COST AND SCHEDULE ANALYSIS OF A STRUCTURE USING EARN VALUE MANAGEMENT

Submitted in partial fulfillment of the requirements

of the degree of

Master of Engineering (Civil)

by

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(With Construction Engineering and Management Subjects)

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University of Mumbai

(2015-2016)

Dissertation Report

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CERTIFICATE

This is to certify dissertation report entitled **“Cost and Schedule Analysis of a Structure Using Earn Value Management”** is a bonafide work of **Mr. Manojkumar Rajendra Shukla (Roll no. Anjuman 10)** submitted to the University of Mumbai in partial fulfilment of the requirements for the award of the degree of **Master of Engineering** in **Civil Engineering** with specialization in **Construction Engineering and Management** course conducted by University of Mumbai in Anjuman-I-Islam’s Kalsekar Technical Campus, New Panvel.

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CERTIFICATE

This is to certify that dissertation report entitled **"Cost and Schedule Analysis of a Structure Using Earn Value Management"** is the own work of **Mr. Manojkumar Rajendra Shukla (Roll no. Anjuman 10)** in partial fulfilment of the requirements for the award of the degree of **Master of Engineering** in **Civil Engineering** with Specialization in **Construction Engineering and Management,** in the Department of Civil Engineering of Anjuman-I-Islam's Kalsekar Technical Campus under my supervision during the period of 2015-2016.

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Declaration

I hereby declare that this written submission entitled "**Cost and Schedule Analysis of a Structure Using Earn Value Management"** represents my ideas in my own words and where others ideas or words have been included, I have adequately cited and referenced the original sources. I also declare that I have adhered to all principles of academic honesty and integrity and have not misrepresented or fabricated or falsified any data/fact in my submission. I understand that any violation of the above will be cause for disciplinary action by the institute and can also evoke penal action from the sources which have thus not been properly cited or from whom proper permission has not been taken when needed.

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Dissertation Approval for M. E.

This dissertation entitled ***Cost and Schedule Analysis of a Structure Using Earn Value Management*** by ***Manojkumar Rajendra Shukla*** is approved for the degree of ***Master of Engineering*** *in* ***Civil Engineering*** with specialization in ***Construction Engineering and Management***.

Examiners

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Place: Panvel

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Date: **Manojkumar Rajendra Shukla**

ABSTRACT

High rise residential projects suffer from cost overrun and time overrun due to multiple reasons. Earned value management tool can act as control check to review project cost and schedule of high rise project. Although, EVM is originated from manufacturing and industrial engineering, it can be applied to construction sector. EVM is not practiced in many residential projects due to lack of understandings the importance. The main objective of this project is to apply EVM to a high rise residential project and identify budget overruns and probable schedule slippages in the project through the parameters such as schedule variance, cost variance, schedule performance index, cost performance index. This research shall provide early indication of performance of projects based on the schedule and cost analysis and forecasting for the estimated work to complete in a residential high rise project. Using this EVM tool to track a ongoing project is extremely beneficial and gives an immediate feel about the performance of the project. The expected outcome of the project will show the difference in scheduled performance and actual performance of the project for a particular phase of the construction project. Based on the results and observations arise from EVM tool, corrective action can be suggested to revive the profitability of the high rise residential project. In this report, study of ongoing construction project of Mahindra Aura is done. Calculation of construction data cost wise as well as month and activity wise plan value, Actual cost and Earned value for the project. From the study I come to a conclusion majority of construction projects are delayed due to time overrun and cost overrun. From the project parameters it is found that, the ongoing project is behind the schedule as well as over budget. Original completion time for the project is 31 months but project will take 3 months more for final completion work also the estimated cost increased from 27 crores that was planned to 27.83crore. Using this EVM tool to track a ongoing project is extremely beneficial and gives an immediate feel about the performance of the project.

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Abbreviation Notation and Nomenclature

AC	Actual Cost
AD	Actual Duration
AT	Actual Time
BAC	Budgeted Actual Cost
BCWP	Budgeted Cost of Work Performed
BCWS	Budgeted Cost of Work Scheduled
CPI	Cost Performed Index
ACWP	Actual Cost of Work Performed
AD	Actual Duration
AT	Actual Time
BAC	Budgeted Actual Cost
BCWP	Budgeted Cost of Work Performed
BCWS	Budgeted Cost of Work Scheduled
CPI	Cost Performed Index
CPM	Critical Path Method
CR	Critical Ratio
CRC	Cost Reimbursable Contract
CV	Cost Variance
DOD	Department of Defense
EAC	Estimate at Completion
EAC (t)	Estimate at Completion at time t
ED	Earned Duration
ES	Earned Schedule
ETC	Estimate to Completion
EAC (t)	Estimate to Completion at time t
EVM	Estimate Value Management
FP	Fixed Price contract
IEAC (t)	Independent Estimate at Completion at time t
P	P-factor
PC	Percentage Completed
PD	Planned Duration

PD (t)	Planned Duration at time t
PM	Project Manager
PF	Performance Factor
PCWR	Planned Cost of Work Remaining
RACI	Responsible, Accountable, Consulted, and Informed
RB	Re-Baselined
RM	Risk Management
SCI	Schedule Cost Ratio
SP	Serial-Parallel indicator
SPI	Schedule Performed Index
SPI (t)	Schedule Performed Index at time t
SV	Schedule Variance
SV (t)	Schedule Variance at time t
TCPI	To Complete Performance Index
TV	Time Variance
VM	Value Management
WBS	Work breakdown Structure

Chapter 1

Introduction

1.1 General

In writing this report it was my goal to conduct some interesting research that could be compared against the theory. I found this possibility in the area of project management where people have done research in Earned Value Management (EVM). This methodology was developed to help Project Managers in following up their projects and take appropriate action when the project gets out of hand. (Marshall 2005).

This subject caught our specific interest as we noticed the simplicity and effectiveness of EVM in controlling projects. We were really eager to check if this method could also proof useful in a construction sector where it still had to earn stripes. Although the construction sector is one of the stereotype sectors when talking about projects, the implementation of EVM had not gone smoothly (Marshall 2005). Therefore, the question was asked by us "if this method would be implemented, would it then provide some value added for PM's and companies in following up projects?"

When we were looking for real life data we contacted several of the construction companies together with some smaller ones. Out of the large bunch of contacted company's data was obtained concerning two projects have no intention validating any theory or whatsoever. Therefore, the sample size is too large. It rather aimed at providing an extensive qualitative research where all possible influencing factors were discussed and explained based on our findings.

This thesis is written so that readers unfamiliar with EVM can find all necessary basics in the first part before starting with the summarizing some of the most interesting findings concerning this method in the second part. The third part focuses on EVM implementation and efficiency in the construction sector and hereby concludes the theoretical part. In part four introductions are given of our study and the methodology is explained. The sixth part gives an overview of the result of the research and is followed by the overall conclusion.

1.2 Importance of Study

Construction industry is an important industry at both the global level and national level. It is second largest sector in India. It provides huge employment to the people and plays a vital role in our country's economy. Project delay is a rare problem in the construction industry. Project overruns due to time and cost result in delays during project execution. In developing countries project overruns is a serious core where implementation of project faces many uncertainties. It results in wastage of scare financial resources, delays in providing facilities, development and also make construction costlier. With globalisation and technology driven economic growth all over the world, a scientific and systematic approach to project management becomes imperative to ensure that project objectives are attained within the constraints of time and resources.

EVM is the process of measuring performance of project work against a baseline plan. EVM application helps in providing performance standard for the evaluation of progress report of project and it also act as a control device to take care of time and cost. It provides better performance picture of project and gives better forecast of the final completion cost. Earned Value is an enhancement over the traditional process of cost accounting.

