage error of 15.75% (Chen, 2006).

4) Regression Model for Category 2 for Sebeta mieso project (16.15% to 53.78%)

- The selected equation is Quadratic (QUA) equation combined with logarithmic transformation as show on table 4.19 and 4.13
- Quadratic (QUA)…………………………$Y=b_o+b_1*X+b_2*X^2$
- Where,

Y=T
bo= 4395.118
b1= -1004.282
b2= 57.478
X= Log C

$T= b_o+b_1*\text{Log } C+ b_2*(\text{Log } C)^2$

T= 4395.118 – 1004.282*(Log C) + 57.478* (Log C)^2 ……………………………………………………….equation 4.4

Example 4. if we take randomly as an example the 7th and 10th month, the cumulative executed amount is 279,485,511.90 and 731,193,519.38 respectively

T at 7th month = 4395.118 – 1004.282*(Log 279,485,511.90) + 57.478* (Log 279,485,511.90)^2 = 7.17 month, so the percentage error is -2.49% which is acceptable as it is below maximum average percentage error of 15.75% (Chen, 2006).

T at 10th month = 4395.118 – 1004.282*(Log 731,193,519.38) + 57.478* (Log 731,193,519.38)^2 = 7.17 month, so the percentage error is 7.62% which is acceptable as it is below maximum average percentage error of 15.75% (Chen, 2006).

Regression model for the whole project for Sebeta -Miesso (up to 53.78%)

- The selected equation is Quadratic (QUA) equation combined with logarithmic transformation as show on table 4.19 and 4.13
- Quadratic (QUA)…………………………$Y=b_o+b_1*X+ b_2*X^2$

Where,

$Y=T$
bo= 188.75
b1= -51.537
b2= 3.542
X= Log C

$T= b_o+b_1*\text{Log } C+ b_2*(\text{Log } C)^2$

$\mathbf{T= 188.75- 51.537*(Log\ C) + 3.542* (Log\ C)^2}$

Example. If we take randomly as an example the 5th and 10th month, the cumulative executed amount is 231,059,784.98 and 731,193,519.38 respectively.

T at 5^{th} month = 188.75– 51.537*(Log 231,059,784.98) + 3.542* (Log 231,059,784.98) ^{2} = 5.48 month, so the percentage error is -9.67% which is acceptable as it is below maximum average percentage error of 15.75% (Chen, 2006).

T at 10^{th} month = 188.75– 51.537*(Log 731,193,519.38) + 3.542* (Log 731,193,519.38) ^{2} = 10.23 month, so the percentage error is -2.28% which is acceptable as it is below maximum average percentage error of 15.75% (Chen, 2006).

5) Regression Model for Category 1 for Mieso dewanle project (up to 12.65%)

- The selected equation is Cubic (CUB) equation combined with SQRT transformation as show on table 4.19 and 4.13 , but when we try the model by using SQRT, the average standard error is very high, if we use LOG transformation the average standard error of the model is very low , so it better to use LOG transformation

- Cubic regression (CUB)…………………………$Y=b_o+b_1*X+ b_2*X^2 + b_3*X^3$

Where,

Y=T
bo= -14336.454
b1= 5466.714
b2= -695.039
b3= 29.469
X= Log C

$$T= b_o+b_1*\text{Log C}+ b_2*(\text{Log C})^2 + b_3*(\text{Log C})^3$$

$$\mathbf{T= -14336.454 + 5466.714*(Log\ C) – 695.039(Log\ C)^{2} + 29.469* (Log\ C)^{3}}$$ **………………………………………….equation 4.5**

Example 5. if we take randomly as an example the 3rd and 5th month, the cumulative executed amount is 105,839,723.30 and 177,322,423.16 respectively.

T at 3rd month= -14336.454 + 5466.714*(Log 105,839,723.30) – 695.039(Log 105, 839,723.30) ^{2} + 29.469* (Log 105, 839,723.30) ^{3} =3.00 month, so the percentage error is 0.00% which is acceptable as it is below maximum average percentage error of 15.75% (Chen, 2006).

