ADDIS ABABA UNIVERSITY
SCHOOL OF GRADUATE STUDIES

FACULTY OF TECHNOLOGY
DEPARTMENT OF CIVIL ENGINEERING

Time – Cost Relationships for Public Road Construction Projects in Ethiopia

ABRAHAM ASSEFA

Advisor: - **Dr. Ing. Wubishet Jekale Mengesha**
Co -Advisor: - **Eng. Zerfu Tessema**

A Thesis Submitted to School of Graduate Studies in Partial Fulfillment of the Requirements for the Degree of Master of Science in Civil Engineering (Construction Technology and Management Major)

MAY 2008

ADDIS ABABA UNIVERSITY
SCHOOL OF GRADUATE STUDIES

Time – Cost Relationships for Public Road Construction Projects in Ethiopia

BY ABRAHAM ASSEFA

APPROVED BY BOARD OF EXAMINERS:

Dr.Ing. Wubishet Jekale	______________	______________
ADVISOR	DATE	SIGNATURE
Prof. Dr.Ing. Abebe Dinku	______________	______________
INTERNAL EXAMINER	DATE	SIGNATURE
Dr.Ing. Gashaw Yayehyirad	______________	______________
EXTERNAL EXAMINER	DATE	SIGNATURE
Ato Daniel Shawel	______________	______________
CHAIRMAN	DATE	SIGNATURE

ACKNOWLEDGMENTS

It might be honest to state that a research work can not be carried out by oneself without the help of the others. My deepest gratitude goes to my advisor, Dr. Ing. Wubishet Jekale, for his continuous support and interest on my research work. His attitude for the development of a modern construction industry for our country is something to emulate for all involved in the industry. My heartfelt thanks also go to my co – advisor Eng. Zerfu Tessema for facilitating the data collection of this research.

I would like also to thank the staff of the Ethiopia Road Authority, Contract Administration Division, for providing the data for this research. This work might have not been possible if it was not for their help. A special thanks goes to Ato Samuel Taffesse for all his help.

Last, but not least the support of my family is invaluable and thus this work is dedicated to my late father Ato. Assefa Tsehaye and my lovely mother W/ro Lemlem Barki.

ABSTRACT

This research work has tried to test the time – cost relationship of road projects by using the hypothesized empirical and graphical models developed for the concept. Based on the Empirical Bromilow's Model, the duration of Ethiopian Federal Road Construction Projects has been modeled by a time - cost formula expressed in the form of $T = KC^B$, where T is the actual construction time in calendar days, C is the final cost of contract in Ethiopia Birr, K is a constant characteristic of time performance, and B is a constant indicative of the sensitivity of time performance to cost level. This thesis applied the relationship to 33 projects based on the two categories International Contractor (IC) and Domestic Contractor (DC) Projects and on the adjusted and unadjusted cost basis.

Analysis using both linear and multiple regression technique was performed between project duration (i.e., time), project cost, project length and type of construction (asphalt concrete, double surface treatment, and gravel surface). The analysis results indicated that the above principle is valid to IC projects and is invalid to DC projects based on T – test. Though the Bromilow's principle has been found to invalid for DC projects, the relationship between contract Time and length has been developed. In addition the research has developed a cost prediction model for IC projects.

Based on the Graphical Model, the time – cost relationship has been reviewed by using the cumulative time – cost curve(S – curve) concept and the earned value management techniques (EVM). The applicability of this curve was tested by using two case study projects. The test for smoothness of the curve was carried out by testing the reliability index using Weibull probability functions. In addition to that EVM techniques like Schedule Variance, Schedule Performance Index and Estimate to Completion were used to view their applicability. The analysis results clearly indicated that the S- curve concept is not applicable to the case study projects and the tools of EVM technique are better indicators of the performance than the S – curve.

Key Words: Construction Management; Time - Cost relationship; Bromilow's Principle; S-Curve; Earned Value Management.

ABBREVIATIONS/ACRONYMS

AC	Asphalt Concrete Surfaced Road Project
ADB	African Development Bank
BaTCoDA	Building and Transport Construction and Design Authority
DBST	Double Surface Asphalt Treatment Road Project
ERA	Ethiopian Roads Authority
ERTTP	Ethiopian Rural Travel and Transport Program
ETB	Ethiopian Birr
EVM	Earned Value (Performance) Management Technique
FDRE	Federal Democratic Republic of Ethiopia
GS	Gravel Surfaced Road Project
GTZ	Abbreviation for German Technical Cooperation
IDA	International Development Agency
MDA	Multilateral Development Agencies
MoWUD	Ministry of Works and Urban Development
RFA	Road Fund Administration
RSDP	Road Sector Development Program
SMEC	Snowy Mountains Engineering Corporation

GLOSSARY

DC – Domestic Contractors – This research has considered DC projects carried out by a contractor under the Conditions of Contract of the National Competitive Bidding.

IC – International Contractors – This research has considered IC projects carried out by a Contractor under the Conditions of Contract of the International Competitive Bidding.

S – Curve – is a time - phased budget developed by summing the project activities on monthly basis and plotted against time and used as a basis against which project performance is measured, monitored and controlled. It shall represent the terms Cost Base Line and/or Performance Measurement Base Line.

Table of Contents

List of Tables and Figures

List of Tables

List of Figures

PART I - RESEARCH BASIC INFORMATION

1 INTRODUCTION

1.1 The Research Background

A client, be it public or private agency, an entrepreneur, or a builder, undertakes development facilities like housing, roads and power plants with certain objective or long term aims. For example, the typical objectives or the strategic aims of a government in developing infrastructure like road may include economic growth (Chitkara, 2000).

A project is a unique process, consisting of a set of co-ordinated and controlled activities with an assumed start and known finish dates, undertaken to achieve an objective conforming to specific requirements including constraints of time, cost and resources (Lockyer & Gordon, 1996). It also adds that the organization is temporary and is established for the life of the project and forms part of a large project structure and the objectives and product characteristics may be defined and achieved progressively during the course of the project.

Abebe (2003) stated that in project management the above constraints have been identified as the Triple Constraints which are managing Cost, Schedule (time) and Quality simultaneously. Accordingly, projects can better be managed in ways that balance these constraints. Among these, often most projects focus on checking cost over runs and time delays because of their ability for performance measurement. Thus, a realistic forecasting tool of construction time and cost is a good service to contract administration as the predicted duration and cost forms a basis for budgeting, planning, monitoring, and even in solving construction disputes.

In practice, estimates for construction time and cost are first estimated from the clients' available budget and time like occupancy or service need. Then a through analysis of work to be done and resources required are estimated using estimates of the time and cost requirements of each specific activity. It should be noted however that the detailed estimation usually depends on the estimators experience and judgment on project and site information. In addition it is customary for contractors to submit their schedule and show the S – Curve pattern for resources (Choudhury & Rajan, 2003).

Clients and also other parties involved in the construction are looking for an acceptable time and cost estimate starting from the front end assessment stage of the planning phase. Hence, time - cost relationship is a critical issue to be taken care of while managing construction projects. Thus the investigation of this relationship will be useful to develop an estimate for time at the initial stage of planning. Further more, this relation is vital for measuring cost – time performance evaluation and for variance identification and adjusting these variances based on the submitted schedule and the S – curve indicating the overall performance.

Different studies have been carried out to find a time – cost relationship for estimating time for building projects, the principal one being the Bromilow's principle (Bromilow, 1974). But these researches have not dealt the road construction which is one of the project categories under infrastructure construction. And also the time related cumulative forecast of main input resources and output, in momentary value, when plotted graphically against the project time scale, follow an ' S ' curve pattern, which is commonly used for cost – time performance evaluation. However the S – curve concept has not been used in detail in many projects (Daneshmand & Khreich, 2006).

1.2 The Research Objective

Nick (2000) stated that the importance of research aims and objectives cannot be over- stressed and it is vital to have a clear understanding of what the research is about and what it tries to actually achieve. According to Kumar (1999) the research objectives wording shall be clear, complete and specifically communicate with readers. The questions behind this research have been developed and presented as shown on Table 1-1, adopted from Nick (2000). Thus, the following objectives have been developed:

1. Proving or disproving Bromilow's Principle developed for Time - Cost relationship. If the relationship is not applicable, testing the existence of a Time - Cost relationship for the Ethiopian Road Projects and develop another relationship or equation.

2. Using Earned Value Analysis to develop the pattern of the cumulative cost time curve and checking it against with the S – Curve pattern.

Questions	Answers
What is the research trying to achieve?	Provide a reasonable time estimation and performance measurement tool
What are the important issues?	Construction Time, Cost, Performance and managing them.
Who will benefit from, or be affected by the project?	Clients, Consultants, Contractors, etc
What things will change as a result of the project?	Time estimation methods and performance management tools
Why has the project been established?	For an academic achievement and also to provide a useful tool for the practitioners

Table 1-1: Research Questions

1.3 The Research Hypothesis

Main Hypotheses of this research are:

1. Verify the validity and applicability of Bromilow's principle for public road construction projects in Ethiopia.

2. Verify the validity of S – curve pattern for cumulative cost – time curve for public road construction projects in Ethiopia.

The above hypothesis will be tested by using the Null hypothesis.

1.4 The Research Contents

This thesis report includes the following four parts:

Part I. The Research Basic Information

Part II. The Research Framework

Part III. The Research Analyses and Discussions

Part IV. The Research Conclusions and Recommendations

Part I presents the introduction part. Here the background for the research and its hypothesis are discussed.

Part II presented the three basic part of research namely: Context, Concept and Methodology. *Chapter 2* presents the contextual frame work of the research. The researcher believes that providing a contextualized concept on the stated hypothesis can be better achieved by first focusing on the context of the research. Here, the Ethiopian road construction sector and previous researches on the area are reviewed. *Chapter 3 and Chapter 4* present the conceptual frame work of the research based on a basic and thematic literature reviews. *Chapter 5* presents the Methodological part of the research and focuses on the nature of the research, the data collected and the processing of the data.

Part III presented the analysis of the data to test the two main hypothesis of this research. The results have been discussed with the conceptual and contextual frame works of the research.

Part IV presented the conclusion and recommendation of the research.

PART II – RESEARCH FRAMEWORK

2 CONTEXTUAL FRAMEWORK

The Research Context

The concepts behind this research are not that much new to researchers and practitioners of the Construction Industry. However, the main task lies at having a contextualized concept for a developing country like Ethiopia. Context in this research is focused on the Ethiopian Road Construction Projects, as the focus of the research lies in the development of a contextualized concept for time – cost relationships.

2.1 Ethiopia and its Road Construction Sector

2.1.1 Ethiopia: - General Information

Ethiopia is located in the North Eastern part of Africa. It covers an area of about 1.13 million square km and the topography of the country is rugged ranging with an altitude from 125m below sea level to 4,620m above sea level. The population of Ethiopia in 2007 was 76,511,887 (Population (2008)). In that year approximately 3% of the population was over 65 years of age, with another 44% of the population under 15 years of age. The capital city, Addis Ababa, had a population of 2,534,000 in 2003 and other urban centers include Dire Dawa, Desse, Harer, Jima, Nazret, and Gonder (Ethiopia Population (2008)). Table 2.1 shows the important facts about the country:

Full name:	Federal Democratic Republic of Ethiopia
Population:	74.2 million (UN, 2005)
Capital:	Addis Ababa
Area:	1.13 million sq km (437,794 sq miles)
Major languages:	Amharic, Oromo, Tigrinya, Somali
Major religions:	Christianity, Islam
Life expectancy:	46 years (men), 49 years (women) (UN, 2005)
Main exports:	Coffee, hides, oilseeds, beeswax, sugarcane, flower
GNI per capita:	US $160 (World Bank, 2006)

Table 2 - 1: County Profile of Ethiopia, Source (BBC.com)

Ethiopia has undergone considerable political and economical changes following the decline of the cold war and with the emergence of a new Government in 1991. Politically, the unitary state was replaced by a decentralized federal system in 1995. This resulted into the formulation of nine Regional States and two Administrative cities (Refer to Figure 2 -1).

Figure 2-1: Regional States and Administrative Cities in Ethiopia (Wubishet, 2004)

Economically, a new policy was adopted in 1992. The policy was based on the principle of free and market – oriented economic exchange. With 85% of the population living in rural area, the Ethiopian economy has been dominated by peasant agriculture that accounts for 45% of the total GDP, 80% of the total employment and 85% of the country's exports (Wubishet, 2004). Ethiopia has long been placed under the highly indebted poor countries list of the World Bank.

Thus, there is lack of basic infrastructure, example road, in a poor country like Ethiopia. The current road infrastructure in Ethiopia stands as follows:

- The classified road network is one of the least developed in Africa with a density of 35.9 km per thousand square kilometers and 0.53 km per thousand population compared to the Africa region average of over 50 km/1000 square km(ERA, 2006),
- The current road network covers 39,477 km only and of which only 47 % is in good condition (ERA, 2006),

The FDRE introduced sectoral programs in mid way of 1990s to improve the existing infrastructure and other needs of the country. In line with the Government's priority areas of intervention, Road Construction, Agriculture Development Programs and the Social Sector (mainly Education and Health) were given an increasing share of public expenditure (Mekonnen, 2000).

The Government had therefore put forward, since 1997, three primary Sector Development Programs for improving road transport (Road Sector Development Program - RSDP), education (Education Sector Development Program - ESDP) and health (Health Sector Development Program - HSDP) services in the country. This study is focused to Road Sector Public Construction Projects under RSDP. Ethiopia's need to accomplish the projects under this sector program within the envisaged time is not questionable as they are basic requirements for the development policy the FDRE has envisaged.

In Ethiopia it is thought that industry and service will increasingly play a prominent role in the growth process of the country. This is mainly because the countries strategy aims to bring industry as leading sector in the coming 10 – 20 years. The construction industry as part of the industry and service area has then a tremendous responsibility to change the existing infrastructure to augment the development of the country in general. Unfortunately, the capacity of the country to ameliorate these problems is limited. This is because the need for investment in infrastructural facilities requires considerably large capital; and these together with other resources could not be available locally (Wubishet, 2004).

Besides, the capacities of the local construction companies are low. Only 9 out of the 27 general contractors have the capacity to carry out road infrastructure projects (Bekele, 2005). As a result, this stressed the necessity for external assistance. This is the case for most infrastructural projects such as road, water works, and electrical & communication structures in developing countries in general and in Ethiopia in particular (Wubishet, 2004).

The above and other factual sources indicated Ethiopia yet has a long way to go to achieve requirement average to the Sub-Saharan African countries. Then, it becomes obvious that the construction industry is vital towards accomplishing these objectives through the provision of infrastructural developments via constructing, rehabilitating, upgrading and maintaining new and existing buildings, roads, and other civil work structures.

2.1.2 Brief History of Roads in Ethiopia

The earliest modern roads in Ethiopia connecting Addis Ababa to Addis - Alem and Harar to Dire Dawa date back to the first half of the twentieth century (Construction Ahead, 2005). These roads were part of Emperor Menelik's attempt to modernize Ethiopia, however much has not been done until the time of the Italian occupation (1936 – 41). The Italian government invested much capital to expand the very limited infrastructure that then existed. Within one year period, close to 60,000 Italians were working on these projects. The road network even then was designed to radiate outward from Addis Ababa connecting the Italian occupied ports of Massawa and Mogadishu. When the occupation was terminated in 1941, the Italians left behind 7,000 km of roads, of which about half were surfaced with asphalt.

The reinstated Imperial regime was however unable to continue from where the Italians left off as it lacked expertise, adequate funds and equipment. The Government established the Imperial Highway Authority in 1951 with the help of World Bank and technical assistance from the United States Bureau of Public Roads. The Ethiopian highway network kept on lagging behind the countries need. After the overthrow of the Imperial Regime in 1984, Derg restructured the highway authority as the Ethiopian Roads Authority and the Rural Roads Task Force. The latter had the objective of developing rural roads outside the main system and extending feeder roads within the main system. The World Bank, African Development Bank and others provided assistance for new road construction and maintenance. Despite these efforts, Ethiopian's road network remained quite limited, even by African standards. Expansion of the rural road network accounted for much of the roads constructed thereafter until the change of government in 1991 and the network was further reduced with Eritrea as a new state. In 1993 the Ethiopian Roads Authority (ERA) was reestablished with a legal autonomy and being responsible for overall planning, construction, maintenance and management of the country's trunk and major link roads. It now has three technical departments – each headed by deputy general manager: Regulatory and Engineering Services, Human Resources & Finance and the Operations Departments.

In l991, in addition to the l3, 000 kilometers of all-weather roads, of which about 4,000 were asphalted and 8,900 were all-weather gravel roads, there were 4,900 kilometers of rural dirt roads, making a total of nearly 18,000 kilometers of all types of roads. The total road network of the country has reached to 39,477 km in June 2006. With a total land area of 1.1 million sq. km, the current road density is 35.9 km per 1000 sq. km. Overall road network in Ethiopia has been increasing on the average by 8% each year between 1997 and 2006. Road transport by now is the means of movement accounting for about 93 percent of freight and 95 percent of all passengers (ERA, 2006).

2.1.3 The Road Sector Program – Phase I and Phase II (RSDP I and RSDP II)

In the context of Ethiopia's geography, pattern of settlement and economic activity it is needless to say that transport plays a crucial role in facilitating economic development. Recognizing the importance of the road transport in supporting social and economic growth and in meeting poverty reduction objectives, the FDRE has placed increased emphasis on improving the quality and size of the road infrastructure. To address the constraints in the road sector related to restricted road network coverage and low standards, the Government formulated a 10-year Road Sector Development Program in 1997 (RSDP, 1997-2007) by dividing it into two as RSDP I the first program (1997-2002) and RSDP II (2002 – 2007) (ERA, 2006).

The first phase of RSDP (1997-2002) focused on the restoration of the road network to acceptable condition. Specifically the Program focused on a) rehabilitation of main roads; b) upgrading of main roads; c) construction of new roads; and d) effecting the necessary regular maintenance on the network. Side by side the Program also considered major policy and institutional reforms. The Road Fund Administration (RFA) was consequently established in 1997 as a separate financing body for road maintenance works carried out by urban regional road authorities and ERA. Following these reforms, the new institutional arrangements were introduced at the federal and regional levels. The federal arrangement thus has ERA and RFA under the Ministry of Infrastructure, while rural road authorities, municipal road agencies, community roads, private roads are to be managed by regional governments. This research is mail focused on federal roads handled by the ERA in the past ten years. The first phase of RSDP ended in 2002 with an overall physical implementation of 88% of the program, without fully meeting expectations, and with a disbursement of ETB 11.3 Billion. Wubishet (2004) stated that the above performance is based on a revised program reducing the work by 45% and 55 % by finance. Therefore the actual accomplishment is only 39.6% of the original plan. At the time this was attributed to **an unrealistic original schedule** or the slow pace of implementing civil works.

While the second on-going phase (2002-2007) aims to consolidate the achievements of the first phase, it aims at increasing the network connectivity and providing a sustainable road infrastructure to rural areas. Until end of June 2006, a total of 18,026 km[1] of roads were constructed, upgraded/rehabilitated and maintained of which 8,495 km are federal roads and 9,531 km were newly constructed/maintained regional roads since July 1997. The total cost of projects planned for execution during the same period amounted to Birr 18.7 billion (US$ 2.174 billion), while the total sum of money disbursed in the same period amounted to Birr 18.4 billion (US$ 2.140 billion); which is 98.4% of the planned target(refer to Table 2 -2) (ERA, 2006).

Table 2- 2: Nine years accomplishment of RSDP (ERA, 2006)

Physical (in km)			**Financial (in Million Birr)**		
Plan	**Accomplished**	**%**	**Budget**	**Disbursed**	**%**
14,142	18,026	127	18,700.5	18,445.1	98.4

RSDP II (2002 – 2007) also introduced another program designed to address the deficiencies in rural infrastructure at village level: Ethiopian Rural Travel and Transport Program (ERTTP). Of the total physical works registered so far, 9,317 km (more than 52%) road works has been undertaken during the second phase of RSDP II over a period of four years (July 2002 – July 2006). Specifically, during this period, 2,035 km of roads were rehabilitated and upgraded, 369 km were constructed as new gravel road and emergency/heavy maintenance was carried out on 3,382 km of asphalt and gravel roads. As compared to planned target for four years, rehabilitation and upgrading and construction works exhibited about 117% and 88% accomplishment rate, respectively. All in all, during the four years of RSDP II, a total sum of ETB 11.3 billion[2] (US$

[1] This figure would increase to 51,437 km as construction of community roads by regions is added.

[2] Excluding expenditure on community roads.

1.314 billion) has been disbursed. This figure is higher by 60 percent compared to what was disbursed during the five-year period of RSDP I. This indicates that the performance and also institutional capacity has improved from the first phase.

The participation of local contractors/consultants has increased to more than 60% during RSDP II period on projects financed mostly by the FDRE (see Figure 2- 2) , however involvement of locals on big construction contracts is still marginal with contract values averaging ETB 68 million for the period of 1992-June 2006. Besides, ERA is still carrying out few civil works by its own force account.

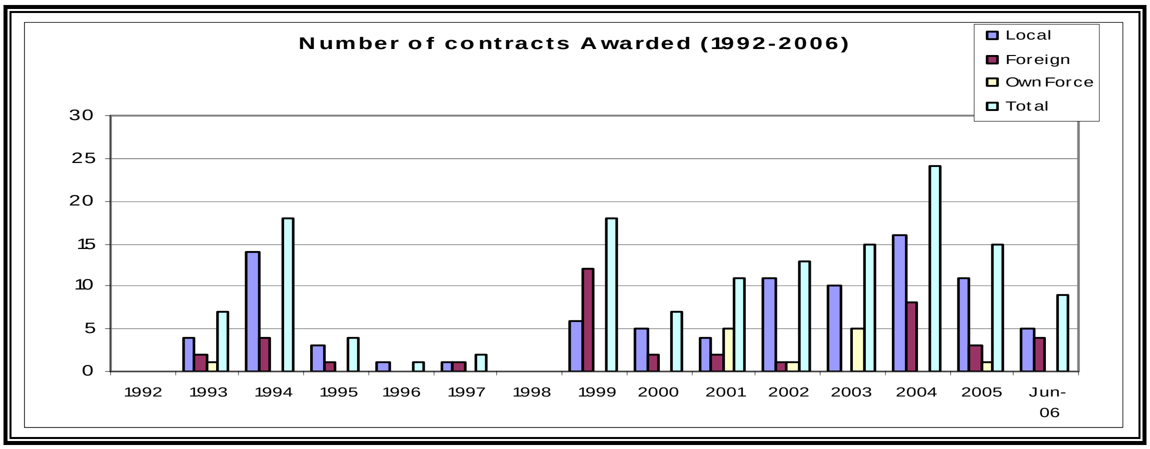


Figure 2-2: Consultancy and Construction Contracts awarded (1992 – 2006) (ERA, 2006)

In terms of funding of RSDP during the nine years period, by category of financiers, a little more than 60% has come from internal sources (the Government, the Road Fund and the Community) while the remaining substantial amount of funds (39%) has been pooled from the international community. Specifically, the share of the Government of Ethiopia is the highest (40%), followed by IDA (25%), the Road Fund (14%) and EU (9%).

RSDP III (2007 – 2012) on the federal level is expected to accomplish rehabilitation and upgrading of 3,541 km trunk roads, construction of 1,019 km trunk roads, upgrading of 3,729 km link roads, construction of 3,982 km new link roads and heavy maintenance on 2,604 km with an estimated budget of 56.4 billion ETB. Similar undertakings will also be carried out at regional and community levels. Accordingly, out of the Ethiopian Budget for the 2007/08 fiscal year, ETB 13.2 billion of the ETB 43.9 billion is allocated for the economic sector (public infrastructure development), out of which ERA will receive about ETB 3.6 billion though requested ETB 8.8 billion (Fortune (2007)).

Adding all the above facts indicates that the Ethiopian public road construction sector will, without any doubt, be the leading construction sector in the country. Thus providing usable research out puts based on the previous experience will be highly advantageous for all future endeavors in the road construction sector.

2.2 Road Construction Industry in Ethiopia

2.2.1 General

The construction industry in Ethiopia can be viewed by using six distinct periods for its evolution (Wubishet, 2004). These distinct periods cover:

1. Pre - 1968: Foreign companies dominated construction industry,
2. 1968 – 1982: Emergence of small scale domestic construction companies,
3. 1982 – 1987: Parastatal Companies dominated construction industry,
4. 1987 – 1991: Fragmentation between design services & construction works,
5. 1991 – 2001: Parastatal Domination legally abolished, and
6. 2001 – Now: Integration Dominated construction industry.

The last two periods are important for the context of this research. Following the change in government in 1991, market – based economy and decentralization was introduced that resulted in the following, among the list, policy reforms to the construction industry (MEDaC, 1999b cited by Wubishet, 2004):

- Local and foreign private investors were allowed to participate in all areas of construction activities,
- Direct awards to state – owned construction companies were minimized to create competitive environment which was encouraging development.

Construction industry in Ethiopia nowadays is at an infant stage as it has not developed well even to the level of other developing countries. *This might be a reason why in the past construction time-cost relationships related factors have not been developed well.*

In general, two types of construction sectors exist in Ethiopia: private and public. Most of the construction works in the public sector are foreign fund initiated. Funding for a high percentage of construction projects come from multilateral development agencies (MDA) like the World Bank or African Development Bank. For large MDA funded projects, it is a usual practice to go for international competitive bidding. Most public contracts are awarded on the basis of the lowest responsive tenders submitted by contractors. Local contractors are given a margin of preference to secure public sector tenders under MDA funding. The maximum premium is 7.5 percent. For the private sector the project owners initiate the funds.

Construction is second to agriculture in generating employment in Ethiopia (Wubishet, 2004). Capacities in construction, as well as in manufacturing of construction materials, are in a better setting than in other sectors. This is because fairly reasonable institutional and infrastructure bases exist for design and construction in both the public and private sectors.

2.2.2 Capacity of the Construction Industry in Ethiopia

A study by SMEC International (an Australian company), 1999; MoWUD, 2001; and ERA, 2002 all cited by (Wubishet, 2004) concluded that the general state of the domestic construction industry in Ethiopia is low. The deficiencies were characterized by:

- An inadequate capital base, specifically to construction contractors,
- Old and limited numbers of equipment and their low level of utilization,
- Deficiencies in human resources with regard to technical, managerial, financial and entrepreneurial skills, and
- Very limited experience and participation in private sector for road, bridge and water related construction works and provisions of consulting services.

The local construction firms are broadly classified based on trend of work as follows:

A. General Contractors
B. Building Contractors
C. Road Contractors
D. Specialized Contractors

The first three categories are again divided into ten grades with different resource requirements. The Ministry of Works and Urban Development (MoWUD) has placed the basic human and equipment requirements to attain the different licenses with different grades. According to a data on 2007, there are 2,818 contractors on a federal level out of which only 54 are grade one with different specialties (Mendeke (2007)). There are 27 Grade One General Contractors out of which only 9 have the real capacity to carry out road infrastructure projects (Bekele, 2005).

2.3 Projects under the case study

This study has used completed projects under the Federal level by the Ethiopia Roads Authority (ERA). Using data from ERA and discussion with research advisors the projects shown in Table 6 -1, 6 – 2, and 6 – 23 were selected.

2.4 Research in Construction Management in Ethiopia

Construction Management as a field of study is about five years old in Ethiopia. The only graduate program in the area is given at Addis Ababa University and an undergraduate program is given at the same and another private institute. Research around the area has been done for many years but has been highly decentralized and also less coherent with the countries requirement.

This research came across with one PhD, two Masters, and three Undergraduate dissertations focusing on the time planning and performance issues in the country. But with the strengthening of both the undergraduate and graduate studies in the area, it is expected that, the countries construction industry will have more research out puts each year.

There is none or negligible expenditure on research and development (R&D) related to the industry. There are no research programmes currently running in the academic institutions. There is little or no coordination between various institutions or between departments and much of the direction comes from individual inclinations or interest. There is almost no budget allocated for research and study for the construction industry, though there is a small amount provided by the Commission for Science and Technology. Surprisingly this is also the same for countries like

Hong Kong where data on individual projects and amounts of expenditure had shown a total around HK$10 million per annum, which amounts to approximately 0.02% of the annual gross output, compared with the typical R&D expenditure of 1% of the annual turnover in most Japanese large contractors (Overseas Construction Association of Japan, 1989), this is insignificant (Chan, 1999).

2.5 Time - Cost Relationships: Previous Researches

Construction project time performance has long been identified, together with cost, quality and safety as one of the four main critical success factors in any construction project, be it in developed or developing countries. Thus establishing a time cost relationship becomes an important tool for predicting the future time performance based on the existing data and experience. In a country where about 30% of the capital budget is allocated for road construction, developing such a relationship will be vital to realize the ambitious plans provided in the Road Sector Programs within a realistically possible time (Wubishet, 2004).

A study on developing Time - Cost relationships for the Ethiopian construction industry began some twenty years back but unfortunately the only two principal studies are the one documented by Building and Transport Construction Design Authority (BaTCoDA) and one undergraduate thesis (Andient et al, 2006). Both research focused on the building construction sector. The ERA had long been using the S-curve as a project performance measurement tool but there have been no research on the appropriateness of using such a tool and on it efficacy.

2.5.1 BaTCoDA Formula

The Building and Transport Construction Design Authority (BaTCoDA), the former government building regulatory body, in 1987 formulated completion time based on cost by using the data on completed projects. Even though information is not available on the methodology and data used, the results of the study as shown in the study by (Andient et al, 2006) are presented as follows.

The study identified the level of uncertainty of the project and the level of head office and profit contribution of the project to the organization as main categories to classify the projects. The document classified project into three prospects based on uncertainties as follows:

- ❖ Prospect 1 – Project with full of uncertainties and thus taking longer completion period.
- ❖ Prospect 2 - Project with a reasonable uncertainties and thus taking a moderate completion period, and
- ❖ Prospect 3 - Project which has a natural curve prospects with the data gathered in the past.

And also classified the projects into two alternatives based on the level of head office and profit contribution of the project as shown below:

- ❖ Alternative 1 – Project with varying head office contribution and profit of the organizations, and
- ❖ Alternative 2 - Project with Constant head office contribution and profit of the organizations.

A graph of time versus cost has been plotted for prospect 3 of the first category and the result is as shown in Figure 2 -3. Using the graph for prospect 3 (i.e. based on the data available) the formula for time – cost relationship has been identified as:

$$\mathbf{T= 8\ C^{1/3}} \qquad \text{(Eqn. 2 – 1)}$$

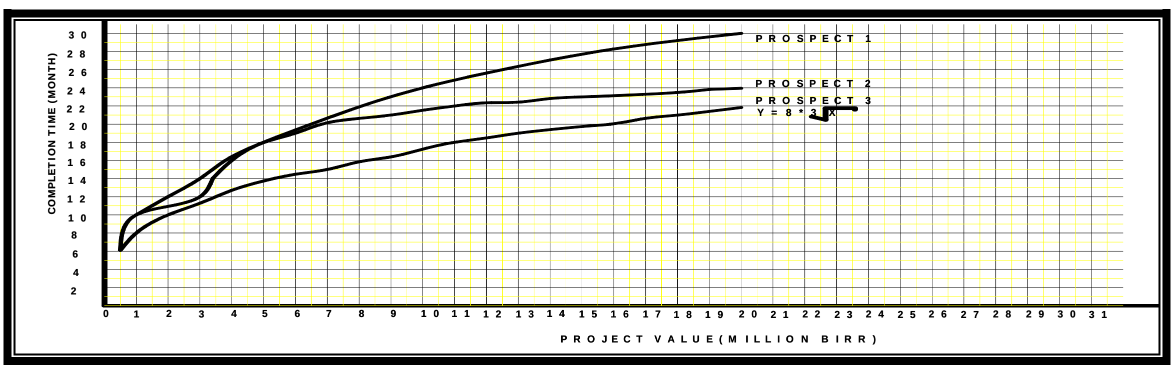


Figure 2-3: Project value and completion time curve used by BaTCoDA, 1987

The above time estimated based on cost have to be multiplied by the multiplying factors based on the combination of the different prospect and alternative to consider the level of head office contribution. The multiplying factors for the different combinations (prospect 1 and alternative 2, prospect 2 and alternative 2, prospect 1 and alternative 1, and prospect 2 and alternative 1) based on the project cost are as shown in Figure 2 -4.

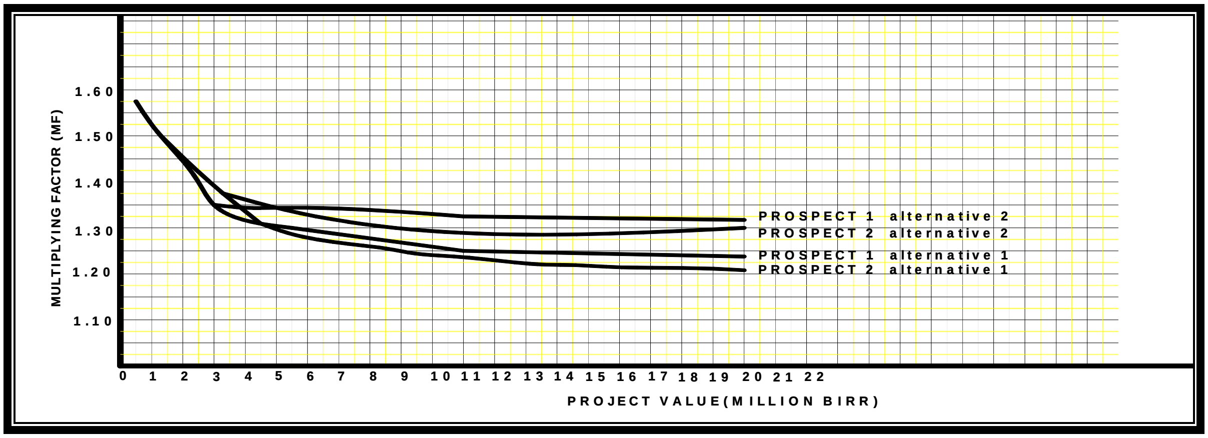


Figure 2- 4: Project value and multiplying factor used by BaTCoDA, 1987.

The above results can be summarized by the following relation

T = 7 to 12 $C^{1/3}$ (Eqn. 2 – 2)

Where:

- 7 - Stand for small sized buildings and 12- taken for most complex building projects.
- T – actual completion time in months
- C – actual project cost Birr in millions

The limitations of the study for today use are:

- does not consider other project types like roads,
- does not consider other project parameters like distance,
- is limited to public or governmental projects only,
- does not consider procurement and delivery systems, inflations, locations, etc.

There are no considerations of years of execution as the most recent project information is important to compare and contrast the standard of the present technologies and method of construction from past completion periods. This indicates that such a formula shall be revised periodically.

2.5.2 A study on time cost relationship: educational building projects in Ethiopia

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*$COST^{0.47}$ (Eqn. 2 – 3)

This relationship between time and cost can be easily shown by using Figure 2 -5.

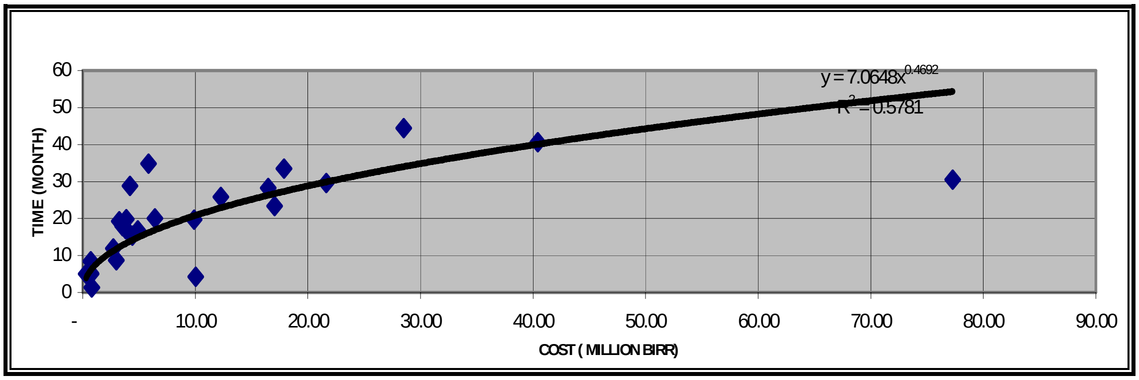


Figure 2 -5: Actual time – cost relationship of educational buildings in Ethiopia

The comparison made between the results of Andinet et al (2006) and that of the BaTCoDA study indicate a significant difference in the estimated required time to complete projects as shown in Figure 2 -6.

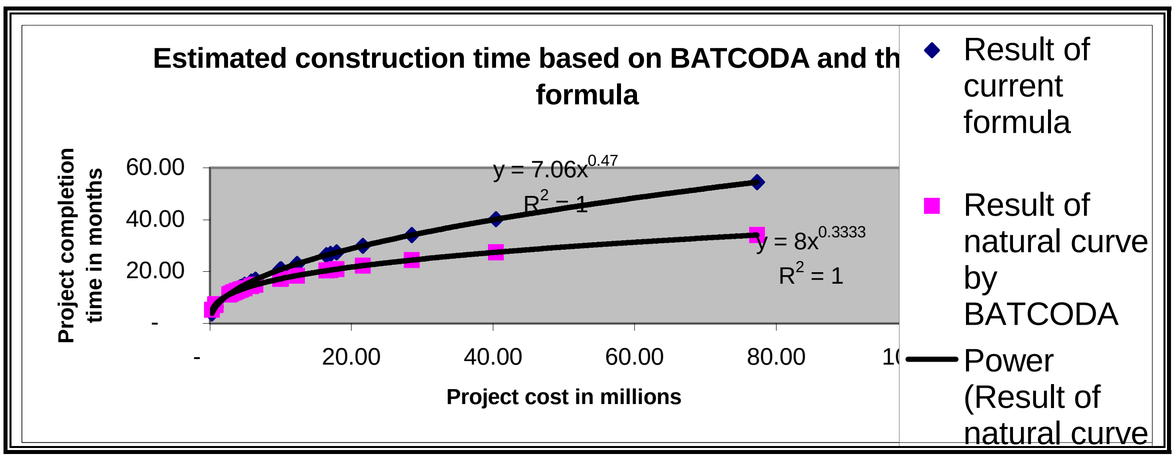


Figure 2- 6: Estimated completion time based on current formula and BaTCoDA (1987) natural curve on time-cost model

Both the above studies indicate that there is a strong relationship between time and cost for public building projects in Ethiopia. In addition to that the studies indicate that the duration of construction projects has increased from the previous estimates by BaTCoDA. This research will focus on extending the above research findings to the road construction sector of the country and also tries to develop the globally much unused S-Curve concept for performance measurement of projects (Daneshmand & Khreich, 2006).