Traditionally the budgeted cost is evaluated by computing the difference between planned cost and actual cost incurred in a project. The focus was on planned expenditure and actual costs. Earned Value reveals future opportunities and it also examines actual accomplishment, With the help of EVM project managers get sufficient help to keep deep intuitive understanding into potential risk areas. So that with the help of clearer picture of the project cost performances, managers can create risk mitigation plans based on actual cost, schedule and technical progress of the work. It is like an alarm for the managers to identify and control problems by taking timely corrective actions before they become too great to overcome.

It provides better understanding of the project in terms of time and cost schedule. Earned value Management system is a set of guidelines to provide satisfactory completion of project. It has been seen that to cover cost overrun, project team undergoes cost reduction either by reducing the project scope and quality or by providing additional measures. Similarly, in case of time overrun, they plan crashing of activities or fast tract programs. Therefore, with the use of EVM system, project goals are achieved in a better way.

1.3 Objectives of Study

The experimental work is carried out to find the effect of varying proportions of cementitious materials on workability and compressive strength of concrete. Pursuant to this, following objectives are proposed in the present investigation.

- To identify causes of cost overruns and potential schedule slippage.
- Time management using EVM to deliver the project on or before deadline.
- Cost management using EVM to deliver the project in the estimated cost to attain higher profits.
- To evaluate the performance of construction project in terms of cost performance index (CPI) and schedule performance index (SPI)
- Creating a WBS from which an MS Project and preparing the Schedule.
- Co-relating the data after the WBS is prepared, with the original plan and finding the reasons for the delay in time and rise in cost.

1.4 Scope of Study

In view of the aforementioned problem as specified from the literature review. In this study factual evidence is presented for most of the theories treated in literature concerning the EVM methodology. In addition, the study reached many enthralling findings, following scope is outlined for the present study.

- Preparation of work plan on Gantt chart.
- Permission for site visit and collection of Primary data by studying live project.
- Preparation of all construction activities on Gantt chart on MSP.
- Listing of all activities with scheduled duration.
- Various calculation includes: S Curve chart, Cumulative EV, PV, AC and Cost *v/s* Duration Chart.
- Preparation of project performance indicators and tracking the schedule and activities and resource allocation.
- Final result and conclusion

1.5 Project Approach

The construction projects are so vast and complex in nature and therefore for simplification of work use of software came into existence. The project was scheduled and monitored using MSP. MSP software is a Project Management Software used for planning, scheduling and controlling the construction project. The steps involved in construction work of case study. The WBS for the project is created and several activities are identified, the durations of the activities are estimated on the basis of literature review, reviews from project managers and application of analysis of rates. The relationships are examined and applied to the activities.

1.6 Organization of Dissertation

The document on thesis topic organized in the following manner:

Chapter 1 gives an overview of research which includes introduction to the topic on performance analysis of EVM in construction industry, the importance of the study, its scope and objectives.

Chapter 2 is dedicated to the literature review that provided important information and played a vital role in the formation of this report.

Chapter 3 is the application of different projects scheduling techniques and basics of Earn Value Management.

Chapter 4 is dedicated to the materials and methods undertaken in the making of earned value analysis.

Chapter 5 is dedicated to recommendations results and discussions.

Chapter 6 is dedicated to the conclusions and future scope of the study.

Chapter 2

Review of Literature

2.1 General

Earn Value Management was invented in United States Department of Defense. In the 1960's DOD decided more appropriate control was needed to manage their huge projects and related finance. To be more specific it was them intend to obtain early warning signals and predict the outcome of their projects much earlier in the project life (BARR 1996).

Let's take a brief look at the history of EVM:

1960's: Earned Value based performance management began in the 60's based initially on department of defense cost/ schedule control systems criteria.

a. Earned value was used as an objective measure for progress i.e physical accomplishment.

1970-80’s: The DOD continued the use of earned value in response to bearing cost and scheduling risk in cost-plus contracting.

a. Contractors pushing high tech, newly developed weaponry.

b. Military having critical schedule needs (Arms Race)

1990’s: Policy moved Earned Value into all Federal agencies.

- OMB Circular: A-11, NASA Policy Directive 9501.3 DOD 5000.2R and DOE Order 413.3 to name a few (Durrenberger, 2003).

This was realized by creating a standard method to measure and evaluate a project’s performance based on basic measures. Since then EVM has proven to be very valuable as a control system for project managers who want to keep track of their projects in a quantitative way. EVM provides an analysis of both the cost and schedule performance of a project. This is done by analysing on a regular basis the value if the work that was planned, that is really executed and its actual cost. All values are expressed in monetary units, a main characteristic of EVM.

The unique interaction of the three project management elements (scope, time and cost) that is done by EVM provides PM’s with the crucial information on the performance and progress of their project during its life cycle. This information helps PM’s to identify what needs to be done to bring the project back on track, cost and schedule wise. The following section gives an overview of the basics of EVM. Based on several books and articles including Anbari (2003), Fleming Q.W and Koppelman J.M (2005), Vanhoucke (2009).

Besides the traditional EVM methods, the section also includes Earned Schedule (ES). This recently developed extension overcomes certain pitfalls of EVM, especially in forecasting duration. The section about ES is based on the article “Schedule is different” (Lipke, 2003).

2.2 Concept of EVM

Earned Value is a program management technique that uses “work in progress” to indicate what will happen to work in the future. EVA uses cost as the common measure of project cost and schedule performance. It allows the measurement of cost in currency, hours, worker-days, or any other similar quantity that can be used as a common measurement of the values associated with project work. EVA uses the following project parameters to evaluate project performance,

1. Planned Value
2. Earned Value
3. Actual Value

As noted, there are many ways to calculate the EV, PV and AC of work packages that are un progress, Comparison of those figures can serve to identify specific work packages in which performance and progress is inadequate or advanced, which will hopefully lead to remedial action by the project manager and team. Cost and schedule performance should be measured and analyzed as feasible with regularity and intensity consistent with project management need including the magnitude of performance risk. Analysis should be progressive and should follow the principle of management by exception. Variance thresholds should be established in the planning phase and should be used to guide the examination of performance (lipke 2003). Earned value project management is a well-known management system that integrates cost, schedule and technical performance. It allows the calculation of cost and schedule variances and performance indices and forecasts of project cost and schedule duration. The earned value method provides early indications of project performance to highlight the need for eventual corrective action (Lipke, 2005).

2.3 Definition of Earn Value Management

Some of the important definitions of earned value management referred in the published literature are:

Project Management Institute defines it as, “A methodology used to measure and communicate the real physical progress of a project taking into account the work complete, the time taken and the costs incurred to complete that work” (Antvik, 1998).

Englert and associates (2000), Inc, defines it as, “A method for measuring project performance. It compares the amount of work that was planned with what was actually accomplished to determine if cost and schedule performance is as planned.”

The user guide for Microsoft Project 2003 defines Earned value as, “a method for measuring project performance. It indicates how much of the budget should have been spent, in view of the amount of work done so far and the baseline cost for the task, assignment, or resources".

NASA defines it as, "An integrated management control system for assessing understanding and quantifying what a contractor or field activity is achieving with program dollars. EVM provides project management with objectives, accurate and timely data for effective decision making" (Henderson 2008).

Earned Value project management is well-known management system that integrates cost, schedule and technical performance. It allows the calculation of cost and schedule variances and performance indices and forecasts the project cost and schedule duration (Nadepour A 2011).

Earned Value analysis is a method of performance measurement. Eared value is a program management technique that uses "work in progress" to indicate what will happen to work in the future. Earned Value management is system for planning and controlling the project cost performances. EVM establish work packages earned value baseline by integrating project scope, time schedule and cost objectives (Verma A 2014).