T at 5th month= -14336.454 + 5466.714*(Log 177,322,423.16) – 695.039(Log 177,322,423.16) ^{2} + 29.469* (Log 177,322,423.16) ^{3} = 5.13 month, so the percentage error is -2.58% which is acceptable as it is below maximum average percentage error of 15.75% (Chen, 2006).

6) **Regression Model for Category 2 for Mieso dewanle project (12.65% to 49.24%)**

- The selected equation is Cubic (CUB) equation combined with SQRT transformation as show on table 4.19 and 4.13, but when we try the model by using SQRT, the average standard error is very high, if we use LOG transformation the average standard error of the model is very low , so it better to use LOG transformation
- Cubic regression (CUB)………………………… $Y=b_o+b_1*X+ b_2*X^2 + b_3*X^3$

  Where,

  Y=T
  bo= -354497.785
  b1= 123206.240
  b2= -14272.760
  b3= 551.123
  X= Log C

T= bo+b1*Log C+ b2*(Log C)2 + b3*(Log C)3

T= -354497.785+ 123206.240*(Log C) – 14272.760(Log C) 2 + 551.123* (Log C) 3 ………………………………………….equation 4.6

Example 6. if we take randomly as an example the 6th and 9th month, the cumulative executed amount is 297,340,228.99 and 613,263,449.49 respectively.

T at 6th month = -354497.785+ 123206.240*(Log 297,340,228.99) – 14272.760(Log 297,340,228.99) 2 + 551.123* (Log 297,340,228.99) 3 = 5.92 month, so the percentage error is 1.41% which is acceptable as it is below maximum average percentage error of 15.75% (Chen, 2006).

T at 9th month = -354497.785+ 123206.240*(Log 613,263,449.49) – 14272.760(Log 613,263,449.49 $)^2$ + 551.123* (Log 613,263,449.49 $)^3$ =

9.001 month, so the percentage error is -0.01% which is acceptable as it is below maximum average percentage error of 15.75% (Chen, 2006).

Regression model for the whole project for Mieso Dewanle (up to 49.24%)

- The selected equation is Cubic (CUB) equation combined with SQRT transformation as show on table 4.19 and 4.13, but when we try the model by using SQRT, the average standard error is very high, if we use LOG transformation the average standard error of the model is very low , so it better to use LOG transformation
- Cubic regression (CUB)…………………………$Y=b_o+b_1*X+ b_2*X^2 + b_3*X^3$

Where,

Y=T
bo= -8055.809
b1= 2971.281
b2= -365.36
b3= 14.985
X= Log C

T= bo+b1*Log C+ b2*(Log C)2 + b3*(Log C)3

T= -8055.809+ 2971.281*(Log C) – 365.36 (Log C) 2 + 14.985* (Log C) 3

Example. If we take randomly as an example the 5th and 10th month, the cumulative executed amount is 177,322,423.16 and 648,106,966.04 respectively.

T at 5th month= -8055.809+ 2971.281*(Log 177,322,423.16) – 365.36(Log 177,322,423.16) ^{2} + 14.985* (Log 177,322,423.16) ^{3} =4.25 month, so the percentage error is 14.95% which is acceptable as it is below maximum average percentage error of 15.75% (Chen, 2006).

T at 10th month= -8055.809+ 2971.281*(Log 648,106,966.04) – 365.36(Log 648,106,966.04) ^{2} + 14.985* (Log 648,106,966.04) ^{3} =10.11 month, so the percentage error is -1.07% which is acceptable as it is below maximum average percentage error of 15.75% (Chen, 2006).

7) Regression Model for Category 1 for Sebeta dewanle project (up to 17.72%)

- The selected equation is Cubic (CUB) equation combined with SQRT transformation as show on table 4.19 and 4.13, but when we try the model by using SQRT, the average standard error is very high, if we use LOG transformation the average standard error of the model is very low , so it better to use LOG transformation
- Cubic regression (CUB)…………………………$Y=b_o+b_1*X+ b_2*X^2 + b_3*X^3$