3 BASIC CONCEPTUAL FRAME WORK

Basic Literature Review

Cost, schedule, and quality are the three major indicators for construction project performance (Jung & Kang, 2007). However, the main concerns in construction projects are Time and cost. In the construction industry, consultants and contractors usually use previous experiences to estimate the project duration and cost of a new project. Thus this research is focused on developing the relationship between time and cost for road construction projects in Ethiopia to facilitate the time prediction and also provide a continuous performance measuring tool. The literature review has been constructed to first define the basic concepts behind the research and then focus on detail thematic literature of related researches carried out around the world.

3.1 Project and Project Management

3.1.1 Project: Definition

PMI (2000) Organizations perform work to achieve a set of objectives. Generally, work can be categorized as either projects or operations, although the two sometimes overlap. The common characteristics shared include, Performed by people, Constrained by limited resources, and they are planned, executed, and controlled. Projects and operations differ primarily in that operations are ongoing and repetitive, while projects are temporary and unique.

Projects are a means of organizing activities that cannot be addressed within the organization's normal operational limits. Projects are, therefore, often utilized as a means of achieving an organization's strategic plan, whether the project team is employed by the organization or is a contracted service provider.

PMI (2004) defines a project as '*a temporary endeavor undertaken to create a unique product, service, or result*'. Projects shall accordingly have the following characteristics:

Temporary: Temporary means that every project has a definite beginning[3] and a definite end[4]. Temporary does not necessarily mean short in duration; many projects last for several years. In every case, however, the duration of a project is finite. Projects are not ongoing efforts.

Unique Products, Services, or Results: A project creates unique deliverables, which are products, services, or results. Uniqueness is an important characteristic of project deliverables. For example, many thousands of office buildings have been developed, but each individual facility is unique-different owner, different design, different location, different contractors, and so on. The presence of repetitive elements does not change the fundamental uniqueness of the project work.

Progressive Elaboration: Progressive elaboration is a characteristic of projects that accompanies the concepts of temporary and unique. Progressive elaboration means developing in steps, and continuing by increments. For example, the project scope will be broadly described early in the project and made more explicit and detailed as the project team develops a better and more complete understanding of the objectives and deliverables.

Dennis Lock, 1987 cited by Wubishet (2004) states that three broad categories of projects can be identified each with its own characteristics: **Manufacturing projects, Projects requiring external organizations**, and **Management projects.**

Manufacturing projects: Projects in this category involve the following activities: original design work, prototype testing: if necessary, manufacturing, assembling, installation and commissioning. Except installation and commissioning works, most of the activities are carried out under the control of the manufacturer. Such projects are often made for a fixed price, promised delivery dates, and a set of unambiguous data – specifications – that define the performance.

Projects requiring external organizations: Such projects include **civil engineering, construction**, petrochemical, mining, etc; which aims to establish buildings or operating plant on required sites requiring external or supplementary organization to the mother organization on these sites. Such

[3] Beginning for this research means the date the contract is signed.

[4] End for this research means the date the site is handed over upon substantial or full completion.

projects need more attention to the problems of communications and organization than the manufacturing projects.

Management projects: Such projects adhere to the employment of an external manager or managing teams offering services to organizations: to ensure effective and efficient management system, to ensure efficient installation and start up of new approaches, to follow projects of the above nature on behalf of clients and / or financiers, etc.

Halpin (2006) Construction projects can be broadly classified as:

a) Building Construction (includes facilities for habitational, institutional, educational, light industrial (e.g. warehouse), commercial, social and recreational purposes),
b) Engineered Construction (includes highway and heavy (e.g. dams, sewage plant) construction), and
c) Industrial Construction.

Hassanein and Moselhi (2004) stated that road projects can be classified as a linear repetitive project. Though the projects might have the presence of repetitive elements, it does not change the fundamental uniqueness of the project work (PMI, 2004). Repetitive projects can be classified into two broad categories: linear (such as highways and pipelines) and nonlinear (such as high-rise and multiple housing constructions) (Vorster et al. 1992 cited by Hassanein and Moselhi (2004)). While the former are repetitive due to their geometric layout, the latter are repetitive as crews repeat the same task in all units. For linear projects, assigning crews to nonadjacent units prolongs the construction schedule and increases total cost.

Road Project Definition*: - Thus a road project is a linear repetitive engineered construction project requiring an external organization for its implementation and is a temporary endeavor undertaken to produce a unique product, the road infrastructure.*

3.1.2 Project Management

Project management is the application of knowledge, skills, tools and techniques to project activities to meet project requirements PMI 2000 & 2004. Project management is accomplished through the application and integration of the project management processes of initiating, planning, executing, monitoring and controlling, and closing. The project manager is the person responsible for accomplishing the project objectives.

PMI (2000) managing a project includes: *Identifying requirements, Establishing clear and achievable objectives, Balancing the competing demands for quality, scope, time and cost, adapting the specifications, plans, and approach to the different concerns and expectations of the various stakeholders.*

PMI (2000), PMI (2004) and Abebe (2003) Project managers often talk of a 'triple constraint'- project scope, time and cost-in managing competing project requirements. Project quality is affected by balancing these three factors. High quality projects deliver the required product, service or result within scope, on time, and within budget. The relationship among these factors is such that if any one of the three factors changes, at least one other factor is likely to be affected. Projects can better be managed in ways that balance these constraints as shown in Figure 3 -1. But, overly emphasizing one of these aspects may compromise the other. Changing any of the three without adjusting one or all of the others may affect the quality of the project outputs, thus making the task of having a balance almost impossible. This result in a focus on one of the constraints, either time or cost.

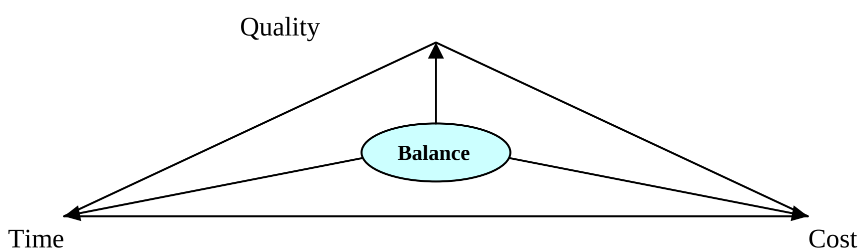


Figure 3-1: Triple Constrains of Project Management

Project managers also manage projects in response to uncertainty. Project risk is an uncertain event or condition that, if it occurs, has a positive or negative effect on at least one project objective.

Project Management can be clearly understood if the following parts of it are well know: context of the project, processes of project management and knowledge areas of project management.

According to PMI 2004, Project Management Context among others includes the project phases and the project stakeholder.

3.1.3 Project Phases and Project Life Cycle

PMI 2000, Organizations performing projects usually divide each project into several project phases each marked with a completion of one or more deliverables mainly for management control. Deliverable is a tangible, verifiable work product such as feasibility study, a detail design, or a working prototype. Project Life Cycle serves to define the beginning and the end of a project or Project Life Cycle - is the collective name for the different project phases.

Most project life cycles share a number of common characteristics:

- Phases are generally sequential and are usually defined by some form of technical information transfer or technical component handoff.
- Cost and staffing levels are low at the start, peak during the intermediate phases, and drop rapidly as the project draws to a conclusion. Figure 3-2 illustrates this pattern.

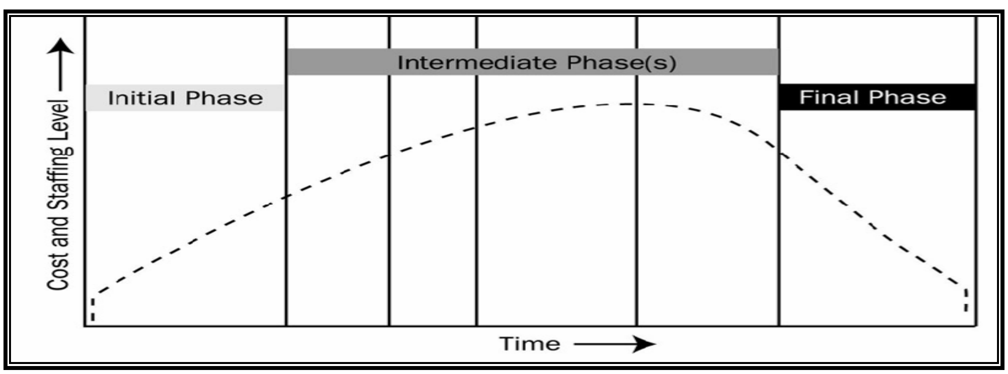


Figure 3-2: Typical Project Cost and Staffing Level across the Project Life Cycle

- The level of uncertainty is highest and, hence, risk of failing to achieve the objectives is greatest at the start of the project. The certainty of completion generally gets progressively better as the project continues.
- The ability of the stakeholders to influence the final characteristics of the project's product and the final cost of the project is highest at the start, and gets progressively

lower as the project continues. A major contributor to this phenomenon is that the cost of changes and correcting errors generally increases as the project continues.

PMI 2000 adopted Morris's life cycles for construction. Morris identified the following Project Life Cycles for Construction Projects:

- ✓ *Feasibility* – project formulation, feasibility studies, and strategy design and approval. A go/ no – go decision is made at the end of this phase.
- ✓ *Planning and Design* – base design, cost and schedule, contract terms and conditions, and detailed planning.
- ✓ *Construction* – manufacturing, delivery, civil works, installation, and testing. The facility is substantially completed at the end of this stage.
- ✓ *Turnover and Start Up* – final testing and maintenance. The facility is in full operation at the end of this phase.

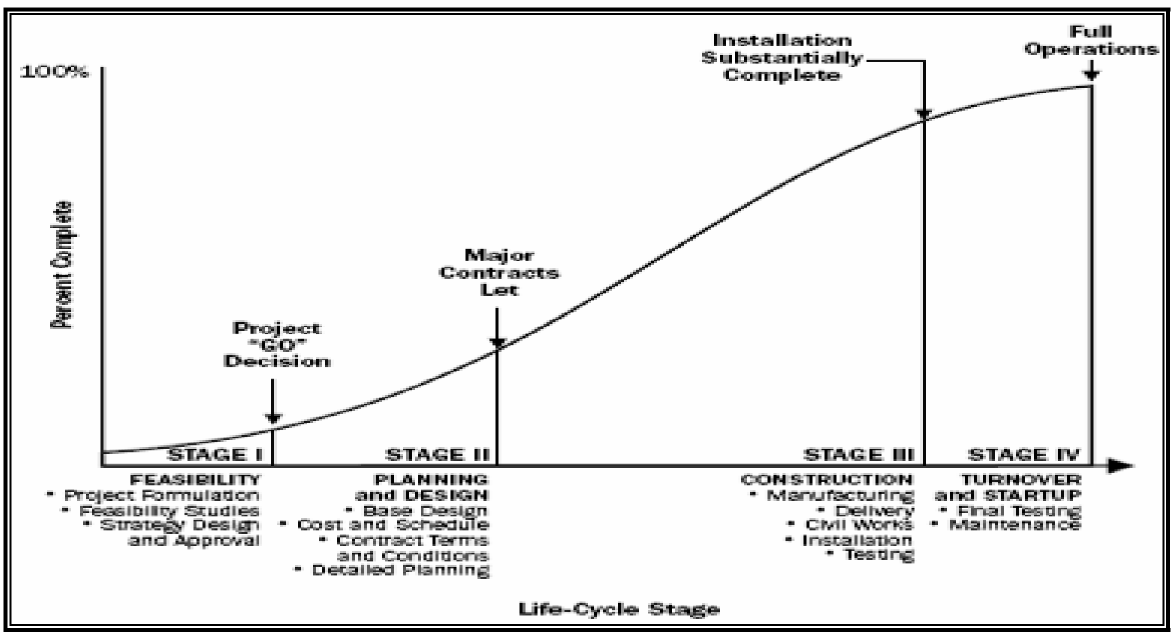


Figure 3 – 3: Representative Construction Project Life Cycle, Morris cited by PMI 2000

3.1.4 Project Stakeholders

PMI 2004, Project stakeholders are individuals and organizations that are actively involved in the project, or whose interests may be affected as a result of project execution or project completion. They may also exert influence over the project's objectives and outcomes. The project management team must identify the stakeholders, determine their requirements and expectations, and, to the extent possible, manage their influence in relation to the requirements to ensure a successful project.

Wubishet (2006) stated that the stakeholders in Ethiopian Public Construction Projects are Project Owners, Project Financiers and/or Regulators, Project Doers/Executers and other Interest Groups on one side and Budgetary, Contractual and Collateral Stakeholders on the other.

3.1.5 Project Management Process

PMI 2000, Project Management is an integrative endeavor – an action, or failure to take action, in one area will usually affect other areas. The interactions may be straight forward and well understood, or they may be subtle and uncertain. For example, a scope change will almost always affect project cost, but it may or may not affect team morale or product quality.

These interactions often require tradeoffs among project objectives – performance in one area may be enhanced only by sacrificing performance in another. Many project management practitioners refer to the project triple constraint as a framework for evaluating competing demands. The project triple constrains is often depicted as a triangle, see Figure 3 -1 above, where either the sides or corners represent one of the parameters being managed by the project team.

Thus latest project management thoughts are focused on developing the necessary processes leading to a successful completion of projects by managing the project constrains. PMI 2004 states that project management is accomplished through *processes*, using project management knowledge, skills, tools, and techniques that receive inputs and generate outputs.

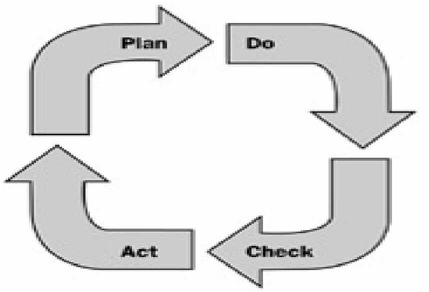
Projects are composed of processes. A process is ‘a series of actions bringing about a result’. Project processes are performed by people and generally fall into one of two major categories: Project Management Processes or Product – Oriented Processes. *Both processes are required for road construction projects as there must be a detailed know how on the product to formulate the scope of the project.* PMI 2004, Project management processes can be organized into five groups:

- Initiating Process Group – authorizes the project or phase.
- Planning Process Group – defines and refines the objectives and selects the best of the alternative course of action to attain the objectives that the project was envisaged for.
- Executing Process Group – coordinates people and other resources to carry out the plan.
- Monitoring and Controlling Process Group – ensures that the project objectives are met by monitoring and measuring progress regularly and identify variances from plan to take a corrective action. Monitoring and Controlling jointly were recognized as Controlling in the PMI 2000.
- Closing Process Group – formalizes acceptance of the project or phase.

The project management processes are presented as discrete elements with well-defined interfaces. However, in practice they overlap and interact in ways that are not completely detailed here. Most experienced project management practitioners recognize there is more than one way to manage a project. An underlying concept for the interaction among the project management processes is the plan-do-check-act cycle, PMI 2004 (as defined by Shewhart and modified by Deming, in the ASQ Handbook, American Society for Quality, 1999). This cycle is linked by results – the result from one part of the cycle becomes the input to another.

The integrative nature of the Process Groups is more complex than the basic plan-do-check-act cycle. However, the enhanced cycle can be applied to the interrelationships within and among the Process Groups. The Planning Process Group corresponds to the "plan" component of the plan-do-check-act cycle. The Executing Process Group corresponds to the "do" component and the Monitoring and Controlling Process Group corresponds to the "check and act" components. In addition, since management of a project is a finite effort, the Initiating Process Group starts these cycles and the Closing Process Group ends them. The integrative nature of project management requires the Monitoring and Controlling Process Group interaction with every aspect of the other Process Groups. Refer to Figure 3 – 4 and 3 – 5.

This research is assumed to be applicable mainly for managers practicing project management tools in the planning and monitoring and controlling processes.



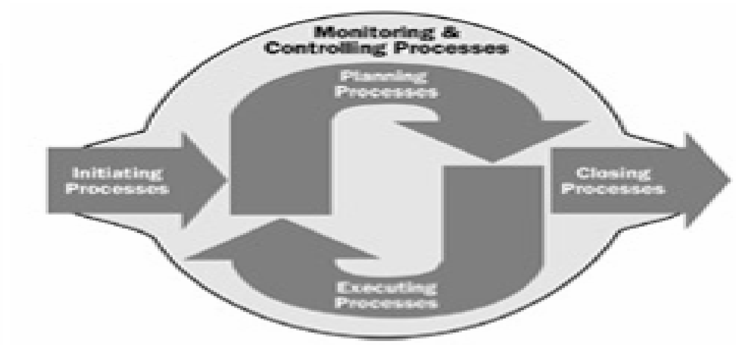


Figure 3 – 4: Plan –Do – Check – Act cycle **Figure 3 – 5:** Project Management Process Groups Mapped to the Plan – Do – Check – Act Cycle PMI 2004

3.2 Time Planning

Kumaraswamy & Daniel (1995), *Construction planning* is a fundamental and challenging activity in the management and execution of construction projects. It involves the choice of technology, the definition of work tasks, the estimation of the required resources and durations for individual tasks, and the identification of any interactions among the different work tasks. A good construction plan is the basis for developing the budget and the schedule for work. Developing the construction plan is a critical task in the management of construction, even if the plan is not written or otherwise formally recorded. In addition to these technical aspects of construction planning, it may also be necessary to make organizational decisions about the relationships between project participants and even which organizations to include in a project.

In developing a construction plan, it is common to adopt a primary emphasis on either cost control or on schedule control (Chris, 1998). Some projects are primarily divided into expense categories with associated costs. In these cases, construction planning is cost or expense oriented. Within the categories of expenditure, a distinction is made between costs incurred directly in the performance of an activity and indirectly for the accomplishment of the project. For example, borrowing expenses for project financing and overhead items are commonly treated as indirect costs. For other projects, scheduling of work activities over time is critical and is emphasized in the planning process. In this case, the planner insures that the proper precedences among activities are maintained and that efficient scheduling of the available resources prevails. Traditional scheduling procedures emphasize the maintenance of task precedences (resulting in *critical path scheduling* procedures) or efficient use of resources over time (resulting in *job shop* *scheduling* procedures). Finally, most complex projects require consideration of cost and scheduling over time, so that planning, monitoring and record keeping must consider both dimensions. In these cases, the integration of schedule and budget information is a major concern.

Scheduling is utilized at many different phases of the construction process, from the planning stage, through the construction, operation, and maintenance (Nunnally (1998) cited by Kris and Michael, 2004). Consequently, a construction schedule has different meanings for each organization involved in the construction process. Owners need an accurate schedule to advise them of when a project will be completed.

If the schedule is properly followed, the project may have an increased chance of being completed on time and within budget. All contractors involved need a schedule to determine resource requirements, when the resources will be needed, and when they must perform their work. Additionally, schedules can assist in planning multiple jobs. Material vendors utilize schedules to know when and how much material to deliver to the construction project site.

PMI 2004, Project Time Management includes the processes required to accomplish timely completion of the project. The Project Time Management processes include the following:

1. *Activity Definition* – identifying the specific schedule activities that need to be performed to produce the various project deliverables.
2. *Activity Sequencing* – identifying and documenting dependencies among schedule activities.
3. *Activity Resource Estimating* – estimating the type and quantities of resources required to perform each schedule activity.
4. *Activity Duration Estimating* – estimating the number of work periods that will be needed to complete individual schedule activities.
5. *Schedule Development* – analyzing activity sequences, durations, resource requirements, and schedule constraints to create the project schedule.
6. *Schedule Control* – controlling changes to the project schedule.

On some projects, especially ones of smaller scope, activity sequencing, activity resource estimating, activity duration estimating, and schedule development are so tightly linked that they are viewed as a single process that can be performed by a person over a relatively short period of time.

Hassanein and Moselhi, 2004, Road projects are typically linear and repetitive. Fitsum et al (2007) also stated that almost all of the Ethiopian Road construction stakeholders use either Bar chart or Critical Path Methods (CPM) for scheduling. Hassanein and Moselhi, 2004 questioned the use of network scheduling techniques, such as the critical path method (CPM), in scheduling road projects by citing (Chrzanowski and Johnston 1986). Consequently, techniques tailored to scheduling repetitive projects were developed (Johnston 1981; Chrzanowski and Johnston 1986; Vorster et al.1992; Harmelink 1995 cited by Hassanein and Moselhi (2004)). Unlike network scheduling, these techniques maintain crew work continuity. Models that consider integrating both techniques were developed (e.g., Russell and McGowan 1993; Suhail and Neale 1994; El-Rayes and Moselhi 1998 cited by Hassanein and Moselhi (2004)) to schedule nonlinear repetitive projects and are not suitable to scheduling linear ones when multiple crews are employed. Additionally, none of these models consider the planning stage, as they are solely concerned with scheduling activities given a predefined sequence of activities.

3.2.1 Schedule Accuracy and Compliance

Kris and Michael, 2004 citing others asserted that much of the prior work done on schedule accuracy has been in the area of delay analysis (Kraiem and Diekmann 1987; Yates 1993; Knoke and Jentzen 1994; Kallo 1996). The majority of this research implies that the as-built schedule of a project may be different from its as-planned schedule (Kraiem and Diekmann 1987; Trauner 1990; Shi et al. 2001). The difference is often considered a delay (Trauner 1990; Arditi and Robinson 1995). Part of this inaccuracy might be attributed to inaccurate estimation of activity duration, usually overestimation (Goldratt 1997 cited by Kris and Michael, 2004). Abdo, 2006 identified that failure to update schedules on time is among the least factors causing a delay in public building projects in Ethiopia. Schedule accuracy in this research is defined as the number of days that the contractor worked on a controlling (critical) activity/activities divided by the total number of days worked. Kris and Michael, 2004 concluded that the Highway Progress Schedule repots in Michigan US do not accurately represent the actual progress of the projects.

Iyer and Jha, 2006 stated that 40% of Indian construction projects are facing time over run. And when schedule compliance is the prime objective, seven factors are observed to have significant influence on the schedule outcome. Three factors: commitment of the project participants; owner's competence; and conflict among project participants have been found to possess the capability to enhance performance level while the remaining four factors: coordination among project participants; project manager's ignorance and lack of knowledge; hostile socioeconomic environment; and indecisiveness of project participants tend to retain the schedule performance at its existing level.

3.3 Cost Management

3.3.1 Overview

The concept behind the S – curve is related to the cost control and performance evaluation methods. To discuss this concept clearly it is recommended that the main aspects of the theoretical back ground be reviewed.

Project Cost Management, one of the knowledge areas for proper management of projects PMI 2004, includes the processes involved in planning, estimating, budgeting, and controlling costs so that the project can be completed within the approved budget. PMI 2004, Cost management includes three stages namely cost estimating, cost budgeting and cost control but PMI 2000 includes resource planning to the stage. PMI 2004 included this stage to the time planning stages by using resource requirements as per the activity defined. Accordingly:

1. *Cost Estimating* – refers to developing an approximation of the costs of the resources needed to complete project activities.
2. *Cost Budgeting* – refers to aggregating the estimated costs of individual activities or work packages to establish a *cost baseline*.

3. *Cost Control* – refers to influencing the factors that create cost variances and controlling changes to the project budget.

PMI 2004, Project Cost Management is primarily concerned with the cost of the resources needed to complete schedule activities. However, Project Cost Management should also consider the effect of project decisions on the cost of using, maintaining, and supporting the product, service, or result of the project. For example, limiting the number of design reviews can reduce the cost of the project at the expense of an increase in the customer's operating costs. This broader view of Project Cost Management is often called life-cycle costing. Life-cycle costing, together with value engineering techniques, can improve decision-making and is used to reduce cost and execution time and to improve the quality and performance of the project deliverable.

Project Cost Management considers the information requirements of the project stakeholders. Different stakeholders will measure project costs in different ways and at different times.

All of the above, as well as other information are included in the cost management plan, either as text within the body of the plan or as appendices. PMI – EVM, 2005 *The cost management plan is contained in, or is a subsidiary plan of, the project management plan and may be formal or informal, highly detailed or broadly framed, based upon the needs of the project.* Accordingly it's customary for all contractors of the Ethiopia Road Projects to submit the cost management plan through an S- Curve with the project management plan specifically with the time management plan.

The cost management planning effort occurs early in project planning and sets the framework for each of the cost management processes, so that performance of the processes will be efficient and coordinated.

As a preface to this research, it is worth highlighting the difference between 'cost' and 'price' as both terms are used extensively throughout this paper: 'Cost' –is commonly used when in reality the focus is on the 'price' likely to be paid for the work rather than how much the input resources may 'cost' to use. Strictly speaking, 'cost' is the cost of labour, plant, materials, etc before any addition of the supplier or contractor profit, overheads and risk margins. However, the term 'cost' is also used in the context of the more global sense of prices paid for construction work aggregated across a part or whole of the construction industry. 'Price' – is the cost of the work in the marketplace after the addition of the supplier or contractor profit, overheads and risk margins. However, it should be noted that the 'price' might be lower that the 'cost' if the contractor bid value less based on other business factors like competition and lack of work. Price is the amount likely to be paid for the work or item by the customer (Major Projects Team, 2006). Thus in this research cost represents the actual price paid to the contractor according to the conditions of the agreement.

3.3.2 Cost Budgeting

PMI (2004) Cost budgeting involves aggregating the estimated costs of individual schedule activities or work packages to establish a total cost baseline for measuring project performance. The project scope statement provides the summary budget. However, schedule activity or work package cost estimates might be prepared prior to the detailed budget requests and work authorization. Figure 3 - 6 below shows the system view point of the process.

One of the outputs of Cost Budgeting is the cost base line. The cost baseline is a time - phased budget that is used as a basis against which to measure, monitors and control overall cost performance on the project.

Figure 3 - 6: Cost Budgeting: Inputs, Tools & Techniques, and Outputs (PMI, 2004)

It is developed by summing estimated costs by period and is usually displayed in the form of an *S-curve*, as illustrated in Figure 3-7. The cost baseline is a component of the project management plan.

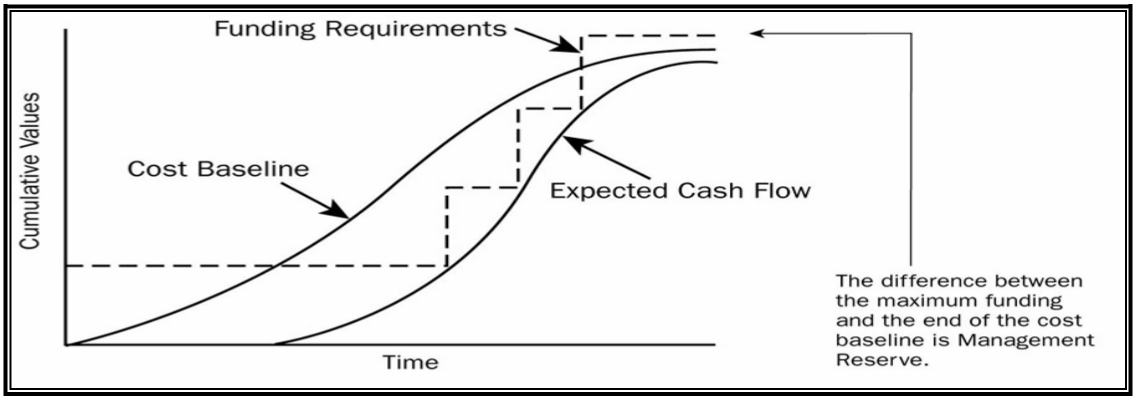


Figure 3-7: Cash Flow, Cost Baseline and Funding Display (PMI, 2004)

Many projects, especially large ones, have multiple cost or resource baselines, and consumables production baselines (e.g., cubic yards of concrete per day) to measure different aspects of project performance. For example, management may require that the project manager track internal costs (labor) separately from external costs (contractors and construction materials) or total labor hours.

3.3.3 Cost Control

PMI 2004 Project cost control includes among others:

- Influencing the factors that create changes to the cost baseline
- Managing the actual changes when and as they occur
- *Monitoring cost performance to detect and understand variances from the cost baseline*
- Recording all appropriate changes accurately against the cost baseline
- Preventing incorrect, inappropriate, or unapproved changes from being included in the reported cost or resource usage
- Acting to bring expected cost overruns within acceptable limits. Project cost control searches out the causes of positive and negative variances and is part of Integrated Change Control. For example, inappropriate responses to cost variances can cause quality or schedule problems or produce an unacceptable level of risk later in the project.

Figure 3 -8: Cost Control: Inputs, Tools & Techniques, and Outputs (PMI, 2004)

One of the tools used for cost control is the performance measurement analysis tool, as illustrated in Figure 3-8. The earned value analysis method is probably the most commonly used tool (PMI 2000, PMI 2004, Lockyer & Gordon (1996) and Chitkara (2000)). The earned value management technique (EVM) compares the cumulative value of the budgeted cost of work performed (earned) at the original allocated budget amount to both the budgeted cost of work scheduled (planned) and to the actual cost of work performed (actual). This technique is especially useful for cost control, resource management, and production. *The earned value technique in its various forms is a commonly used method of performance measurement.* It integrates project scope, cost (or resource) and schedule measures to help the project management team assess project performance.

An important part of cost control is to determine the cause of a variance, the magnitude of the variance, and to decide if the variance requires corrective action. The earned value technique uses the cost baseline contained in the project management plan to assess project progress and the magnitude of any variations that occur. In Ethiopian case, the contractor's schedules (Final Report, 2004 & 2005) also show that the client, ERA, uses the cost base line to monitor projects performances.

3.4 Project Performance

Performance reviews compare cost performance over time, schedule activities or work packages overrunning and underrunning budget (planned value), milestones due, and milestones met.

PMI (2004) Performance reviews are meetings held to assess schedule activity, work package, or cost account status and progress, and are typically used in conjunction with one or more of the following performance-reporting techniques:

- *Variance analysis.* Variance analysis involves comparing actual project performance to planned or expected performance. *Cost and schedule variances are the most frequently analyzed, but variances from plan in the areas of project scope, resource, quality, and risk are often of equal or greater importance.*
- *Trend analysis.* Trend analysis involves examining project performance over time to determine if performance is improving or deteriorating.
- *Earned value technique.* The earned value technique compares planned performance to actual performance.

3.5 Earned Value Management (EVM)

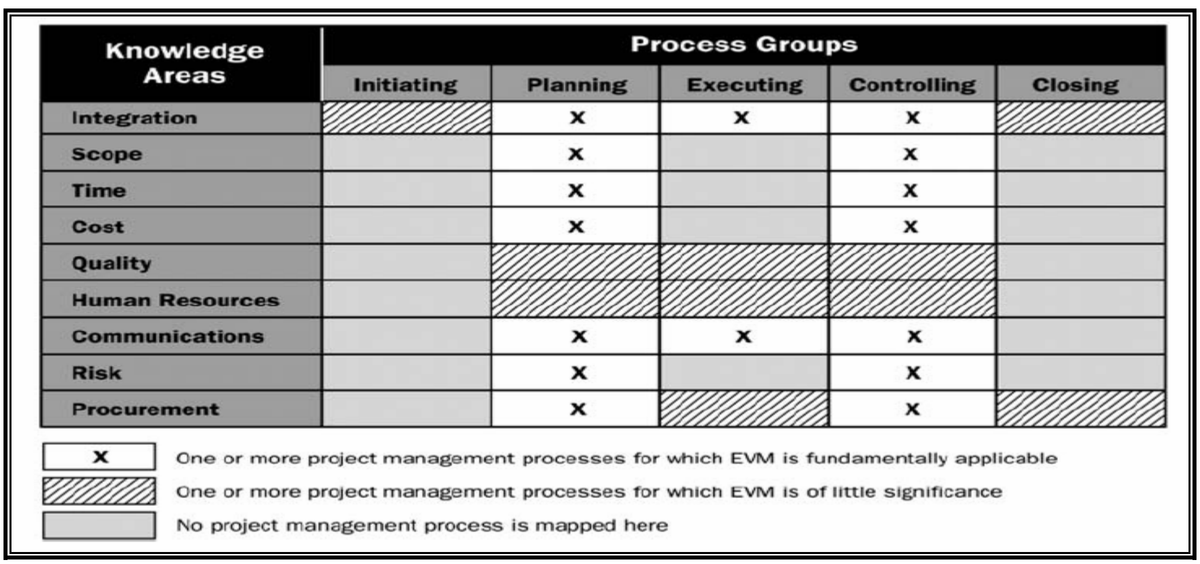
3.5.1 Introduction

PMI – EVM (2005) Feedback is critical to the success of any project. Timely and targeted feedback can enable project managers to identify problems early and make adjustments that can keep a project on time and on budget. Earned Value Management (EVM) has proven itself to be one of the most effective performance measurement and feedback tools for managing projects. It enables managers to close the loop in the plan-do-check-act management cycle shown in Figure 3 – 4 and 3 -5. The best-known practice of Earned Value Management matured over a period of 30 years in the United States and allied countries through its application on large defense systems contracts. According to Christensen (2007), most of the literature on Earned Value Management and most of its professionally active community is grounded in that experience.

PMI (2004) EVM has been called ‘‘management with the lights on’’ because it can help clearly and objectively illuminate where a project is and where it is going—as compared to where it was supposed to be and where it was supposed to be going. Lockyer and Gordon (1996) also asserted that EVM has replaced the traditional performance analysis methods that compare the actual cost incurred to the given date with budgeted or planned expenditure. EVM uses the fundamental principle that patterns and trends in the past can be good predictors of the future. EVM provides organizations with the methodology needed to integrate the management of project scope, schedule, and cost. EVM can play a crucial role in answering management questions that are critical to the success of every project, such as: *Are we ahead of or behind schedule? , How efficiently are we using our time? , When is the project likely to be completed? , Are we currently under or over our budget? , How efficiently are we using our resources? , What is the remaining work likely to cost? , What is the entire project likely to cost? , How much will we be under or over budget at the end?*

If the application of EVM to a project reveals that the project is behind schedule or over budget, the project manager can use the EVM methodology to help identify: *Where problems are occurring, whether the problems are critical or not, what it will take to get the project back on track?*

PMI – EVM, 2005 EVM has a wide application extending from the Planning stage of the project to the Controlling stage. Figure 3 - 9 below indicates the areas of project management where EVM is fundamentally applicable.



Knowledge Areas	Process Groups				
	Initiating	Planning	Executing	Controlling	Closing
Integration		x	x	x	
Scope		x		x	
Time		x		x	
Cost		x		x	
Quality					
Human Resources					
Communications		x	x	x	
Risk		x		x	
Procurement		x		x	

x One or more project management processes for which EVM is fundamentally applicable

One or more project management processes for which EVM is of little significance

No project management process is mapped here

Figure 3 -9: EVM and Project Management Knowledge Areas, Source PMI – EVM, 2005

During the project planning process, EVM requires the establishment of a *performance measurement baseline (PMB) or Cost Base Line (PMI, 2004) or S – Curve (Chitkara, 2000).* This requirement amplifies the importance of project planning principles, especially those related to scope, schedule, and cost. This research principally tests the applicability of this base line (PMB) for Ethiopian Road projects. Project work needs to be broken down—using a work breakdown structure—into executable tasks and manageable elements often called *control accounts*. The key for an effective EVM system is the work break down structure (WBS) (Daneshmand & Khreich (2006)). Either an individual or a team needs to manage each of the work elements. All of the work needs to be assigned to the workforce for execution using an organization breakdown structure (OBS). Refer to Figure 3 – 10.

Most importantly, EVM can be easily extended by increasing the level of detail and frequency of measurement to cater for the two important project situations of *significance* and *uncertainty*.

In the *project planning process,* the means for assessing physical work progress and assigning budgetary earned value also needs to be established. In addition to routine project management planning, earned value measurement techniques are selected and applied for each work task, based on scope, schedule, and cost considerations.

In the *project execution process,* EVM requires the recording of resource utilization (i.e., labor, materials, and the like) for the work performed within each of the work elements included in the project management plan. In other words, actual costs need to be captured in such a way that permits their comparison with the performance measurement baseline.

In the *project control process,* EVM requires that physical work progress be assessed and budgetary earned value be credited (using the selected earned value measurement techniques), as prescribed in the project management plan. With this earned value data, the planned value data from the performance measurement baseline, and the actual cost data from the project cost tracking system, the project team can perform EVM analysis at the control account and other levels of the project work breakdown structure, and report the EVM results as needed.

Project work needs to be logically scheduled and resourced in a work plan; the work scope, schedule, and cost need to be integrated and recorded in a time-phased budget known as a performance measurement baseline (PMB) or S - Curve.