2.4 Review of Earned Value Management

A review of literature uncovered three categories of knowledge regarding the contribution of earned value management to project success. Ample literature offers rational support for EVM's positive contribution (Fleming and Koppelman 1996; Christenson 1998; Abba 2001; Antvik *et al* 2001; Anbari 2003) Works of this type suggest the benefits of EVM across major project management processes including planning, executing, monitoring and controlling (PMBOK 2004). While logical and meaningful, these works are sources of propositional knowledge and in and of themselves, limited to providing theoretical beliefs and assertions.

Another source of knowledge is from the experimental accounts of project practitioners (Antvik 2001; Kauffman P *et al* 2002). These works are important in that, unlike theory, they offer empirical evidence based on personal experience and observations. They generally illustrate EVM's contribution in one or more project management processes. To the extent the author's projects were successful; a contribution to project success can be concluded from these experiential accounts.

A third source of knowledge about EVM's contribution to project success blends both theory and experience (Kim 2000; Vargas 2003). These works offer the highest level of precision in both their methodology and findings and can be said to offer scientific knowledge. Works in this category are research- oriented, and to date rely on qualitative methods to make relevant points. All emphasize EVM's contribution to project control (Kim 2000; Vargas 2003). Additionally, two of the three have emphasized EVM's contribution to project planning along with project control, yet differed on the relative strength of each (Vargas 2003). In Marshall's work, the author found that "…C/SCSC (EVM'S predecessor) have affected a Significant improvement in planning and a, positive but less significant. "Improvement in control." In Vargas's, the author concluded EVM" to be effective in the control of projects, yet dependent on a project's first having established effective plans what we know collectively from these research works is

1. EVM contributes to project planning.
2. EVM contributes to project control but perhaps more or less so than planning.
3. Since EVM contributes to these project management processes, and these processes are believed to positively influence project performance, it can be inferred that EVM, contribute the project success.

Ballard *et al* (2000), presented potential problems of the earned-value method with a brief review of the cost management concept. Traditional cost systems are reviewed in this paper from the viewpoint of work flow. Critique of the earned-value method includes:

1. While each cost account or activity is assumed to be independent in the earned value»; method, they should be considered dependent.
2. Managers can manipulate work sequences when releasing work to the field and it is possible to release work assignments that are not shielded from uncertainty.
3. In order to make cost variance (CV) positive, managers try to decrease the actual cost of work performed (ACWP) as much as possible. Overload resulting from reduced
4. Capacity can make work flow less reliable, which in turn can impact. The performance of downstream production units (PUs).

Cable *et al.* (2004), investigated the use of Earned Value Management (EVM) for tracking project performance across the portfolio, and explores the benefits of an interactive visualization technique called Tree maps to display project performance metrics for the entire portfolio on a single screen.

Jose V.A and Pereira C.A (2006) presented and discussed the main factors involved in the use of Earned Value Analysis (EVA) in the cost management of civil construction projects. These factors include advantages and disadvantages, difficulties and benefits, problems and solutions and criteria and results based on the experience of real case study in Brazil.

Lu *et al.* (2011), proposes a refined EVM approach based on discrete event simulation (scheduling simulation) to tackle complicated resource-constrained scheduling. A case study is used to demonstrate its applications on a resource-constrained schedule under postulated delay scenarios. It is found that this approach is conducive to truthfully reflecting the project performance status given a resource-constrained schedule subject to complicated activity: project delay. Conclusions are drawn by recapitulating the research contributions and addressing the limitations in the end.

Naderpour *et al.* (2011) explored the concept of earned value method, its methods and metrics, performance measurements and forecasting project progress. In order to compare between EVPM method and traditional method and also highlighted project report derived from using earned value method in the project indicated that the manager was able to have exact information about the project details and also mitigate the risks in his decisions in critical conditions of the project. Consequently, the project was finished alter a short period of time.

Azeem *et al.* (2014), contribution to develop thick model to forecast the estimated duration at completion. Two of these models are deterministic; earned value (13V) and earned schedule (ES) models. The third model is a probabilistic model and developed based on kalman filter. Algorithm and earned schedule management.

Mahadik *et al.* (2013) described knowledge about concept of construction project. Management with the application of Earned Value Management System. It also includes schedule monitoring, controlling, cost monitoring, controlling with respect to established baseline standards, and various elements of project management. The observations and knowledge from literature review are applied to analyze the construction project management using earned values analysis and management in Indian construction industry.

Virle *et al.* (2013) discussed the project manager's considerations and applicability of earned value management and earned schedule. It gives alerts to the project manager that where is he in the project. Whether his project is behind schedule, ahead schedule or on schedule.

From the beginning of a project and throughout all its stages, the project manager and the project management team have to address many questions. The most common questions are those who deal with the time schedule and the projected cost of the project. For instance, are we ahead or behind schedule? How efficiently are we using time? When will we likely finish the project? Are we under or over budget? How efficiently are we using our resources? How efficiently must we use our remaining resources? How much is the project likely to cost? Will we be under or over budget at the end of the project? How much will the remaining work cost? (PMI, 2005). Therefore, being able to forecast time and cost in projects and give an answer to the above question, with accuracy, is crucial for any project manager. EVM is a very powerful tool which is able to address the above questions and thus substantially benefits the project manager and the project management team. EVM often steps which are known as the ten steps of EVM. The first six steps concern the planning phase of the project and the next four focus on the project implementation (Antvik, 2013).

PMBOK (2013) defines a successful project as the one which the project manager manages to finish within the programmed time, the programmed cost and with the quality expected from the customers. The same approach we find from Caletka A.F (2009) suggested that the project manager should be able to keep the balance between those constrains. Antvik S (2012) provided a more nuanced approach and discuss the priorities among those elements, highlight that priorities are different from project to project and show how this can affect the balance among them. Antvik S (2012) explained a more practical approach by presenting the different shapes that the 'project management triangle' can take, depending on the element that has the problem each time. Antvik S (2012) insisted the need of a tool that can predict and help the project manager to have a clearer view of the project. Consequently, they propose the 'ten step" model of planning and implementing a project, widely known as the EVM 'ten step' model. The same approach can be found in other sources, and how can Earned Value Management and Lean improve a project management system in the construction industry?

Subramanian *et al* (2014) highlighted the main parameters involved in the calculation of Earned (Value Analysis (EVA) in the cost management of civil construction projects. The purpose of this dissertation is in 3-fold. Firstly, Earned Value Analysis software is developed in Visual studio 2008, SQL Server 2005, .Net (C# language). Next Comparison of selected parameters between MS Project 2007, Primavera P6 and developed software is done. Therefore, it can be concluded that the software could be used in a wide range of projects for Earned Value Analysis calculation.

Among all of the available sources of knowledge. Only certain works specifically address contract type with respect to EVM. Theoretical as well as research works support EVM'S contribution to projects under cost-plus contract arrangements (Fleming Q.W and Koppelman J.M, 1996; Kim, 2000). Similarly, propositional, empirical, as well as research works, exist in support of EVM's contribution to projects under fixed-price arrangements (Fleming Q.W and Koppelman J.M 1996; Antvik 2001; Kauffman *et al*. 2002; Vargas 2003). Qualitative justification is available in support of the belief that EVM contributes to project success generally, and under alternative contract types, in particular. Conspicuously missing from the literature is a quantitative approach.

It provides the practical level of knowledge to the contractor about. Where he is in project? Whether the project is behind the schedule, ahead of the schedule or on schedule? Whether the project is under budgeted or over budgeted? The following questions can be answered with ease (Vyas A.B and Birajdar B.V 2016).