Where,

Y=T
bo= 7021.844
b1= -2630.691
b2= 327.721
b3= -13.569
X= Log C

$T= b_o+b_1*\text{Log } C+ b_2*(\text{Log } C)^2 + b_3*(\text{Log } C)^3$

T= 7021.844 - 2630.691*(Log C) + 327.721(Log C) 2 – 13.569* (Log C) 3

………………………………………….equation 4.7

Example 7. if we take randomly as an example the 3rd and 5th month, the cumulative executed amount is 90,441,928.38 and 204,191,104.07 respectively

T at 3rd = 7021.844 - 2630.691*(Log 90,441,928.38) + 327.721(Log 90,441,928.38) 2 – 13.569* (Log 90,441,928.38) 3 = 2.81 month, so the percentage error is 6.48% which is acceptable as it is below maximum average percentage error of 15.75% (Chen, 2006).

T at 5th = 7021.844 - 2630.691*(Log 204,191,104.07) + 327.721(Log 204,191,104.07) ^{2} – 13.569* (Log 204,191,104.07) ^{3} = 5.28 month, so the percentage error is -5.63% which is acceptable as it is below maximum average percentage error of 15.75% (Chen, 2006).

8) Regression Model for Category 2 for Sebeta dewanle project (17.72% to 51.51%)

- The selected equation is Cubic (CUB) equation combined with logarithmic transformation as show on table 4.19 and 4.13, but when we try the model by using SQRT, the average standard error is very high, if we use LOG transformation the average standard error of the model is very low , so it better to use LOG transformation
- Cubic regression (CUB)…………………………$Y=b_o+b_1*X+ b_2*X^2 + b_3*X^3$

Where,

Y=T
bo= 310332.001
b1= -106461.735
b2= 12171.887
b3= -463.775
X= Log C

$T= b_o+b_1*\text{Log } C+ b_2*(\text{Log } C)^2 + b_3*(\text{Log } C)^3$

T= 310332.001 – 106461.735*(Log C) + 12171.887(Log C) ^{2} – 463.775* (Log C) ^{3}

………………………………………….equation 4.8

Example 8. if we take randomly as an example the 8th and 11th month, the cumulative executed amount is 470,836,876.10 and 840,341,932.66 respectively

T at 8th month = 310332.001 – 106461.735*(Log 470,836,876.10) + 12171.887(Log 470,836,876.10) ^{2} – 463.775* (Log 470,836,876.10) ^{3} = 7.33

month, so the percentage error is 8.39% which is acceptable as it is below maximum average percentage error of 15.75% (Chen, 2006).

T at 11th month = 310332.001 – 106461.735*(Log and 840,341,932.66) + 12171.887(Log and 840,341,932.66) ^{2} – 463.775* (Log and 840,341,932.66) ^{3} = 10.38 month, so the percentage error is 5.66% which is acceptable as it is below maximum average percentage error of 15.75% (Chen, 2006).

Regression model for the whole project for Sebeta Dewanle (up to 51.51%)

- The selected equation is Cubic (CUB) equation combined with logarithmic transformation as show on table 4.19 and 4.13, but when we try the model by using SQRT, the average standard error is very high, if we use LOG transformation the average standard error of the model is very low , so it better to use LOG transformation
- Cubic regression (CUB)…………………………$Y=b_o+b_1*X+ b_2*X^2 + b_3*X^3$

Where,

Y=T
bo= -1647.377
b1= 613.72
b2= -76.722
b3= 3.255
X= Log C

$T= b_o+b_1*\text{Log C}+ b_2*(\text{Log C})^2 + b_3*(\text{Log C})^3$

$$\mathbf{T= -1647.377 + 613.72*(Log\ C) - 76.722\ (Log\ C)^2 + 3.255*\ (Log\ C)^3}$$

Example. If we take randomly as an example the 5th and 10th month, the cumulative executed amount is 204,191,104.07 and 689,650,242.71 respectively

T at 5th month = -1647.377 + 613.72*(Log 204,191,104.07) - 76.722 (Log 204,191,104.07) ^{2} + 3.255* (Log 204,191,104.07) ^{3} = 5.20 month, so the percentage error is -5.63% which is acceptable as it is below maximum average percentage error of 15.75% (Chen, 2006).