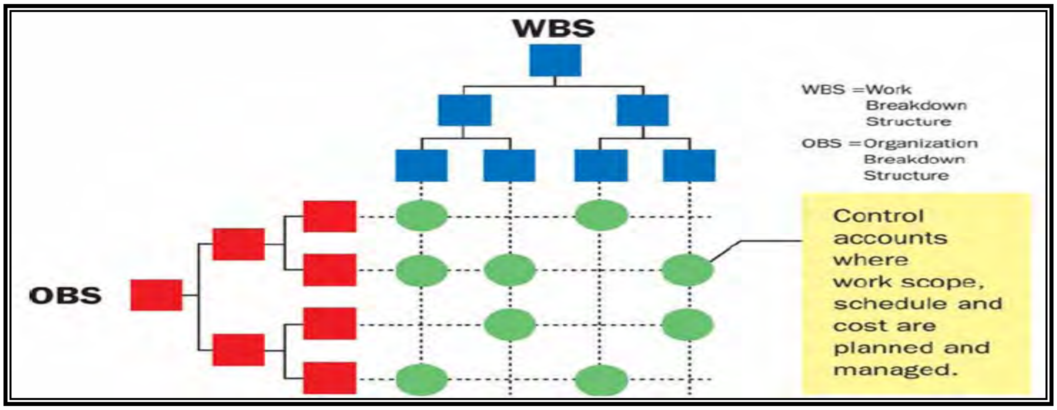


Figure 3 -10: Control Account Matrix, PMI – EVM, 2005

Figure 3-11 & 3 - 12 illustrate a hypothetical work plan with a Gantt (bar) chart, to which earned value measurement techniques have been added.

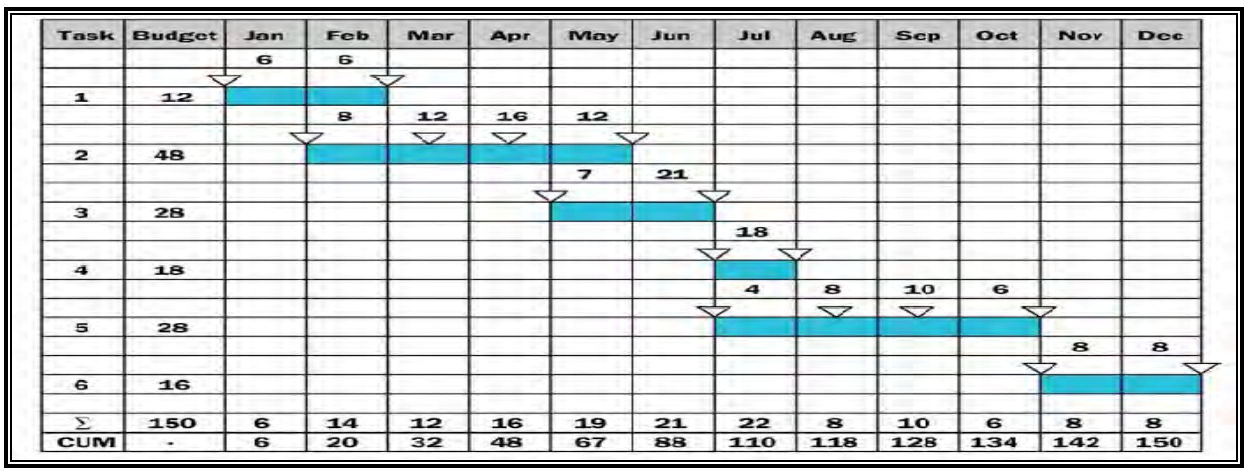


Figure 3 – 11: Work Plan – Gantt (Bar) Chart

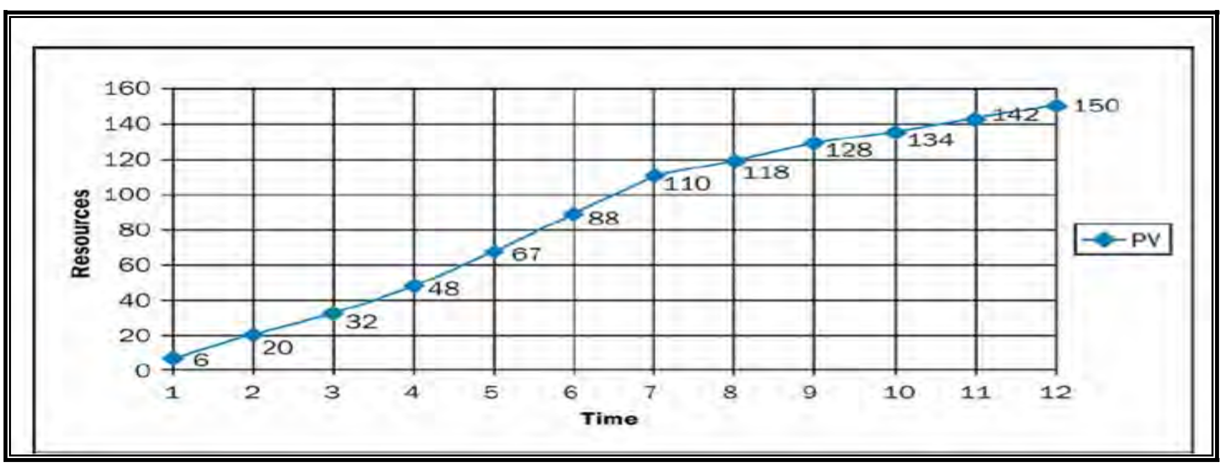


Figure 3 – 12: S –Curve or Performance Measurement Baseline (PMB)

In summary, EVM strategically augments good project management to facilitate the planning and control of cost and schedule performance (PMI – EVM, 2005). The key practices of EVM include:

- Establish a performance measurement baseline (PMB) or S - Curve:
    - Decompose work scope to a manageable level
    - Assign unambiguous management responsibility
    - Develop a time-phased budget for each work task
    - Select EV measurement techniques for all tasks
    - Maintain integrity of PMB throughout the project.
- *Measure and analyze performance against the baseline:*
    - Record resource usage during project execution
    - Objectively measure the physical work progress
    - Credit EV according to EV techniques
    - Analyze and forecast cost/schedule performance
    - Report performance problems and/or take action.

3.5.2 Basic Elements of Earned Value Management

According to PMI 2004 and Practice Standard of EVM (PMI – EVM, 2005), Earned Value Management relies on three key data points: Planned Value (BCWS), Earned Value (BCWP), and Actual Cost (ACWP).

3.5.2.1 Planned Value

*Planned Value (PV)***,** otherwise called (Lockyer & Gordon, 1996) *Budgeted Cost of Work Scheduled (BCWS)* is the budgeted cost for the work scheduled to be completed on an activity or WBS component up to a given point in time PMI 2004 and PMI – EVM, 2005 describes how far along project work is supposed to be at any given point in the project schedule. PMI 2000, PMI 2004, Practice Standard of EVM (2005) & Chitkara (2000), It is a numeric reflection of the budgeted work that is scheduled to be performed, and it is the established baseline (also known as the *performance measurement baseline* or *PMB*) against which the actual progress of the project is measured. Once established, this baseline may only change to reflect cost and schedule changes necessitated by changes in the scope of work. Planned Value is usually charted showing the cumulative resources budgeted across the project schedule. Figure 3 – 12, shows the *Planned Value S-Curve* for Example Project AA.

3.5.2.2 Earned Value

Earned Value (EV) otherwise called (Lockyer & Gordon, 1996) *Budgeted Cost of Work Performed (BCWP),* is the budgeted amount for the work actually completed on the schedule activity or WBS component during a given time period. It reflects the amount of work that has actually been accomplished to date (or in a given time period), expressed as the planned value for that work. Figure 3 -13 show the Earned Value for Project AA at the four-month mark, and indicate that less work than planned has been accomplished.

3.5.2.3 Actual Cost

Actual Cost (AC), otherwise called (Lockyer & Gordon , 1996) *Actual Cost of Work Performed (**ACWP**),* is the total cost incurred in accomplishing work on the schedule activity or WBS component during a given time period. It is an indication of the level of resources that have been expended to achieve the actual work performed to date (or in a given time period). Figure 3-13 shows the Actual Cost for Project AA at the four-month mark, and indicates that the organization has spent less than it planned to spend to achieve the work performed to date.

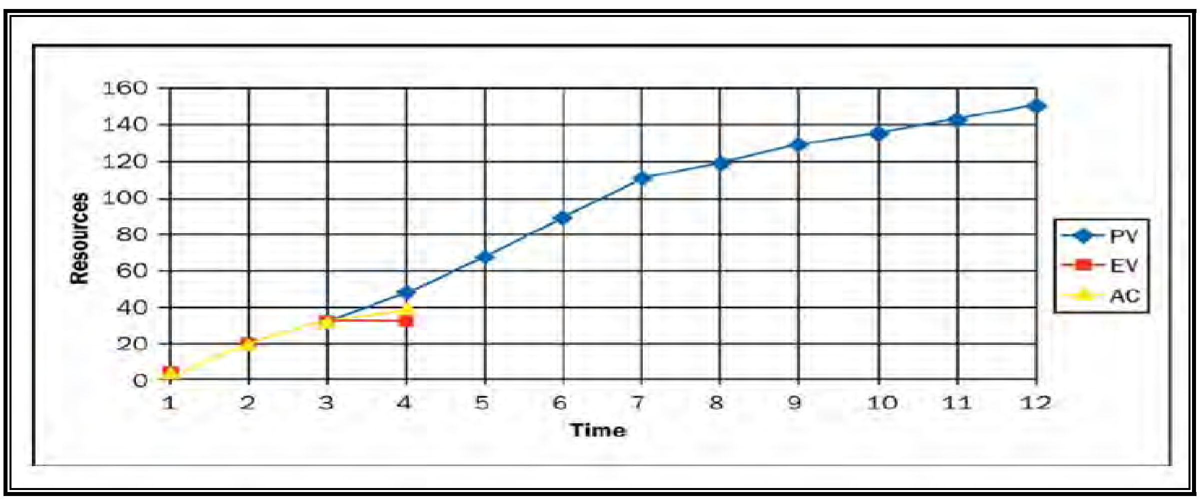


Figure 3 – 13: Cumulative Planned Value, Earned Value and Actual Cost of Project AA

Tasks may be planned and measured in whatever resource units are most suitable to the work, including labor hours, material quantities, and the monetary equivalent of these resources. As discussed in the next section, however, performance management works best when the physical progress of work is objectively planned and measured. The techniques used in EVM to achieve this goal are Earned Value measurement techniques (sometimes called earning and crediting methods).

3.5.3 Derivations of the Basic EVM Elements

3.5.3.1 Planned Value

Again considering the sample project AA, the work plan for Project AA, shown in Figure 3 – 12 is the basis for the Planned Value and the *performance measurement baseline* for the project (see Figure 3 - 13). This work plan establishes a time-phased budget for each task in the project. For example, Task 2 has a budget of 48 resource units, which are phased over a four-month period. The plan for Task 2 calls for varying increments of Planned Value to be earned in each month of the task. As the planned work is accomplished, its budgeted cost becomes Earned Value.

3.5.3.2 Earned Value - Earned Value Measurement Techniques

Earned Value is a measure of work performed. Techniques for measuring work performed are selected during project planning and are the basis for performance measurement during project execution and control. Earned Value (EV) techniques should be selected based on key attributes of the work, primarily 1) the duration of the effort and 2) the tangibility of its product.

The performance of separate and distinct work effort that is related to the completion of specific and tangible end products or services, and which can be directly planned and measured, is called **discrete effort**. In comparison, effort applied to project work that is not readily divisible into discrete efforts for that work, but which is related in direct proportion to measurable discrete work efforts, is called **apportioned effort**, and support-type activity that does not produce definitive end products is referred to as **level of effort**.

Work performance is measured periodically, such as weekly or monthly. The EV technique selected for measuring the performance of discrete effort will depend on its duration and the number of measurement periods it spans. Discrete efforts that span one to two periods are often measured with **fixed formula** techniques, where a fixed percentage of work performance is credited at the start of the work and the remaining percentage is credited at the completion of the work. A typical example of fixed formula is the 50/50 technique, where the 50 percent of the work is credited as complete for the measurement period in which the work begins, regardless of how much work has actually been accomplished. The remaining 50 percent is credited when the work is completed. Other variations include 25/75 and 0/100. Discrete efforts of longer duration (greater than two periods) are measured with other techniques, including those known as **weighted milestone** and **percent complete**.

The above guidelines for selecting EV measurement techniques are outlined in Figure 3 -14, and some of the most common techniques are described in the paragraphs that follow. For this research the percent complete method has been used as the executed works can be compared with the total contact amount of the specific tread of works.

Product of Work	Duration of Work Effort	
	1-2 Measurement Periods	>2 Measurement Periods
Tangible	*Fixed Formula*	*Weighted Milestone* *Percent Complete*
Intangible	*Apportioned Effort* *Level of Effort*	

Figure 3 – 14: Eared Value Measurement Techniques, PMI – EVM, 2005

3.5.3.3 Deriving the Earned Value

While value is planned and measured using the Earned Value techniques outlined above, value is earned by accomplishing the planned work. Earned Value is credited when progress is demonstrated in accordance with the Earned Value technique selected for the planned work. For discrete work, observable evidence of a tangible product or progress is required.

The status of Project AA after four months is presented in Figure 3-16. This progress report indicates that all of the work planned for Task 1 has been accomplished. This discrete work was planned and measured using the 50/50 EV technique. The work was credited with an Earned Value of 6 by demonstrating physical and objective evidence that the task began in January, and it earned the remaining value of 6 in February by demonstrating completion of the work in the same manner. Task 2 of Project EZ is discrete work that was planned and measured using the weighted or valued milestone measurement technique. The progress report in Figure 3-15 shows that some of the work planned for completion by the end of April has not been accomplished. Two of the three scheduled milestones for Task 2 (those in February through April) have been reached, but the third milestone has not, and the Planned Value for that intermediate product has not been credited. To receive the Earned Value for the first two milestones required observable evidence of those tangible outcomes.

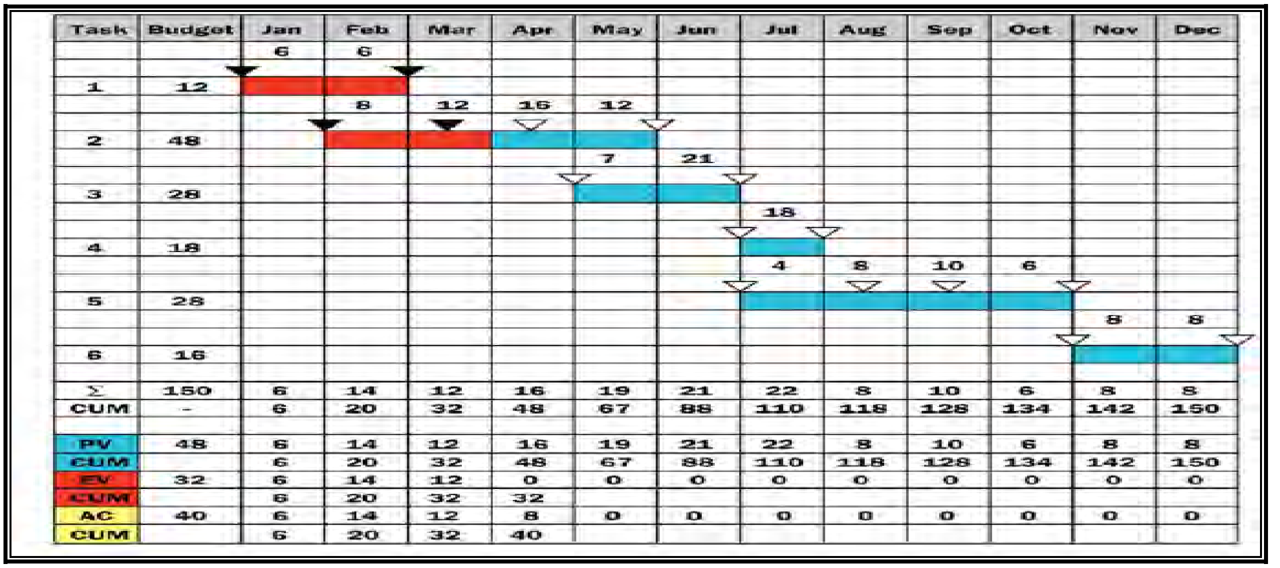
3.5.3.4 Actual Cost

To determine Actual Cost, an organization needs to have in place a system for tracking costs over time and by project component. The sophistication and complexity of this system will vary by organization and project, but, at a minimum, some type of cost tracking system must be in place that can tie costs to the plan and to the way Earned Value is credited. The status of Project AA in Figure 3-15 shows that, although no Earned Value was credited for Task 2 in April, some costs were reflected for that month, which put the task and the project over budget at the end of April, as the Actual Cost exceeded the Earned Value (see also Figure 3 -16).

3.6 EVM Performance Analysis and Forecasting

EVM performance analysis and forecasting examines how the data points of **Planned Value (PV), Earned Value (EV)**, and **Actual Cost (AC)** can be used to analyze the current status of a project and forecast its likely future. EVM looks at project performance for the current period and at cumulative performance to date. EVM is described and illustrated here in terms of cumulative data, using the Project AA data displayed in Figure 3-11 & 3 - 15.

An import data point in EVM analysis is the **Budget at Completion (BAC)**, which is the final data point on the performance measurement baseline (PMB). Budget at Completion represents the total Planned Value for the project. For Project AA, the BAC is 150.



Task	Budget	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	12	6	6										
2	48		8	12	16	12							
3	28					7	21						
4	18							18					
5	28							4	8	10	6		
6	16											8	8
Σ	150	6	14	12	16	19	21	22	8	10	6	8	8
CUM	-	6	20	32	48	67	88	110	118	128	134	142	150
PV	48	6	14	12	16	19	21	22	8	10	6	8	8
CUM		6	20	32	48	67	88	110	118	128	134	142	150
EV	32	6	14	12	0	0	0	0	0	0	0	0	0
CUM		6	20	32	32								
AC	40	6	14	12	8	0	0	0	0	0	0	0	0
CUM		6	20	32	40								

Figure 3 – 15: Work Plan and Status of Project AA (As of April 30)

EVM performance analysis and forecasting includes:

- **Variances:** Schedule Variance (SV); Cost Variance (CV); and Variance at Completion (VAC)
- **Indices:** Schedule Performance Index (SPI); Cost Performance Index (CPI); and To-Complete Performance Index (TCPI)
- **Forecasts:** Time Estimate at Completion (EAC_t); Estimate at Completion (EAC); and Estimate to Complete (ETC). Figure 3-17 shows the relationships among the basic EVM performance measures.

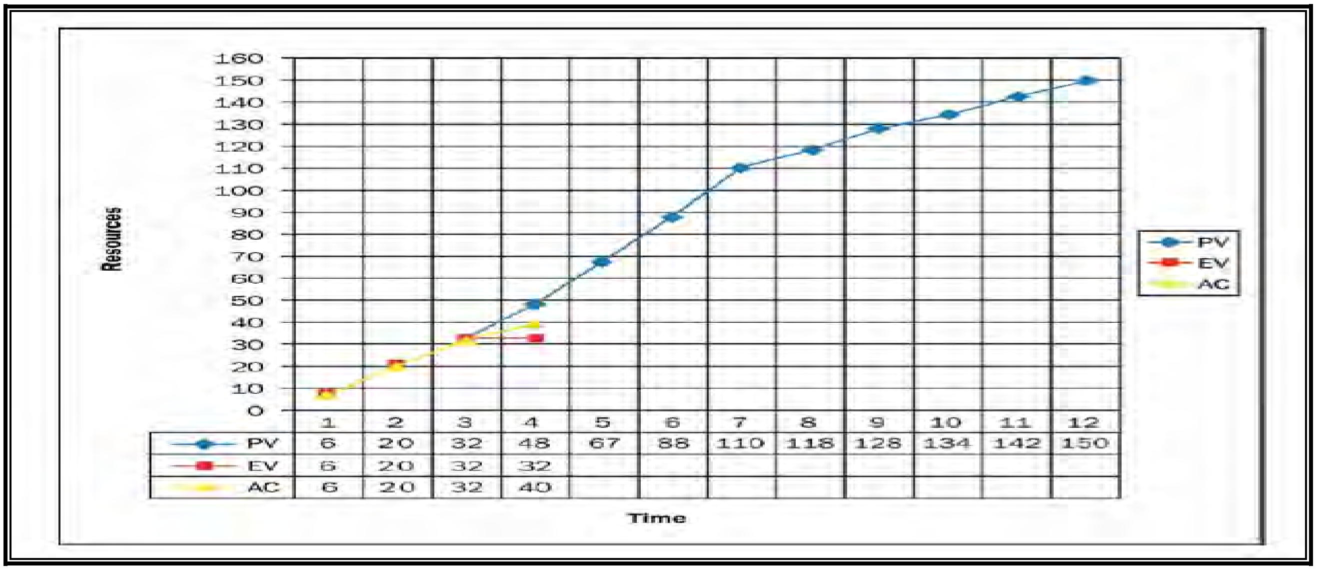


Figure 3 – 16: Summary of PV, EV and AC for Project AA

These variances, indices, and forecasts can be used to answer the key project management questions raised in the introduction part of EVM. Figure 3-18 shows the relationship between those project management questions and the EVM performance measures. Figure 3-19 shows what EVM performance measures indicate about a project in regard to its planned work schedule and resource budget.

3.6.1 Schedule Analysis and Forecasting (How are we doing time wise?)

Schedule Variance ***(Are we ahead or behind schedule?)*** - The Schedule Variance (SV) determines whether a project is ahead of or behind schedule. It is calculated by subtracting the Planned Value (PV) from the Earned Value (EV). A positive value indicates a favorable condition and a negative value indicates an unfavorable condition.

$$SV = EV - PV \qquad \text{(Eqn. 3.1)}$$

The Schedule Variance can also be expressed as a percentage by dividing the Schedule Variance (SV) by the Planned Value (PV):

$$SV\% = SV/PV \qquad \text{(Eqn. 3.2)}$$

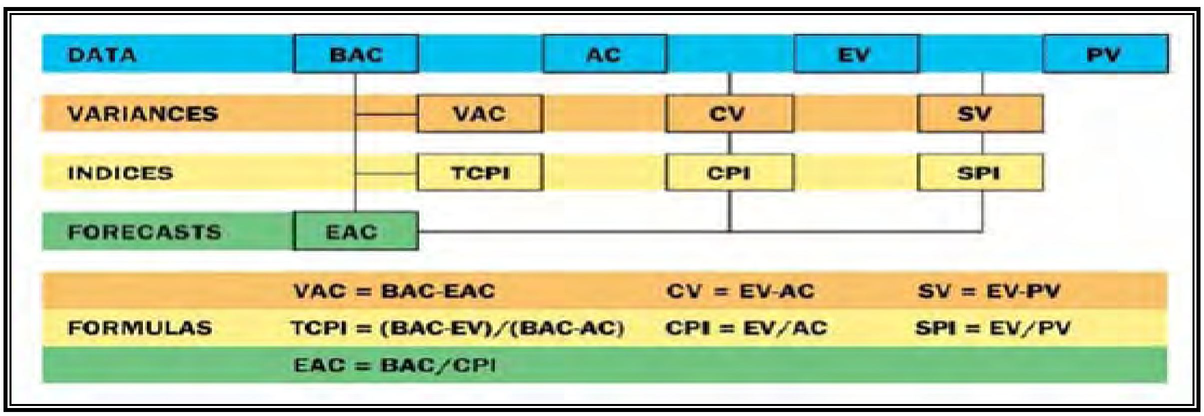


Figure 3 – 17: EVM Performance Measures

Performance Measures		Schedule		
		SV > 0 & SPI > 1.0	SV = 0 & SPI = 1.0	SV < 0 & SPI < 1.0
Cost	CV > 0 & CPI > 1.0	Ahead of Schedule Under Budget	On Schedule Under Budget	Behind Schedule Under Budget
	CV = 0 & CPI = 1.0	Ahead of Schedule On Budget	On Schedule On Budget	Behind Schedule On Budget
	CV < 0 & CPI < 1.0	Ahead of Schedule Over Budget	On Schedule Over Budget	Behind Schedule Over Budget

Figure 3 – 19: Interpretations of Basic EVM Performance Measures

Project Management Question	EVM Performance Measures
How are we doing time-wise?	**Schedule Analysis & Forecasting**
- Are we ahead or behind schedule?	- Schedule Variance (SV)
- How efficiently are we using time?	- Schedule Performance Index (SPI)
- When are we likely to finish work?	- Time Estimate at Completion (EACt)
How are we doing cost-wise?	**Cost Analysis & Forecasting**
- Are we under or over our budget?	- Cost Variance (CV)
- How efficiently are we using our resources?	- Cost Performance Index (CPI)
- How efficiently must we use our remaining resources?	- To-Complete Performance Index (TCPI)
- What is the project likely to cost?	- Estimate at Completion (EAC)
- Will we be under or over budget?	- Variance at Completion (VAC)
- What will the remaining work cost?	- Estimate to Complete (ETC)

Figure 3 – 18: EVM and Basic Project Management Questions

Schedule Performance Index *(How efficiently are we using time?)* - The Schedule Performance Index (SPI) indicates how efficiently the project team is using its time. SPI is calculated by dividing the Earned Value (EV) by the Planned Value (PV).

$$SPI = EV / PV \quad \text{(Eqn. 3.3)}$$

Time Estimate at Completion *(When are we likely to finish work?)* - Using the Schedule Performance Index (SPI) and the average Planned Value (PV) per unit of time, the project team can generate a rough estimate of when the project will be completed, if current trends continue, compared to when it was originally supposed to be completed.

$$EAC_t = (BAC/SPI)/ (BAC/months) \quad \text{(Eqn. 3.4)}$$

In the current practice of EVM, schedule variance and schedule performance are both measures of work scope, not time. The work is represented by its budget cost as recorded in the performance measurement base line. The EVM schedule variance is the difference between works performed to work scheduled. For the sample Project AA stated above,

$$SV = EV – PV = 32 – 48 = -16$$

$$SPI = EV/PV = 32/48 = 0.67$$

If the work continues at this rate, then all of the work of the project would take,

$$EAC_t = (BAC/SPI) / (BAC/months) = (150/0.677) / (150/12) = 18 \text{ months.}$$

These SV and SPI measures are useful indicators and predictors of performance and results. But because they are based on work and not time, they can behave in ways that are not normally expected from of schedule indicators and predictors. This nature can be easily seen when one assumes the above measures at project completion. Whether the project is completed in 12 or 18 months at the end SV = 0 and SPI = 1.0 while the project is delayed by 6 months.

There is an emerging practice in EVM, which uses time – based measures of schedule variance and schedule performance as an alternative or supplement to the traditional work – based measures. This new method avoids the problems of work based method by comparing the actual time with the planned time for the work performed. In case of the Project AA, the work performed after four months, Actual Time (AT) = 4 has a planned time of three months, Planned Time (PT) = 3months. In the manner to EVM, practitioners are beginning to use actual time (AT) and planned time (PT) to compute SV and SPI:

$$SV_{(t)} = PT – AT = 3 – 4 = - 1 \text{ months} \quad \text{(Eqn. 3.5)}$$

$$SPI_{(t)} = PT/AT = 3/ 4 = 0.75 \quad \text{(Eqn. 3.6)}$$

While the work and time – based methods provide comparable results at the four month point in Project AA, the difference is visible at project completion after 18 months.

Work – Based Method	**Time – Based Method**
SV = EV – PV = 150 - 150 = 0	SV = PT – AT = 12 – 18 = - 6 months
SPI = EV / PV = 150 / 150 = 1.0	SPI = PT / AT = 12 / 18 = 0.67

It is important to note that this method generates a fairly rough estimate and must always be compared with the status reflected by a time-based schedule method such as critical path method. It is possible that an earned value analysis could show no schedule variance and yet the project is still behind schedule; for example, when tasks that are planned to be completed in the future are performed ahead of tasks on the critical path.

3.7 Performance Reporting

EVM can provide a great deal of useful information to key stakeholders about the project. However, the level and type of information needed about a project may vary greatly from one stakeholder to another. A number of different methods have evolved for presenting EVM data. These methods are designed to address the diverse stakeholder's needs. Several of these methods may be used on a given project to meet the needs of different stakeholder's audience. The most commonly used methods include: S – Curves, Tables, and Bar Charts.

S – Curves - S – Curves have been used to illustrate the cumulative PMB of EVM. This type of display can be very effective for providing a quick look at the overall performance of a task, a control account, or a project.

Tables - A tabular format can be an effective method for displaying the EVM results by project component. The above values of PV, EV, AC, CV, SV, CPI, SPI, TCPI, BAC, EAC and VAC can provide a complete, concise picture of what is happening with project. It can be used as a logical follow-on to an S – curve to provide more detail on where the project is at a given time.

Bar Chars - Bar charts can be a useful tool for comparing data such as Planned Value to Earned Value.

Figure 3 -20 uses S-curves to display cumulative EV data for a project that is over budget and behind the work plan.

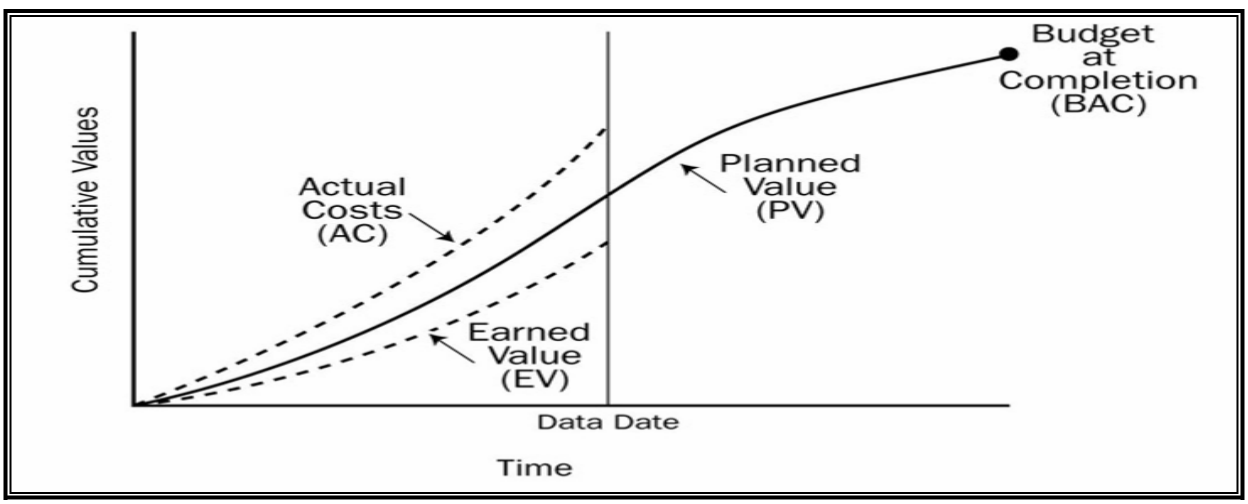


Figure 3-10: Illustrative Graphic Performance Report

4 THEMATIC LITERATURE REVIEW

4.1 Project Planning

Construction project time performance has long been identified, together with cost, quality and safety as one of the four main critical success factors in any construction project (Johansen and Wilson (2006)). The initial planning framework of a project, including contractor commitment to the overall construction timescale, is set during the preconstruction 'first planning' period. Adequate preconstruction planning is therefore recognised as essential to limit potential for later construction delays and cost overruns. However, many recent industry initiatives while recognising the need for accurate planning at the strategic level have resulted in much focus upon improving site-based construction planning (Johansen and Wilson (2006)). This, of course is after the contractor has irretrievably committed to a contractually binding construction project timescale. The production of feasible preconstruction and project master plans is essential to achieve later success during the construction phase and any failure in producing this can affect both the client's and contractor's success and negate or neutralise any successful onsite planning.

This is critically important in Ethiopia construction industry because, the Government of Ethiopia waived the use of completion time and allowed low evaluated cost award system for tender evaluation in 1993 (Wubishet (2004)). Accordingly, Section 1 presents subject to the Ministry's approval, the consultant shall estimate a reasonable time for the completion and announce the same on invitation to bid and the estimated time for completion should satisfy the interest and schedule of the client. This simply meant that time planning for bid and subsequent construction process were decided ahead of time or at the preplanning period (Wubishet (2004)).

There is an increasing need for prediction of construction time at planning and bid preparation stages for including realistic project duration in the bid package. It represents a problem of continual concern and interest to both researchers and contractors. It is also important for the studies related to estimating, scheduling, and management of construction works taught both at the graduate and undergraduate levels in the schools of construction science.

Construction planning is aimed at making effective use of space, people, materials, plant, information, access, energy, time and money in order to achieve the set project objectives and is made up of four main parts: (1) programming and scheduling; (2) method statements; (3) organisational systems; and (4) site set-up and layout (Gidado, 2004 cited by Johansen and Wilson (2006)). These four parts are interdependent both with one another and also with the environment surrounding the project, while the planning strategies proposed are 'refined' by considering the financial and physical constraints imposed with the aim being to implement reliable cost, time, quality and safety plans.

The term 'first planning' as applied in this study describes the initial construction planning which takes place during the preconstruction phase of a project. Depending upon the specific procurement methodology employed, this may take the form of informal strategic planning advice, direct negotiation or competitive bid tendering and also encompasses the development of the project master construction programme. Preconstruction planning efficiency has been identified as of crucial importance in the successful delivery of any project (Dvir et al., 2003; Gidado, 2004; Waly and Thabet, 2002 cited by Johansen and Wilson (2006)). During preconstruction, planners add value by attempting to ensure that planning is based on a robust understanding of the methods, time and space required to carry out tasks while also identifying and communicating the potential risks involved (Kelsey et al., 2001 cited by Johansen and Wilson (2006)). Their output can be highly influential in demonstrating the contractor's competence when tendering for projects not awarded purely on financial criteria (Winch and Kelsey, 2005 cited by Johansen and Wilson (2006)) and set the initial planning framework for later development. An additional concern for first planning is the quality of the planning of design work and its input into the master plan. The levels of concern over this depend, in part, on the procurement method and whether the problem is viewed from the client's or the contractor's point of view. It could be considered that the contractor is less concerned with this in traditionally tendered projects where design is meant to be substantially complete before they are involved in the project. For the contractor, plans are used for cost estimating and cash flow forecasting of the project at the tendering stage (Odeyinka and Lowe, 2001 cited by Johansen and Wilson (2006)) and if the agreed project duration is too short then time-based tender items priced in accordance with the periods shown in the programme may be undervalued and result in consequential financial loss (Laptali et al., 1997 cited by Johansen and Wilson (2006)) and/or liquidated damages arising on late completion (Farrow, 1984 cited by Johansen and Wilson (2006)).Pre – contract determination of the construction duration is essential for proper cash flow forecasting by both the contractor and the client. From the contractor's point of view, it facilitates optimal resource allocation, financial planning, profitability and efficiency of capital flow within a predetermined time limit. An enhanced certainty of the time frame also assists the client's own financial planning and contractor selection.

There is a divergence of research opinion as to the efficacy of detailed front end construction planning (first planning) and its use for strategic or tactical purposes. Johansen and Wilson (2006), considered the challenge of delivering the construction stage and the relationship between first planning and successful project delivery. They viewed the contrasting perspectives of office- and site-based staff upon the accuracy of project timescales together with their dissimilar methods of programme development and preferred first planning detail level. They concluded that there is a divergence in both literature sources and industry practices and is mainly caused by the differing approaches of those who produce first plans and those who deliver the project. Unless there is mechanism to amend this difference construction planning will resume being inefficient.

A review of the literature suggests that there are a number of issues that affect the worth and usefulness of first planning. During the preconstruction stage, planning decisions are made at the macro-level and are mainly concerned with design review, site investigation, selection of the construction sequence and procurement of the major elements required for the execution of the work. It is considered essential to create preconstruction and project master plans that are feasible as their overall reliability and achievability is deemed a prerequisite for later success during the construction phase (Miyagawa, 1997 cited by Johansen and Wilson (2006)). Ballard (2000b) cited by Johansen and Wilson (2006) termed this process 'front end' planning. However, Ballard (2000a) cited by Johansen and Wilson (2006) also suggested that the traditional way of using this front end planning in construction can be considered the ultimate source of 'schedule push' in many projects. This 'pushing' of the plan is seen as a key factor in the perceived lack of success in achieving project time certainty and time to complete.

Laufer and Tucker (1988) cited by Johansen and Wilson (2006) concluded that, while specialist planners have the time to do the work and better strategic decision-making skills, they may have incomplete practical knowledge, limited detailed information available and also lack final decision-making authority. Conversely, construction managers may have improved practical knowledge and possess decision making authority but lack the time available to plan. Laufer (1992) cited by Johansen and Wilson (2006) claims managers often see the delegation of planning authority to others as a threat to their position and treat such plans as irrelevant forecasts. Johansen (1996) cited by Johansen and Wilson (2006) agreed, finding that due to a desire for autonomy and inherent mistrust, construction managers often ignore the formal project master programme and instead adopt their own 'flexible' approach to planning on site.

Laufer and Tucker (1988) cited by Johansen and Wilson (2006) also concluded that detailed planning of activities to be carried out far into the future adds production and monitoring cost, hinders a clear overview of the project and is generally futile owing to uncertainties which cannot be quantified and they recommended that first planning be at the lowest level of detail possible. Ballard (2000b) agreed that the main purpose of 'front end' planning is to demonstrate the feasibility of the overall project duration and does not require a high level of detail, while Ballard and Howell (2003) cited by Johansen and Wilson (2006) highlight the potential waste and early obsolescence in proceeding with early detailed planning. These views contrast with Gidado (2004), who recommended that more detailed planning is required to improve preconstruction planning efficiency. Faniran et al. (1999) cited by Johansen and Wilson (2006) also investigated the relationship between construction planning effort and planning effectiveness to attempt to identify the optimum level of planning and concluded that both too little and too much planning can lead to poor project performance. Burrows et al. (2004) cited by Johansen and Wilson (2006) reported that the 2003 national key performance indicators (KPIs) demonstrated that the industry's ability to predict the time a building will take to construct is significantly worse than its ability to predict how much it may cost, with some 25% of projects experiencing increased costs over the construction period, but with nearly 40% overrunning their originally contracted timescale. In practice, the ability to estimate the completion time is often considered a matter of individual intuition, and its reliability really depends on the skill and experience of the planning engineer. Despite the use of planning and programming methodologies in the feasibility study phase, a reliable estimate of the duration of a construction project is rarely easily formulated at the outset. A specific sample survey conducted by Chan and Kumaraswamy (1995) in early 1994 in Hong Kong identified this common weakness in the construction industry. However, the results indicated that some kinds of in – house standard time norms and related guidelines were often adopted in setting time targets or in making project completion time forecasts, especially in standardized public housing in Hong Kong and buildings in the People's Republic of China.