It provides better understanding of the project in terms of time and cost schedule. Earned Value Management System is a set of guidelines to provide satisfactory completion of project. It has been seen that to cover cost overrun, project team undergoes cost reduction either by reducing the project scope and quality or by providing additional. Similarly, in case of time overrun, they plan crashing of activities or fast tract programs. Therefore, with the use of EVM system, project goals are achieved in better way. The research at hand fills the gap

2.5 Summary

Most of the studies on EVM demonstrate the use of mathematical equations to develop the performance indices. Limited studies have been reported on the use of Project management software to evaluate the project performance in terms of Earn value management in the construction sector. However, estimating the project performance using EVM parameters in the residential sector are not yet reported. Different factors influence the performance of a project and systematic evaluation of these factors gas to be addressed properly to minimize time overrun and cost overruns in the construction project. Therefore, the main goal of this study is to understand and measure project performance using EVM parameters in residential sector.

2.5.1 Critical Research Questions

The unique nature of construction industry works being project-based, varying in size and focus, and relying on a highly transient subcontractor workforce and thus applying the same management strategy from previous completed project is not useful for successful completion of project. There are various factor influences the project performance. This study explores the project performance using Earned Value Method analysis in the residential sector and aimed at answering the following research questions.

Concluding the hypothesis of this study can be formulated in four general questions:

1. Does EVM have significance in construction projects?
2. Which EVM forecasting method can be suitably applied for construction projects?
3. When it will be suitable to re-base lining in the construction project?
4. What is the influence of project characteristics on the performance of EVM?

The above questions can be answered from the following study.

Chapter 3

Project Management Techniques

3.1 General

A project is a temporary endeavor undertaken to create a unique product or service. Temporary means that every project has a definite beginning and a definite end. Unique means that the product or service is different in some distinguishing way from all similar products or services. The end is reached when the project's objectives have been achieved, or when it becomes clear that the project objectives will not or cannot be met and the project is terminated. 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.

In addition, temporary does not generally apply to the product or service created by the project. Most projects are under taken to create a lasting result. For example; a project to erect a national monument will create a result expected to last centuries. Many undertaking are temporary in the sense that they will end at some point (Anbari, 2011).

3.1.1 Construction Project Classification

The construction project can be categorized by nature of construction works, mode of execution, cost and time constraints, the inherent uncertainly or by the combination of these. Broadly, depending upon the nature of construction facility, the major construction projects are grouped into four types as mentioned below (Meredith and Mentel, 2000).

- **Building work** includes all types of buildings such as residential and commercial complexes, educational and recreational facilities, hospitals and hotels, estates and offices, warehouse and shelters. The building works are mostly designed by the Architect-engineering firms, and are financed by government, public sectors (Newell, 2003).
- **Infrastructure construction projects**, these are capital intensive and heavy-equipment oriented works, which involves large quantity of bulk materials like earth, steel and concrete. These works include dams and canals, highway and airports, railways and bridges, oil/gas pipelines and transmission lines, large water supply and sewage disposal networks, docks and harbors, nuclear and thermal power plants and other specialist construction activities which build up the infrastructure for the growth of the economy (Meredith and Mentel, 2000).
- **Industrial construction projects,** these works include construction of manufacturing processing and industrial plants like steel mills, petroleum refineries and consumer goods factors. These works involve high investment and high specialization (Newell, 2003).
- **Special purpose projects,** these include environmental protection works, emergencies, remedial works, utility services and complex key operations (Meredith and Mentel, 2000).

3.2 Project Management

Project management is the application of knowledge, skills, tools, and techniques to project activities in order to meet or exceed stakeholder needs and expectations from a project. Meeting or exceeding stakeholder needs and expectations invariably involves balancing competing demands among (Caletka, 2009).

1. Scope, time, cost, and quality.
2. Stakeholders with differing needs and expectations.
3. Identified requirements (needs) and unidentified requirements.

The term project management is sometimes used to describe an organizational approach to the management of ongoing operations. This approach, more properly called management by projects, treats many aspects of ongoing operations as projects in order to apply project management to them

Projects and project management operate in an environment broader than that of the project itself. The project management team must understand this broader context, managing the day-to-day activities of the project is necessary for success but not sufficient (Caletka, 2009).

3.3 Application of Project Management

The project management knowledge areas describe project management knowledge and practice in terms of its component processes. These processes have been organized into nine knowledge areas as describes below (Anbari, 2003).

- **Project Integration Management** describes the processes required to ensure that the various elements of the project are properly coordinated. It consists of project plan development, project plan execution, and overall change control.
- **Project Scope Management** describes the processes required to ensure that the project includes all the work required, and only the work required, to complete the project successfully. It consists of initiation, scope planning, scope definition, scope definition, scope verification, and scope change control.
- **Project Time Management** describes the processes required to ensure timely completion of the project. It consists of activity definition, activity sequencing, activity duration estimating, schedule development, and schedule control.
- **Project Cost Management** describes the processes required to ensure that the project is completed within the approved budget. It consists of resource planning, cost estimating, cost budgeting, and cost control.
- **Project Quality Management** describes the processes required to ensure that the project will satisfy the needs for which it was undertaken. It consists of quality planning, quality assurance, and quality control.

- **Project Human Resource Management** describes the processes required to make the most effective use of the people involved with the project. It consists of organizational planning, staff acquisition, and team development.
- **Project Communications Management** describes the processes required to ensure timely and appropriate generation, collection, dissemination, storage, and ultimate disposition of project information. It consists of communications planning, information distribution, performance reporting, and administrative closure.
- **Project Risk Management** describes the processes concerned with identifying, analyzing, and responding to project risk. It consists of risk identification, risk qualification, risk response development, and risk response control.
- **Project Procurement Management** describes the processes required to acquire goods and services from outside the performing organization. It consists of procurement planning, solicitation planning, solicitation, source selection, contract administration, and contract close-out
- **Project Stakeholder Management** describes the processes required to identify the stakeholders and to manage them efficiently. It consists of identifying the project stakeholder, plan stakeholder management, manage stakeholder engagement, and control stakeholder engagement (Anbari, 2003).

3.4 Project Mission

Each project has specified mission or a purpose to be achieved. A construction project mission is to create a desired facility like housing complex or fertilizer plant. It is not a routine activity like regular maintenance of building or roads (Jacob, 2003). Each project mission is unique in itself, and no two projects are ever alike. Project differ from each other in one or more influencing factors such as client and contractors, quality specifications, resource employ, responsibilities delegated and project environments. Each one of these factors has decisive effect on the development of the project.

In general construction projects are high value and employ huge resources of men, material, and machineries. Major works involve heavy investments, say from million dollars to a few billion dollars, required high level of technology and need effective management of resources. Construction projects are time bound. Each project has a predetermined duration with definable beginning and identifiable end. Its start point is the time when client describes to undertake construction and commit his financial resources. It is completed as soon as mission is accomplished. The time span between the star and the completion of the project represents the project life cycle. The completion period of the project varies from few months to few years.

Each project is assigned predetermined objectives; these objectives quantify the measurable results to be achieved for accomplishing the mission. Generally, the construction projects objectives are stated in terms of project completion time, budgeted cost and stipulated quality specification (Jacob, 2003).

3.5 Project Environment

Most construction project has one or more following characteristics associated with them

1. Details of work are not precisely defined.
2. Scope of work gets modified during execution.
3. Nature of work varies from job to job.
4. Site of works are located at remote places.
5. Places of works are spread out.
6. Resource requirements and organization of works differ with each task.
7. Investment involved large and the decisions entail risk.
8. Performance is sensitive to the unexplored site geology, uncertain weather and unforeseen natural calamities (Abba w., 2006)

Engineering failures such as ill-define scope of work, inadequate field investigations, faulty designs, absence of quality consciousness and lack of construction experience can delay completion and increase and the cost. The success of the project depends upon the efficiency with which the project management is done and the work done by utilizing the planned resources of men, materials, mad-nineties, money and time (Abba w., 2006) as shown in Figure 3.1 total quality management is the effective utilization of all the three factors Time, Cost and Resource.