T at 10th month = -1647.377 + 613.72*(Log 689,650,242.71) - 76.722 (Log 689,650,242.71) ^{2} + 3.255* (Log 689,650,242.71) ^{3} = 10.25 month, so the percentage error is -5.96% which is acceptable as it is below maximum average percentage error of 15.75% (Chen, 2006).

4.2.7 Regression Model Validation

The next step is to test the validity of the estimate from the model and compare it with the actual results. Chen (2006) used average percentage errors to validate his model and accepted the result with a maximum average percentage error of 15.75%. Endut et al (2006) rejected the relationship based on the coefficient of determination without showing the basis for rejecting the results. Love et al (2005) simply showed the root mean square error (221.15), mean absolute error (130.3), and mean absolute percentage error (50.4).

The average percentage error of the model was as follows:

1. LRT Project category 1 (up to 18.31%) ……………………..1.89%
2. LRT Project category 2 (from 18.31% to 78.79%)………….....0.78%
3. LRT the whole project(up to 78.79%)…………………………1.19%
4. Sebeta Mieso Project category 1 (up to 16.15%)………………-9.26%
5. Sebeta Mieso Project category 2 (from 16.15% to 53.78%)……-2.67%
6. Sebeta Mieso the whole project (up to 53.78%)……………..…-11.84%
7. Mieso Dewanle Project category 1 (up to 12.65%)…………….-0.26%
8. Mieso Dewanle Project category 2 (from 12.65% to 49.24%)…..-1.31%
9. Mieso Dewanle the whole project (up to 49.24%)…………………5.25%
10. Sebeta Dewanle Project category 1 (up to 14.23%)………………-4.60%
11. Sebeta Dewanle Project category 2 (from 14.23% to 53.78%)……-1.69%
12. Sebeta Dewanle the whole project (up to 53.78%)…………………-3.27%

All the above results depict that the average percentage error for all projects and categories are less than the maximum average percentage error 15.75% chen (2006), so the model for time prediction is a very good fit of the data.

CHAPTER FIVE

5. CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

Calculations confirmed the universal character of the Bromilow's time-cost model. Certainly, the model has some advantages: it is simple and at least for the considered sample, statistically correct. Time-cost regression models for repeatable projects (e.g. buildings of the same function, structure type, similar layout and location, Road projects laid on similar terrains, Railway projects constructed on similar topography and the likes) could be more precise. Similarly, if more independent variables were considered, and samples were larger, better models could be provided. A number of researchers report their achievement in this field Irfan et al. (2011) and there exists at least one commercial regression-based duration calculator BCIS (2009). This may serve as evidence of practical applicability of parametric models in planning construction duration. Such models have some advantage over other models based on experience, regression models are expressed as equations, and to use them, one does not need to dispose of the whole database or software. Moreover, the reasoning process behind the model is quite obvious. This may be the reason why, in the time of quick development of artificial intelligence methods, statistical analyses do not loose on popularity Agata Czarnigowska and Anna Sobotka, (2012).

Some Ethiopian construction projects are synonymous with time and cost overruns; hence the need for a pragmatic approach to provide early warning devices to reduce these twin problems. This study has confirmed that Bromilow's widely reported time-cost model is suitable for the Ethiopian situation. It is however to be noticed that all Railway projects in the country are under construction by International Contactors. Bromilow,s time-cost model may not be suitable if the projects are executed by Domestic or Local Contractors, so to check this we need additional researches by the time when Railway projects awarded for Ethiopian Contractors.

5.2 Recommendations and Future Research

5.2.1 Recommendations

The client can use the developed model to predict time and cost during bidding stages, apply the formula developed for first planning of their respective of Railway project ,are used for bid evaluation ,are used to check submitted schedules, are used to check the master plans and the likes but the models need continuous update with additional project data's.

The Consultant can use the developed model for feasibility and other studies, Check on the master plan for the proposed method and stipulated performance as the model is simple to use and does not need many parameters. This model is also useful for Contractors during bidding and construction stage. Even if this model is recommended for different uses, it has the following limitations:-

- The model does not address price escalation and any other related factors
- Sufficient literatures for railway projects are not incorporated in the study due to lack of literatures.
- As the projects are not yet completed till June 2015, the model needs update with additional project data's.