Research by Johansen and Wilson (2006) confirmed that many contractors view their own plans as likely to be unachievable. Kelsey et al. (2001) suggested that systematic review of completed projects to improve planning are in fact rare; claiming planners tend not to refer to past job records as they are either non-existent or considered inaccurate and that those who could potentially contribute most to this process have the least motivation to expose their own errors. Johansen and Porter (2003) cited by Johansen and Wilson (2006) highlighted the need for improved subcontractor planning competence, their increased input and closer involvement in the planning process and the availability and distribution of accurate subcontract trade performance output and resource data.

Winch (2002) cited by Johansen and Wilson (2006) proposed that overall project programme methodology is often effectively formed during the tender or preconstruction period and quickly becomes enshrined within the master construction programme; therefore subsequent programmes developed to actually manage the project are constrained by decisions often made in haste during preconstruction. Ward et al. (1991) cited by Johansen and Wilson (2006) identified that clients' project duration expectations are either formed from their own past experience of similar works or based upon guidance from specialist advisers. Thus, the initial assessment of overall project duration stipulated to the contractor may be carried out by the client, an architect, an engineer or a trained planner. Various mathematical models have been produced and tested which are claimed to predict construction time to an acceptable level of accuracy using partial correlations and multiple linear regression analysis (Love et al., 2005 cited by Johansen and Wilson (2006)). One other area of interest is the use of predictive models to assist planning.

Johansen and Wilson (2006) stated that the potential use of predictive models to estimate project duration was not initially familiar to the industry professionals and indicated that the model is either in its extreme infancy (although, as the Nedo study was published some 18 years ago, this appears unlikely) or alternatively, has perhaps lacked sufficient publicity and exposure to many industry professionals to date.

Though planners seem to be polarized against the use of predictive models, contractor's project managers are receptive to the model (Johansen and Wilson (2006)). It is surprising that planners are negative to a concept which uses previous data where they are used to using previous data themselves.

Thus, having detailed first planning is not that much useful as it is difficult to produce accurate plans at a time when the uncertainties in project are not clearly identified (Johansen and Wilson (2006)). And the promotion and use of predictive models shall be encouraged.

4.2 Factors affecting Construction Duration

There is no consensus in the literature on the identification of factors which affect stipulated, planned or achieved construction time of buildings, Nkado (1995). One reason for this is that researchers have largely viewed the subject from diverse perspectives.

According to Chan and Kumaraswamy (1995) a range of significant factors influencing the duration of a construction project are postulated hierarchically as illustrated in Figure 4 - 1, which is based on the general international literature, observed common construction practice and survey results. These factors include both qualitative and quantitative contributors. The construction duration can be regarded as a function of all these hierarchical factors, that is, construction time = f (all the factors in the hierarchy of Figure 4 - 1). The factors shown in Figure 4 -1 can be reviewed into three levels namely: Primary, Secondary and Tertiary levels. Primary factors include construction cost, type of construction, location, stakeholder's priorities, productivity, type of contract and post contractual developments. Looking at for example post contractual developments at the secondary level, factors like variation, and conflicts will be noticed. Detailing the variation factor even further will result in the tertiary factors like magnitude, interference level and timing of the variation. Though they did not identify a conclusive detail, productivity and factors affecting it have been determined as key factors that can affect duration of construction projects.

Nkado (1995) stated that site productivity, which impliedly affect construction time, is affected by buildability (which is not clearly defined), management and leadership, knowledge of subcontractors work, the nature of the relationships between the general contractor, subcontractor and client’s agent and the degree of coordination in design information and the completeness of project information. Other factors include work space availability, attendance of operatives, learning curve, weather, labour relations, project complexity, foundation condition and effectiveness of supervision.

Walker (1995) stated that there are four factors that significantly affect construction time performance. These are: *Construction Management Effectiveness, Sophistication of Client and the Client’s representative in terms of creating and maintaing a positive project team relationship with the construction management and design team, Design team effectiveness in communicating with construction management and client’s representative teams, and a small number of factors describing project scope and complexity.*

Walker (1995) developed a model for predicting the causal factors affecting construction time performance. The model as shown in Figure 4 - 2 indicates that the project scope is a significant input to the determination of the predicted time of completion.

Kumaraswamy and Chan (1995) studied determinants of construction duration by using data from 111 questionnaire responses. The results indicated that the factors affecting construction durations are the same as has bee identified by the trio on Chan et al (1995).

Nkado (1995) also stated that from the system viewpoint, the construction project can be distinguished from the environment in which the project takes place. Sidwell (1982) cited by Nkado (1995) opined that the environment describes all external influences on the building process. Walker (1980) enumerated factors in the environment which can affect the construction time, cost and quality performance of a project as legal/political, institutional, cultural/sociological, technological ad economic/competitive. Huges (1989) added to the list aesthetic, financial and physical factors.

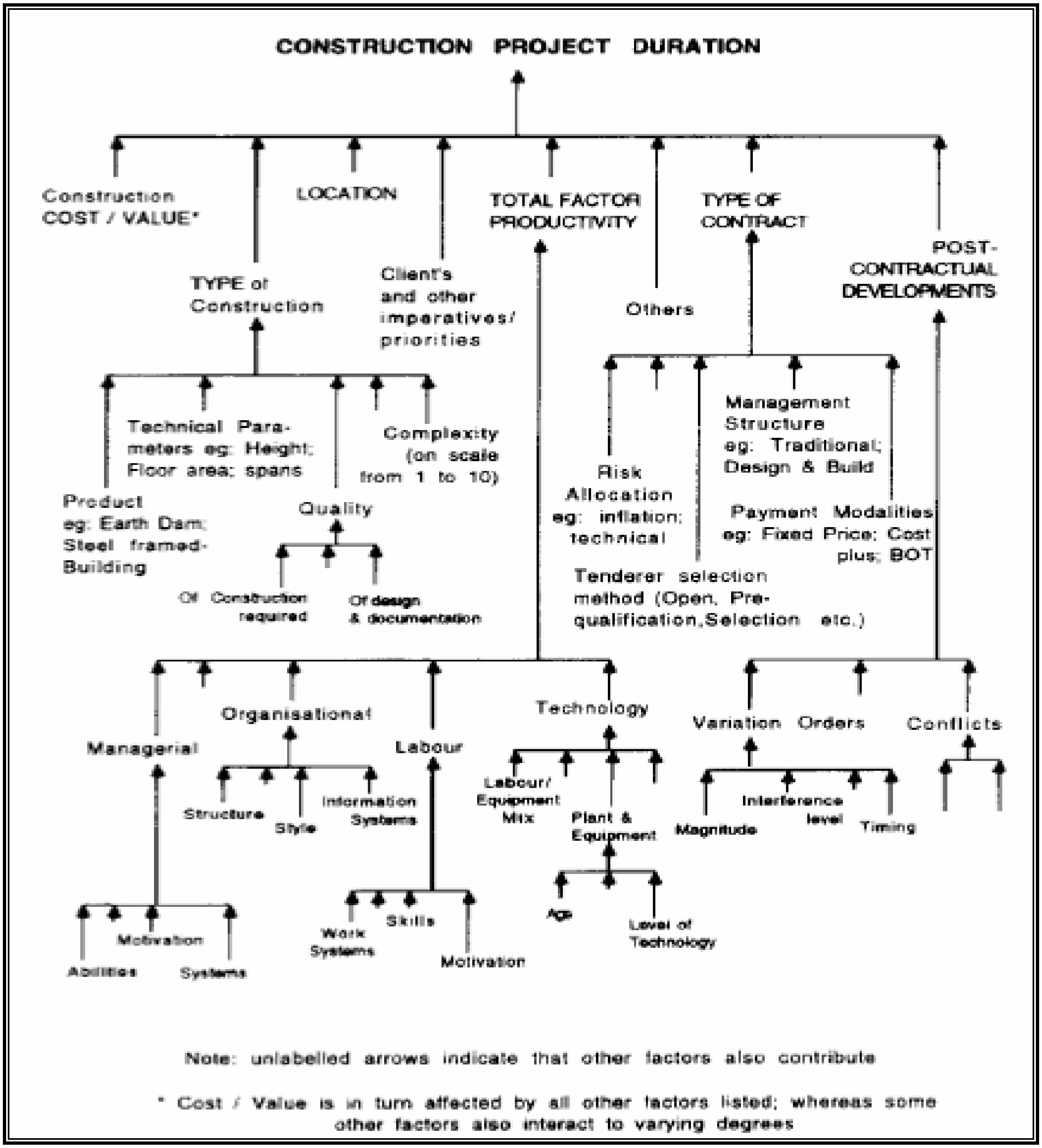


Figure 4 – 1: Some factors affecting construction project duration (Chan et al (1995)

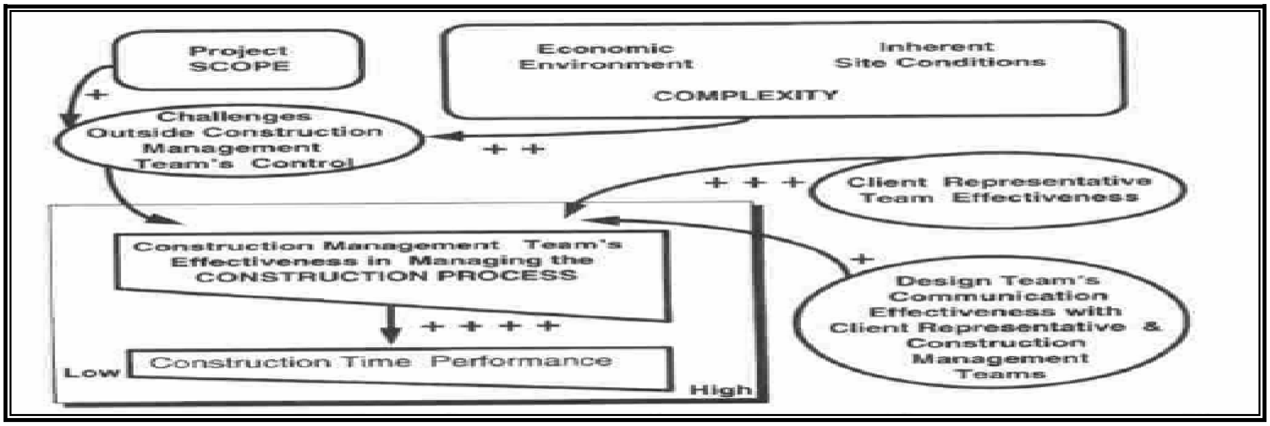


Figure 4 – 2: Influence Diagram: construction project duration (Chan et al (1995)

According to Farzard (1984) the following additional factors reflect the environment of **developing countries**, educational, natural resources, industry, religious and demographic factors (Nkado (1995)). Chan (1999) tried to develop other influencing factors of construction durations. Citing Ireland (1983), Sidwell (1982), and Nkado (1995) Chan (1999) stated that cost or project value is the most important one and the other factors affecting can be assessed explicitly.

In summary the factors affecting construction durations are Project Scope (measured by Cost or Value), Type of Construction, Location, Productivity, Type of contract, Post Contractual development, Construction Management Team Effectiveness and Environmental Factors.

4.3 Prioritizing Time - Influencing Factors

According to Nkado (1995) time influencing factors need to be prioritized if used as a basis to model construction time. Gray (1986) and Nkado (1992) cited by Nkado (1995) have demonstrated how models for predicating construction times at an early design stage mostly seek to avail the design team of the expertise of the construction planner so that the impact on time of design decisions can be evaluated quickly and guide the development of the design. Therefore, planner's perspective of important factors affecting construction time is relevant for modeling construction time. Nkado (1995) conducted a research to verify that time influencing factors can be actually prioritized for the UK construction industry. Accordingly the ten most important factors and the least important factors have been stated as shown in Table 4 – 1.

Obviously, the above factors need to be prioritized according to the research context developed in Chapter Two of this research to be realistically used for the time prediction model. The above literatures have all in common specified project scope measured by cost/value and construction team effectiveness as factors affecting project time (Nkado (1995), Chan (1999), Kumaraswamy and Chan (1995) and Walker (1995)). In addition Nkado (1995) and Walker (1995) identified type of construction or buildability as another factor. Based on the above literature review, the most important factors affecting construction durations of Ethiopian Road Projects can be summarized as follows:

1. Project Time Scope – measured by Cost/Value and Length
2. Type of Construction – Surface type
3. Construction Team Effectiveness
4. Project Environment – level of the industry, natural resources, and education.

Most important factors	***Least important factors***
1. Client's specified sequence of completion,	1. Form of contract and its suitability for the project,
2. Contractor's programming of the construction work,	2. Work of statutory undertakers,
3. Form of construction,	3. Previous working relationship with and provision for ease of communication with design team
4. Designer's team priority on construction time,	4. Weather,
5. Complexity of project,	5. Client type i.e. private or public,
6. Client's team priority on construction time,	6. Effect of regulations,
7. Project Location,	7. Possibility of variations to design.
8. Buildability of design,	
9. Availability of construction management team,	
10. Project Information (completeness ad timely).	

Table 4 – 1: Time Influencing Factors

Project Time Scope – Love et al. (2005) citing Walker (1994) considered project scope to be a measure of project size, which can be described as construction costs, project duration, gross floor area (GFA), and number of stories, building type, and procurement method. Accordingly

Cost has been found to be the most significant predictor of project time in Australian projects (Bromilow et al. 1980; Ireland 1983; Walker 1994; Yeong 1994 cited by Love et al. (2005)).

This research is limited to validate the Bromilow's time - cost relationship in the Ethiopian Road Projects, which is entirely based on project scope measured by cost. Choudhury and Rajan (2003) stated that though cost is detrimental, it will be useful to include other variables such as productivity of the workforce, impact of client decision making, management attributes, construction materials, and project environment, and analyze their effect on total construction time. Thus, this research will also include the other factors like project scope through length, surface type and type of contractor in its analysis. Future research work can be directed to test sensitivities to other factors and incorporate coefficients or weightings as appropriate.

4.4 Modeling Construction Time – Cost Relationship

Having reviewed the Ethiopian Construction Industry and mainly the Road Construction Sector in Chapter Two, the aim is to establish a time – cost relationship for the road projects enabling the stakeholders to compute the construction duration of a project based on previous data, therefore various construction time models and their application will need to be discussed.

A time cost model is useful for all parties associated with the construction industry to predict the mean time required for the delivery of a project, when the cost of the project is known. It provides an alternative and logical method for estimating construction time, both by bidders and clients, to supplement the prevailing practice of estimation predominantly on individual experience. The study will hopefully generate enough interest to do further research for deriving models for time-cost relationships of construction projects in other sectors and in construction industries in different regions. Developing time-cost relationship models for different construction industries will have a far-reaching effect on both national and international competitive bidding.

According to Kaka and Price (1991), the need for evaluation of performance of building contracts arose in the late 1960s. In 1967, the Commonwealth Scientific and Industrial Research

Organization undertook a pilot study on the performance of building contracts. This was the first step in a larger programme of research into the structure of the building industry. The results published in the Annual Report of the Division of Building Research (1968) showed that the extent of change, as measured by construction duration, cost, number and value of variations was in fact larger than had previously been supposed. A fuller investigation, using a larger number of projects, was subsequently performed. In 1969, Bromilow published the results, and the first relationship between cost and duration of building contracts appeared.

This research is partly based on the validation of this model for the Ethiopian Road Construction Projects, thus a detailed literature review is carried out and summarized as follows.

4.4.1 Bromilow's Principle

Bromilow (1974)

A relationship between completed construction cost and the time taken to complete a construction project was first mathematically established by Bromilow (1974) subsequently updated by Bromilow, et al. (1980). Bromilow (1974), from a survey of 370 Australian building projects, developed a model which predicts construction time in the form of the formula:

$$T = KC^B \qquad \text{(Eqn. 4 -1)}$$

where T is the duration of the construction period from date of site possession to practical completion, in working days, C is the final cost of building in millions of dollars, adjusted to constant labour and material prices, K is a constant describing the general level of time performance for a \$1 million project, and B is a constant describing how the time performance is affected by project size, as measured by cost.

This model indicates that one factor (scope of the project as measured by construction costs in 1972 Australian dollars) principally determines construction time. This model was a function of the cost C of the project. A total of 329 building projects with a total value exceeding 270 Million Australian dollars (A$) were analysed. These projects were conducted in Australia during the period between June 1964 and June 1967. The relationship may be summarized (Bromilow, 1974) as:

$$T = 313\, C^{0.3} \qquad \text{(Eqn. 4 - 2)}$$

Bromilow made use of mathematical models to show the relationship between cost and time, variations, and preconstruction time. These provided norms for the speed of the building process and the occurrence of variations. He also analyzed overruns on time and cost, which provided a measure of the accuracy of the industry's time and cost prediction.

Bromilow et al. (1980) re – studied the relationship between the value and duration performance of building contracts in order to determine whether the above relationship held, Kaka and Price (1991). The survey, conducted by the Australian Institute of Quantity Surveyors, was carried out on building projects completed in the period 1970 – 76. The number of projects analysed was 408, of which 290 were government projects and 118 were private ones. The results showed that the relationship between construction duration and project cost in the 1960's still holds.

Endut et al. (2006) Taking a cue from Bromilow et al., some other studies have been performed to make similar predictions for either a specific sector of construction or construction industries, in general, around the world Chan (1999). Ireland (1986) cited by Chan (1999) replicated the study to predict construction time for high-rise buildings in Australia; Kaka & Price (1991) conducted a similar survey both for buildings and road works in the United Kingdom; Kumaraswamy & Chan (1995) investigated the effect of construction cost on time with particular reference to Hong Kong building and civil engineering projects and claimed that standardization in public housing projects leads to more consistency in durations of the projects.; Chan (1999) did a similar research for Malaysian construction industry; and Choudhury et al (2002) conducted a study on health sector construction projects in Bangladesh.

Yeong (1994) cited by Chan (1999) reported similar study for Australian and Malaysian building construction projects. The study includes 67 Australian government projects, 20 Australian private projects and 51 Malaysian government projects.

Chan (1999) did a similar study for public and private projects in Hong Kong. Chan (2001) conducted a study on public sector projects in Malaysia, while Choudhury and Rajan (2003) indicate that there is a relationship between duration and cost for the residential construction projects in Texas. Ogunsemi and Jagboro (2006) cited by Endut et al. (2006) conducted similar research for Nigerian building construction projects and find out poor predictive abilities using Bromilow's time-cost model.

Almost all of these studies found that the mathematical model presented by Bromilow et al. holds good for prediction of construction time if the cost of construction is known. Details of these studies will be reviewed to look at the similarities and differences.

Ireland (1983) cited by Chan (1999)

Ireland (1983) reported similar research to predict the construction time of high-rise commercial projects in Australia. He concluded from an analysis of 25 high-rise building construction projects that the best predictor of average construction time of high-rise commercial buildings based on cost (in millions indexed to June 1979) was, with R^2 value of 0.576 and a significance level of 0.001:

$$T = 219C^{0.47} \quad \text{(Eqn. 4 - 3)}$$

Kaka and Price (1991)

Kaka and Price studied the time – cost relationship so as to use it for a corporate finical model developed at Loughborough University. 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. The analysis has been summarized in the following Table 4 – 2 based on fixed and indexed prices.

Effective groups	*B*	*K*
Public fixed	0.3178	398.80
Public index	0.2050	486.70
Private fixed	0.2120	274.40
Private index	0.0817	491.22
Civil fixed	0.4693	258.10
Civil index	0.4370	436.30

Table 4 – 2: B and K values for six project groups

Yeong (1994) cited by Chan (1999)

Yeong (1994) studied the time - cost relationship of building projects in both Australia and Malaysia. Based on 67 Australian government projects, 20 Australian private projects and 51 Malaysian government projects, Yeong' s study confirmed the Bromilow' s model at the 0.00 level of significance and that the time-cost relationships of the various projects could be represented by the following equations.

Project Type	Equation	
Australian private projects:	$T = 161C^{0.367}$	(Eqn. 4 - 4)
Australian government projects:	$T = 287C^{0.237}$	(Eqn. 4 - 5)
All Australian projects:	$T = 269C^{0.215}$	(Eqn. 4 - 6)
Malaysian (government) projects:	$T = 518C^{0.352}$	(Eqn. 4 - 7)

Chan and Kumaraswamy (1995)

Studied 111 projects, through questionnaires in Hong Kong. The project sample included public housing (16), other public buildings (21), private commercial (23), private housing (13), road works (15), and other civil works (23). The result for civil engineering projects is summarized on Table 4 – 3, where the estimated values are based on the planned contract values and the actual values are based on what was actually achieved.

	Estimated			Actual		
Type of civil works	K	B	R	K	B	R
Total civil projects	252.5	0.213	0.80	291.4	0.205	0.78
Roadworks	233.1	0.248	0.89	301.4	0.215	0.80
Other civil projects	270.6	0.190	0.71	272.3	0.211	0.77

Table 4 – 3: Time- cost performance for civil engineering projects

Chan (1999)

Chan (1999) by using the Time and Cost data of (Chan, 1996) of 110 Hong Kong building projects which were completed between the late 1980's and the early 1990's developed the following equations:

Project Type	Equation	
All building projects:	$T_{all} = 152C^{0.29}$	(Eqn. 4 - 8)
All public projects:	$T_{public} = 166C^{0.28}$	(Eqn. 4 - 9)
All private projects:	$T_{private} = 120C^{0.34}$	(Eqn. 4 - 10)

Chan concluded that statistically the time-cost relationship for all the Hong Kong building projects sampled, all public projects sampled, and all private projects sampled can be expressed in the form $T = KC^B$.

Choudhury and Rajan (2003)

After studying 55 completed residential projects in Texas, United States, they concluded that the Bromilow et al. s' model holds good for the Texas Industry. And time-cost relationship for the residential industry in Texas can be expressed using the model developed by Bromilow et al. (1980). It can be expressed in the form:

$$T = 18.96*C^{0.39} \qquad \text{(Eqn. 4 - 11)}$$

Love et al. (2005)

Using, multiple regression technique with weighted least square, examined 161 construction projects completed in Australian States. The analysis was performed between project duration (i.e., time), project type, procurement method, tender type, gross floor area (GFA), and number of stories. An alternative model to that proposed by Bromilow more than three decades ago for forecasting time and cost performance was proposed. It was shown that GFA and the number of stories in a building are key determinants of time performance in projects. Furthermore, the results indicate ***that cost is a poor predictor of time performance****. Accordingly they suggested that since we do not know cost (ex-post) before a project is completed, there is no practical use for the time–cost relationship to predict (ex ante) project time.* Yousef and Baccarini (2001) cited by Love et al. (2005) found unreliable predictions using current methods [i.e., Eqn. (4-1)], since a number of projects were completed rather differently from that estimated by client's project managers at tender award (rather than based on actual cost). Thus, Love et al. argue that it is more sensible to predict project time based on GFA and the number of floor levels, rather than cost. They suggested that project time (*T*) can be predicted using the following model:

$$\text{Log } (T) = \beta_0 + (1 + \beta_1) \log(\text{GFA}) + \beta_2 \log(\text{Floor}) \qquad \text{(Eqn. 4 - 12)}$$

Thus, generated the following forecasting model based of Eqn. (Eqn. 4 - 12):

$$\text{Log } (T) = 3.178 + 0.274 \log(\text{GFA}) + 0.142 \log(\text{Floor}) \qquad \text{(Eqn. 4 - 13)}$$

Their findings indicated that cost and time were both different at the end of the project than expected at the beginning and stated that change orders and rework are the primary reasons for such deviations. A significant amount of rework, and too some extent change orders, can be eliminated with effective design and project management (Love 2002 cited by Love et al. (2005)).

Chen and Huang (2006)

Chen and Huang studied 132 reconstruction projects of elementary and preliminary schools in Taiwan, and their analytical results demonstrate that the floor area provides a good basis for estimating the cost and duration of school reconstruction projects, and suggest that the neural network model with back-propagation learning technique is a feasible approach that yields better prediction results than the regression model for school reconstruction projects. They studied both time and cost predication models and found out that the duration prediction models present better prediction results than the cost prediction models do for all categories of reconstruction projects. The study used floor area and cost as independent variable for duration predication by selecting cubic equations (CUB) and power equation (POW) from the nine regression models investigated. The results of the study for time predication are as shown in Table 4- 4 below.

Category	Model type	Independent variable	Regression model
Central agency	CUB	Floor area	$T=131+0.018*A-1.085E-6*A^2+3.675E-11*A^3$
Local government	POW	Floor area	$T=42.280*A^{0.1966}$
Private sector	POW	Cost	$T=18.085*C^{0.1942}$

Note: *A* denotes the floor area in m^2; *C* denotes the cost in dollars; *T* denotes the duration in days.

Table 4 – 4: Regression models for duration predication

Endut et al. (2006)

Using a questionnaire survey to collect information on 359 Malaysia projects form 1994 to 2005, they concluded that there is no evidence to suggest that all the project parameters considered follow the Bromilow relationship. The constant value of K ranged between 135 to 276 days and B ranged from 0.111 to 0.455 when contract time and cost are used. However, when actual duration and cost are used the K value which ranges from 207 to 405 days and B from 0.127 to

0.396. The results show that the estimation of projects duration is far shorter than the actual time it takes to complete suggesting time overrun of Malaysia projects.

Andinet et al. (2006)

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:

$$TIME= 7.06*COST^{0.47} \quad \text{(Eqn. 4 - 14)}$$

The comparison made between the results of this study and that of the BaTCoDA study indicate a significant difference in the estimated required time to complete projects as shown in Figure 2 -8.

Note: The above reviews and values of K and C are summarized on Table 4 - 5.

4.4.2 Conclusion

The above results and studies can be summarized as follows:

- Relationship holds good for building projects and also civil engineering projects around the world.
- The model is useful for all parties associated with the construction industry to predict the mean time required for the delivery of a project, when the cost of the project is known.
- The relationship serves as a convenient, alternative, logical and useful tool for project managers and clients to predict the reasonable time required for the delivery of a construction project and will supplement the prevailing practice of estimation which is predominantly based on individual experience, as construction industry mainly utilizes experience (Dogan et al. (2006)).
- The relationship provides an alternative and objective method of estimating construction time to supplement the current practice of estimation based largely on the individual manger's experience.
- Provides an important bench mark for future studies in time performance of project.

4.4.3 Limitations of the Model

Completion of construction projects is affected by numerous factors apart from the cost. This has been seen in Section 4.2 of this research. Studies show a relationship between attitude of the workforce and management practices affecting the duration of a construction project (Ireland, 1986; Nkado, 1995). A contractor may choose different crew sizes, equipment, and construction methods to complete the activities. These decisions may ultimately effect cost of a project and, thereby, the duration of construction. Adjustments are needed to change the resource assignments to optimize the resource allocations that yield the desired duration to a minimum cost. The ability to accurately predict the client's financial commitment, which also forms the basis of the contractor's eventual revenue, has many implications on the duration of a project. For large construction projects, consisting of independent units and for situations where a number of projects are concurrently running, an indication of an overall cash commitment can be crucial.

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 road 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.

4.5 Effect of time on cost data of projects

This research relies on cost data collected for projects completed during the RSDP I & II phases. And since the time data values range from 1994 to 2007, necessary price adjustments are required to be carried out. Major Projects Team (2006), there is two distinctly different adjustment aspects: *Adjustment to reflect the way in which prices move*; and *Adjustment to reflect the way costs move*.

Estimates for construction work are produced at a specific point in time and the prices used therein are (unless other parameters are specifically set) relevant only for that date. This is because prices for items supplied and work undertaken are continually subject to market forces. These forces arise from two main directions: Inflation (and potentially and alternatively, 'deflation') and the ever-changing relationship between supply and demand for construction in the market place.

Authors	Year	Country	Type of project	Cost and time model
Bromilow	1974	Australia	Building project (370)	$T=313C^{0.3}$
Ireland	1985	Australia	High rise building project (25)	$T=219C^{0.47}$
Kaka and Price	1991	United Kingdom	Public building (Fixed price contracts) Private building (Adjusted price contracts) Private buildings Civil Engineering(Tendered) Civil Engineering (Actual) Public building -Open competition -Selected -Negotiated	$T=398.8C^{0.318}$ $T=486.7C^{0.205}$ $T=274C^{0.212}$ $T=258.1C^{0.469}$ $T=245.0C^{0.432}$ $T=407.4C^{0.293}$ $T=424.1C^{0.342}$ $T=367.5C^{0.272}$
Yeong	1994	Australia and Malaysia	All projects Public projects (67) Public projects (20) Public projects (51)	$T=269C^{0.215}$ $T=287C^{0.237}$ $T=161C^{0.367}$ $T=518C^{0.352}$
Kumaraswamy and Chan	1995	Hong Kong	Total public building projects Public housing projects Public building projects Total private building projects Private commercial projects Private housing projects Civil projects	$T=182.3C^{0.277}$ $T=188.8C^{0.262}$ $T=166.4C^{0.294}$ $T=202.6C^{0.233}$ $T=232.7C^{0.187}$ $T=160.2C^{0.306}$ $T=252.5C^{0.213}$
Chan	1999	Hong Kong	Building projects(110) Public projects Private projects	$T= 152C^{0.29}$ $T= 166C^{0.28}$ $T= 120C^{0.34}$
Chan	2001	Malaysia	Building projects	$T=269C^{0.32}$
Ng et al.	2001	Australia	Overall building projects Public building projects Private building projects	$T=131C^{0.31}$ $T=129C^{0.32}$ $T=132C^{0.30}$
Choudhury and Rajan	2003	Texas, US	Residential projects	$T=18.98C^{0.39}$
Ogunsemi and Jagboro	2006	Nigeria	Building projects	$T=63C^{0.262}$

Table 4 - 5: Summary of Duration and Cost Relationships, Endut et al (2006)

Major Projects Team (2006), the driver for price increases in respect of both of the above is primarily related to supply capacity relative to demand. In the case of inflation, the effect is at a macro level, generally affecting the whole economy. In an economist's term, inflation is often described as 'too much money chasing too few goods' – demand itself being ineffectual unless the capacity to purchase is also present. In the case of basic supply and demand, this can have a significant affect on construction prices in various ways:

- on specific materials (a good example in this respect is the price of steel: which were being driven up by strong demand from China relative to world capacity)
- on specific components (lifts and escalators are a good example of where because of long lead-in periods supply is unable to flex easily to meet sudden peaking in demand and this can impact on prices)
- on trades (whilst prices can be affected by national wage agreements availability of skilled craftsmen in particular localities where there is a period of high construction activity can impact on prices)
- on tender prices (this can also be localised and or regionalised and may vary according to the type of construction work)

Major Projects Team (2006), thus estimates and previous costs at completion times need to be properly adjusted in order to provide meaningful figures. The adjustments are usually carried out to cover for effect of inflation and change in tender price index. The adjustment for inflation can be carried out by taking the average inflation rate which is usually based on the change of the consumer price index. According to the practice in UK, the adjustment for change in tender price index is carried out by adjusting the prices by the tender price index developed and index in each year. However this has not be practiced in Ethiopia as the tender price index is not developed by the Central Statistical Authority of the country.

4.5.1 Adjustment for Inflation

Considerations shall be taken for effects of inflation on cost comparisons (Congressional Research Service (2003)). In Ethiopian Economy where the market is not fully indexed for inflation, the effect of inflation shall be carefully considered. The inflation rate of Ethiopia is assumed to be high (Index of Economic Freedom, Ethiopia, (2007)).

Hazlitt (1965) No subject is so much discussed or so little understood as *inflation*. The definition of Inflation can be traced as follows: According to the American College Dictionary, the first definition of inflation is given as follows: "Undue *expansion* or increase of the *currency* of a country, esp. by the issuing of paper money not redeemable in specie."

In recent years, however, the term has come to be used in a radically different sense. Hazlitt 1965, this is recognized in the second definition given by the American College Dictionary: "A substantial rise of prices caused by an undue expansion in paper money or bank credit." Now obviously a rise of prices caused by an expansion of the money supply is not the same thing as the expansion of the money supply itself. A cause or condition is clearly not identical with one of its consequences. The use of the word "inflation" with these two quite different meanings leads to endless confusion. Hazlitt (1965) strongly argues that the true cause of inflation is inflated money at the hand of the consumer or the increase in debt by the government not by the increase in price. He suggested that the solution for inflation can not be price fixing as inflation is not caused by increase in price.

Major Projects Team (2006), the rise in the general level of prices, the essence of inflation, is measured by using a price index. Ideally, the price index used should be broad based and one in which the individual prices are weighted to indicate their importance to the economy. Three separate price indexes can be used. The first two are very broad based and derived from the measurement of the Nation’s gross domestic product (GDP). They differ in the quantities that are used to weight the prices. The first uses side-by-side year quantities (that move every year) and is called, the *chain weight deflator*. The second uses current year quantity weights and is called the *implicit price deflator*. The third index is the *Consumer Price Index (CPI)*, which prices a “market basket” of goods and services purchased by an urban family, a market basket whose individual items are weighted by how much the urban family spent on them in a base year period currently 1994 -2007.

The inflation data for Ethiopia, shown in Table 4 – 6 below, has been obtained from IMF's International Financial Statistics CD-ROM (International Monetary Fund (2006)) but since the data for the latest two years were not on IFS, the inflation data for the last two years was taken from the African Economic Outlook (2008) (forthcoming) Master data file, and interpolated through linear regression the figures for CPI. There is no reason to believe that the data generated by the process is faulty.

Year	*CPI %*		*Year*	*CPI %*
1994	7.59		2001	-8.24
1995	10.02		2002	1.65
1996	-5.07		2003	17.76
1997	2.40		2004	3.26
1998	2.58		2005	11.61
1999	7.94		2006	10.10
2000	0.66		2007	17.80

Table 4 – 6: Ethiopian Inflation Data

(Source: International Monetary Fund (2006) & African Economic Outlook (2008))

Accordingly the research cost data collected for both the international and domestic contract and final amounts have been adjusted to January, 2008.

4.5.2 Adjustment for Tender Price Index

One method that can be used to change prices from later date to current date is to use the Tender Price Index (TPI) and multiply the cost by the yearly or quarterly factors (Major Projects, 2006). TPI is prepared for the specific projects based on historic cost data that is updated by a forecasted Tender Price Index (TPI) (Thomas et al (2006) citing Tysoe, 1981; Smith, 1995). The reliability of the forecast or change in cost based on TPI depending significantly on accurate projections being obtained of the TPI for the forthcoming quarters– the degree of accuracy of the projections being determined by their use and form, time horizon and data availability ((Fitzgerald and Akintoye, 1995, O'Donovan, 1983; Bowerman and O'Connell, 1987 cited by Thomas et al (2006)).

BCIS (2003), in simplified terms, the project TPI is calculated by dividing the bill of quantities into trades or work packages (excavation, in-situ concrete, reinforcement, brickwork, blocks work, etc). Each project has had a tender price index (TPI) calculated which is an objective measure of the pricing level of that scheme. In simplified terms, the project TPI is calculated by dividing the bill of quantities into trades or work packages (excavation, insitu concrete, reinforcement, brickwork, blocks work, etc). Each trade is examined separately and the largest item by value selected. An attempt is made to re-price this item using a standard schedule of rates. The second largest item is then selected and the process repeated until at least 25% of the trade by value has been matched. This is repeated for all trades and the trade results allow an estimate of the value of the project as priced at the base schedule to be calculated. This is compared with the actual price of the contract to give an objective measure of the pricing level of the project which is independent of the quantity and specification of the building work in the project. The project index produced will reflect tender price inflation, regional differences, differences in pricing level resulting from size of the contract, site problems (other than those which have design implications) and any other factor which has influenced the price quoted by the accepted tenderer. One of the most comprehensive TPI found is the one produced by Building Cost Information Service (BCIS) of U.K, which has been prepared as of 1985 (BCIS (2003)).

Many researches on the same area have used this index for considering the effect of price fluctuations on the analysis of the cost (Endut et al (2006), and Kumaraswamy (1995)). The tender price index for many countries has kept on increasing (RLB (2006) & BCIS (2006)). In UK case the price increase has exceeded the prevailing inflation rate by many times, BCIS (2006), stating that 'Tender prices are expected to rise by more than two-and-a-half times the rate of inflation over the next five years, rising by 33% against a background of 12% general inflation.'

It is often difficult to produce tender price indexes for projects and entails a highly subjective prediction of future market conditions and inflation (Akintoye, 1991; Akintoye and Fitzgerald, 2000 cited by Thomas et al (2006)). Thus this research has not used the tender price indexes due to the fact that they are developed for highly integrated and industrialized countries which are not the case for the context of the projects under analysis.

4.6 S – Curve and Earned Value– Thematic Literature Review

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.

4.6.1 Project Monitoring & Control

The road construction industry is often judged by analysts to be relatively inefficient compared to performance seen in the manufacturing industry (Daneshmand and Khreich (2006)). It is highly unlikely to proceed in all respects entirely according to plan. Small deviations between plan and actual performance may locate within the limits of uncertainty of the model, but significant variations however may require a revision of the plan to meet the project's objectives. A key obstacle to improved performance in construction industry, and hence improved productivity and client satisfaction, is current accurate performance information availability (Daneshmand and Khreich (2006)).