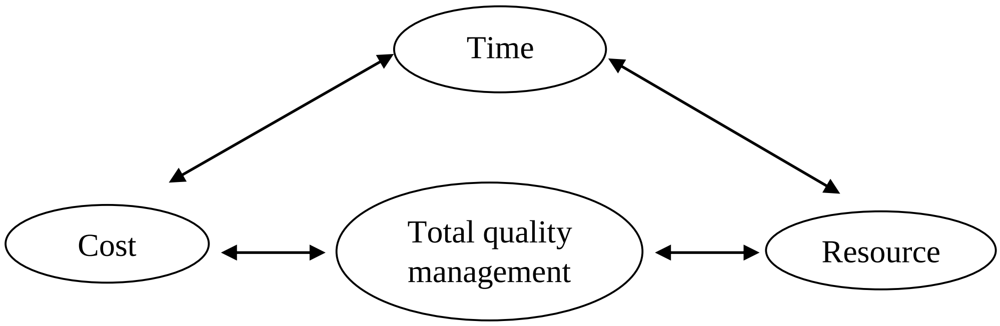


Fig 3.1- Project objective interrelations

(Abba w., 2006)

3.6 Project Phases and Life Cycle

Because projects are unique undertakings, they involve a degree of uncertainty. Organization performing projects will usually divide each project into several project phases to provide better management control and appropriate links to the ongoing operations of the performing organization. Collectively, the project phases are known as the project life cycle (Custer, 2008).

3.6.1 Characteristics of Project Phases

Each project phase is marked by completion of one or more deliverables. A deliverable is a tangible, verifiable work product such as a feasibility study, a detail design, or a working prototype. The deliverables, and hence the phases, are part of a generally sequential logic designed to ensure proper definition of the product of the project.

The conclusion of a project phase is generally marked by a review of both key deliverables and project performance in order to

- Determine if the project should continue into its next phase and
- Detect and correct errors cost effectively.

These phase-end reviews are often called phase exits, stage gates, or kill points. Each project phase normally includes a set of defined work products designed to establish the desired level of management control. The majority of these items are related to the primary phase deliverable, and the phases typically take their names from these items: requirements, design, build text, start-up, turnover, and others as appropriate (Custer, 2008).

3.6.2 Characteristics of Project Life Cycle

The project life cycle serves to define the beginning and the end of a project. For example, when an organization identifies an opportunity that it would like to respond to, it will alone authorize a feasibility study to decide if it should undertake a project. The project life cycle definition will determine whether the feasibility study is treated as the first project phase or as a separate, stand-alone project

The project life cycle definition will also determine which transitional actions at the end of the project are included and which are not. In this manner, the project life cycle definition can be used to link the project to the ongoing operations of the performing organization. The phase sequence defined by most project life cycles generally involves some form of technology transfer or hand-off such as requirements to design, construction to operations, or design to manufacturing. Deliverables from the preceding phase are usually approved before work starts on the next phase. However, a subsequent phase is sometimes begun prior to approval of the previous phase deliverables when the risks involved are deemed acceptable. This practice of overlapping phases is often called fast tracking (Custer, 2009).

3.7 Project Management Functions

The overall aim of the management is to create enterprise to create within the enterprise an environment which will facilitate the accomplishment of its objectives. In doing this management has to perform certain functions. Although the development of a theory and tin science of management suffers from disagreement from the scholars and mangers, a general pattern of functions which management has to perform, has emerged (Lewis, 2001). Traditionally, management functions are grouped under six headings, namely

3.7.1 Planning

Planning involves deciding in advance what is to be done, how and in what order it is to be done in order to achieve the objectives. Planning aims at desiring upon the future course of the action (Lewis 2001). A plan shows the committed course of action. Schedule depicts when planned activities are to be carried, it puts the plan on calendar date scale. In brief planning involves the following:

- Crystallizing the objectives.
- Collecting and synthesizing information.
- Developing alternative courses of action within specified constraints.
- Comparing alternatives in terms of objectives feasibility and consequences.
- Selecting the optimum course of action.
- Establishing policies, procedures, methods, schedules, program, systems, standards and budgets for accomplishing the project objectives

3.7.2 Organizing

Organizing is the process of establishing the structural relationship among functions of people, so as to formulate effective machinery for streamlining the achievement of assigned objectives (Lewis, 2001), Organizing involves the following main tasks.

- Dividing the work into component activities.
- Designing job structures.
- Defining performance targets and responsibilities.
- Allocating resources.
- Delegating authority commensurate with responsibility.
- Establishing structural relationship to secure coordination

3.7.3 Staffing/Procuring

It implies managing and keeping manned the position created by organization structure and providing them the right quality resources at the right time (Lewis, 2001). These resources include people, material, machinery and money. The connected project management tasks include the following.

- Preparing resource procurement schedule.
- Developing specifications for required resources.
- Deciding appropriate sources of procurement.
- Budgeting resources and arranging approvals and purchasers.
- Preventing wastage during resource holding at site.
- Supplying on time required quality and quantity of resources to project construction

3.7.4 Directing or Leading

It involves influencing people so as to enable them to contribute the organizational goals effectively and efficiently (Lewis, 2001). Direction implies the following tasks

- Providing effective leadership.
- Motivating participant's behavior.
- Communicating instructions and orders.
- Providing a suitable climate for subordinate's development

3.7.5 Controlling

Controlling involves the monitoring of the performance and applying corrective measures in case of deviations from the plan. The process of control can be sub-divided into following stages (Lewis, 2001).

- Specifying the factors to be controlled
- Stating the methods of measuring control factors.
- Evolving systems for generating performance data.
- Monitoring the data received and formulating the corrective options
- Applying corrective measures to put a plan on the schedule path.
- Re-planning, when necessary

3.8 Project Scheduling

A schedule is a work program, set date-wise in a logical sequence; it is a time table for action. Time scheduling is the process of developing the work program. It implies the programming of the chosen work plan on a calendar basis and provides the base against which time progress is measured. A work schedule is an action plan with calendar date targets, whereas networking is the planning technique. A network needs to be scheduled in order to determine commencement and termination dates of each activity, using the optimum resource or working within the resource constraints.

The project employs rectum of men, materials, machines and annoy to execute the activities, Time and resource to be employed in an activity are utter-related. In most of the construction activities, increase in vital activity from a certain level decrease duration of the activity. But the uneven employment of vital resources can reduce productivity, increase the cost and create management problems (Kim et al, 2003).

The basic approach of all scheduling techniques is to than a network of minty and event relationship that graphically portrays the sequential relations between the tasks in a project. Such a network is a powerful tool for planning and controlling a project and has the following benefits:

1. It is a consistent framework for planning, scheduling, monitoring, and controlling the project.
2. It illustrates the interdependence of all tasks, work packages, and work elements.
3. It denotes the times when specific individuals and resources must be available for work on a given task.
4. It aids in ensuring that the proper communications take place between departments and functions.
5. It determines an expected project completion date.
6. It identifies so called critical activities that, if delayed, will delay the project completion time.
7. It also identifies activities with slack that can he delayed for specified periods without penalty, or item which resources may be temporarily borrowed without harm
8. It determines the dates on which tasks may be started or must be started if the project is to stay on schedule.
9. It illustrates which tasks must be coordinated to even resume or timing conflicts.
10. It also illustrates which tasks may be run, in parallel to achieve the predetermined project completion date.
11. It relieves some interpersonal conflict by clearly showing task dependencies.
12. It may, depending on the intimation used, allow an estimate of the probability of project implementation by various dates, or the date corresponding to a particular a prior probability (Kim *et al* 2003).