5.2.2 Future research

Several areas for future research presented themselves through the completion of this work. The research topics proposed here build on the work performed and generate new lines of questioning, research, and understanding. These areas for future research pertain to ERC and general construction industries are expected to be beneficial to the overall construction industry body of knowledge. Based on the findings of the research the following areas need further investigation.

1. Time-Cost relationship model should be developed for Domestic (Local) contractors alone for Railway projects and other constructions in Ethiopia.

2. There are other influential factors on duration other than cost, so they have to be considered and modeled.
3. There is no consensus on duration –influential factors in the construction industry. So, further investigation should be developed on a consensus of Duration-influential factors worldwide.
4. Adoption of Methodology will undoubtedly contribute to the construction body of knowledge and further understanding of duration estimation based on early-known construction details.

REFERANCES

1**. Abdo Abatemam** (2006**)**. Delays in public building construction projects and their consequences

2. **Abebe Dinku** (2003). Construction Management and Finance, Addis Ababa University Press, 2003

3. **Abraham Assefa** (2008)**,** Time – Cost Relationships for Public Road Construction Projects in Ethiopia

4. **Agata Czarnigowska and Anna Sobotka** (2012) Time-Cost Relationship for Predicting Construction Duration

5. **Al-Momani, A.** (2000) Construction delay: a quantitative analysis. International Journal of Project Management,

6. **Anchalee jenpanitsub,** (2011), Cost Overruns in Transport Projects - Experiences from Sweden

7. **Andinet, Behailu, and Derbachew** (2006). Time Cost Relationship: Educational Building Projects in Ethiopia. Final year project, AAU, Ethiopia

8. **Angelo, W., & Reina, P**. (2002). Megaprojects Need More Study Up Front to Avoid Cost

9. **Assaf, S., Al- Khaliil, M., Al-Hazmi, M.** (1995) Causes of delay in Large building construction projects. Journal of Management in Engineering,

10. **Assaf, S. and Al-Hejji, S**. (2006) Causes of delay in large construction projects. International Journal of Project Management,

11. **Barraza, Gabriel A., Back, W. Edward and Mata, Fernando** (2004). Probabilistic Forecasting of Project Performance Using Stochastic S Curves. Journal of Construction Engineering and Management,

12. **BCIS (2003)**. The Relationship between Contract Sum and Tender Price Levels in Housing Schemes and Contract Sum Related to Number of Units. Report prepared for Nottingham Trent University by Building Cost Information Service (BCIS) Ltd, 6 February 2003

13. **BCIS (2006).** Inflationary pressures grow in the UK construction sector: BCIS five year forecast of tender prices to 1st quarter 2011'. Press Release (2006)

14. **Bhokha, S**. (1998) Application of Artificial Neural Networks to Cost and Duration Forecasting for Buildings. Ph. D. Dissertation, Asian Institute of Technology, Bangkok.

14. **Blyth, Karl and Kaka, Ammar, (2006)**. A novel multiple linear regression model for forecasting S– Curves". Journal of Engineering Construction and Architectural Management, Vol. 13

15.**Bromilow, F. J.** (1969). "Contract time performance expectations and the reality." Building Forum, 1(3).

16. **Bromilow, F. J., Hinds, M. F., and Moody, N. F.** (1980). "AIQS Survey of Building Contract Time Performance." The Building Economist,

17. **Burrows, T. K., Pegg, I., and Martin, J.** (2005). "Predicting Building Construction Duration." AACE International Transactions,

18. **Chabota Kaliba,** (2010) Cost escalation, schedule overruns and quality shortfalls on construction projects

19. **Chan, A.** (2004). Key performance indicators for measuring construction success,

20. **Chang, A.S.** (2002). Reasons for cost and schedule increases for engineering design projects, Journal of Management and Engineering, 2002: 29-36 (accessed February, 2010).

21. **Chan, Albert P.C.** (1999). Modeling building durations in Hong Kong. Construction Management and Economics, Vol. 17, pp. 189 - 196.