An ideal control system sets the baseline and performance indicators, measures the project performances and compares them with the expected plan. Integrated project performance includes the four main elements of a construction project: cost, schedule, quality, and safety

(Oberlander 1993 cited by (Daneshmand and Khreich (2006)). Typically, two parameters, which are widely used for performance assessment, are *Time* and *Cost*. A time-phase spend plan is usually prepared and updated by the project planning manager monthly. On the other hand, finance department calculates cost figures and actual costs. However, what is missing from most of these models is any understanding of how much work has been accomplished during the project and how this progress is reported.

4.6.2 Progress Measurement in Construction Projects

Several different progress measurement methods are developed and used in construction projects. Definitions and classifications may vary slightly. Thomas and Mathews (1986) identified the three major types of measurement methods categorized as: Estimated percent complete method, Earned value method, and Physical measurement method. As listed in Table 4 - 7, each method has strengths and weaknesses. Among these three measurement methods, the earned value method may utilize various techniques for different type of work packages. Fleming and Koppleman (1996) specify seven techniques including percent complete estimate, weighted milestones, fixed formula by task, percent complete and milestone gates, earned standards, apportioned relationships to discrete work, and level of effort. Note that Fleming and Koppleman categorize “percent complete estimate” as one of the earned value techniques whereas Thomas and Mathews (1986) separate it, as described in Table 4 - 7.

Nassar et al, 2005 Construction projects are seldom “on-schedule” all the time. The amount of work performed on the project usually fluctuates from one period to the other. In fact, according to the “80/20” rule (suggested by the 18th Century economist, Pareto) 80% of the effort will be expended during 20% of the project duration. This creates a significant problem in trying to monitor the actual performance of the project schedule and specifically trying to decide whether or not the project can finish on time (i.e., the reliability of the project schedule performance). The earned value method (EVM) is often used as a project control technique to provide a quantitative measure of schedule performance. In the EVM, the schedule and cost performance indices (C/SPI) are used for constant monitoring of the project’s cost and schedule based on an original critical path method (CPM) schedule (Chang , 2001). Unfortunately, CPM scheduling in general creates an unrealistic expectation regarding project schedule performance. Starting a project one day and expecting that the project will finish on an exact date some two or three years in the future is unrealistic. Therefore, there is a need to extend schedule analysis techniques, like the EVM, to provide means for probabilistically analyzing the schedule performance and measuring the risks involved.

Method	Techniques[a]	Advantages[b]	Disadvantages[b]
Estimated percent complete	• Percent complete estimate • Percent complete and milestone gates	Simple Relatively small effort required Suitable for straightforward items	Relying exclusively upon an individual's ability
Earned value	• Weighted milestones • Fixed formula by task • Earned standards • Apportioned relationships to discrete work • Level of effort	Greater detail and objectivity than the "estimated percent complete" method	Not detailed as the "physical measurement method"
Physical measurement		The most detailed and reliable Relatively objective Easy to audit	Lack of timely information High cost of data collection

[a]The techniques are defined by Fleming and Koppleman (1996) and regrouped here by the writers.
[b]The advantages and disadvantages discussed by Thomas and Mathews (1986)

Table 4 – 8: Progress Measurement Methods

(Adapted from Thomas and Mathews 1986; by Fleming and Koppleman 1996)

Jung and Kang, 2007, by definition, "progress" refers to the "advance toward a specific end." The degree of "advance" for a construction project can be determined in many different ways. In their study for measuring construction productivity, Thomas and Mathews (1986) cited by Jung and Kang (2007), assert that the "progress in terms of work unit completed" and "the associated cost in terms of man-hours or dollars" are typically tracked in order to measure productivity. For the purpose of construction payment, progress can be explained as the "percentages of direct cost incurred plus a portion of overhead and profit" (Stokes, 1978). From the viewpoints of cost engineers or scheduling engineers, somewhat different considerations for progress may also be inferred. Nevertheless, the most commonly perceived concept of progress implies the "work completed" and the "associated cost." Therefore, progress in this study is defined as the "actual work completed in terms of budgeted cost." This definition is identical to the meaning of "earned value, EV," or budgeted cost for work performed (BCWP) in EVM.

4.6.3 Earned Value Management – Thematic Literature Review

The term ``earned value'' (EV) has been in use since the 1960s when the Department of Defence adopted it as a standard method of measuring project performance. Its detractors often cite the cost and effort involved in making it work as being too great for the benefits reaped and the limited benefit derived from its implementation. The proponents, conversely, will cite the significant cost savings to the project overall, the improved analysis, communication and control derived from its implementation. The truth, as ever, lies somewhere in between and depends on the way in which it is applied (Raby (2000)). Christensen, 1999 However, earned value and the related cost management reports can be used without the criteria on projects of any size. On large government projects, where the risk of cost growth is often carried by the government, the planning and control discipline fostered by the criteria is essential. On other kinds of projects, a full-scale application of the criteria is not necessary (Fleming and Koppelman (1996) cited by Christensen (1999)).

4.6.3.1 EVM Background

According to Daneshmand and Khreich (2006), the genesis of EVPM was in industrial manufacturing at the turn of the 20th century, but the idea took root in the US Department of Defense (DoD) in the 1960’s. In 1967, the DoD established a criteria-based approach, using a set of 35 criterions called Cost/Schedule Control Systems Criteria (C/SCSC). At best, C/SCSC was generally considered a financial control tool that could be delegated to analytical specialists. In the early 1990’s, EVM emerged as a project management methodology. An overview of EVM was included in first PMBOK Guide in 1987 and expanded in subsequent editions. Recently, efforts to simplify and generalize EVM have gained momentum. PMI 2000 included EVM methods briefly under the cost control and performance topics. PMI 2004 provided detail coverage of the method under the cost control. In addition to that PMI has published a practice guide for EVM method in 2005, PMI – EVM (2005). This research has used this practice guide published by PMI (PMI – EVM (2005)) for the development and application of EVM methods. Else where, Efforts are also being taken by project management associations to develop a simplified and generalized EVM methods, accordingly the Australians have developed a standard, AS 4817-2006, to be used for Earned Value Performance Measurement (EVPM) -014, Daneshmand and Khreich (2006).

Jung and Kang, 2007 Benefits from integrating cost and schedule control through EVM have been asserted by numerous researchers and practitioners since this idea was first promoted in the 1960s. The basic concept utilizes the focal point for the integration of scope, cost, and scheduling (Rasdorf and Abudayyeh 1991; Fleming and Koppleman 1996). According to a document of the American National Standard Institute (ANSI) for EVM, a “control account” (CA) as the focal point acts for “a management control point at which budgets and actual costs are accumulated and compared to earned value for management control purposes” (EIA 1998 cited by Jung and Kang, 2007). The progress (earned value, or BCWP) is used as a baseline to which the planned schedule (budgeted cost for work scheduled, BCWS) and the actual cost (actual cost of work performed, ACWP) are compared in order to measure the schedule performance and cost performance, respectively. The results of performance variances and indices are used for further analysis, including estimating cost at completion, identifying latent risks, and re-planning for remaining work packages.

A study by Liberatore et al (2001) indicated that construction managers who are members of Project Management Institute of US (PMI), the largest professional organization of PM professionals in the world with over 43,000 members, heavily use earned value analysis for projects.

4.6.3.2 EVM Process

The following process has been developed for application of EVM methods by referring to Daneshmand and Khreich (2006) and Raby (2000):

Step 1: Decompose the project by Work Breakdown Structure (WBS)

The key for an effective EVPM system is the Work Breakdown Structure (WBS). WBS breaks the project down into manageable discrete elements of work and may be expressed in an organization chart format. The WBS needs to be defined down to at least the level at which EVM reporting will be applied. Making decisions about this level is critical. Too low will create an overload of data and too high could lead to the masking of some vital information. According to the literature, most construction projects will find 3-4 levels within a WBS will adequately meet their data requirements for running a reliable EVM system. However for more complex projects and systems, breaking down to level five or six has been recommended Howes (2000) cited by Daneshmand and Khreich (2006).

Step 2: Assign Responsibility

Once the WBS has been developed into manageable elements, responsibility is assigned for the performance of the work elements. An Organization Breakdown Structure (OBS) may be used to identify the project hierarchy responsible for work accomplishment. A Responsibility Assignment Matrix (RAM) may be used to map WBS elements to the OBS elements.

Step 3: Planning/Scheduling

All elements of the work are scheduled into a logical sequence, which identifies durations, activities, milestones and interdependencies. For construction projects, activity durations in the performance measurement programme will usually be in the 2-4 weeks range, but with exceptions. Activities and milestones will be linked with dependencies to produce a network schedule such that the critical paths can be determined and the float can be determined for every activity and milestone. Grouping the activities with start and finish milestones helps creating the closed network.

Step 4: Develop time – phased budget

The next step will be allocating the cost required to accomplish the tasks. The activities shall have costs as they will consume the valuable commodity of the project, TIME!

Step 5: Objective measures of performance

Objective measures of performance largely depended on activity content, size and duration. There is no definitive set of techniques, but a widely used method is the technique termed ‘milestone’ where EV is only claimed when the milestone is completed. Another technique termed ‘percent complete’ is used to claim partial completion when the objective measurement of the percentage completion of an activity is possible. This research has used the percent complete for measuring performance.

Step 6: Set the performance baseline (PMB) or S – Curve

This step involves in tabulating and plotting the results of the time phased budget of the projects. 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)).

Step 7: Monitor, Report and Take Action

An accurate scoped, estimated schedule is essential for good project performance measurement. As the project progresses, assessment of progress and data collection for actual information in regular bases shall be carried out. Then EVM uses this information to calculate various performance indicators such as Percent Complete Planned (PCP), Percent Complete Achieved (PCA), Schedule Performance Indicator (SPI), Cost Performance Indicator (CPI), Schedule Variance (SV) and Cost Variance (CV). One sample of EVM report can be seen at Figure 4 - 3.

According to the programme report, the appropriate action shall be taken when there are variances and a new baseline shall be created when the process is well documented and traceable Daneshmand and Khreich (2006). A very typical mistake in project rescheduling is the assumption that the project will catch up in the later phase and finish on the remaining period; this is practically never the case (Ferle (2007)).

4.6.3.3 Project Variances, Indices and Forecasts using EVM

Daneshmand and Khreich (2006), Chang (2001) and Nassar (2005) stated that EVM provides forecasts in terms of schedule and cost. And that based on the Planned Value (PV), Earned Value (EV) and Actual Cost (AC), variances, indices and then forecasts can be developed. The formulas used in all the above literatures are identical to the practice Standard of EVM, PMI – EVM (2005). EVM performance analysis and forecasting includes:

- **Variances:** Schedule Variance (SV); Cost Variance (CV); and Variance at Completion (VAC)
- **Indices:** Schedule Performance Index (SPI); Cost Performance Index (CPI); and To-Complete Performance Index (TCPI)

- **Forecasts:** Time Estimate at Completion (EAC_t); Estimate at Completion (EAC); and Estimate to Complete (ETC). Figure 3 - 17 & 19 shows the relationships among the basic EVM performance measures.

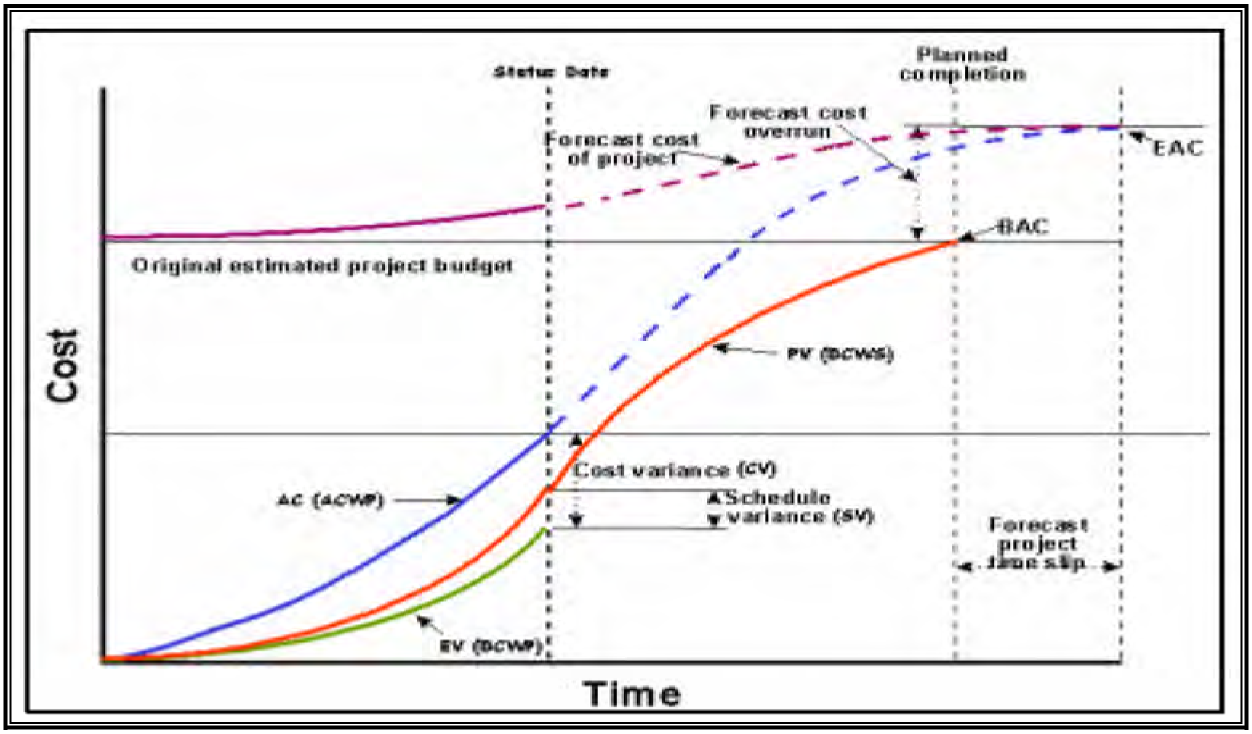


Figure 4 – 3: EVM Presentation

4.6.3.4 Project Indices

Learning the specialized language and concepts of performance measurement is a significant challenge. Remembering the meanings of PMB (S – Curve), BAC, PV(BCWS), EV(BCWP), AC(ACWP), SV, CV, SPI, CPI, EAC and a host of other acronyms, can be quite challenging by itself. When this unique jargon is combined with the task of learning concepts such as earned value and baseline maintenance, it is little wonder why many struggle to get out of performance measurement as soon as possible, and define C/SCPI (Christensen (1989)).

Cost/schedule performance indices (C/SPIs) are one application of the earned value (EV) method to measure project performance (Construction Industry Institute (CII) 1988 cited by Chang (2001)). According to Chang (2001), although the concept of the EVM method and C/SPIs is well established, they are underused (Fleming and Koppleman, 1994). Applications were mostly performed at a summary level, and little have been implemented throughout the engineering/design phase (Eldin 1988 cited by Chang (2001)). Since C/SPIs are not yet well used to measure performance, fewer studies are done with their values to distinguish performance levels. Eight C/SPIs were developed to support qualitative measures in evaluating design performance (Chang and Ibbs 1998) as shown in Figure 4 -4.

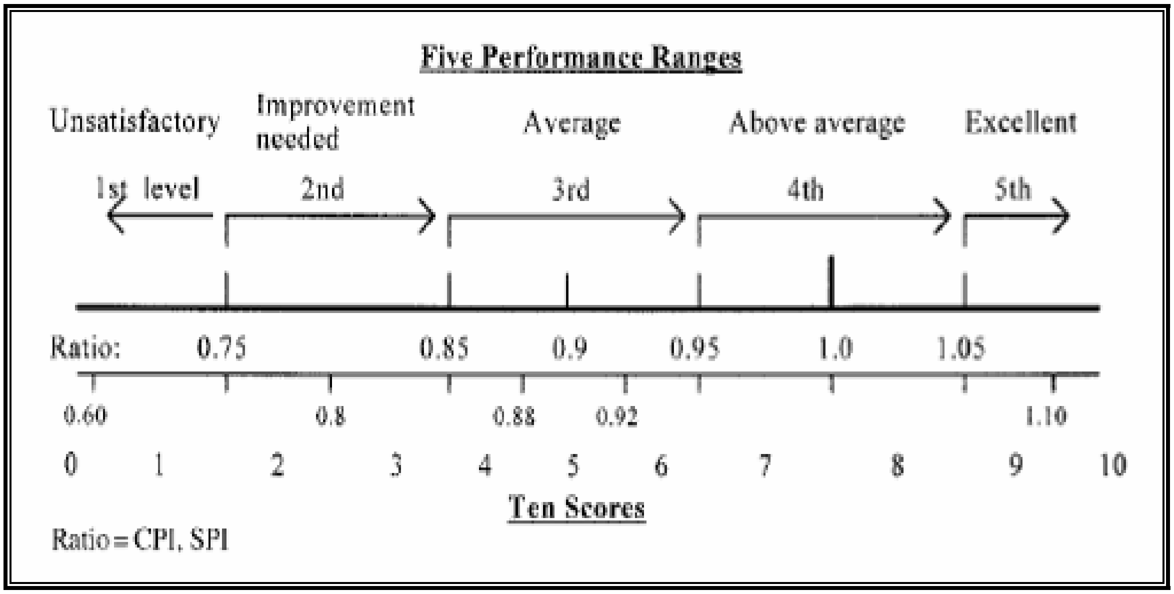


Figure 4 – 4: Ranges and Scores for C/SPI. Source: (Chang and Ibbs 1998)

Chang (2001) also tried to develop the Cost/schedule performance indices for design projects carried out at the California Department of Transportation. Defined C/SPI rations can further examine and organize variances and are actually better measurement tools (Sink (1985) cited by Chang (2001)).

Christensen and Payne (1992) A stable CPI is evidence that the contractor's management control systems, particularly the planning, budgeting, and accounting systems, are functioning properly. A stable CPI may thus indicate that the contractor's estimated final costs of the authorized work, termed "Estimated at Completion," are reliable. In addition, knowing that the CPI is stable may help the analyst evaluate the capability of a contractor to recover from a cost overrun by comparing the CPI with other key indicators, such as the To-Complete Performance Index. Christensen and Payne (1992) questioned the assumption that CPI will not vary by more than

10% after the project is 50% or more completed and found out that it was stable from the 50% completion point.

An interesting research carried out by Nassar (2005) used the C/SPI for two different projects and fitted a probability distribution function and developed the performance graph which indicates the performance probability based on Schedule Index values as shown in Figure 4 – 5 below. The fact that the distribution function is resulting in an S – Curve indicates that the projects activities are performed according to the normal distribution of activity durations.

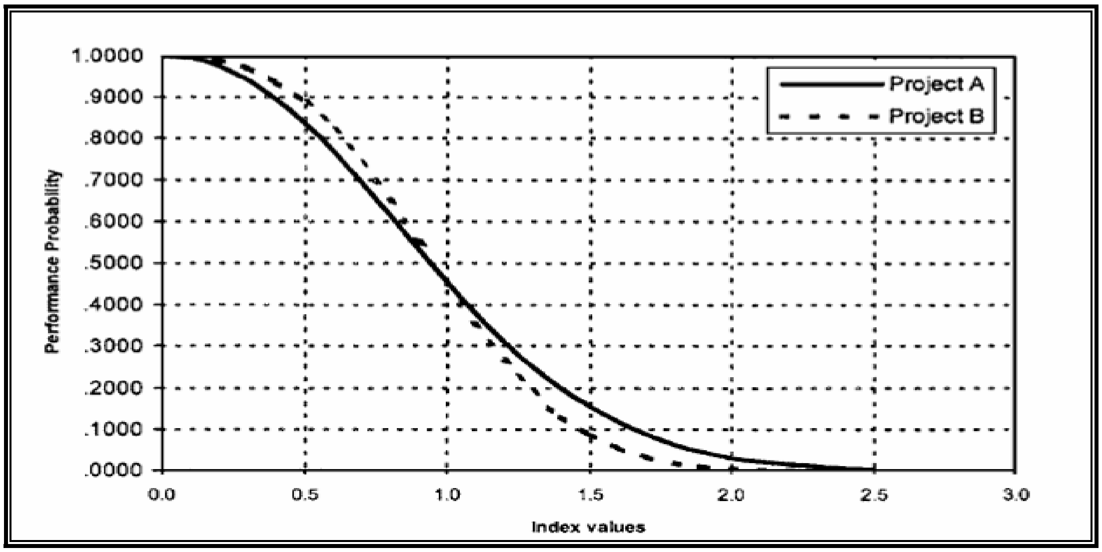


Figure 4 -5: Performance Graph based on SPI. Source: Nassar (2005)

4.6.3.5 Project Forecasts

When controlling project performance, it is important to not only monitor cost and time variances for actual project progress, but also to properly establish the actual project status based on objective predictions (forecasts) of final project performance. At completion project performance can be predicted by comparing estimates of planned total budget and final duration with their respective most likely forecasted values (Ahuja et al. 1994 cited by Barraza et al. (2004)). Gowan et al (2006) Earned value provides an early warning for projects that need a corrective action. It can be said that EVM can forecast final results as early as the 15 percent completion point. Such forecasts are necessary for the project manager to determine if corrective actions are required to minimize the expected variances from planned performance. The forecasts using EVM include the Time Estimate at Completion (EACt) and Estimate at Completion. This research focuses on using Time Estimate at Completion as the available data will not enable the analysis of the estimate at completion (EAC). The estimate at completion (EAC) is a useful forecast as it indicates where the project cost is heading (Daneshmand and Khreich (2006) and Raby (2000)). Calculating the EAC is one of the significant benefits of using EVM approach to a project (Raby (2000)). The actual formula to use for this calculation is a matter of some discussion as presented below.

4.6.3.6 Earned Value Management Challenges

If the calculation of ETC is based on past performance, in some instances the EVM may not be correct because future work may be entirely different and unrelated to that already completed. SV relates purely to cost performance only and no account is taken of time as it relates to the completion of project activities in their logical sequence (Howes et al. 1993 cited by Daneshmand and Khreich (2006). In its basic mode, EVM does not account for variations to the project in the form of additions and/or omissions. The budget and forecast information shall be taken into consideration to ensure a meaningful measurement approach is in place. Daneshmand and Khreich (2006) stated that this powerful tool for project performance measurement has no provision to measure project quality and client satisfaction and other management tools should be used in conjunction.

Data on the basic EVM parts i.e. PV, EV and most importantly AC shall be provided for proper analysis of the method. Christensen (1990) stated that the responsible analyst should be involved in the entire decision process and have the necessary data. The analyst's shall deliver the required by effectively transforming the EVM data into information and be wary of the many associated assumptions and pitfalls of the techniques.

4.6.4 S – Curve – Thematic Literature Review

The researcher 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 analysed 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 standardise 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. These problems has helped shape the nature of this research to test similar projects for the second hypothesis by selecting two projects, Project A and Project B which are both an Asphalt Concrete surface projects.

5 METHODOLOGICAL FRAMEWORK

The Research Methodology

Research methodology is a way to systematically solve the research problem and research methodology shall identify the research basis, research hypothesis or questions, research design and research analysis (Kothari (2004)). Accordingly the following chapter covers the methodological framework of this research.

5.1 Introduction

5.1.1 Research Definition

Kumar (1999) citing Kerlinger (1986:10) stated that scientific research is a systematic, controlled empirical and critical investigation of propositions about the presumed relationships about various phenomena. Kumar (1999) defines research as a process, that is undertaken within a frame work of set of philosophies, uses procedures, methods and techniques that have been tested for their validity and reliability; and designed to be unbiased and objective.

5.1.2 Type of Research

There are many different types of research. According to Nick (2000), academic research is primarily concerned with developing a theoretical explanation or understanding of an issue. He stated that the academic research is carried out at undergraduate, masters' and doctorate levels. Accordingly at masters' level the requirement is not really to produce definitive answers, rather it is to demonstrate that the candidate can handle research methods, and data, satisfactorily. In addition for PhD researches need to critically frame the research question or hypothesis in such a way that it can be tested through empirical research. This study aims to show both capabilities by using a well framed research hypothesis and well analysed data.

Kumar (1999) classifies research based on three perspectives (Figure 5 – 1):

1. The *application* of the research study;

2. The *objectives* in undertaking the research; and
3. The *type of information* sought.

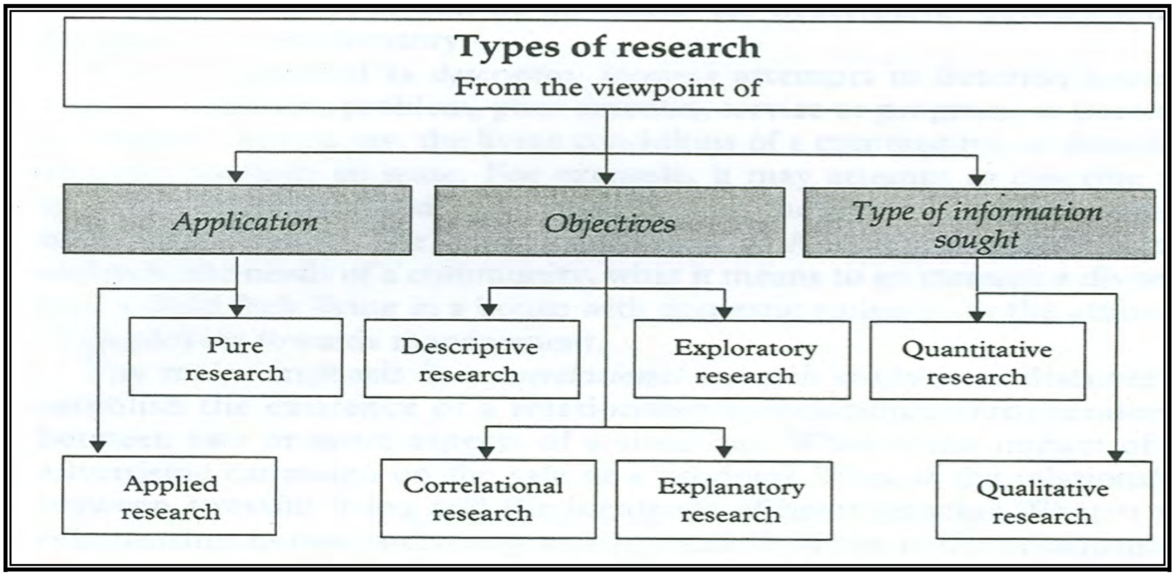


Figure 5 – 1: Types of Research (Kumar (1999))

This research has adopted the above classification and is thus applied, descriptive & correlational and quantitative research. It is *applied* as the information gathered can be used in policy formulation (setting contract duration), administration (performance management) and enhancement of understanding of the phenomenon. It is *descriptive* as it tries describing the relationship by systematically viewing the problem and undoubtedly seeks for the *correlation* among construction time and cost for road construction projects in Ethiopia. It is *quantitative* as it tries to quantify the relationship and develop parameters for future use. And as it is a masters' thesis it is academic in nature. It should be noted however that a mixed approach of quantitative and qualitative is possible (Nick (2000) and Kumar (1999)).

5.1.3 Research Process

Most social research involves collecting data about the subject, processing the data, analyzing and interpreting it to arrive at the conclusions (Nick, 2000). The research process is therefore concerned with collecting data and processing it into information. People can use the information thus created to add to their knowledge, perhaps even developing wisdom.

This research agrees with the research process developed by Kumar (1999) based on the model by Festinger and Katz (1966: vi). Thus this research process has eight steps as shown in Figure 5 – 2.

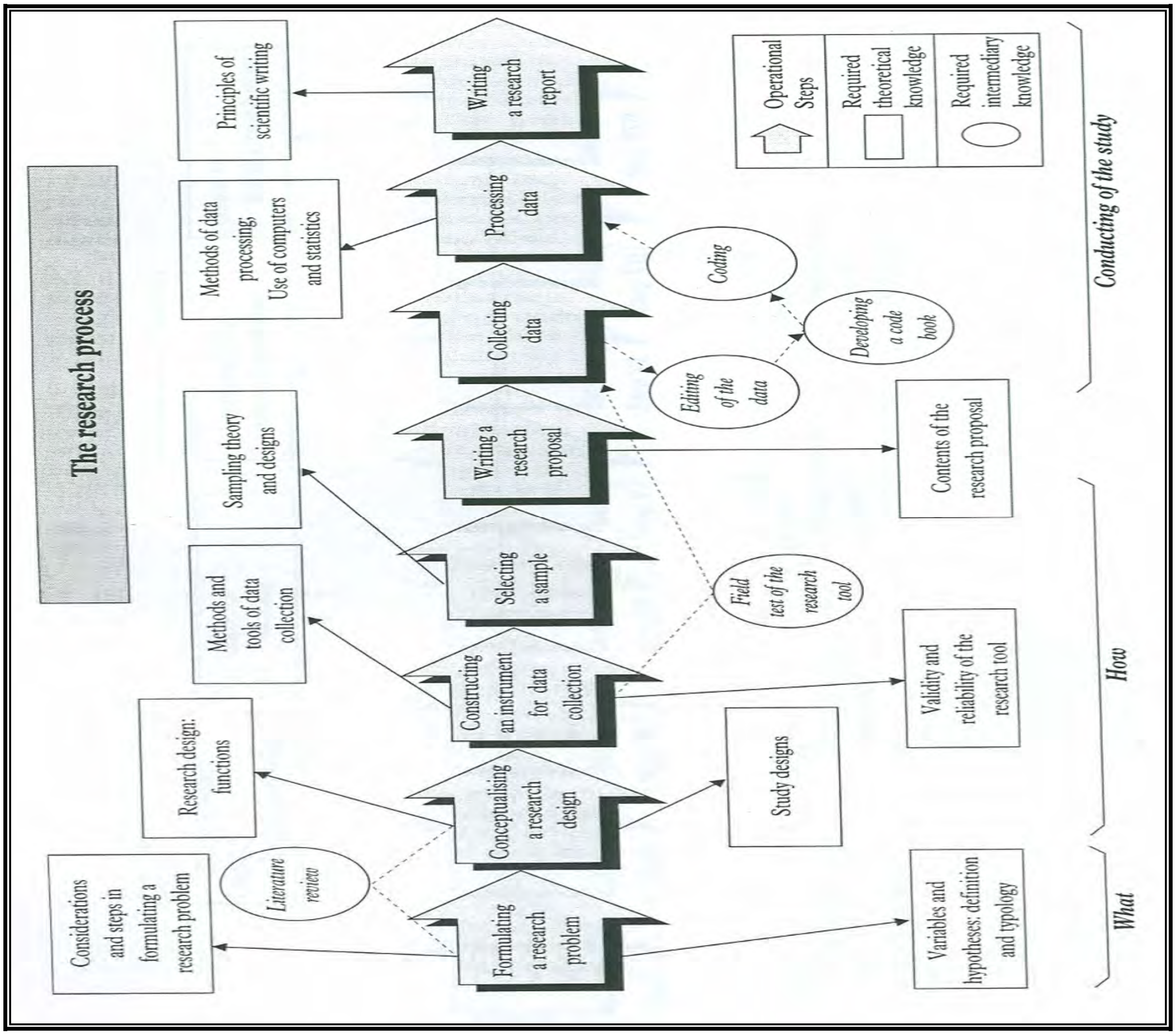


Figure 5 – 2: Research Process (Kumar (1999))

5.2 Research Hypothesis

According to Powers (1985:38) cited by Kumar (1999) 'Potential research questions may occur on a regular basis, but the process of formulating them in a meaningful way is not at all an easy task'. Creswell (2003) stated that in quantitative research the hypothesis and research questions are often based on theories that the researcher seeks to test. Theory for this study is based on the definition of theory by Kerlinger (1979) cited by Creswell (2003) ' a set of interrelated constructs (variables), definitions, and proportions that presents a systematic view of phenomena by specifying relations among variables, with the purpose of explaining natural phenomena'. And Creswell (2003), states that theories develop when researches test a prediction many times.

Thus based on the above definition and as shown in the conceptual frame work of this study the two main theories *Bromilow's Principle* and the *S – Curve* have fairy developed as a theory (Andinet (2006), PMI (2000), PMI (2004), Practice Standard for EVM (2005), Christensen (2007), Johansen & Wilson (2006), Walker (1995), Chan (1999), Choudhury & Rajan (2003), Love et al (2005), Kaka & Price (1991), Bromilow (1974), Endut et al (2006), Chen & Huang (2006), Nassar et al (2005), Barraza (2004) and Chang (2001).Thus this research is focused on testing the following theories:

1. Verify the validity and applicability of Bromilow's principle for the public road construction projects in Ethiopia.
2. Verify the validity and applicability of S – curve pattern for cumulative cost – time curve by using Earned Value Management Technique for the public road construction projects in Ethiopia.

According to Creswell (2003) the quantitative studies use theory deductively and use the theory as shown in Figure 5 – 3 below to reach at the research conclusions.

5.2.1 Research Objectives

Nick (2000) stated that the importance of research aims and objectives cannot be over- stressed and it is vital to have a clear understanding of what the research is about and what it tries to actually achieve. According to Kumar (1999) the research objectives wording shall be clear, complete and specifically communicate with readers. The objectives of this research have been developed based on the Table 5 -1, developed by Nick (2000).

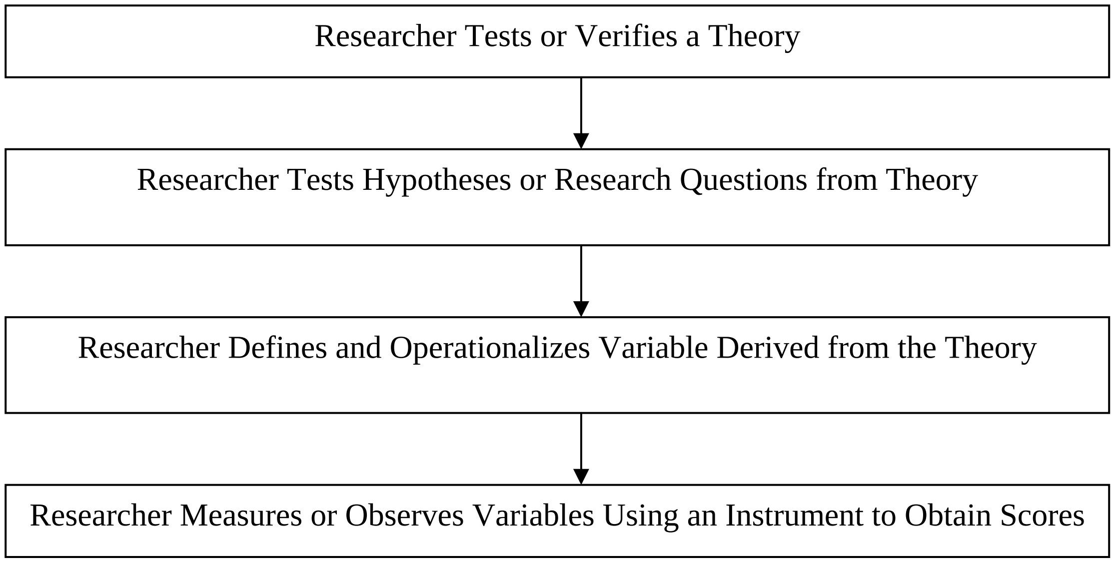


Figure 5 – 3: The deductive research approach typically used in Quantitative Research (Adopted Creswell (2003))

Questions	Answers
What is the research trying to achieve?	Provide a reasonable time estimation and performance measurement tool
What are the important issues?	Construction Time, Cost, Performance and managing them
Who will benefit from, or be affected by the project?	Clients, Consultants, Contractors, etc
What things will change as a result of the project?	Time estimation methods and performance management tools
Why has the project been established?	For an academic achievement and also to provide a useful tool for the practitioners

Table 5 -1: Research Questions

Thus, the following objectives have been developed:

1) Proving or disproving the developed Time - Cost relationship by Bromilow. If the relationship is not applicable, testing the existence of a Time - Cost relationship for the Ethiopian Road Projects and Develop another relationship or equation. Refer to Figure 5 – 3.

2) Using Earned Value Analysis to develop the pattern of the cumulative cost time curve and checking it against the S – Curve pattern.
3) Providing : -
    a. Reasonable time estimate for the pre – construction stage.
    b. A cost base line curve (S - curve) for performance measurement & monitoring of the public road construction projects in Ethiopia.