Some of the methods of scheduling are explained as follows:

3.8.1 Critical Path Method (CPM)

Critical path is the sequential activities from start to the end of a project. Although many projects have only one critical path, some projects may have more than one critical path depending on the flow logic used in the project. If there is a delay in any of the activities under the critical path, there will be a delay of the project deliverables. Most of the times, if such delay is occurred project acceleration or re-sequencing is done in order to achieve the deadlines (Walt, 2009).

Critical path method is based on mathematical calculations and it is used for scheduling project activities. This method was first introduced in 1950s as a joint venture between Remington Rand Corporation and DuPont Corporation. The initial critical path method was used for managing plant maintenance projects. Although the original method was developed for construction work, this method can be used for any project where there are interdependent activities. In the critical path method, the critical activities of a program or a project are identified. These are the activities that have a direct impact on the completion date of the project (Walt, 2009). Basic Steps in CPM are,

3.8.1.1 Advantages of CPM

Following are the advantages of critical path methods:

1. Offers a visual representation of the project activities.
2. Presents the time to complete the tasks and the overall project.
3. Tracking of critical activities (Walt, 2009).

3.8.1.2 Disadvantages of CPM

Following are disadvantages of critical path method:

1. Practically impossible to draw diagrams for large projects.
2. Too much of confusion when dealing with a complex project.
3. It does not account for resource allocation.
4. It does not help in scheduling each personnel for each task.
5. There is usually uncertainty in time determination for complex projects.
6. It can sometimes, end up being complicated (Walt, 2009)

3.8.2 Program evaluation and review technique (PERT)

PERT (Program Evaluation and Review Technique) is one of the successful and proven methods among the many other techniques, such as, CPM, Function Point Counting, Top-Down Estimating. PERT was initially created by the US Navy in the late 1950s. The pilot project was for developing Ballistic Missiles and there have been thousands of contractors involved.

3.8.2.1 Advantages of PERT

PERT is employed for planning and controlling the project involving uncertainties. PERT is an event oriented technique. Its basis is a network of events in which the activities are derived by connecting the events. It lays stress on measuring the uncertainty in activity times by using three times duration estimation method. For computation of critical path, the PERT three times probabilistic network is covered into single time deterministic CPM model. PERT studies the implications of uncertainties on project time scheduling and slack of events by employing statistical tools. After PERT methodology was employed for this project, it actually ended two years ahead of its initial schedule (Fleming and Koppelmen, 2004).

3.8.2.2 Disadvantages of PERT

1. Project activities have to be clearly defined, independent, and stable in their relationships.
2. Precedence relationships must be specified and networked together.
3. Time estimates tend to be subjective and are subject to fudging by managers.
4. There is an inherent danger of too much emphasis being placed on the longest or critical path (Fleming and Koppelmen, 2005).

3.8.2.3 CPM Vs PERT

Table 3.1 explains the clear difference between the two major construction management techniques CPM and PERT.

Table 3.1-Difference between CPM AND PERT *(Payne, 1990)*

Factors	CPM	PERT
Field of application	Deterministic projects like in construction	Project involving uncertainties like research and development
Model emphasis	Activity oriented	Event oriented
Activity duration estimation	One-time method	Three times method
Time-cost trade-off	Feasible	Not feasible
Resource optimization	Feasible	Not feasible
Technique complexity	Simple	Comparatively difficult

CPM was developed for planning, scheduling and control of civil works, while PERT originated in response to the complexities of the uncertainty in research and development projects for controlling their multifarious time schedules. Originally, thus, their field's applications were quite different. In network modeling CPM laid emphasis on breaking the projects onto various works or activities. In PERT, the project breakdown was in terms of milestones which were planned to occur during its execution. Therefore, CPM was activity oriented were as PERT was event oriented [Payne, 1990].

Originally, the application of CPM was confined to construction work were the activities were familiar and their duration could be easily estimated from the one-time estimate. Since a PERT was designed to cope up with uncertainties it 'uses the three-time estimate. In CPM, activity duration was related to cost. This provided a means of assessment of different activity duration with varying costs and made crashing of activities possible. PERT dealt with events and their probable time of occurrence. This enabled adoption of probabilistic approach in time scheduling.

The CPM schedule enabled optimization of resources as the activity durations were defined in terms of resources employed. This was not possible with PERT. CPM, which used the one-time estimate, was simpler to follow, while PERT required statistician to interpret the results (Payne, 1990).

3.8.3 Work Breakdown Structure (WBS)

Dividing complex projects to simpler and manageable tasks is the process identified as Work Breakdown Structure (WBS). Usually, the project managers use this method for simplifying the project execution. In WBS, much larger tasks are broken-down to manageable chunks of work. These chunks can be easily supervised and estimated. WBS is not restricted to a specific field when it comes to application. This methodology can be used for any type of project management (Vanhoucke, 2009).

Following are a few reasons for creating a WBS in a project.

- Accurate and readable project organization.
- Accurate assignment of responsibilities to the project team.
- Indicates the project milestones and control points.
- Helps to estimate the cost, time, and risk.
- Illustrate the project scope, so the stakeholders can have a better understanding of the same.

3.8.3.1 Construction of WBS

Identifying the main deliverables of a project is the starting point for deriving a work breakdown structure. This important step is usually done by the project managers and the subject matter experts (SEMS) involved in the project. Once this step is completed, the subject matter experts start breaking down the high-level tasks into smaller chunks of work.

In the process of breaking down the tasks, one can break them down into different levels of detail. One can detail a high level task into ten sub tasks while another can detail the same high level task into 20 sub tasks. Therefore, there is no hard and fast rule on how you should breakdown a task in WBS. Rather, the level breakdown is a matter of the project type and the management style followed for the project.

In general, there are a few "‘rules" used for determining the smallest task chunk. In "two weeks" rule, nothing is broken down smaller than two weeks work of work. This means, the smallest task of the WBS is at least two-week long. 8/80 is another rule used when creating a WBS. This rule implies that no task should be smaller than 8 hours of work and should not be larger than 80 hours of work. One can use many forms to display their WBS. Some use tree structure to illustrate the WBS, while others use lists and tables. Outlining is one of the easiest ways of representing a WBS (Vanhoucke, 2009).

There are many design goals for WBS. Some important goals are as follows:

- Giving visibility to important work efforts.
- Giving visibility to risky work efforts.
- Illustrate the correlation between the activities and deliverables.
- Show clear ownership by task leaders.

The criteria for creating WBS are explained in following Table 3.2. It clearly describes the work level packages and the main criteria for its completion.

Table 3.2- Criteria for Creating WBS (Vonhoucke, 2009)

Level	Description	Main criteria
1	Sub-project level	An independent deliverable end product requiring processing of multi task having large volume of work
2	Task level	An identifiable and deliverable major work containing one or more package
3	Work-package level	A sizeable, identifiable, measure, cost able and controllable work item/package of activities
4	Activity level	Identifiable lower level job, operation, or process, which consumes time and possibly resources
5	Operations level	A lowest level day to day operations or process, which apart of an activity.

3.8.4 Bar Chart Method

Simple projects can be scheduled directly in the bar chart format by experienced hands. However, it is the network plans of complex projects and large size repetitive projects need to be scheduled using scheduling techniques. Nevertheless, all time schedules are finally presented in the format of bar charts.