22. **Chan, Daniel W.M. and Kumaraswamy, Mohan M.** (1995). A study of the factors affecting construction durations in Hong Kong. Construction Management and Economics

23**. Chang, Andrew and Shing – Tao** (2001). Defining Cost/Schedule Performance Indices and their ranges for design Projects. Journal of Management in Engineering,

24. **Chen, Wei Tong and Huang, Ying - Hua.** (2006). Approximately predicting the cost and duration of school reconstruction projects in Taiwan. Construction Management and Economics,

25. **Chitkara, KK** (2000). Construction Project Management, Planning, Scheduling and Controlling.

26**. Choudhury, Ifte and Rajan, Siva Shanka**, (2003).Time Cost relationship for residential construction Texas. Texas A & M University, College Station, Texas.

27. **Endut, Intan Rohani, Akintoye, Akintola and Kelly, John** (2006). Relationship between duration and cost of Malaysian Construction Projects. Proceedings of the International Conference in the Built Environment in the 21st Century (ICiBE 2006)

28. **Dantata, nasiru a., touran, ari and schneck, donald** c. trends in u.s. rail transit project cost overrun. transportation research board. s.l.: annual meeting cd-rom, 2006.

29. **Dissanayaka, S. M. and Kumaraswamy, M. M.** (1999). Evaluation of Factors Affecting Time and Cost Performance in Hong Kong Building Projects. Engineering, Construction and Architectural Management, 6, 287-298.

30**. Dissanayaka, S. M. and Kumaraswamy, M. M.** (1999). Comparing Contributors to Time and Cost Performance in Building Projects. Building and Environment, 34, 31

31. **ERC** (Ethiopian Railway Corporation reports)

32. **Farqahl, S. H., and Everett, J. G.** (1997). "Learning Curves: Accuracy in Predicting Future Performance." ASCE Journal of Construction Engineering and Management,

33. **Fourie, F.** (2003). "Time-for Versus Time-of Performance." AACE International Transactions, CDR211-CDR215.

34. **Flyvbjerg, B.M.S. Holm and Buhl, S.** (2002**)**. Understanding Costs in Public Works Projects: Error or Lie? Journal of the American Planning Association, 68 (3): 279-95 (accessed March, 2010).

35. **Flyvbjerg, Bent, Bruzelius, Nils and Rothengatter, Werner.** Megaprojects and risk: An anatomy of ambition. United Kingdom : Cambridge University Press, 2003.

36. **Fetene Nega** (2008). Cauase and effects of cost overrun in public building construction projects in Ethiopia. MSc Thesis. Addis Ababa University, Ethiopia.

37**. Gören, S. G.** (1998). Kamu İnşaat Projelerinin Gerçekleştirilmesinde Süre Uzama Nedenlerinin Analizi. Ph. D. Dissertation, Department of Architecture, İstanbul Technical University, Turkey.

38. **Getachew Tsegaye** (2009). Design Risk Management in Ethiopian Federal Road Projects. MSc Thesis. Addis Ababa University, Ethiopia

39. **Helvacı, A.** (2008). Comparison of Parametric Models for Conceptual Duration Estimation of Building Projects. M. Sc. Dissertation, Department of Civil Engineering, Middle East Technical University, Turkey.

40. **Hsieh, T., Lu, S., Wu, C.** (2004) Statistical analysis of causes for change orders in metropolitan public works. International Journal of Project Management, 22 (8), 679-686.

41**. Ibbs et al**. (2007). Quantified Impact of Project Change, Journal of Professional Issues in Engineering Educations& Practices, Vol. 133.No 1, January 1, 2007.

42. **Jason A. Weeks,** (2008), Understanding the issues of project cost and time in sustainable construction from a general contractor's perspective:

43. **Kaming, P., Olomolaiye, P., Holt, G., Harris, F.** (1997) Factors influencing construction time and cost overruns on high-rise projects in Indonesia. Construction Management and Economics, 15 (1), 83-94.

44. **Karslı, E. D.** (1998). İnşaat Süresini Etkileyen Faktörler ve İnşaat Süresi Tahmin Modelleri. M. S. Dissertation, Department of Architecture, İstanbul Technical University, Turkey.