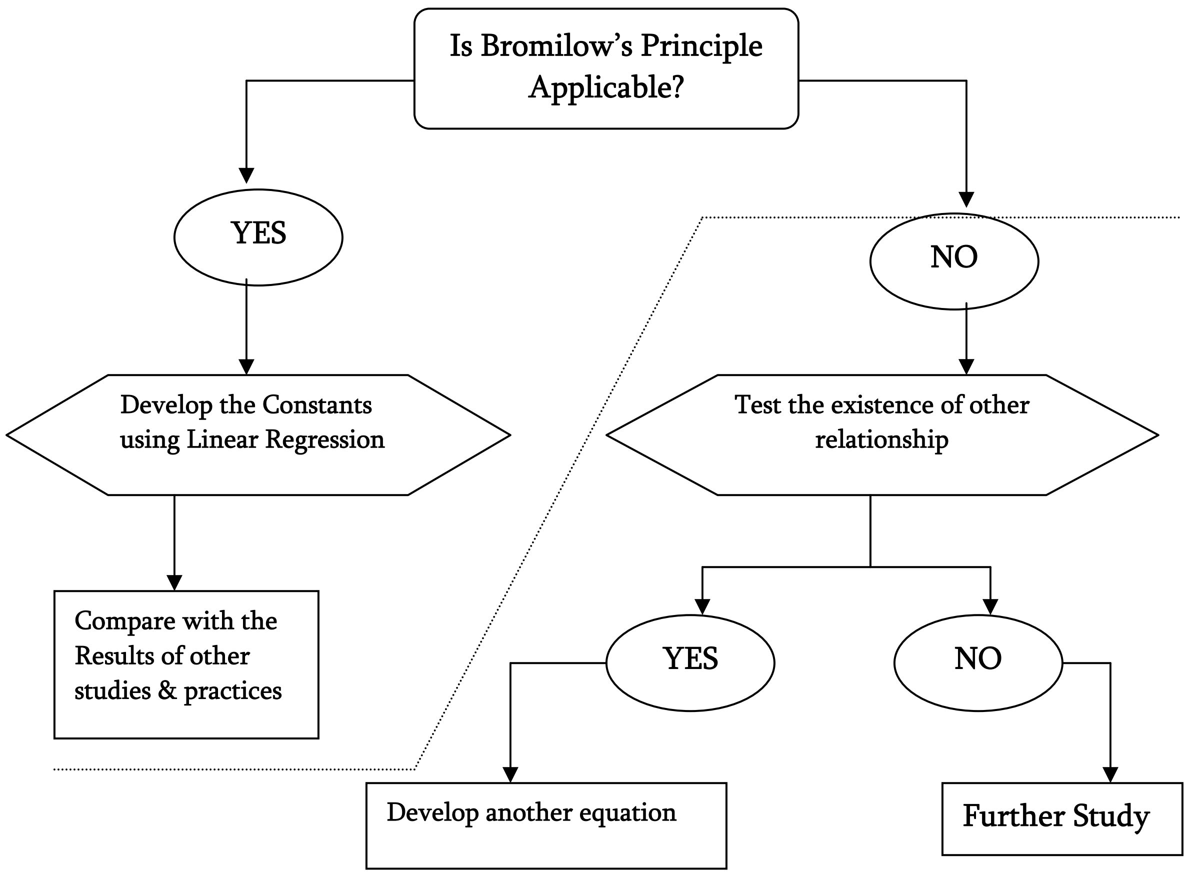


Figure 5 – 3: Research Approach for Hypothesis One

5.3 The Study Scope and Limitation

The scope of a research can be built using four different parameters: Significance, Delimitation, Definition and Limitation of the study (Creswell (2003) citied by Wubishet (2004)). Creswell (2003) stated the above points on the use to delimit a research proposal, nevertheless this research has used the above four parameters to determine the scope of the research it self.

Locke et al. (2000) citied by Creswell (2003) stated that terms shall be *defined* that individuals outside the field of study may not understand and that go beyond common language.

Two parameters for a research study establish the boundaries, exceptions, reservations, and qualification inherent in every study: Delimitation and Limitations (Castetter & Heisler, 1977 citied by Creswell (2003)). This study is delimited by the nature of the research. The basic nature lies in that the time – cost relationship can be modeled and studied in detail, thus the factors affecting the relationship are delimited by the conceptual frame work carried out in Chapter 4.

Punch (2000) citied by Creswell (2003) describes limitations as limiting conditions or restrictive weaknesses, which are unavoidably present in research. The limitations of this research are it only focuses on length and cost as factors affecting time in road construction projects. In addition, lack of available data, mainly the Actual Cost (AC) data on the test of the second hypothesis will limit its application.

Punch (2000) citied by Creswell (2003) describes significance of a study as its justification, importance, or contribution. Creswell (2003) states that significance of a study shall be related, to what the study adds to scholarly research and literature in the field; how the study helps improve practice; and reasons why the study will improve policy. The significance of this research is mainly for planning and monitoring phases of the project. In Ethiopian road projects are given a standard duration of 1,096 days (Three Years), which applies to most projects but with different resource constrains. Having a realistic time estimate based on previous data will replace this method of assigning constrained time for projects. Developing a realistic S - Curve and consequent evaluation methods using Earned Value Management (EVM) will result in a better performance evaluation tool.

5.4 The Research Design

A research design is the arrangement of conditions for collection and analysis of data in a manner that aims to combine relevance to the research purpose with economy in procedure (Selltiz (1962) quoted by Kothari (2004)). A research design is largely determined by the aim and objective of the study. Though researches are constrained by money, time and expertise there is much to do in the design of the research (Nick (2000)).

According to Kothari (2004), Research design decision shall be in respect of:

a) What is the study about?
b) Why is the study being made?
c) Where will the study be carried out?
d) What type of data is required?
e) Where can the required data be found?
f) What periods of time will the study include?
g) What will be the sample design?
h) What techniques of data collection will be used?
i) How will the data be analysed?
j) In what style will the report be prepared?

Nick (2000) presented the six principles for selection of the most appropriate research, namely, keep things simple, borrow from others, collect only what is needed, beware the distortion that research creates, use available expertise and accept that some things cannot be measured. Creswell (2003) stated that the framework for quantitative study is based on Experiments and Surveys and stated also that the research methods are predetermined; include performance data with statistical analysis. Thus based on the above ideas, the research has been designed as shown in the following sections.

5.4.1 Selection of Research Method

Nick (2000), Research methods are the tools of the researcher's trade and states that the perfect researcher will be familiar with the widest possible range of methods and will deploy them selectively to meet the requirements of different circumstances. Accordingly, Nick (2000) identified the following research approaches:

1. Survey Research – based on questioner, historical data and asking people
2. Experimental Research – based on conducting tests

3. Action Research – based on actual study of causes and effects
4. Case Study Research – based on looking in detail of number of instances or cases

This research has selected two approaches for its two hypotheses. For the first hypothesis a survey (using ***33*** projects) approach has been selected. This is mainly because the research is focused on data analysis and developing a correlation between time and factors affecting time (i.e. cost and length). However, for the second hypothesis the research has opted to use case study approach as the data available was only for limited number of projects and has used ***two*** projects for the case study.

According to Burns (2000), case study research includes historical case studies, observational case studies, clinical case study and multi – case studies. He also stated that case studies shall be conducted to provide in depth analysis and shallow studies will not contribute to knowledge. This research used historical case studies and also multi – case studies to develop the knowledge and findings behind the concept of S – Curve and EVM. Though case study research approach is questioned for its lack of sufficient information required for scientific generalization and openness to subjective bias, it has been favored for its capability to view concepts in detail.

5.4.2 Data Source and Collection

Most researches recognize a distinction between the use of quantitative and qualitative method's for collecting data. Quantitative methods collect information about things that you can count and Qualitative method is concerned with information about things that are less easily understood by counting them – like the attitudes that managers have towards the motivation of staff. According to Nick (2000), quantitative research techniques have become very sophisticated and it is possible to take a quantitative approach to many issues that are qualitative in nature.

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.

Kumar (1999) stated that the prerequisites for data collection include motivation by respondents to share the required information, clear understanding of the question, and possession of the required information. Fortunately, for this research, Ethiopian Road Authority personnel (the source of data for this research), without exception, had shown all the above prerequisites and many admirations go to them. According to Kumar (1999) the following ethical issues shall be looked into by any researcher in data collection: avoiding bias, provision or deprivation of treatment, using appropriate research methodology, correct reporting and using information. This research has tried to consider the above ethical issues in the stage of data collection.

Sampling: According to Kumar (1999) sampling theory is guided by two principles: the avoidance of bias in selection of a sample; and the attainment of maximum precision for a given outlay of resources. Kumar (1999) there are three categories of sampling:

1. Random/probability sampling;
2. Non- random sampling; and
3. 'Mixed' sampling techniques.

Fink (1998) also stated that the types of sampling can be divided as:

1. Simple Random Sampling
2. Systematic Sampling
3. Stratified Sampling – where the population is divided into groups or strata
4. Cluster Sampling – where the population is divided into batches.
5. Convenience Sampling – based on easy to get data.

This research has considered some of the above methods. Because of lack of available data for the first research hypothesis, all possible data has been taken resulting in a data based on the population rather than sample. But for the second research hypothesis clustered, non – random based on convenience sampling has been considered.

5.5 Research Validity and Reliability

It is natural for a researcher to attempt to establish (and for a reader to question) the quality of the results, that is, to seek to establish their validity. Validity is defined as the degree to which the researcher has measured what he has set out to measure (Smith 1991:106 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.

The greater the degree of consistency and stability in an instrument, the greater its reliability, therefore a scale or test is reliable to the extent that repeat measurements made by it under constant conditions will give the same result (Moser and Kalton (1989) cited by Kumar (1999)).

5.6 Research Processing

Nick (2000), once you have collected the data you have to do something with it and there are various ways you can do this. First you have to process the data, checking its accuracy and getting it into a form which will enable you to analyse it. Then once the data are organized, you can begin to make sense of it all, interpreting the findings and converting the data into information. This is the really difficult part. After analyzing a data, the researcher will be in a position to test the hypotheses and answer whether the facts support the hypothesis or they happen to be contrary (Kothari (2004).

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

These three approaches are similar in that they all start with a general science/engineering problem and all yield science/engineering conclusions. The difference is the sequence and focus of the intermediate steps as shown below:

For classical analysis, the sequence is

Problem→ Data →Model→ Analysis → Conclusions

For EDA, the sequence is

Problem→ Data→ Analysis→ Model → Conclusions

For Bayesian, the sequence is

Problem → Data→ Model → Prior Distribution → Analysis → Conclusions

Though classical models approach suggests that the model can be identified ahead of analysis, exploratory approach states that the data shall be looked into and methods shall be used to indicate which model is suitable for the data at hand. Classical analysis focus on the model estimating parameters of the model and generating predicted values from the model mean while Exploratory analysis focus on the data: - its structure, outliers, and models suggested by the data.

Classical analyses include regression, analysis of variance (ANOVA), t -tests, chi-squared tests, and F -tests. Exploratory techniques are generally graphical and include scatter plots, character plots, box plots, histograms, bihistograms, probability plots, residual plots, and mean plots. It is argued that such graphical tools are the shortest path to gaining insight into a data set in terms of testing assumptions, model selection, model validation, estimator selection, relationship identification, factor effect determination, and outlier detection NIST (2008). Accordingly, if one is not using statistical graphics, then one is forfeiting insight into one or more aspects of the underlying structure of the data. 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 and residual plot techniques. This analysis have been carried out by using a statistical software namely, SPSS (Statistical Package Social Studies), version 11.

In addition to the above analysis tools, this research has used the Weibull analysis for determining a reliability factor for the schedule performance indexes. According to Nassar et al (2005) Weibull analysis essentially entails fitting a Weibull distribution to a collected data set about some characteristic of a system (usually a quality or performance characteristic), and analyzing the reliability of the system based on the fitted distribution. The Weibull distribution itself represents a useful model for describing the reliability and predicting the failure of various systems (Taylor 1974), and has been found to provide accurate performance models in many empirical studies (Zacks 1992). One of the advantages of using Weibull distribution is that it provides accurate failure analysis and risk predictions worth small sample (Nassar et al (2005)). This is in part due to the extreme flexibility of the Weibull distribution, as will be discussed below. The Weibull function is a probability distribution function (PDF) that takes a number of different shapes, depending on its parameters. The density function for the Weibull is generally expressed as:

$$f(x) = \begin{cases} \frac{\beta}{\alpha}\left(\frac{x-L}{\alpha}\right)^{\beta-1} e^{-[(x-L)/\beta]^{\beta}} & \text{if } x \geq L \\ 0 & \text{otherwise} \end{cases}$$

(Eqn. 5 – 1)

The α and β parameters are the scale and shape parameters, respectively. Both α and β must be greater than zero. In the case of L=0 and β =1, the Weibull distribution takes the same form of the exponential distribution function. Similarly when β =3.25 the Weibull approximates the normal distribution (Evans and Olson 1998). Note that when β =1, Weibull distribution can be reasonably approximated to exponential distribution with mean 1/α, and as β grows the distribution becomes more symmetric. Further, the α and β parameters have a physical meaning. The Weibull shape parameter, β, indicates whether the rate of the considered performance characteristic is increasing, constant or decreasing. A β <1.0 indicates that the characteristic has a decreasing rate and a β >1.0 indicates an increasing rate. The Weibull scale parameter, α, is a measure of the scale, or spread, in the distribution of data. It so happens that α is the value at which approximately 37% of the population lies past. These facts make it a very robust distribution in modeling performance in general and the C/SPI in particular, as will be described in section 6.3.

Once the considered characteristic is fitted to the Weibull distribution, the risks associated with the system, like the probabilities of meeting specific performance or quality levels, can be measured and analyzed. Therefore, the application of the Weibull analysis to the EVM entails fitting C/SPI data of the project to the Weibull distribution and then analyzing the schedule and cost performance along with the risks involved. After developing the SPI, the next step will be developing the shape and scale factor of the Weibull function. The SPI was fitted to the Weibull cumulative distribution function (CDF), which is given by:

$$F(x) = 1 - e^{-(x/\alpha)^{\beta}} \quad \text{for } x > 0 \qquad \text{(Eqn. 5 – 2)}$$

This research has used the median ranking method. This method is relatively simple and easy to use, making it an ideal method for project managers, Nassar et al (2005). The median method mainly involved in raking the SPI data inn ascending order and developing their rank. The median rank of each data point is calculated next as (Rank No. – 0.3)/ (No. of points + 0.4). It has been shown mathematically that the value of ln [ln (1/1 – median rank)]] plots as a straight line against ln (SPI) for the SPI data points (Ireson and Cooms (1988) cited by Nassar et al (2005)).

This will result in a straight line in the form of y = m x +b, resulting that the β parameter = m, and α parameter = $e^{(b/\beta)}$. The next step will be to determine the probability of attaining certain values, i.e. a certain performance. If the probability of achieving a SPI value close to or more than 1 is high, then this indicates that there is strong chance of the project finishing within the budgeted cost. This can be thought of as the reliability of achieving the particular SPI value and is equal to 1 – "the performance probability''. The performance probability can be determined using a probability table or using the Excel's built – in Weibull function as: = WEIBULL (index value, shape parameter, scale parameter, TRUE). The steps have been summarized as shown below.

1. Collection of percent-complete data of the first project and calculating the SPI
2. Ranking SPI (smaller value is given a rank of 1)
3. Calculating the median rank (rank No. −0.3)/(No. of points+0.4)
4. Calculating ln(ln(1/1-median rank)) values and drawing a straight line (trend line in *MS EXCEL)* between them and ln SPI in separate chart and choosing the option of showing the straight line equation (in the form of $y = mx+b$)
5. $\beta = m$ and $\alpha = e^{b/\beta}$
6. Calculating the PDF for Weibull distribution in *MS EXCEL* using Weibull function = WEIBULL[index value, shape parameter (β), scale parameter (α), TRUE]
7. Drawing the PDF against the index value
8. Performing the previous steps for the second project; and
9. Comparing the performance of the two projects.

5.7 Research Writing

Writing the report is the last and, for many, the most difficult step of the research process (Kumar (1999)). This research is presented in four parts and seven chapters.

6 PART III - RESEARCH ANALYSIS AND DISCUSSION

The Research Analysis

6.1 Introduction

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. 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.

6.2 Analysis of Hypothesis I

The first 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:

$$T = K\,C^{B} \qquad \text{Eqn. (4 – 1)}$$

Where T is the actual construction time in calendar days, C is the final cost of contract in Ethiopia Birr, 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 Public Road Construction projects. This research in addition to cost plans to test length as an independent variable as the length will indicate the scope of the work. This has been done either by replacing the cost component of the above relationship or by testing both cost and length as independent variable through multiple regressions. 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

6.2.1 Data Collection

The data on projects was collected from the Ethiopia Road Authority, the client for all projects. The projects are all carried out at the federal level. The data collected consists of contract duration/ contract signing date, final completion date/ final contract amount, pavement type of project, contractor origin (International or Domestic), and final length of the road way. The data sources were contract documents, final payment certificates, and interim and completion reports. The Ethiopian Road Authority has developed a road classification category based on the major routes originating from the capital city, Addis Ababa, ERA (1997). The road collected data has been sorted based on the functional road classification of Ethiopia Roads and projects with adequate data have been used for the hypothesis testing.

6.2.2 Data Processing

The data collected has been first divided into two categories based on the bidding document used for the contract (i.e. ICB (International Competitive Bidding) or NCB (National Competitive Bidding)). This is mainly because the contract conditions for International and Domestic contracts are different when it comes to provisions for price escalation. In addition to that project team effectiveness is one of the major factors affecting duration of construction projects. The two project categories thus are based on projects carried out by International Contractors (IC) and Domestic Contractors (DC) as the contracts for international contractors differ from the domestic ones as the later are not allowed for price escalation except for those provided for escalation in the price of reinforcement bars, cement, asphalt and fuel.

Thus, a separate analysis has been necessary from the onset of the research analysis. Thus 33 projects have been identified where 21 are IC projects and 12 are DC projects. Out of the 21 IC projects 14 are AC Surface projects and 7 are DBST surface projects. All the 12 DC projects are Gravel Surface projects. The summary of the data collected is presented on Table 6 – 1 and 6 – 2.

Table 6 - 1: Data List International Contractors (IC) Projects

No.	Project	C_c	T_c	C_f	T_f	L
Asphalt Concrete (AC) Projects						
1	Addis - Modjo - Awasa	310,979,872.92	1,096.00	386,197,700.31	1,487.00	263.40
2	Modjo - Awash Arba	227,449,546.00	1,096.00	254,539,566.00	2,102.00	160.30
3	Awash Arba - Gewane	192,002,109.84	912.00	225,000,000.00	1,196.00	135.80
4	Gewane - Mille	216,353,945.75	912.00	350,305,821.01	1,218.00	146.03
5	Logia - Semera (Cont. 1)	74,643,378.57	720.00	88,200,000.00	1,080.00	41.00
6	Tarma Ber - Kombolcha	457,812,822.26	900.00	529,867,929.24	2,294.00	187.00
7	Addis - Gohatsion Section 1 (5.5 - 31.5 km)	58,937,356.28	522.00	58,937,356.28	522.00	26.00
8	Addis - Gohatsion Section 2 (31.5 - 76.5 km)	58,937,356.28	522.00	58,937,356.28	522.00	45.00
9	Addis - Gohatsion Section 3 (76.5 - 95.0 km)	58,937,356.28	871.00	58,937,356.28	871.00	18.50
10	Debre Markos - Merawi	327,070,830.00	1,096.00	412,366,861.18	2,156.00	219.80
11	Merawi - Gondar	395,575,960.57	1,096.00	455,860,533.11	1,906.00	208.00
12	Modjo - Awash Arba	227,449,546.00	1,096.00	254,539,566.00	2,102.00	160.30
13	Awash - Hirna	256,542,439.10	1,096.00	297,426,124.01	1,887.00	140.40
14	Hirna - Kulubi	188,084,957.20	1,203.00	273,023,657.27	2,382.00	91.00
Double Surface Treatment (DBST) Projects						
15	Kulubi - Dengego - Dengeno - Dire Dawa	162,178,583.00	913.00	204,561,000.00	1,557.00	80.00
16	Woldiya - Alemata	150,329,634.00	1,096.00	226,421,169.16	2,425.00	78.30
17	B/Mariam - Wukero	203,410,054.65	1,096.00	211,588,154.43	1,987.00	273.26
18	Mekenajo - Nejo	138,601,822.00	720.00	151,414,167.27	1,018.00	61.00
19	Nejo - Medi	147,768,639.37	720.00	165,089,053.53	896.00	70.00
20	Alemgena - Butajira	223,651,990.00	1,472.00	237,889,773.88	1,247.00	118.00
21	Butajira - Husana	217,465,178.66	912.00	174,076,527.70	1,028.00	100.00

Where: C_c - Contract Cost (Birr), C_f - Final Cost (including variation & price escalation) (Birr), T_c - Contract Duration (Calendar days), T_f - Actual Duration (Calendar Days) and L – Length of the road (km)

Table 6 - 2: Data List Domestic Contractors (DC) Projects

No.	Project	Cc	T_c	C_f	T_f	L
1	Alemata - Muhane - Maychew	68,880,600.00	365.00	87,576,104.04	446.00	67.40
2	Shire - Shiraro - Humera I	18,217,309.83	730.00	30,276,030.75	2,022.00	70.50
3	Shire - Shiraro - Humera II	39,591,367.14	730.00	41,146,137.15	1,292.00	69.08
4	Humera - Ludgi	57,663,337.21	455.00	57,169,230.63	845.00	67.00
5	Tekeze - Humera	154,271,535.40	1,092.00	176,109,267.89	2,126.00	127.77
6	Ghint - Wohni	33,573,414.89	365.00	30,281,715.50	576.00	39.00
7	Mohane - Hiwane	128,348,934.77	644.00	125,237,159.79	571.00	67.78
8	Wohni - Shehedi	24,429,668.94	365.00	26,273,574.70	733.00	25.50
9	Shehedi - Kokit	24,429,668.94	538.00	26,273,574.70	798.00	69.80
10	Kokit - Metema	25,285,823.38	365.00	30,734,594.07	800.00	23.98
11	Fincha - Lemlembereha	74,926,964.87	720.00	77,315,332.38	1,673.00	43.60
12	Shkhusien - Mecheta II	124,728,864.00	1,440.00	116,338,160.73	1,692.00	145.00

The data collected along time line based on completion time with project costs is shown in Figure 6 -1.

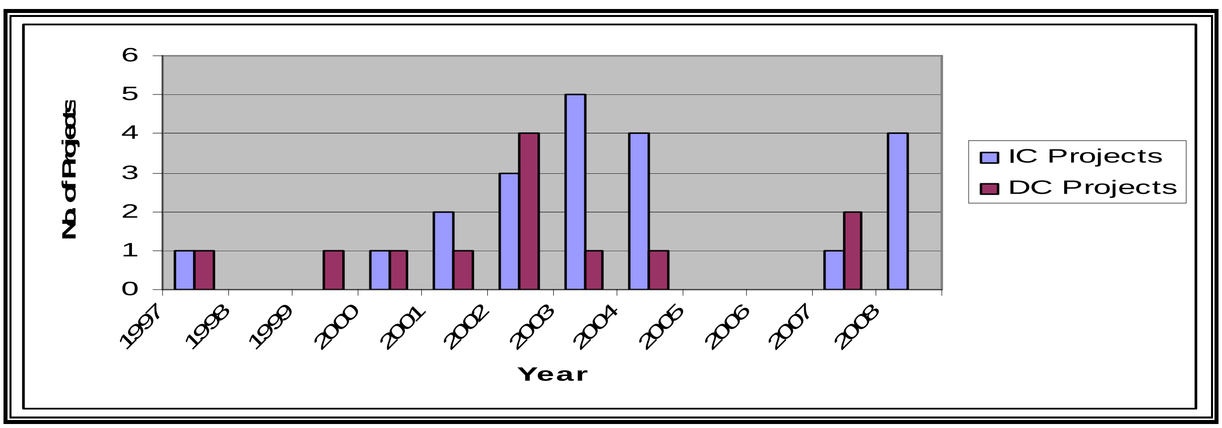


Figure 6 – 1: Project Data Time Line

The data identified for this research includes 33 projects which are all from a single employer, ERA. The first Bromilow model was developed based on 370 building 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 researcher acknowledges that the size of the data is small compared to the data used by Bromilow. But the data size has been found to be adequate for federal road construction projects where the number of completed road projects (rehabilitation, upgrading, feeder and new rural roads) in ten years of the Road Sector Development Program is about 67 (ERA (2005)). And as stated above researches by Chan and Kumaraswamy (1995) and Andient et al (2006) have used data comparable to this research. The researcher believes that the models developed shall be revised each year or so to result in a better prediction capacity. Extending the application to projects from the regional road authorities shall also be employed to develop a comprehensive national time prediction tool.

6.2.3 Exploratory Analysis of Data and Test on Correlation of Data

The two sets of data for unadjusted and adjusted conditions of inflation were used and the data for testing Hypothesis I was categorized into the following sections:

A. International Contractors
    a. Asphalt Concrete Projects (AC)
    b. Double Surface Treatment Projects (DBST)
B. Domestic Contractors
    a. Gravel Surface Projects (GS)

The average time over run and cost over run projects carried out by International contractors and Domestic contractors is shown in Table 6 – 3. The data indicates that International contractors have a better time performance compared to domestic ones. Not surprisingly the costs over run of international contractors are larger than the domestic ones as additional cost will be incurred due to price escalations.

Contractor		Time Over Run (%)	Cost Over Run (%)
International	All	57.00	17.00
	AC	59.00	19.00
	DBST	48.00	13.00
Domestic	All	77.00	11.00

Table 6 – 3: Time and Cost overrun of projects

The time- cost data has been tested for correlation and the results of the Pearson's coefficients are shown in Table 6 – 4. The test has been carried out on the unadjusted data and also adjusted data where the costs have been adjusted for inflation. The result indicates that the correlation among variables for DBST Project is low which is mainly caused due to lack of sufficient number of projects. Thus the analysis results for all projects will be used for analysis of DBST projects. Thus the International contractor's category was reduced to *All projects* and *AC projects*.

Table 6 – 4: Correlation coefficients of variables of projects

Table 6 – 4A: Correlation coefficients of variables of projects (Unadjusted Data)

A. Unadjusted Data	Variable			Variable		
	Time – Cost - Length			Time – Cost - Length		
Category	Contract (Duration/ Amount)			Final (Amount / Duration)		
I. IC	Time	Cost	Length	Time	Cost	Length
All	1	0.528	0.559	1	0.684	0.583
AC	1	0.758	0.710	1	0.845	0.782
DBST	1	0.684	0.387	1	0.678	0.393
	Cost - Length			Cost - Length		
	Cost		Length	Cost		Length
All	1		0.786	1		0.765
AC	1		0.967	1		0.954
DBST	1		0.540	1		0.366
II. DC	Variable			Variable		
	Time – Cost - Length			Time – Cost - Length		
	Contract (Duration/ Amount)			Final (Amount / Duration)		
	Time	Cost	Length	Time	Cost	Length
All	1	0.685	0.891	1	0.381	0.578
	Cost - Length			Cost - Length		
	Cost		Length	Cost		Length
All	1		0.731	1		0.725

Table 6 – 4B: Correlation coefficients of variables of projects (Adjusted Data)

B. Adjusted Data	Variable			Variable		
	Time - Cost			Time - Cost		
Category	Contract (Duration/ Amount)			Final (Amount / Duration)		
	Time	Cost	Length	Time	Cost	Length
I. IC						
All	1	0.546	0.559	1	0.635	0.583
AC	1	0.646	0.690	1	0.685	0.652
DBST	1	0.803	0.387	1	0.602	0.393
	Cost - Length			Cost - Length		
	Cost		Length	Cost		Length
All	1		0.810	1		0.796
AC	1		0.899	1		0.927
DBST	1		0.653	1		0.368
II. DC	Variable			Variable		
	Time - Cost			Time - Cost		
	Contract (Duration/ Amount)			Final (Amount / Duration)		
	Time	Cost	Length	Time	Cost	Length
All	1	0.710	0.891	1	0.293	0.578
	Cost - Length			Cost - Length		
	Cost		Length	Cost		Length
All	1		0.748	1		0.632

The transformation of a data by using SQRT, LOG or INVERSE functions yields better results for correlation models (NIST (2008)). Thus the data for final contract amount and completion time has been transformed by using SQRT and LOG functions only as INVERSE functions will reduce the significance figure of the cost values which are in millions.

The results shown in Table 6 – 5 clearly indicate that LOG transformations result in a better correlation for International contracts and Observed data are preferable for Domestic contractors. This might indicate that the transformation of data according to the Bromilow's model might not be applicable for domestic contracts.

Table 6 – 5: Correlation coefficient for transformed data

Final Time and Cost		IC Projects			DC Projects		
A. Adjusted		Observed	LOG	SQRT	Observed	LOG	SQRT
All	Correlation (T - C)	0.635	***0.798***	0.724	*0.293*	0.232	0.171
	Correlation (T - L)	0.583	*0.712*	0.661	***0.578***	0.535	0.466
	Correlation (C - L)	0.796	***0.897***	0.855	***0.632***	0.641	0.632
AC	Correlation (T - C)	0.685	***0.833***	0.768			
	Correlation (T - L)	0.652	*0.762*	0.720			
	Correlation (C - L)	0.927	***0.949***	0.940			
B. Unadjusted		Observed	LOG	SQRT	Observed	LOG	SQRT
All	Correlation (T - C)	0.684	***0.811***	0.755	*0.381*	0.311	0.239
	Correlation (T - L)	0.583	*0.712*	0.661	***0.578***	0.535	0.466
	Correlation (C - L)	0.765	***0.895***	0.841	***0.725***	0.702	0.669
AC	Correlation (T - C)	0.845	***0.932***	0.903			
	Correlation (T - L)	0.782	*0.829*	0.828			
	Correlation (C - L)	0.954	***0.951***	0.958			

The correlation coefficients shown in Table 6 – 4 indicate that the there is a better correlation among time – cost than time – length for IC projects. *Thus Cost shall be taken as an independent variable for IC projects*. However the correlation results for DC projects indicate that time is more correlated to length than cost based on contract data's. *Thus Length shall be taken as an independent variable for DC projects for analysis of contract values of time and length.* In addition there is a strong relationship among Cost and Length for IC projects based on the unadjusted data and there seems to be a good relationship among the same for DC projects based on the unadjusted data.

The existence of a relationship was also checked by using exploratory methods; mainly scatter plots for observed and transformed data's for DC and IC respectively. The results shown in Figures 6 – 2 to 6 – 5 indicate that there is a relationship between time and cost for IC Projects. The results shown in Figures 6 – 6 and 6 – 9 indicate that there is a weak relationship between time and cost for DC Projects. In addition to that the scatter plots were used to identify outliers. The outliers have been investigated in detail for sources of errors. The model used has neglected some data's which are at the extreme limits. Such outliers have neglected based on the tolerance limit of the SPSS tools.

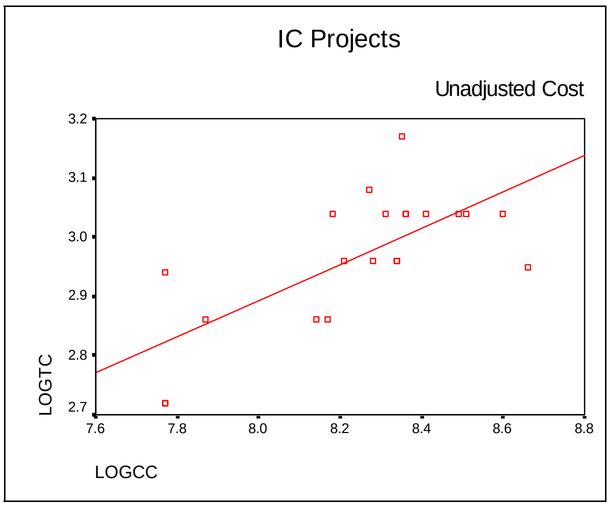


Figure 6 – 2: Contract Time – Cost (Unadjusted)

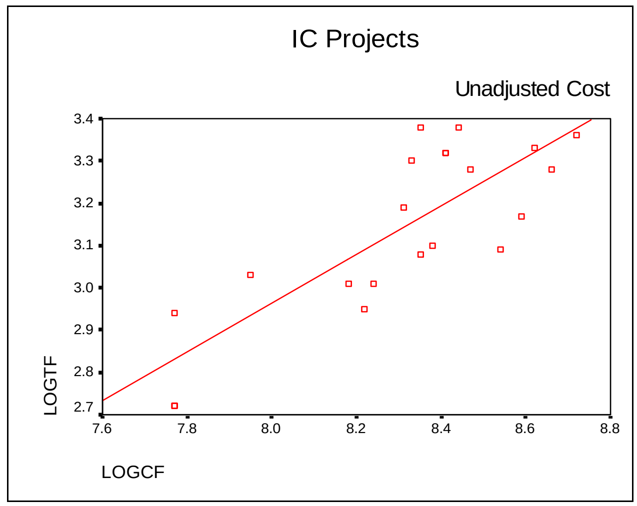


Figure 6 – 3: Final Time – Cost (Unadjusted)

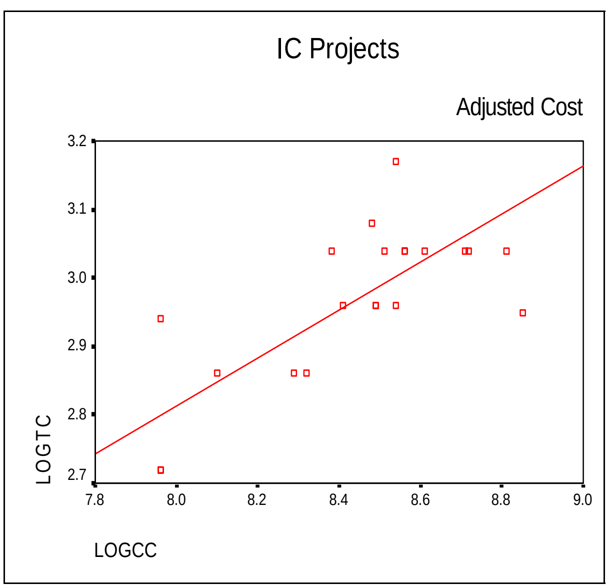


Figure 6 – 4: Contract Time – Cost (Adjusted)

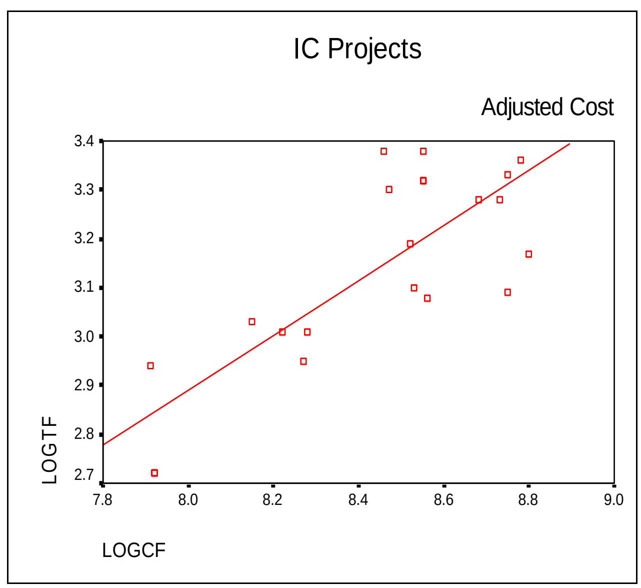


Figure 6 – 5: Final Time – Cost (Adjusted)

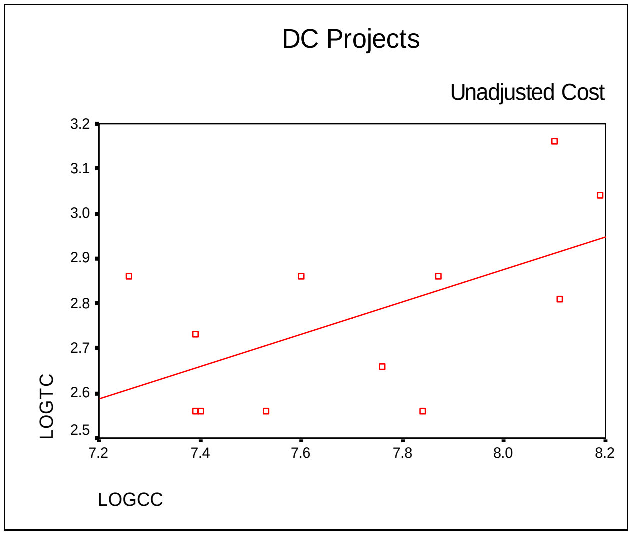


Figure 6 – 6: Contract Time – Cost (Unadjusted)

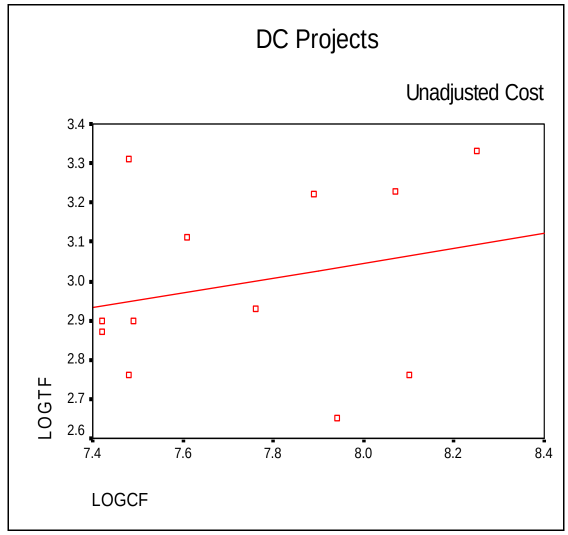


Figure 6 – 7: Final Time – Cost (Unadjusted)

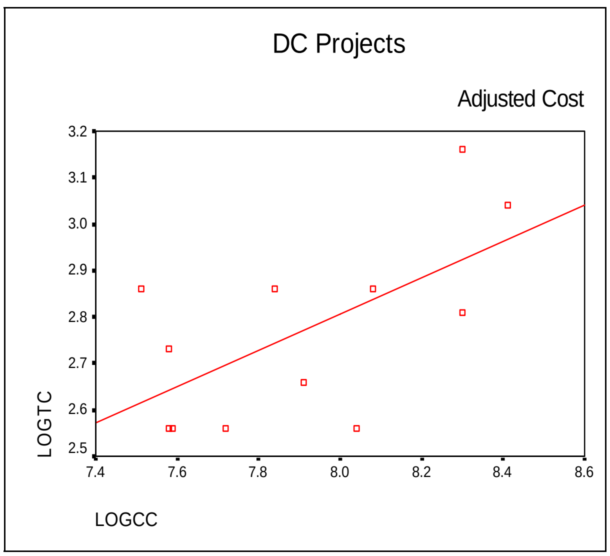


Figure 6 – 8: Contract Time – Cost (Adjusted)

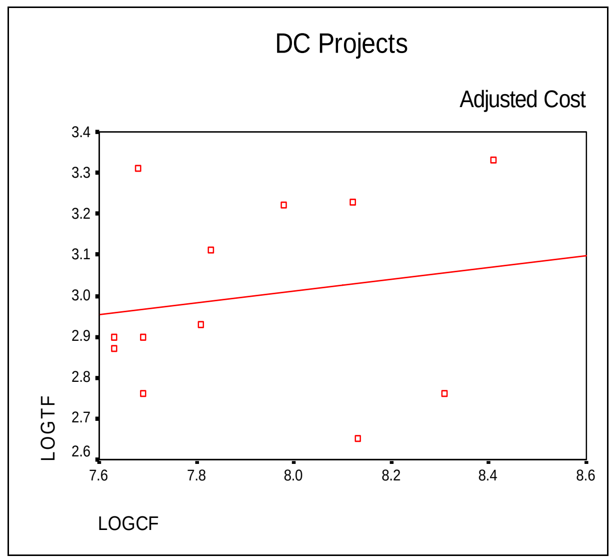


Figure 6 – 9: Final Time – Cost (Adjusted)

6.2.4 Hypothesis Testing

One of the objectives of this research is to test the applicability of Bromilow's model to Ethiopian road construction 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 6 -5 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 road 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% ($\rho > 0.05$).