In the bar chart method works are first split in to activities. These activities are then listed in order of construction priorities, generally on the left hand side column, while the time scale shows project calendar, and the scale can be plotted horizontally on the top and/or bottom of the chart. The chart can be vertically divided into three divisions. The left division group activities are generally listed in the sequence of their execution. The central portion contains the data relating to activities. The right division depicts the calendar and schedule of activities. Graphically, the vertical segments of the bar charts can be arranged in the following ways,

- Activity description, data and calendar. This is commonly adopted sequence.
- Activity description and calendar. This is used where data is omitted.
- Calendar with activity (or work package or tasks) only with description written inside or at the end of the bar. It is particularly useful for making a schedule for a large project.
- Data followed by calendar with description inside or at the end of the bar. This facilitates scheduling of long duration projects (Vanhoucke, 2009).

The bar against each activity represents each activity of work. The start of the bar marks the commencement of the activity and the end of the bar, its completion. The length of the bar on the calendar scale represents the duration of the project. Horizontally, each row depicts the activity description, activity data and the rectangular shape bar represents the activity schedule.

The time base for bar charts and, for that matter, all scheduling techniques is the project calendar. Generally, this calendar covers the project's construction span for the date start to date of final completion. Let specifies the dates when the activities are scheduled. The bar chart calendar is divided into months, weeks, working days, weekend non-working days and holidays. The calendar weeks may have the five or six working days. The detailed calendar also highlights the working days, and non-working days such as the weekends and national and other holiday, as applicable. This project calendar and its parts are invariably, represented in a formatted horizontal bar. Figure 3.2 explains a short example of bar chart drawn for a few set of activities and how does a bar chart looks.

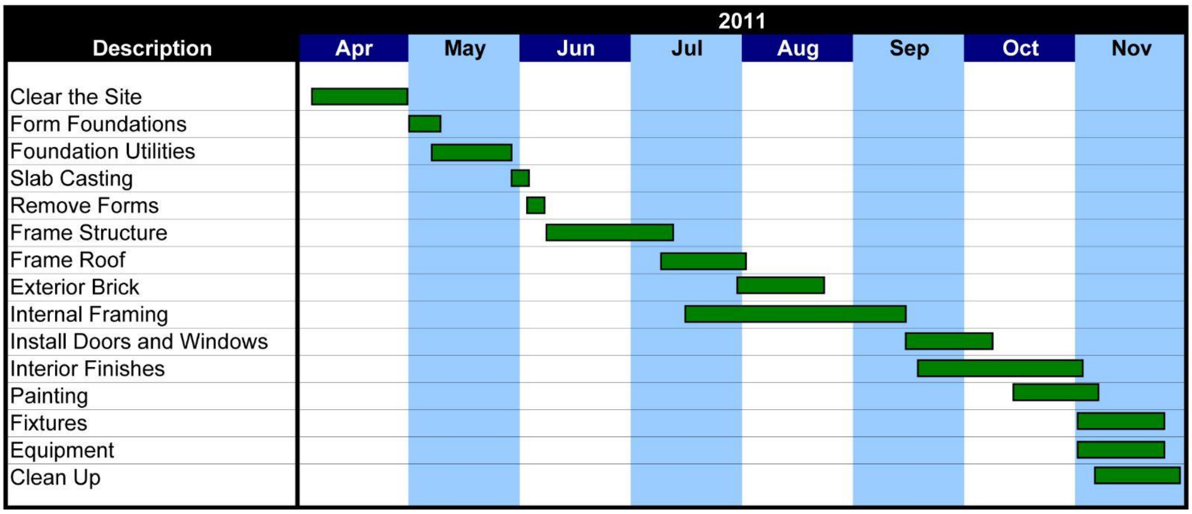


Fig 3.2- Construction Schedule Bar Chart

(Source:icgpm.net/every-step-counts-successful-project-management)

3.8.4.1 Merits and Demerits of the Bar Charts Method

The prerequisite for drawing the bar chart is the person drawing the bar chart must be one who is experienced in similar projects. Bar charts are easy to plot, comprehend and communicate, and are most appropriate for representation of schedules. However, as a planning technique, the bar charts are not suitable for complex projects due to the following reasons.

- It does not reflect the relationship between the various activities, which are common feature of all complex projects, unless a time scale network is plotted.
- It cannot identify and highlight the engineering critical tasks needing special attention for preventing Schedule slippages, time overruns, contractual disputes and other bottlenecks.
- In complex projects, time durations are often educated guesses. Any change in schedule or time duration would require a drawing of the multi-task bar chart schedule.

Thus, it can be said that bar chart format is most suitable for representation of schedules, but as a planning techniques. It is not suitable for planning of a complex projects (Alvarado, 2004).

3.8.5 Line of Balance Method (LOB)

The LOB activity schedule chart show the graphics plan of work execution in linear or ‘8’ curve shape. The graph representing the cycle of work are referred to as ‘cyclographs’ or ‘cyclograms’. The time units in a cyclograms are represented along the horizontal axis, while the vertical axis shows the number of similar work units of the projects. The time units reflected on the horizontal axis can be further being divided into calendar months after assessing the working days available in each month (Prentice, 2003).

3.8.6 Importance of Project Scheduling

Work scheduling serves the following purposes:

- It simplifies the project plan
- It validates the time objective
- It optimizes the resource employed.
- It evaluates the implication of scheduling constraints (Prentice, 2003).

3.9 Earned Value Method

Earned value method (EVM) is a systematic approach to the integration and measurement of cost, schedule, and technical (scope) accomplishments on a project or task. It provides both the government and contractors the ability to examine detailed schedule information, critical program and technical milestones, and cost data. Earned value method is intended to provide data born a contractor's management system to the government in standard data elements that:

- Relate time-phased budgets to contract tasks
- Integrate cost, schedule, and technical performance.
- Indicate work progress objectively.
- Are valid, timely and auditable.
- Are from the internal system the contractor uses to manage.
- Are at a practical level of summarization (Vargas, 2003).

By using Earned Value and implementing an Earned value method System (EVMS), the following questions can be answered objectively:

1. Where have we been?
2. Where are we now?
3. Where are we going?

3.9.1 Key EVM Parameters

For implementing EVM, a clear project scope is required together with a project budget and a project schedule. The project budget must reflect all planned costs incurred by the activities of which the project consists. The budget is then distributed over all the activities in the project schedule. By cumulating these budgeted costs over time a first measure is obtained, the Planned Value (PV). The PV is the value that was planned to have been spent according to the original plan at a certain point in time (Lipke, 2003). The Budget at Completion (BAC) is the total cost of the project as it was budgeted at the start of the project and is equal to the planned value at the end of the project (Figure 3.3).

Figure 3.3 clearly explains the during project execution two more measures are obtained so that a comparison can be made between reality and plan. Earned Value (EV) is the monetary value of the activities that are “finished at a certain point in time. Another way of putting it, is that the EV equals the BAC multiplied by the percentage completed (PC) at a certain point in time (EV = PC * BAC) (Lipke, 2003).