45**. Kerzner, H.** (2003) Project Management A Systems Approach to Planning, Scheduling, and Controlling. John Wiley and Sons InC., New Jersey.

46**. Kumaraswamy, M. and Chan, W.** (1998) Contributors to construction delays Construction Management and Economics, 16 (1), 17-29.

47. **Love, P. E. D., Tse, R. Y. C. and Edwards, D. J.** (2005). Time–Cost Relationships in Australian Building Construction Projects. Journal of Construction Engineering and Management, 131, 187-194.

48. **Mansfield, N, Ugwu, O., Doran, T.** (1994) causes of delay and cost overruns in Nigerian construction projects. International Journal of Project Management,

49. **Nkado, R. N.** (1992). Construction Time Information System for The Building Industry. Construction Management and Economics, 10, 489-509.

50. **Nkado, R. N**. (1995). Construction Time-Influencing Factors: the Contractor's Perspective. Construction Management and Economics, 13, 81-89.

51. **Nicholas, J.** (2001) Project Management for Business and Technology. Prentice Hall, New Jersey.

52**. O'Brien,J.J.** (1998).Construction Change Order. McGraw Hill, New York,NY Oxford

53. **Pickrell, Don H. Urban Rail Transit Projects**: Forecast versus Actual Ridership and Costs. U.S. Department of Transportation. s.l. : Urban Mass Transportation Administration, 1990.

54. **Priemus, Hugo, Flyvbjerg, Bent and Wee, Bert van**. Decision-Making on Mega-Projects (Cost-Benefit Analysis, Planning and Innovation). s.l. : Edward Elgar Publishing Limited, 2008..

55. **RLB** (2006). Tender Price Indices and Cost Trends in Hong Kong. RLB Quarterly ConstructionCost Report, Hong Kong, December 2006.

56. **Robert C. Williams,** 2008. The development of mathematical models for preliminary prediction of highway construction duration

57. **Saraç, S.** (1995). A Time Information System for the Construction Industry. M. S. Dissertation, Department of Architecture, İstanbul Technical University, Turkey.

58. **Sezgin, Y.** (2003). Tasarım/Yapım Organizasyonları için Proje Gerçekleşme Süresinin Tahminine Yönelik Bir Bütünleşik Model Önerisi. M. S. Dissertation, Department of Architecture, İstanbul Technical University, Turkey.

59. **Skitmore, R. M. and Thomas Ng, S.** (2003). Forecast Models for Actual Construction Time and Cost. Building and Environment, 38, 1075-1083.

60. **Singh, Ram.** Delays and Cost Overruns in Infrastructure Projects: An Enquiry into Extents, Causes and Remedies. Department of Economics, Delhi School of Economics, Centre for Development Economics. 2009.

61. **Tadesse Ayalew** (2009). Causes and Effects of Variations in Ethiopian Federal Road Projects. MSc Thesis, Addis Ababa University Faculty of Technology, Addis Ababa,Ethiopia.

62**. Turkey wakjira**, 2011, risk factors leading to cost overrun in Ethiopian federal road construction projects and its consequences.

63. **Yakubu Adisa Olawale, Ph.D., MCIOB and Ming Sun, Ph.D. (Professor),** cost and time control of construction projects: inhibiting factors and mitigating measures in practice

64. **Yeong, C.M.** (1994) Time and cost performance of building contracts in Australia and Malaysia, unpublished MSc thesis, University of South Australia.

65. **Yogeswaran, K., Kumaraswamy, M., Miller, D.** (1998) Claims for extension of time in civil engineering projects. Construction Management and Economics

DECLARATION

I, the undersigned, declare that this thesis is my original work and has not been presented for a degree in any other university. All sources of materials used for the thesis have been duly acknowledged.

NAME: ANTENEH BIRHANE

SIGNATURE: ___________________________

PLACE:

ADDIS ABABA UNIVERSITY, SCHOOL OF GRADUATE STUDIES,

FACULTY OF TECHNOLOGY,

DEPARTMENT OF CIVIL ENGINEERING

RAILWAY ENGINEERING

DATE: July, 2015