6.2.5 Test of Hypothesis for International Contractors Projects

6.2.5.1.1 Relationship between Contract Time and Contract Cost

Figure 6 – 2 and 6 – 4 shows the relationship between contract time and cost for International Contractors (IC) for adjusted and unadjusted cost basis. Table 6 – 6 shows the coefficient and linear regression results of the relationship.

6.2.5.1.2 Relationship between Final Time and Cost

Figure 6 – 3 and 6 – 5 shows the relationship between final time and cost for International Contractors (IC) for adjusted and unadjusted cost basis. Table 6 – 7 shows the coefficient and linear regression results of the relationship.

Table 6 – 6: **IC Projects:** Regression Analysis of the Time – Cost relationship based on the Log (T_c = Contract Time) and Log (C_c = Contract Cost)

Regression Results	Contract Time and Unadjusted Contract Cost	Contract Time and Adjusted Contract Cost
R	0.706	0.722
R^2	0.498	0.522
Adjusted R^2	0.472	0.496
F	18.875	20.709
Significance (F)	0.000	0.000

Table 6 – 7: **IC Projects:** Regression Analysis of the Time – Cost relationship based on the Log (T_f = Final Time) and Log (C_f = Final Cost)

Regression Results	Final Time and Unadjusted Final Cost	Final Time and Adjusted Final Cost
R	0.814	0.800
R^2	0.663	0.639
Adjusted R^2	0.645	0.620
F	37.351	33.665
Significance (F)	0.000	0.000

6.2.5.1.3 Multiple Regressions

A test of multiple regressions was carried out to identify if time can be better modeled by using the two independent variables identified: cost and length. The results of the multiple regressions are shown in Table 6 – 8.

Table 6 – 8: **IC Projects:** Regression Analysis of the Time – Cost – Length

	Contract		Final	
Regression Results	Contract Time and Unadjusted Contract Cost	Contract Time and Adjusted Contract Cost	Final Time and Unadjusted Final Cost	Final Time and Adjusted Final Cost
R	0.712	0.730	0.812	0.796
R^2	0.507	0.532	0.659	0.634
Adjusted R^2	0.453	0.480	0.621	0.594
F	9.268	10.240	17.419	15.609
Significance (F)	0.002	0.001	0.000	0.000

The results of the multiple regressions do not show better results than the linear regression equations. In addition, the problem with multi-regression of the above variables is the analysis will be highly affected by *Multi-collinearity* as in multiple regressions the regression coefficients become less reliable as the degree of correlation between independent variable increases (Kothari, (2004)). The degree of correlation between cost and length is quite high and thus the multiple regressions will not be as predictable as the linear regression ones.

Conclusion: The test of the null hypothesis for international contracts (based on final time and cost) was rejected for significance levels of $\rho < 0.0001$ and thus the IC projects have been found to be accepted for Time – Cost relationship according to Bromilow's principle.

6.2.6 Test of Hypothesis for Domestic Contractors Projects

6.2.6.1 Relationship between Contract Time and Contract Cost

Figure 6 – 6 to 6 – 8 show the relationship between contract time and cost for Domestic Contractors (DC) for adjusted and unadjusted cost basis. Table 6 – 9 shows the coefficient and linear regression results of the relationship.

6.2.6.2 Relationship between Final Time and Cost

Figure 6 – 7 and 6 – 9 shows the relationship between final time and cost for Domestic Contractors (DC) for adjusted and unadjusted cost basis. Table 6 – 10 shows the coefficient and linear regression results of the relationship.

Table 6 – 9: **DC Projects:** Regression Analysis of the Time – Cost relationship based on the

Log (T_c = Contract Time) and Log (C_c = Contract Cost)

Regression Results	Contract Time and Unadjusted Contract Cost	Contract Time and Adjusted Contract Cost
R	0.582	0.623
R^2	0.339	0.388
Adjusted R^2	0.273	0.327
F	5.12	6.339
Significance (F)	*0.047*	*0.031*
T – test (K)	-0.021	-0.261
Significance (t)	*0.984*	*0.800*
T – test (Cc)	2.263	2.518
Significance (t)	*0.047*	*0.031*

Table 6 – 10: **DC Projects:** Regression Analysis of the Time – Cost relationship based on the

Log (T_f = Final Time) and Log (C_f = Final Cost)

Regression Results	Final Time and Unadjusted Final Cost	Final Time and Adjusted Final Cost
R	0.242	0.173
R^2	0.059	0.030
Adjusted R^2	-0.035	-0.067
F	0.624	0.308
Significance (F)	*0.448*	*0.591*
T – test (K)	0.826	0.879
Significance (t)	*0.428*	*-0.400*
T – test (Cf)	0.79	0.555
Significance (t)	*0.448*	*0.591*

Conclusion: The F – test result of the linear regression for final time and cost has a significance level of 0.448 and 0.591 for unadjusted and adjusted costs respectively. Both results are way above the assumed 5% significance level. Thus the null hypothesis has been accepted resulting in the rejection of the Bromilow's model to Ethiopian Road projects carried out by domestic contractors (DC Projects).

6.2.6.3 Multiple Regressions

A test of multiple regressions was also carried out to identify if time can be better modeled for DC projects by using the two independent variables identified: cost and length. The results of the multiple regressions are shown in Table 6 – 11.

The results of the multiple regressions do show better results than the linear regression equations. But the final results have a t – test significance of $\rho > 0.05$ and thus the null hypothesis test has been accepted resulting in the rejection of the multiple regression results.

Table 6 – 11: **DC Projects:** Regression Analysis of the Time – Cost – Length				
	Contract		Final	
Regression Results	Contract Time and Unadjusted Contract Cost	Contract Time and Adjusted Contract Cost	Final Time and Unadjusted Final Cost	Final Time and Adjusted Final Cost
R	0.809	0.813	0.482	0.499
R^2	0.654	0.661	0.232	0.249
Adjusted R^2	0.577	0.585	0.062	0.082
F	8.494	8.759	1.361	1.492
Significance (F)	*0.008*	*0.008*	*0.304*	*0.276*
T – test (K)	1.069	0.845	1.424	1.559
Significance (t)	0.313	0.420	0.188	0.153
T – test (C)	0.492	0.656	-0.339	1.621
Significance (t)	0.634	0.528	0.743	0.14
T – test (L)	2.861	2.689	1.426	-0.564
Significance (t)	0.019	0.025	0.188	0.586

Conclusion: The test of the null hypothesis for domestic contracts was accepted for a significance level of $\rho > 0.05$ and thus the model based on multiple regression of final Time with final cost and length as independent variables is not applicable for domestic contracts.

6.2.7 Developing Regression Models

The above analysis of the hypothesis has indicated that the Bromilow's principle is applicable only to IC projects and DC project have related with Length than Cost. The following models are developed to provide the much required time prediction tool.

6.2.7.1 International Contractor Projects

The regression model results for final completion times have 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 6 - 12 presents the basic forms of the equations for these regression models, where X denotes the independent variable; Y denotes the dependent variable, and b_0, b_1, b_2 denote constants.

Regression model	Regression equation
Linear regression (LIN)	$Y=b_0+b_1*X$
Logarithmic regression (LOG)	$Y=b_0+b_1*\ln X$
Inverse regression (INV)	$Y=b_0+b_1/X$
Quadric regression (QUA)	$Y=b_0+b_1*X+b_2*X^2$
Cubic regression (CUB)	$Y=b_0+b_1*X+b_2*X^2+b_3*X^3$
Composite regression (COM)	$Y=b_0*b_1^X$
Power regression (POW)	$Y=b_0*X^{b_1}$
S-curve regression (S)	$Y=e^{(b_0+b_1/X)}$
Exponential regression (EXP)	$Y=b_0*e^{(b_1*X)}$

Note: Y denotes the dependent variable; X denotes the independent variable; and b_0, b_1, b_2 denote constants.

Table 6 – 12: Equation forms of regression models

The models for Time were developed for both unadjusted and adjusted cost conditions under the IC category for ALL and AC projects. The equation for ALL is assumed to be used for DBST projects. The results of the regression models shown in Table 6 – 13 indicates that Cubic (CUB) and Quadratic (QUA) equations combined with logarithmic transformation of the data result in a better correlation among variables. The cubic model has been selected based on the F – values. Thus the equations for the different categories have been developed as follows:

I. Unadjusted Cost Basis

ALL Projects

$$Log(T) = -16.482 + 3.2915\ Log(C) - 0.0134\ (Log(C))^3 \quad \text{(Eqn. 6 – 1)}$$

AC Projects

$$Log(T) = -41.576 + 10.3533\ Log(C) - 0.5974\ (Log(C))^3 \quad \text{(Eqn. 6 – 2)}$$

II. Adjusted Cost Basis

ALL Projects

$$Log(T) = -32.759 + 6.1661\ Log(C) - 0.0268\ (Log(C))^3 \quad \text{(Eqn. 6 – 3)}$$

AC Projects

$$Log(T) = -47.058 + 8.7640\ Log(C) - 0.0394\ (Log(C))^3 \quad \text{(Eqn. 6 – 4)}$$

Where T – Time in calendar days and C – cost in Ethiopian Birr (not in million ETB)

Table 6 – 13 : R^2 of regression equations for time prediction (IC Projects)

Regression Model	Project Category			
	Unadjusted		Adjusted	
	ALL	AC	ALL	AC
LIN	0.663	0.747	0.639	0.696
LOG	0.667	0.752	0.645	0.702
INV	0.67	0.756	0.651	0.707
QUA	0.682	0.79	0.702	0.784
CUB	**0.682***	**0.790***	**0.702***	**0.784***
COM	0.672	0.751	0.65	0.704
POW	0.676	0.756	0.656	0.71
S	0.68	0.76	0.662	0.716
EXP	0.672	0.751	0.65	0.704
* F - value	19.28	20.63	21.23	19.98
*ρ - Value	0	0	0	0

Table 6 – 14: R^2 of regression equations for contract time prediction (DC)

Regression Model	Project Category
	Unadjusted/ Adjusted
	ALL
LIN	0.794
LOG	0.627
INV	0.425
QUA	0.845
CUB	**0.859**
COM	0.728
POW	0.644
S	0.493
EXP	0.728
* F - value	16.3
*ρ - Value	0.001

6.2.7.2 Domestic Contractor Projects

The correlation coefficient shown on Table 6 – 5 indicates that there is a strong relationship between time and length based on contract values. Using this relation will provide a tool to estimate the contract times used for road projects carried out by domestic contractors. In any case, though the relationship with final Time would have helped much, having a tool to predict contract time based on length is not useless.

The transformation of the data by using the Square Root (SQRT) and Logarism (LOG) functions indicated that the observed values better correlate than the transformed data. The existence of a relationship was checked by using exploratory methods, mainly scatter plots for observed data. The result shown in Figure 6 – 10 indicate that there is a relationship between contract time and cost for domestic Projects. For developing the regression model, the above stated nine regression models were investigated to identify the best format for this correlation.

The results of the regression models shown in above Table 6 – 14 indicates that Cubic (CUB) equation results in a better correlation among variables. Thus the equation for the contract value based on length has been developed as follows:

ALL Projects

$$(T_C) = 15.0615 + 20.2224\ (L) - 0.2631\ (L)^2 + 0.0013\ (L)^3 \qquad \text{(Eqn. 6 – 5)}$$

Where T – Time in calendar days and L – Project Length in Km

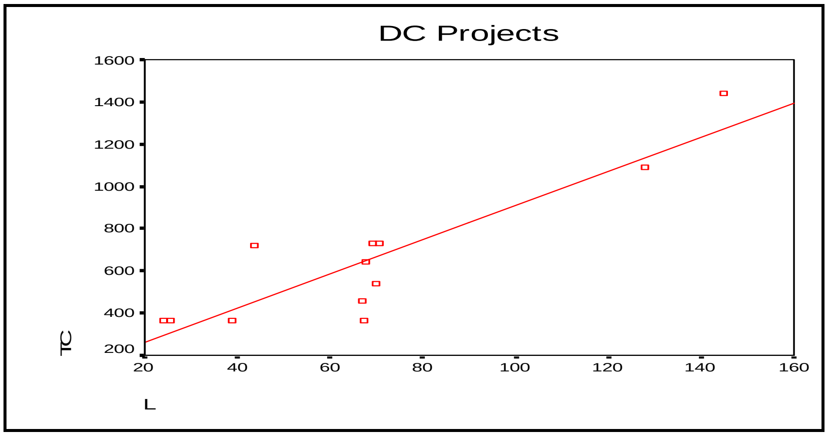


Figure 6 – 10: Contract Time – Length (Unadjusted / Adjusted)

6.2.8 Cost Model

Cost prediction models are also useful tools for project management. The data available has been used to develop a cost prediction model by taking length as an independent variable. The data for both IC and DC projects are separately used to develop the models.

6.2.8.1 International Contracts

The correlation coefficients shown in Table 6 – 5 clearly indicate that there is a strong relationship between cost and length. In addition Table 6 – 6 indicates that the transformed data based on LOG function has resulted in better correlation among these variables. Thus the Log transformed data has been used for developing the cost prediction model for IC projects. Figure 6 -11 and 6 -12 also indicate this relationship.

Linear regressions among the variables indicate that the model can be accepted by rejecting the null hypothesis by an F – test significance value < 0.0001 (Refer to Table 6 -15). Using the nine regression equations state above, the Cubic (CUB) equations have been found to better fit the data as shown in Table 6 – 16.

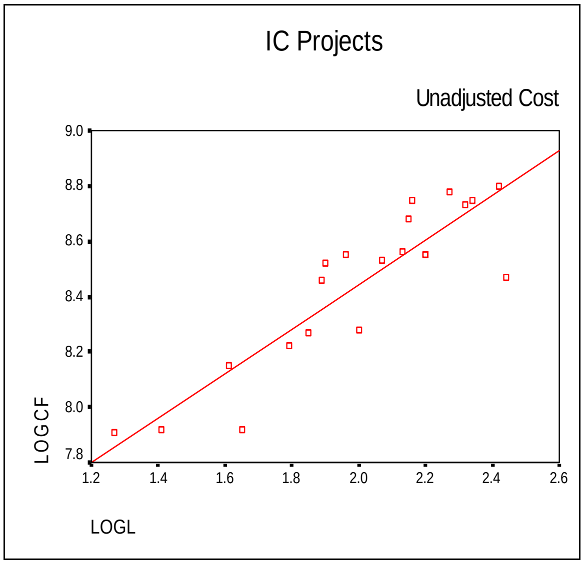


Figure 6 – 11: Final Cost – Length (Unadjusted)

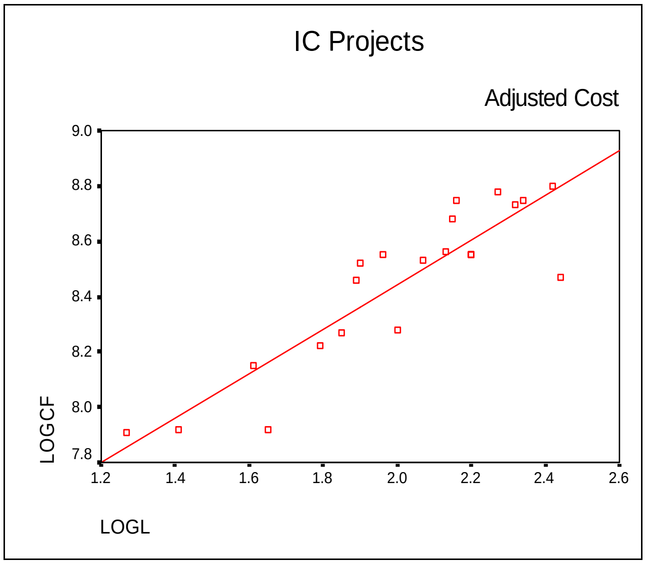


Figure 6 – 12: Final Cost – Length (Adjusted)

Thus the cost prediction models are developed and shown as follows:

I. Unadjusted Cost Basis

ALL Projects

$$Log\ (C) = 5.9046 + 1.4598\ Log\ (L) - 0.0603\ (Log\ (L))^3 \qquad \text{(Eqn. 6 – 6)}$$

AC Projects

$$Log\ (C) = 7.1383 + 0.4076\ (Log\ (L))^2 - 0.0581\ (Log\ (L))^3 \qquad \text{(Eqn. 6 – 7)}$$

II. Adjusted Cost Basis

ALL Projects

$$Log\ (C) = 6.2154 + 1.3132\ Log\ (L) - 0.0464\ (Log\ (L))^3 \qquad \text{(Eqn. 6 – 8)}$$

AC Projects

$$Log\ (C) = 6.9174 + 0.6332\ Log\ (L) + 0.0683\ (Log\ (L))^2 \qquad \text{(Eqn. 6 – 9)}$$

Where C – Cost in Ethiopian Birr and L – Project Length in Km

Table 6 – 16 - R^2 of regression equations for cost prediction (IC Projects)

Regression Model	Project Category			
	Unadjusted		Adjusted	
	ALL	AC	ALL	AC
LIN	0.802	0.913	0.804	0.911
LOG	0.806	0.902	0.808	0.901
INV	0.79	0.878	0.792	0.877
QUA	0.81	0.914	0.812	0.912
CUB	**0.813**	**0.914**	**0.814***	**0.912***
COM	0.804	0.913	0.807	0.912
POW	0.810	0.904	0.812	0.902
S	0.795	0.880	0.797	0.879
EXP	0.804	0.913	0.807	0.912
* F - value	39.02	58.25	39.48	56.86
*ρ - Value	0.000	0.000	0.000	0.000

Table 6 – 15: **IC Projects:** Regression Analysis of the Cost - Length relationship based on the (D)

Log (C_f = Final Cost) and Log (L = Length)

Regression Results	Unadjusted Final Cost & Length	Adjusted Final Cost & Length
R	0.896	0.897
R^2	0.802	0.804
Adjusted R^2	0.792	0.794
F	76.989	78.186
Significance (F)	0.000	0.000

6.2.8.2 Domestic Contracts

The correlation coefficients shown in Table 6 – 4 clearly indicate that there is some relationship between cost and length for domestic contract projects. The result also indicates that only the Unadjusted data has a correlation coefficient higher than 0.70. Thus the data for unadjusted cost and length for domestic contractors are used for analysis of the relationship.

In addition Table 6 – 5 indicates that the observed data has resulted in better correlation than the transformed data's. Thus the observed data has been used for developing the cost prediction model for DC projects. Figure 6 -13 indicates that the relationship between cost and length for domestic contract is existent.

Using the nine regression equations state above, the Cubic (CUB) equations have been found to better fit the data as shown in Table 6 – 17 & 6 -18. But the t – test for the regression model has a significance level of ρ = 0.067 which is greater than the assumed level of significance (ρ = 0.05).

Thus the null hypothesis has bee accepted and thus the relationship between cost and length for DC projects have been rejected.

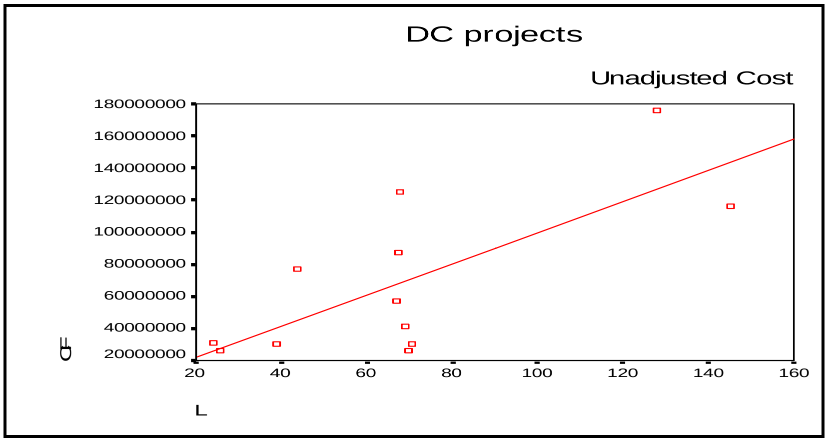


Figure 6 – 13: Final Cost – Length (Unadjusted) for DC projects

Table 6 – 18 - R^2 of regression equations for cost prediction (DC Projects)	
	Project Category
Regression Model	Unadjusted
	ALL
LIN	0.525
LOG	0.455
INV	0.336
QUA	0.527
CUB	0.571
COM	0.475
POW	0.447
S	0.365
EXP	0.475
* F - value	3.550
*ρ - Value	0.067

Table 6 – 17: **DC Projects:** Regression Analysis of the Cost - Length relationship based on the (D)	
C_f = Final Cost and L = Length	
Regression Results	Unadjusted Final Cost and Length
R	0.725
R^2	0.525
Adjusted R^2	0.478
F	11.062
Significance (F)	0.008

6.2.9 Regression Model Validation

The next important step is to test the validity of the estimate from the model and compare it with the actual results. Chan and Huang (1999) and Choudhury and Rajan (2003) used scatter plots of residuals for validating their relationship. 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 with out 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).

According to Devore (2000), the error of a regression model is the difference between the actual and predicted value called residual. The sum of the residual shall be zero for a perfect regression model. But having a sum of numbers with different signs will have a neutralizing effect and thus the square sum of the residuals will result in a better evaluation of the model. The time and cost prediction models developed for IC and DC projects above have been validated by using the average percentage error, the standard deviation of the square of residuals and a scatter plot of the residual versus the predicated values.

6.2.9.1 Time Prediction Models

6.2.9.1.1 IC PROJECTS

The standard deviation of the square of residuals for models based on adjusted data (shown by Equation 6 – 3 & 6 – 4) was 0.01359 for *All road projects,* 0.01277 for *AC road projects* and 0.01768 for *DBST projects* however for models based on unadjusted data (shown by Equation 6 – 1 & 6 – 2) was 0.01416 for All road projects, 0.01195 for AC road projects and 0.02359 for DBST projects. The results indicate that the models based on ***Adjusted*** data shall be selected for prediction of construction Time for IC projects. Thus the time prediction model shall be:

AC Road Projects

$$Log\ (T) = -47.058 + 8.7640\ Log\ (C) - 0.0394\ (Log\ (C))^3 \qquad \text{(Eqn. 6 – 10)}$$

DBST Road Projects

$$Log\ (T) = -32.759 + 6.1661\ Log\ (C) - 0.0268\ (Log\ (C))^3 \qquad \text{(Eqn. 6 – 11)}$$

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

The average percentage error of the model was 2.00 % for *All road projects*, - 2.00 % for *AC road projects* and 2 % for *DBST projects*. The results indicate that the model for time prediction is a very good fit of the data. The results are better that the model predicted by Chen (2006). The residual plots of the model for time – prediction indicate that there is no correlation with the residuals and thus the relationship can be accepted.

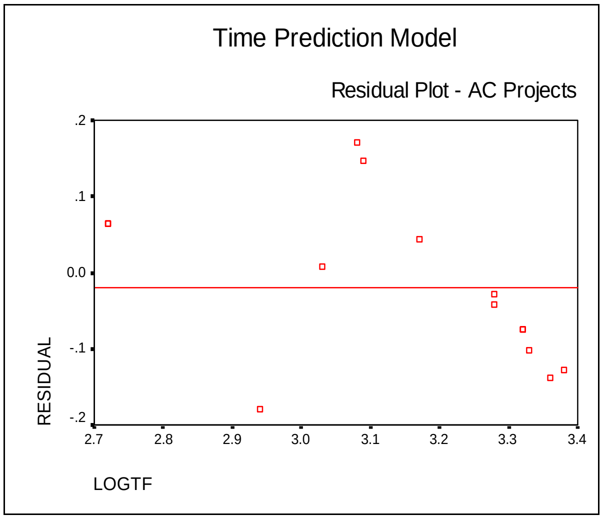


Figure 6 – 14: Residual Plot for AC - projects

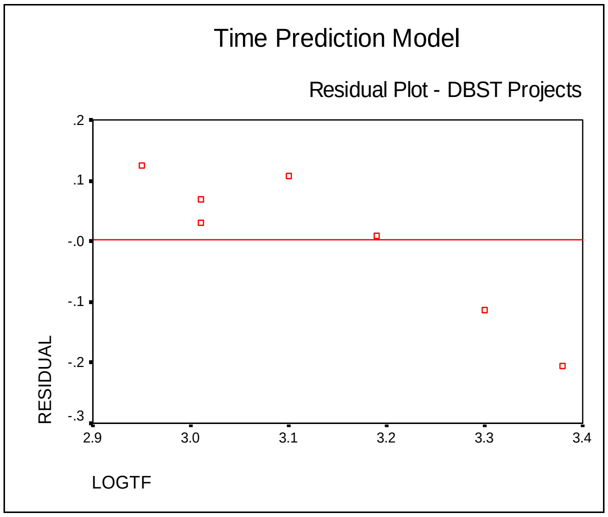


Figure 6 – 15: Residual Plot for DBST - projects

6.2.9.1.2 DC PROJECTS

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 in Equation 6 – 5. The standard deviation of the square of residuals for models based on adjusted data was large compared to IC projects. The mean of the data was 650 days but the mean for the model is 635 days. The standard deviation of the data is 332 days but that of the model is 284 days. The average percentage error was 4.00 % for *gravel surface road projects*. The results indicate that the model for time prediction is a very good fit of the data. These results are still above the model predicted by Chen (2006).

The residual plots of the model for time – prediction indicate that there is no correlation with the residuals and thus the relationship can be accepted.

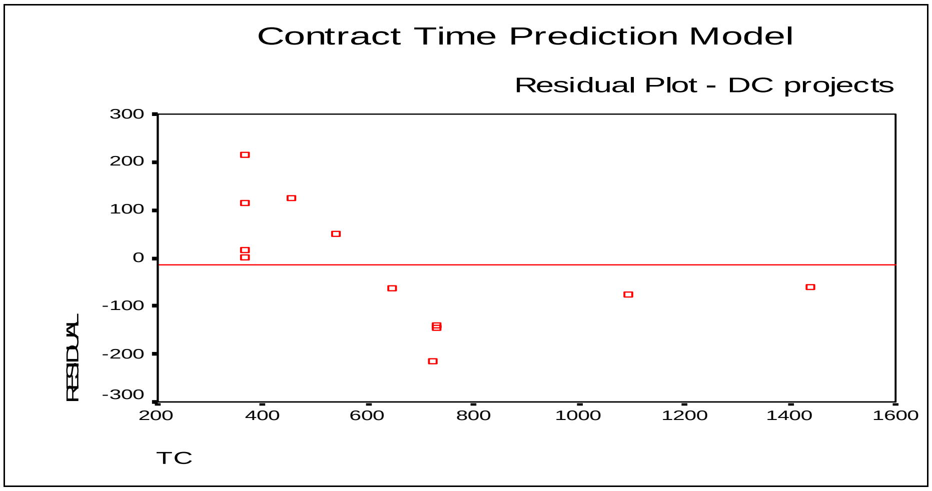


Figure 6 – 16: Residual Plot for DC – projects

6.2.9.2 Cost Prediction Models

6.2.9.2.1 IC PROJECTS

The standard deviation of the square of residuals for models based on adjusted data was 0.01075 for *All road projects*, 0.03006 for *AC road projects* and 0.10705 for *DBST projects* however for models based on unadjusted data was 0.01556 for *All road projects*, 0.04019 for *AC road projects* and 0.14790 for *DBST projects*. The results indicate that the models based on ***Adjusted*** data shall be selected for prediction of cost or construction cost for IC projects. Thus the cost prediction model shall be:

AC Road Projects

$$Log\ (C) = 6.9174 + 0.6332\ Log\ (L) + 0.0683\ (Log\ (L))^2 \qquad \text{(Eqn. 6 – 12)}$$

DBST Road Projects

$$Log\ (C) = 6.2154 + 1.3132\ Log\ (L) - 0.0464\ (Log\ (L))^3 \qquad \text{(Eqn. 6 – 13)}$$

Where C – Cost in Ethiopian Birr and L – Project Length in Km

The average percentage error was -4.00 % for *All road projects*, -8.00 % for *AC road projects* and -10.00 % for *DBST projects*. The results indicate that the model for cost prediction is a very good fit of the data. The results are above the cost model predicted by Chen (2006) which is

13.5%. The residual plots of the model for cost – prediction indicate that there is no correlation with the residuals and thus the relationship can be accepted.

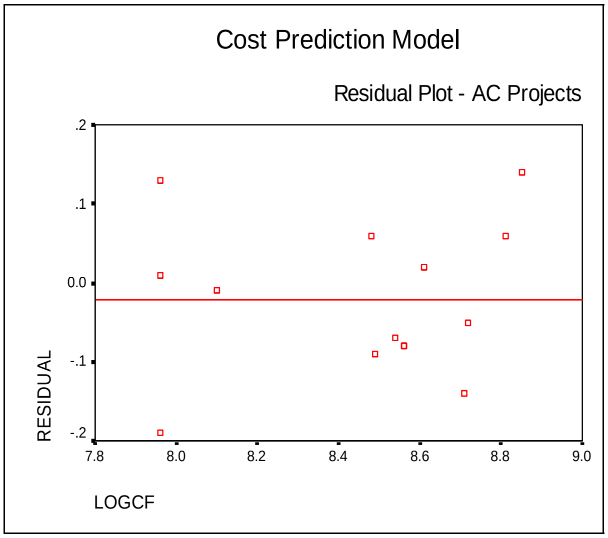


Fig. 6 – 17: Residual Plot for AC – projects (Cost Prediction Model)

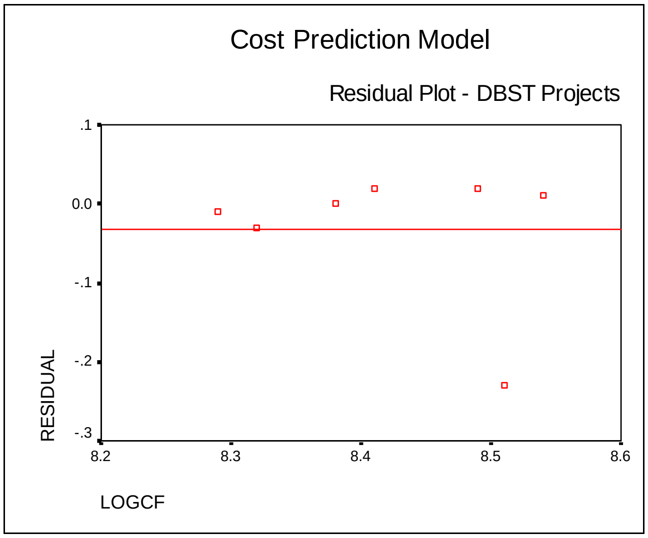


Fig. 6 – 18: Residual Plot for DBST – projects (Cost Prediction Model)

6.2.9.3 Discussion on Time Prediction Models

Numerous factors affecting construction time have been stated in Chapter 4 section 4.2 and the prioritized list for Ethiopian Road Projects has been based on;

1. Project Time Scope – measured by Cost and/or Length
2. Type of Construction
3. Construction Team Effectiveness
4. Project Environment

The results for IC projects have reviled that project time scope measured by *cost* rather than *length* or *cost and length: considered together* has been the major factor affecting the construction Time. This conclusion is in line with the Bromilow's and others assumption (Bromilow (1974)), Chan (1999), Choudhury (2003), Kaka (1991) and Chen (2006). The cubic formulas generated for time prediction have been found to be in line with the results given by Chen and Huang (2006) who got a better regression correlation by using cubic equations in stead of linear equations. Secondly the type of construction as modeled by the type of pavement work carried out in this project has been found also to affect construction duration, thus resulting in separate equations for Asphalt Concrete (AC) and Double Surface Treatment (DBST) projects. The model indicated that for a same amount of project cost AC projects will take longer time than DBST projects.

The results of the Bromilow Principle are coefficients which indicate the performance of the given project sector. After analysis one might be tempted to compare the coefficients developed for different project types and also project contexts. Endut et al (2006) stated that there is no meaning in comparing the coefficients so as to compare the results. As a result, model result coefficients have not been compared with International results as the coefficients are based on different situations and currencies.

The results for DC projects indicated that project time is less affected by cost and also by length, indicating that project time scope measured by cost and length is not applicable to domestic contractor in Ethiopian Road Construction case. This conclusion is inline with the recent study made by Endut et al (2006) which states that cost is poor predictor of time for Malaysian construction industry (including the civil/road construction projects). Love (2005) also concluded that cost is a poor predictor of time performance for Australian building projects. Ogunsemi and Jagboro (2006) cited by Endut et al (2006) found out the same for Nigerian building construction projects. Mean while Andinet et al (2006) found out that the time – cost model is applicable to Ethiopian building projects. So time prediction based on cost might not be a general case failure for developing countries.

Unfortunately domestic contractors are mainly engaged in the construction of Gravel Surface road and type of construction measured by surface type will not result in any conclusion. In addition to that since most gravel surface roads are new constructions problems related with location and accessibility will be critical, unlike DC, IC projects are mainly rehabilitation and upgrading where accessibility and location are less critical. Then the two major factors affecting project time for domestic contractors are construction time effectiveness and project environment. Since both are qualitative factors, not dealt in this quantitative study, then they have to be thoroughly researched to develop the real factors. In addition models other than regression shall be tested to identify a relationship. A good example is the research made by Chen and Huang (2006) which used neural network model with back propagation learning technique.

The fact that cost is not related to time in domestic contractor's project in Ethiopia indicate that DC projects have less contract amount and high actual contract completion dates. Then one critical question might be: ***"Are domestic contractors carrying out projects with less contract amount but with higher degree of difficulty resulting in excessive time overruns?"*** The results shown in Table 6 – 3 clearly indicate that the average cost overrun of DC project is only 11% compared to 19% for IC projects but the average time overrun is 77% compared to 59 % for IC projects.

To answer the question raised above the researcher collected contract documents of ***32*** projects of which 22 were IC projects and 10 were DC projects. Then an analysis of the contract bill of quantities based on the following group of works or treads was carried out based on Table 6 – 19. The summary of the results is shown in Table 6 – 20.

Group Name	Group Description of Works
Group I – General / Site Works	Living quarters, Offices, Laboratories, Vehicles with operating costs
Group II – Earth Works	Clearing & grubbing, Common earth work, rock and borrow excavation, Overhaul, sub -grade preparation, and capping layers.
Group III – Pavement Works	Sub – base, base , surface coatings and asphalt concrete works
Group IV – Major / Minor Drainage Works	Culvers, Structures (bridges), Pipes, Drainage works
Group V – Miscellaneous / Incidental Works	Road furniture: guide post, curbs, signs and retaining walls
Group IV – Day Work Provisions	Provisions made for different day work rates

Table 6 – 19: Work Treads for Project Comparison

The result of all projects indicated that DC project have 42% of the contract amount as earth work but IC projects have only 18% of contract amount. This clearly indicates that the DC projects will spend most of their time for earth work parts unlike IC projects.

Additional, DC projects have only 28 % as pavement works but IC projects have 52% for the same. But the results for DBST projects indicated that both have 20% as earth work. Pavement works will not require much time compared to earth works and thus the IC projects will not spend much time on them but will get the bulk of the payment from such works.

		DC Projects			IC Projects			
Item No.	Description	ALL	DBST	Gravel	ALL	AC	DBST	Gravel
Group I	General/ Site Preparation	**7%**	**13%**	**5%**	**11%**	**12%**	11%	8%
Group II	Earth Works	***42%***	***20%***	***48%***	***18%***	***10%***	***20%***	***36%***
Group III	Pavement	***28%***	***48%***	***23%***	***52%***	***65%***	***47%***	***20%***
Group IV	Major / Minor Drainage	**16%**	**12%**	**18%**	**11%**	**6%**	13%	26%
Group V	Miscellaneous	**7%**	**7%**	**7%**	**6%**	**5%**	7%	9%
Group IV	Day Work	**0%**	**0%**	**0%**	**2%**	**2%**	1%	2%
		100%	100%	100%	100%	100%	100%	100%

Table 6 – 20: Works Amount for DC and IC Projects

The above analysis indicates that DC projects face the most difficult part of the work which has less value. The researcher believes that the reason behind the non – validity of Bromilow principle for DC project but the opposite one for IC projects is mainly caused due to the above fact and other facts including lack of appropriate equipments, poor financial management, lack of clear strategic plan, lack of specialized banks catering the needs of the industry and involvement in many projects mainly to avoid liquidity problems (ERA (2005)).

Nevertheless the data analysis for DC projects has showed that there is a relationship between contract time and length. This implies that the contract time is affected by length than cost or cost and length. This result is inline with the research by Love et al (2005) who stated that building construction time is affected more by other factors like gross floor area and number of floor levels than cost.

6.2.10 Discussion on Cost – Prediction Model

Not many researches have developed cost prediction models as they were focused on developing a time – cost relationship where time and cost are the only variables. Chen and Huang (2006) developed a cost prediction model based on Floor area and number of floor levels for school reconstruction projects. Love et al (2006) also used the above variables to develop cost models. The research results indicate that IC projects yield a good relationship with length. Not surprisingly again DC projects have not yield any relationship. The reasons for DC projects not following the relationship with length indicate that cost is dependent on other factors than length. Further research is required to identify and develop a cost prediction model for DC projects.

6.3 Analysis of Hypothesis II

One of the theories of this research is the S – Curve concept which as shown in Chapter 4 & 5 has developed as a theory (PMI (2000), PMI (2004), Practice Standard for EVM (2005), Christensen (2007), Johansen & Wilson (2006), Walker (1995), Chan (1999), Choudhury & Rajan (2003), Love et al (2005), Kaka & Price (1991), Bromilow (1974), Endut et al (2006), Chen & Huang (2006), Nassar et al (2005), Barraza (2004) and Chang (2001). Thus this research was focused on testing the following:

- *Verify the validity of S – curve pattern for cumulative cost – time curve for the public road construction projects in Ethiopia by using Earned Value Management (EVM)*

As shown in the methodology part two case study projects have been selected to carry out the analysis. The selection has been made based on available data. The first project – Project A was the Debre Markos – Merawi road project and the second one – Project B was the Kulubi Denego Harar road project.

The analysis of the second hypothesis has been carried out according to the following steps:

1. Developing the Planned Value (PV) and Earned Value (EV) Data
2. Plotting the S – Curve for PV and EV
3. Validate on the S – Curve concept
4. Compute the schedule variances: Schedule Variance (SV) and Schedule Performance Index (SPI)
5. Develop the performance reliability index
6. Forecast the Estimated at completion based on time (EAC_t)

7. Discuss on Results based on SPI values and reliability indexes

The EVM is highly dependent on the level of work breakdown structure (WBS) of the project. The WBS needs to be defined down to at least the level at which EVM reporting will be applied. Making decisions about this level is critical. Too low will create an overload of data and too high could lead to the masking of some vital information. According to the literature, most construction projects will find 3-4 levels within a WBS will adequately meet their data requirements for running a reliable EVPM system, Howes (2000) cited by Daneshmand and Khreich (2006). However this research has used the WBS developed for the projects provided in the final reports (Final Report (2005) & Final Report (2004)). Since the case study involved two projects, it was found necessary to standardize the tasks according to the table shown in Table 6 – 21 below. The activities were categorized based on the Ethiopian Road Authority Standard: Standard Technical Specification (ERA (2002)).

Table 6 – 21: Standardized Tasks

Task No.	***Description***	***Detail***
1	General	Preliminary Works (Office, Laboratory, Engineer's Accommodation) & Traffic Diversion and Management Works
2	Site Clearance	Clearing, Grubbing, Removal of existing structures.
3	Drainage	Drains (Open Drains or Ditches), Culverts and Erosion protection works
4	Earth Works	Preparation of road bed, excavation, Borrow and Embankment construction
5	Subbase - Base Works	Construction related to Subbase and base layers
6	Surfacing Works	Prime coat, tack coat, and surface treatment works (DBST or AC)
7	Structures	Bridges, Foundations, and Stone Masonry works
8	Ancillary Works	Gabions, posts, guardrails, road signs.
9	Miscellaneous Works	Sundries, Day works and provisional sums.

6.3.1 Case Study (Project A and Project B)

Project A was carried out from April 1999 – June 2005 and Project B was carried out from June 1999 – August 2005. The basic information of the projects is tabulated in Table 6 – 22 below. The analysis based on the steps developed above is presented as follows:

6.3.1.1 Developing the Planned Value (PV) and Earned Value (EV) Data

The Project A's final completion report (Final Report (2005)) has tabulated the planned values based on the original plan (effective from April 1999) and the revised or accelerated plan (effective from August 2000). The project B's final completion report (Final Report (2004)) has tabulated the planned values based on the final, 9th revised plan (effective from December 2003). The consultants of the two projects have tabulated the actual performance of the contract by using "actual accomplishment'' of the works.

Table 6 – 22: Case Study Projects Basic Information [35 & 36]

Works Contract Details	Project - A	Project - B
Name of Project	Debre Markos - Merawi	Kulubi – Dengego – Dire Dawa & Dengego - Harar
Client	Ethiopian Road Authority	Ethiopian Road Authority
Contractor	China Wanbao Engineering Corporation	China Road and Bridge Corporation (CRBC)
Consultant	Black & Veatch Africa in assc. with Continental Consultants	Wilbur Smith Associates in assc. with Pan African Consultant
Financing	IDA and GoE	IDA and GoE
Location	Western Part of Ethiopia	Eastern Part of Ethiopia
Surface Finish	Asphalt Concrete (AC)	Asphalt Concrete (AC)
Date of Contract Signature	19th March 1999	1st June 1999
Commencement Date	4th April 1999	8th June 1999
Completion Date	3rd April 2002	7th December 2001
Contract Time	1,096 days	913 days
Final Completion Date	15th February 2005*	18th September 2004
Final Completion Time	2,136 days	1,907 days
Extension of Time	822 days	662 days
Original Contract Price (excluding price variation)	ETB 327,070,830.00	ETB 162,178,583.00
Final Contract Amount (including price variation)	ETB 412,366,861.18	ETB 209,413,902.63
Value of Variation	ETB 85,309,861.18	ETB 3,271,355.83
Value of Price Escalation	ETB 204,139,270.10	ETB53,795,289.88
Final Length	219.80 Km	80.00 Km
Liquidated Damages		ETB 14,710,970.76
Currencies and Proportions of Payments	30% ETB and 70% US $	25% ETB and 75% US $
Contractual Exchange Rate	1 US$ = 7.227 ETB	1 US$ = 7.502 ETB
Advance Payment	20 %	20 %
	* Additional Work carried out during the defects liability period	

It was assumed that the actual accomplishment has been carried out by measuring the work performed in the given period of time. As the measurement tool assumed for this research is the discrete percent completed method, the actual accomplishment has been take as the *earned value*. Thus the earned value of the project has been tabulated by the percent complete method which will have better results as long as the proper measures employing the actual completed work compared to the total work to be completed are used. This research has reviewed the interim payment certificates of the project to ascertain that the said works have been carried out in the payment period. The results indicated that the earned values from the "actual accomplishment'' of the works are in compliance with the amount paid to the contract in the stated period of the payment.

The values of the planned value and earned values for each activity has been developed and showed in Appendix: Appendix A.1 for project A and Appendix B.1 for project B.

6.3.1.2 Plotting the S – Curve for PV and EV

The S – Curve (PMB) for Project – A has been developed as shown in Appendix A. 2 and that of Project – B has been shown in Appendix B.2.

6.3.1.3 Validate on the S – Curve concept

The S – Curve concept relies on the smoothness of the curve. Project - A has showed no progress from the date of commencement up to beginning of 2000. Actual commencement on the site was on November 1999. The S – Curve for Planned value both original and revised one do not fulfil the basic assumption of an S – curve. The curves indicate that the planned construction from March 2000 to September 2004 is zero. This is totally unacceptable for a huge project like the one under this case study. This might indicate that the contractor was not utilizing the plan and the consultant has also accepted that the plan can not be implemented. The S – Curve for Earned Value (EV) is rather reasonable. Though the project started late by about eight months, the progress from October 2000 seems reasonably smooth.

Project – B has showed an excellent progress at the beginning but the progress from then onwards was below the planned one. Since the planned value has been computed based on the last revised plan which was submitted towards the end of the project, the difference between the planned and earned curves reviles a relative closeness.

6.3.1.4 Compute the schedule variances: Schedule Variance (SV) and Schedule Performance Index (SPI)

The SV for the projects has been shown in Appendix A. 1 and B. 1. The data plot of the SV for Project – A indicated that the project was ahead of schedule only for a brief five months time i.e. March 2004 – September 2004; refer to Appendix A.3. Similarly, the data plot of the SV for Project – B indicated that the project was ahead of schedule only for a brief five months time i.e. October 1999 – May 2000; refer to Appendix B.3.

The SPI for the projects has been shown in Appendix A.1 and B.1. The SPI for project A was almost always below 1.00. The data plot of the SPI indicated that the project was ahead of schedule only for a brief five months time i.e. March 2004 – September 2004; refer to Appendix A.3. In contrast, the SPI for the project - B was greater than 1.00 for 12% of the time. 45 % of the time the SPI of the project was between 0.90 – 1.00. The data plot of the SPI indicated that the project was ahead of schedule only for a brief five months time i.e. October 1999 – May 2000; refer to Appendix B.3.

According to Chang (2001), performance indexes can be used to categories performance ranges. As shown in Figure 4 – 3, the Project – A performance can be categorized as below unsatisfactory up to February 2003. The performance from February 2003 – January 2004 was unsatisfactory and for the next three months was average. The performance towards the end of 2004 was towards excellent range and for the remaining period was above average and that of Project – B can be categorized as excellent towards the beginning and above average for most of the time. This result couldn’t represent the real progress of the project as the final revised plan, which is developed towards the end of the project was used.

6.3.1.5 Develop the performance reliability index

Nassar et al (2005) developed performance reliability index based on SPI. This research has adopted the same method to develop the reliability index which indicates with what probability the project will be achieving the specified SPI.

Since project - A has not shown any planned progress until the 21st month (November 2000), the SPI data before that was not used to develop the reliability index. The same was done for project – B and the data before September 1999 was neglected. The Weibull probability functions have been used to develop the reliability index. According to the steps shown in section 5.6, the analysis was carried out in spreadsheet formats and the results indicated the following Figure 6 – 19 and 6 - 20.

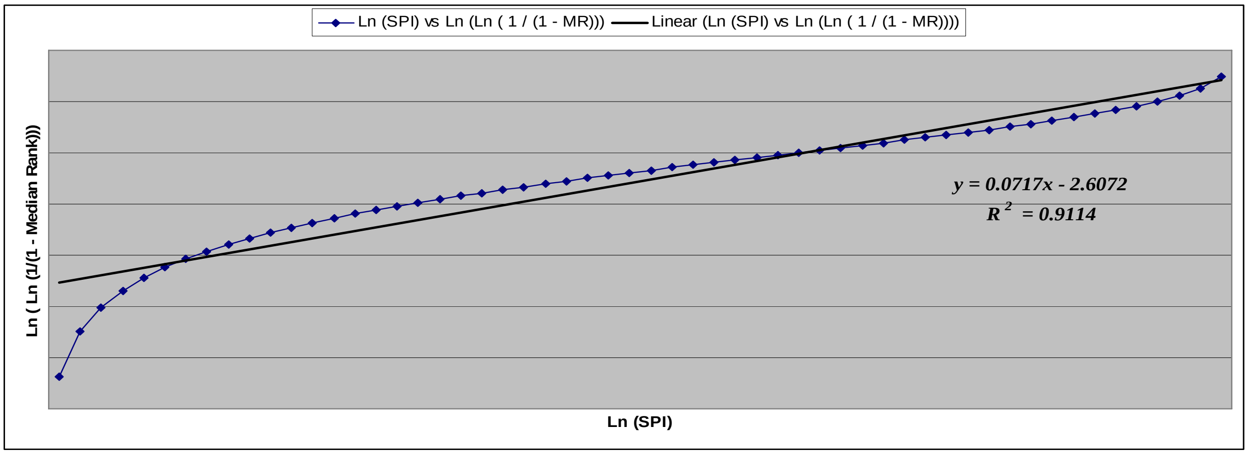


Figure 6 – 19: Goodness of fit – Weibull Function Parameters – Project A.

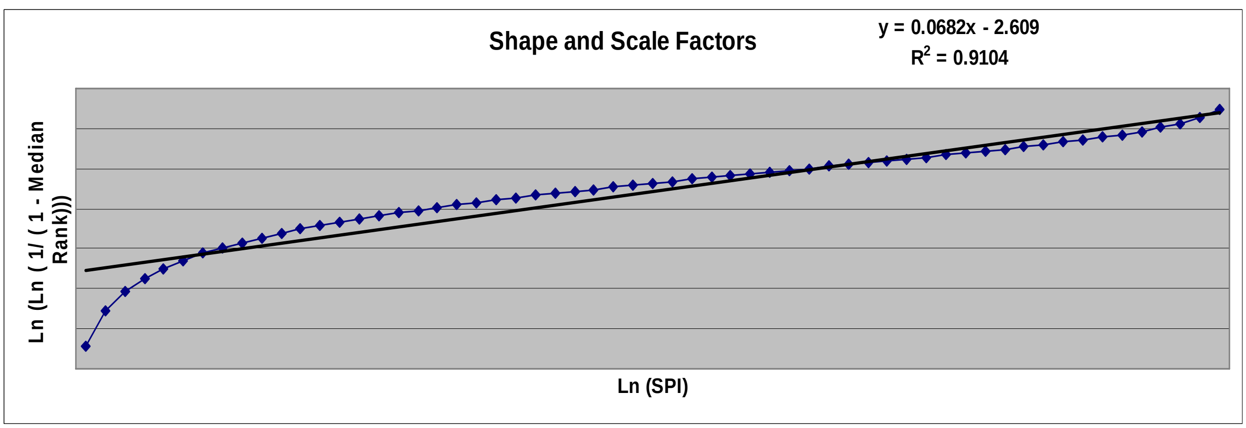


Figure 6 – 20: Goodness of fit – Weibull Function Parameters – Project B.

The above result for Project - A indicated that:

$\beta = m = 0.07171$ *and,* (Eqn. 6 – 14)

$\alpha = e^{b/\beta} = e^{(-2.6072/0.07171)} = 1.61404 \times 10^{-16}$ (Eqn. 6 – 15)

The result for Project - B indicated that:

$\beta = m = 0.0682$ *and,* (Eqn. 6 – 16)

$\alpha = e^{b/\beta} = e^{(-2.609/0.0682)} = 2.43224 \times 10^{-17}$ (Eqn. 6 – 17)

Based on the above shape and scale factors, the performance probability and reliability of not achieving the specified performance were developed as shown in Figure 6 – 21 and 6 - 22.

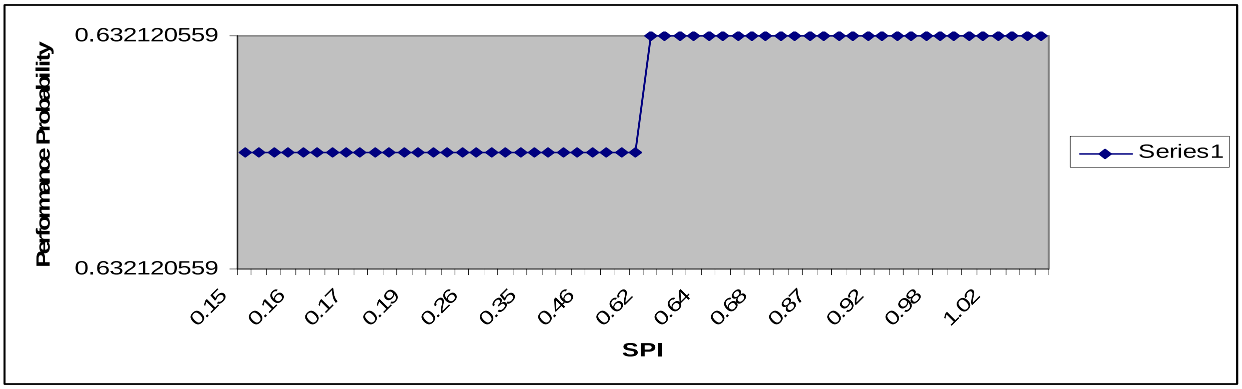


Figure 6 – 21: Performance Graph – Project A

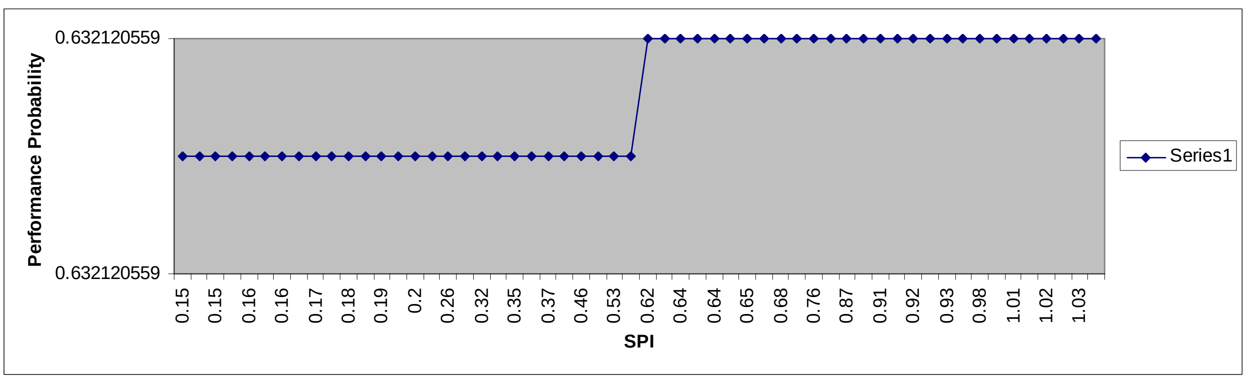


Figure 6 – 22: Performance Graph – Project B

The charts clearly indicate that the probability of achieving any of the performance levels is the same. The major advantage of using Weibull distribution was the fact that it is robust enough to assume a number of different distributions (including the normal, exponential and beta distribution). Usually predefined distribution assumptions are often used for example when modeling activity Times for probabilistic scheduling techniques like PERT (Program Evaluation Review Technique). The above figure clearly indicates that the probability function of any form did not fit the data, indicating the normal activity distribution used to develop the S – curve is not applicable to Ethiopian Road Projects. Thus, the S – curve theory has been rejected for the case study projects.

The parameters α and β had also a history to tell. According to Nassar et al (2005) in SPI's terms, the shape parameter β indicates whether the performance of the project in terms of SPI is increasing, constant or decreasing. A $\beta > 1.0$ indicates that the project has an increasing index rate, i.e., there is an improvement in the performance of the project from one period to another. A $\beta = 1.0$ indicates a constant index rate and $\beta < 1.0$ indicates a decreasing index rate. The desired rate is therefore $\beta \geq 1$. The scale parameter α (or the Weibull characteristic life) is a measure of the performance variability. A high alpha means more variability in the project performance in terms of the index values.

For both Project A and Project B, the β_A = *0.07171 and* β_B = *0.0682 respectively, are very close to zero than to 1. Using the shape factor alone, it can be concluded that the performance of the contractors is very poor. The very low value* scale *parameter (α) indicated that the projects performance is less variable. Though this has been obvious through out the project phase, the consultant for Project A did not mention a detail of it in its final report (Final Report (2005). The consultant for project B clearly and explicitly indicated that the contractor's performance was poor (Final Report (2004). The Consultant further stated that if performance was scaled from 1 to 10, the contractor for project B would score a low 5.*

6.3.1.6 Forecast the Estimated at completion based on time (EACt)

The Estimated at completion based on time (EAC_t) has been calculated based on the formula shown below:

$$EAC_t = \frac{BAC}{SPI} \times \frac{BAC}{Months}, \text{ where} \qquad \text{(Eqn. 6 – 18)}$$

BAC – Budget at completion = 385.323 Million ETB for Project – A and 147.89 Million ETB for Project – B

Months – The Original planned (original completion time + Extension of Time) completion time in months = 64 Months for Project – A and 53 Months for Project - B

The results of the estimate at completion indicated that the time required to complete the project ranges from hundreds to thousands, indicating that estimate at completion (EACt) is not a good measure for forecasting completion time when the performance of the project much below the requirement as the SPI will be quite small resulting in unrealistic time estimates.

6.3.2 Discussion – Hypothesis II

The hypothesis indicating that the project performance can be measured using an S – curve has been tested for Ethiopian Road Projects by using two projects as a case study. The results have indicated that the S – curve concept which is based on a normal distribution of activity progress was not valid for the case study projects as shown above by using the Weibull probability distribution function.

The fact that the performance is low in the first year of both projects might be related with lack of huge investment or misleading project time provision. According to Ballard (2000a) cited by Johansen and Wilson (2006), an extended project duration might result in a 'schedule push' where many activities are assumed to be executed towards the end of the project.

It can be well read that both projects did not have a proper master plan and Project B had nine revised plans. PMI (2004) states that high level of uncertainty and low staffing levels are common during first planning by the contractor and the resulting plans are less critical. Faniran et al. (1999) cited by Johansen and Wilson (2006) concluded that both too little and too much planning can lead to poor project performance. In addition to that the use of S – curve is further complicated when there is considerable request for extension of time resulting in unrealistic curves based on the original completion time. A very typical mistake in project rescheduling for both case study projects was the assumption that the project will catch up in the later phase and finish on the remaining period; this is practically never the case (Ferle (2007)). Research by Johansen and Wilson (2006) confirmed that many contractors view their own plans as likely to be unachievable.

The schedule variance and schedule performance indexes have not also provided a reasonable performance measurement tool mainly because project – A is well below the schedule and Project – B is using a plan prepared close to the end of the project. Surprisingly, Kris and Michael, 2004 concluded that the Highway Progress Schedule reports in Michigan US do not also accurately represent the actual progress of the projects. Miskawi (1989) cited by Blyth and Kaka (2006) stated that the reliability and accuracy of S – Curves is still in question Singh and Lakanathan (1992) cited by (Daneshmand and Khreich (2006)), concluded that the application of “S curves” for cash flow projections can achieve an accuracy of approximately 88-97%.

In addition estimate at completion (EAC_t) is not a good measure for forecasting completion time for Ethiopian Road Projects as the Schedule Performance Index (SPI) is quite low.

7 PART IV - RESEARCH CONCLUSION AND RECOMMENDATION

7.1 The Research Conclusion

This part will present "What were the hypotheses tested?" and "What were the findings?" Accordingly the results will be showed based on the two hypothesis tested.

7.1.1 Hypothesis I – Bromilow's Principle

The conclusion from the first hypothesis and its results have been categorized into time and cost prediction models.

7.1.1.1 Time Prediction Models

The Bromilow's principle has been found valid for IC projects carried out under International Competitive Bidding Contracts. The formula to calculate time for the project categories would be:

IC - AC Road Projects

$$Log(T) = -47.058 + 8.7640\ Log(C) - 0.0394\ (Log(C))^3 \quad \text{(Eqn. 7 – 1)}$$

IC - DBST Road Projects

$$Log(T) = -32.759 + 6.1661\ Log(C) - 0.0268\ (Log(C))^3 \quad \text{(Eqn. 7 – 2)}$$

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

The Bromilow's principle has been found to invalid for DC projects carried out under National Competitive Bidding Contracts. 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:

DC – GS Road Projects

$$(T_C) = 15.0615 + 20.2224\ (L) - 0.2631\ (L)^2 + 0.0013\ (L)^3 \quad \text{(Eqn. 7 – 3)}$$

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

7.1.1.2 Cost Prediction Models

The cost predication models for IC projects were developed based on the project types as shown below:

IC - AC Road Projects

$$Log\ (C) = 6.9174 + 0.6332\ Log\ (L) + 0.0683\ (Log\ (L))^2 \qquad \text{(Eqn. 7 – 4)}$$

IC - DBST Road Projects

$$Log\ (C) = 6.2154 + 1.3132\ Log\ (L) - 0.0464\ (Log\ (L))^3 \qquad \text{(Eqn. 7 – 5)}$$

Where C – cost in Ethiopian Birr and L –project length in km

The cost predication model was not applicable for DC projects.

The results for DC projects indicated that project time is less affected by cost and also by length, indicating that project time scope measured by cost and length is not applicable to domestic contractor in Ethiopian Road Construction case.

The above analysis indicated that DC projects face new construction where location and access are critical and thus the most difficult part of the work with less value. The researcher believes that the reason behind the non – validity of Bromilow principle for DC project but the opposite one for IC projects is mainly caused due to the difficult construction, lack of appropriate equipments, poor financial management, lack of clear strategic plan, lack of specialized banks catering the needs of the industry and involvement in many projects mainly to avoid liquidity problems.

7.1.2 Hypothesis II – S – Curve

The finding of the second hypothesis clearly indicated that the S – curve theory is not valid for the case study projects. 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.

7.2 The Research Recommendation

The following recommendations are forwarded for respective project stake holders:

Project Owners –

A. Ethiopian Road Authority and other regional road authorities shall utilize the developed models to predict project Time and Cost and apply the formulas developed for first planning of their respective road projects.
B. Need to continuously update the formula with additional project data's.
C. Use completion time as one criteria for bid evaluation
D. Check on schedules submitted and approved by the engineer for validity of the proposed method and stipulated performance.
E. Use EVM techniques with S – curve for performance measurement and forecasts.
F. Provide funds for research on project basis.

Consultants –

A. Apply the formulas developed for feasibility and other studies.
B. Check on the master plan for the proposed method and stipulated performance.
C. Check on the S – curve by using EVM techniques and use the variances and performance indexes to evaluate the status of the project.

Contractors –

A. Use the models developed to predict time and also cost during bidding stages.

B. Apply the EVM for their project by monitoring the Planned, Earned and Actual Cost Values to determine schedule and cost variances and also forecasts.

7.3 Recommendation for Future research

A. Other factors affecting duration of road projects shall be studied in order to provide a comprehensive model.

B. Investigation shall be carried out to identify other relationships for DC projects.

C. The probability distribution functions shall be developed for road project activities and a model to predict S – curves based on a number of projects shall be developed.

D. A case study shall be carried out to effectively implement the earned value management technique and check the planned, earned and most importantly the actual cost values of a project.

References

Abdo Abatemam (2006). *Delays in public building construction projects and their consequences*. Master's Thesis. Addis Ababa University, Ethiopia

Abebe Dinku (2003). *Construction Management and Finance.* Addis Ababa University Press, Addis Ababa, pp.11 -12

African Economic Outlook (2008). *Master data file*. Forthcoming

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

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*, Vol. 130, No. 1, pp. 25 – 32

BBC (2007). http:// www.bbc.com, viewed 10 May 2007

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

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

Bekele Negussie (2005). *The Ethiopian Reporter*. Posted on Friday, June 02, 2005

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, No. 1, pp. 82 – 95.

Bromilow, F. J. (1974). Measurement and scheduling of construction time and cost performance in building industry. *The Chartered Builder*, 10.

Burns, Robert B. (2000). *Introduction to Research methods London.* Sage Publications.

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

Chan, Daniel W.M. and Kumaraswamy, Mohan M. (1995). *A study of the factors affecting construction durations in Hong Kong*. Construction Management and Economics, Vol. 13, pp. 319 - 333.

Chang, Andrew and Shing – Tao (2001). *Defining Cost/Schedule Performance Indices and their ranges for design Projects*. Journal of Management in Engineering, Vol. 17, No. 2, pp. 122 – 130.

Chen, Wei Tong and Huang, Ying - Hua. (2006). *Approximately predicting the cost and duration of school reconstruction projects in Taiwan.* Construction Management and Economics, Vol.24, pp. 1231 - 1239.

Chitkara, KK (2000). *Construction Project Management, Planning, Scheduling and Controlling*. pp. 8 -9 & pp. 341 -365.

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

Chris Hendrickson (1998). *Project Management for Construction, Fundamental Concepts for Owners, Engineers, Architects and Builders.* Carnegie Mellon University, Pittsburgh, Chapter 9.

Christensen, David S. (2007). Comprehensive Bibliography of Earned Value Literature,http://www.suu.edu/faculty/christensend/ev-bib.html, viewed 20 October 2007.

Christensen, David S. (1989). Management Control Systems Theory and C/SCSC. *National Estimator*, 8:29-34, (Fall).

Christensen, David S. (1990).The Role of Analysis in C/SCSC. *Program Manager*, pp. 26-33 (July-August).

Christensen, David S. (1993). Determining an Accurate Estimate At Completion. *National Contract Management Journal*, Vol. 25 pp. 17-25.

Christensen, David S. (1993). The Estimate At Completion Problem: A Review of Three Studies. *Project Management Journal*, Vol. 24 pp. 37-42 (March).

Christensen, David S. (1999).Using the Earned Value Cost Management Report To Evaluate the Contractor's Estimate At Completion. *Acquisition Review Quarterly (summer).*

Christensen, David S., and Kirk Payne (1992). CPI Stability – Fact or Fiction? *Journal of Parametrics* Vol. 10, pp. 27-40.

Congressional Research Service (2003). Inflation: Causes, Costs, and Current Status, *Report for Congress, Congressional Research Service*, The Library of Congress May 20, 2003.

Construction Ahead (2005). Going a long way. *Issue 2*, Vol. 6, pp. 29, Ethiopia.

Creswell, John W. (2003). *Research Design: Qualitative, Quantitative and Mixed Methods Approaches.* Second Edition UK: Sage Publications.

Daneshmand, P., Khreich, A., (2006). *Assessing the performance of road construction projects: - The practical application of EVPM Method (Case Study).* Blue Visions management Pty Ltd (BVM) and Leighton Contractors, NSW, Australia.

Devore, Jay L. (2000). *Probability and Statistics for Engineering and the Sciences.* 5th edition, Thomson, Duxbury.

Dogan, Sevgi Zeynep. , Arditi, David. , and Gunaydin, H. Murat. (2006). Determining Attribute Weights in a Case Based Reasoning (CBR) Model for Early Cost Predication of Structural Systems. *Journal of Construction Engineering and Management,* Vol. 132, No. 10, pp. 1092 - 1098.

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)*,13-15 June 2006.

ERA (1997). *Manual Functional Road Classification.* Ethiopian Road Authority, 1997.

ERA (2002). *Standard Technical Specification*. Ethiopian Road Authority, Federal Democratic Republic of Ethiopia.

ERA (2005). *DCI: How Is It Performing Over the RSDP Period? Paper Prepared for Mid-Term review of RSDP*. Planning and Programming Division, Ethiopian Road Authority.

ERA (2006). *Nine Years Report on RSDP by Ethiopian Road Authority* (ERA).

Ethiopia Population (2008).http://www.nationsencyclopedia.com/Africa/Ethiopia population .html [viewed 11 May 2008]

Ferle, Maja (2007). *Implementing Earned Value management on IT projects*, SRC.SI d.o.o., Slovenia.

Final Report (2005). Debremarkos - Merawi Road Project. *Final Report*, Ethiopian Road Authority.

Final Report (2004). Kulubi – Dengego – Harra Road Project. *Final Report,* Ethiopian Road Authority.

Fink, Arlene (1998). *Conducting Research Literature Reviews*, SAGE Publications.

Fitsum, Shimelse and Yihenew (2007). *The practice and challenges of time planning in Ethiopian Road Construction.* Final year project, AAU, Ethiopia

Fortune Newspaper (2007). *Volume 8, No. 371*, June 10, 2007.

Gowan, J. Art, Mathieu, Richard G., Hey, Mark B. (2006). Earned value management in a data warehouse project. *Journal of Information Management & Computer Security*, Vol. 14, No. 1, pp. 37-50.

Halpin, Daniel W. (2006). *Construction Management*. 3rd Edition, John Wiley & Sons.

Hassanein, A. and Moselhi, O. (2004). Planning and Scheduling Highway Construction. *Journal of Construction Engineering and Management*, Vol. 130, No. 5, pp. 638 – 646.

Hazlitt Henry (1965). *What You Should Know About Inflation?* D. Van Nostrand Company, Inc.

Index of Economic Freedom (2007). Ethiopia, pp 173 – 174, 2007.

International Monetary Fund (2006). *International Financial Statistics*. International Monetary Fund (IMF) 2006 CDROM.

Iyer, K.C and Jha K. N. (2006).Critical factors affecting schedule performance: Evidence from Indian Construction Projects. *Journal of Construction Engineering and Management*, Vol. 132, No. 8, pp. 871 - 881.

Johansen, Eric and Wilson, Brian (2006). Investigating first planning in construction', Construction Management and Economics. Vol. 24, No.12, pp. 1305 – 1314.

Jung, Youngsoo and Kang, Seunghee (2007). Knowledge – Based Standard Progress Measurement for Integrated Cost and Schedule Performance Control. *Journal of Construction Engineering and Management*, Vol. 133, No.1, pp. 10 – 21.

Kaka, Ammar and Price A.D.F. (1991). Relationship between value and duration of construction projects. *Construction Management and Economics*, Vol. 9, pp. 383 - 400.

Kothari, C.R. (2004). *Research methodology, Methods and Techniques*. New Age International Limited Publishers.

Kris G. Mattila, and Michael R. Bowman (2004). Accuracy of Highway Contractor's Schedules. *Journal of Construction Engineering and Management*, Vol. 130, No. 5,pp. 647 - 655.

Kumar, Ranjit (1999). *Research Methodology: A step-by-step approach*. London: Sage Publications.

Kumaraswamy, Mohan and Chan, Daniel W.M. (1995). Determinants of construction duration. *Construction Management and Economics*, Vol. 13, pp. 209 – 217.

Liberatore, Matthew J., Johnson, Bruce Pollack and Smith, Colleen A (2001).Project Management in Construction: Software Use and Research Directions. *Journal of Construction Engineering and Management*, Vol. 127, No. 2, March/April, 2001, pp. 101 - 107.

Lockyer, Keith and Gordon, James, (1996). *Project Management and Project Network techniques*. Sixth Edition, Chapter 1 & Chapter 10.

Love, Pete E.D.; Tse Raymond Y.C. and Edwards David J.Mattila (2005). Time–Cost Relationships in Australian Building Construction Projects. *Journal of Construction Engineering and Management*, Vol. 131, No. 2, pp. 187 - 194.

Major Projects Team (2006). *Guide for Adjustment of Prices in Construction Cost Estimates for Inflation and Changes in Market Conditions for Transport Scotland's Major Rail Projects Programme*, Transport Scotland.

Mekonnen Manyazewal (2000). Ethiopia's Development Challenge: Breaking the poverty cycle and the take-off into sustained development http://eea.ethiopiaonline.net/Info/ mekman.html

Medenke (2007). Construction Newspaper, *Issue Number 7*, Published on Wednesday December 10, 2007

Mohan M. Kumaraswamy and Daniel W.M. Chan (1995). Determinants of Construction Duration. *Construction Management and Economics,* issue 13, pp. 209 -217

Nassar, Khaled M., Gunnarsson Hordur G., and Hegab, Mohamed Y. (2005). *Using Weibull Analysis for Evaluation of Cost and Schedule Performance*. Journal of Construction Engineering and Management, Vol. 131, No. 12, pp. 1257 - 1262

Nick Moore (2000). *How to do research: the complete guide to designing and managing research projects*. London: Library Association Publications, 3rd Ed

NIST(2008). NIST/SEMATECH, e-Handbook of Statistical Methods, hosted at http://www.itl.nist.gov/div898/handbook/ viewed 17 January 2008

Nkado, Raymond N. (1995). *Construction time – influencing factors: the contractor's perspective.* Construction Management and Economics, Vol. 13, pp. 81 - 89

Othman, Ahmad Anuar (2006). Factors influencing the construction time of civil engineering projects in Malaysia. *Journal of Engineering, Construction and Architectural Management*, Vol. 13 No. 5 pp. 481-501

PMI (2000). *A guide to the Project Management Body of Knowledge (2000).* PMBOK® Guide 2000 Edition v 1.2

PMI (2004). *A Guide to the Project Management Body of Knowledge (PMBOK® Guide) (2004).* Third Edition by Project Management Institute Project Management Institute © 2004

PMI – EVM (2005). *Practice Standard for Earned Value Management.* Project Management Institute, 2005

Population (2008).http://www.indexmundi.com/ethiopia/population.html[viewed 10 May 2008]

Raby, Michael (2000). Project management via earned value. *Work Study,* Volume 49, Number1, pp. 6-9, MCB University Press, ISSN 0043-8022.

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

Stake, Robert E., (1995). *The art of Case study Research*. SAGE Publications Inc; U.K., India, USA.

Thomas Ng S., Cheung, Sai On, Skitmore, Martin, Wong, and Toby C. Y. (2004). An Integrated Regression Analysis and Time Series Model for Construction Tender Price Index Forecasting. *Journal of Construction Management and Economics*: Volume 22(5):pp. 483-493.

Thomas Uher, (2003). *Programming and scheduling techniques*. University of New South Wales Press Ltd, Australia.

Walker, Derek H.T. (1995). *An investigation into construction time performance*. Construction Management and Economics, Vol. 13, pp. 263 – 274.

Wubishet J. Mengesha (2004). *Performances for Public Construction Projects in Developing Countries: Federal Roads & Educational Building Projects in Ethiopia*. Doctoral Dissertation, NTNU, Norway

Wubishet J. Mengesha, (2007). Time Planning for Construction Projects: Conceptual Developments. *EACE Bulletin* Vol.7, No.2, April 2007.

Wubishet J. Mengesha, (2006). Stakeholders and their relationship for Public Construction Projects: The Case in developing countries. *EACE Bulletin* Vol.7, No. 1, September 2006.

Appendices

A. Hypothesis II –Data Case Study Project A

A.1. Planned and Earned Value Data
A.2. S – Curve
A.3. Schedule Variance (SV) and Schedule Performance Index (SPI) Plots

B. Hypothesis II –Data Case Study Project B

B.1. Planned and Earned Value Data
B.2. S – Curve
B.3. Schedule Variance (SV) and Schedule Performance Index (SPI) Plots

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: ABRAHAM ASSEFA

SIGNATURE: ____________________________

PLACE:

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

DATE: MAY 27, 2008