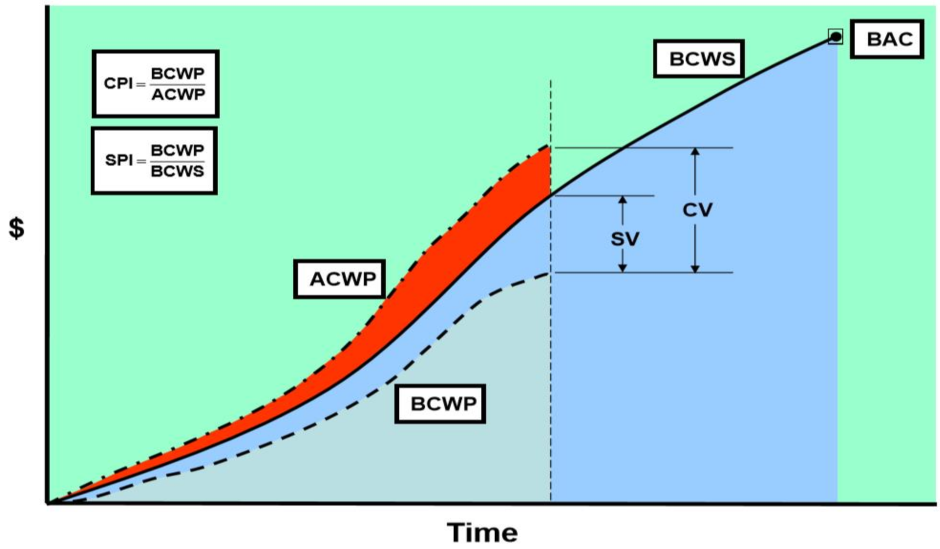


Fig 3.3- Earned Value Basics

(Source: Lipke W 2003)

The other measure is the Actual Cost (AC). This represents the real costs for all work that is executed at a certain point in time. As can be seen in Figure 3.3 these measures are also cumulatively represented over time (Lipke, 2003). Summarized, EVM makes use of three key parameters:

- Planned Value (PV) = (BCWS) Budgeted Cost of Work Scheduled
- Earned Value (EV) = (BCWP) Budgeted Cost of Work Performed
- Actual Cost (AC) = (ACWP) Actual Cost of Work Performed

3.9.2 Performance Measures

When the three key parameters are properly recorded along the project life, PMs are able to calculate two types of performance measures. The first type of performance measures is variances which represent the difference between the current status of the project and its baseline, in monetary terms. The Cost Variance (CV) is used to follow up the project budget.

A negative (positive) value points out that more (less) has been spent for the executed activities than what was originally planned. The Schedule Variance (SV) is an indicator that provides PMs with a value that represents whether the project is on schedule or not. A negative (positive) value means that the project is behind (ahead of) schedule. The variances are also shown in figure 3.4 (Walter 1-1., 2003). The variances can be derived as follows:

- Cost Variance: CV = EV -AC
- Schedule Variance: SV = EV -PV

Another type of performance measures are indices, also calculated from the three key parameters of EVM. The indices are again used to display how well the project is performing, now relatively in comparison with the baseline. Again two types of indices can be distinguished. The first type of index is the Cost Performance Index (CPI), which expresses the cost efficiency of the executed work. CPI is less than one means that the project is currently running over (under) budget. Second index is the Schedule Performance Index (SP1). The SP1 shows whether the project is performing on schedule or not. A SP1 of more (less) than one means that the project is ahead of (behind) plan (Lipke, 2003). The indices can be derived as follows

- Cost Performance Index: CPI = EV / AC
- Schedule Performance Index: SP1 = EV / PV

It is clear that the variances and indices are interrelated. Still it is useful to calculate both performance measures. The variances can give a snapshot of where the project is today (expressed in monetary value) while the indices are rather used to represent the evolution in performance of the project. This is of significant importance to make forecasts about the future of the project (Lipke, 2005).

3.9.3 Predicting the Future with EVM

All of the performance measures help PMs to monitor the progress of the project both item a cost and schedule point of view. Therefore, EVM acts as an early warning system that helps PMs to solve problems and exploit opportunities during project execution. Besides, these measures and indicators are also used to make predictions about the future performance of the project. The next section will describe how cost and time forecasts are made using EVM (Marshall, 2005)

3.9.4 Cost Forecasting

First of all, the predictive power of the cost performance measures is considered. Here the focus lies on predicting the final cost of the project. This final cost will be referred to as the Estimate at Completion (EAC). The EAC consists of the Actual Cost (AC), the cost that has been spent so far and an estimate of the cost of the remaining work (Estimate to Completion, ETC). In some literature, ETC is also referred to as Planned Cost of Work Remaining (PCWR). It can be calculated as follows [Lipke, 2004].

$$ETC = \frac{(BA)}{Performance\ factor}$$

Table 3.3 gives several different formulas exist to calculate the EAC, depending on the performance factor it is used to calculate the ETC. In general, eight commonly used forecasting formulas are accepted by project managers

Table 3.3- Formulas to measure Estimate at completion (Lipke, 2004)

$EAC_1 = AC + (BAC - EV)$	$EAC_5 = \mathrm{AC} + \frac{(\mathrm{BAC} - \mathrm{EV})}{\mathrm{CR}}$
$EAC_2 = \mathrm{AC} + \frac{(\mathrm{BAC} - \mathrm{EV})}{\mathrm{CPI}}$	$EAC_6 = \mathrm{AC} + \frac{(\mathrm{BAC} - \mathrm{EV})}{\mathrm{CP(t)}}$
$EAC_3 = \mathrm{AC} + \frac{(\mathrm{BAC} - \mathrm{EV})}{\mathrm{SPI}}$	$EAC_7 = \mathrm{AC} + \frac{(\mathrm{BAC} - \mathrm{EV})}{\mathrm{wt1} * \mathrm{SPI} + \mathrm{wt2} * \mathrm{CPI}}$
$EAC_4 = \mathrm{AC} + \frac{(\mathrm{BAC} - \mathrm{EV})}{\mathrm{SPI(t)}}$	$EAC_8 = \mathrm{AC} + \frac{(\mathrm{BAC} - \mathrm{EV})}{\mathrm{wt1} * \mathrm{SPI(t)} + \mathrm{wt2} * \mathrm{CPI}}$

Each assumes a discount factor that is equal to one. This means that to estimate the remaining cost of the project, no project performance measure is taken into account. The remaining cost is assumed to equal the planned cost for the remaining work. The most commonly used formula for cost forecasting is EAC_2. In this formula the CPI is used as a discount factor for estimating the remaining cost. EAC_3 and EAC_4 on the other hand are used in cases where the duration has a huge impact on the final cost of the project.

In the last four EAC formulas it is supposed that both the cost and schedule performance indicators have an impact on the cost of remaining work. The discount factor in EAC_5 is called the critical ratio (CR) (Ambary, 2001; Lewis, 2001) or cost schedule index (CSI) (Barr, 1996; Meredith & Mantel, 2000) or schedule cost index (SCI) (Christensen, 1999; Vanhoucke, 2010). It attempts to combine cost and schedule indicators into one overall project health indicator. A CR equal to one indicates that overall project performance is on target while a lower number indicates less than targeted performance.

CR is derived as follows:

$$\text{CR} = \text{CPI} \times \text{SPI}$$

A performance factor equal to the CR (t) substitutes the SPI by the SPI(t). The last 2 equations EAC_7 and EAC_8 are derivative formulas which give a weight to the both CPI (wt_1) and the SPI/ SPI(t) (wt_1). This way a customized formula can be obtained for the project.

3.9.5 Duration Forecasting

EVM has also been used for more than forty years to predict the final duration of projects. This is done analogue to forecasting the EAC. The oldest method calculated the Independent Estimate at Completion (IEAC (t)). This estimate exists of the time that has already elapsed (Actual Time, AT) and the duration of what the remaining work is estimated to take (Estimate to Complete, ETC (t)). The time that is expected to complete the project is calculated by adjusting the work remaining (Estimate to Complete, ETC) for the work rate that is expected on the remaining of the project. ETC (1) is also referred to as Planned Duration of Work Remaining (PDWR) and can be calculated as follows (Lipke, 2003).

$$EAC(t) = \frac{(\text{BAC} - \text{EV})}{\text{WORK RATE}}$$

The Independent Estimate at Completion (IEAC (1)) can be derived as follows:

$$\text{IEAC (t)} = \text{AT} + \text{ETC (t)}$$

Table 3.4 elaborates the four commonly applied work rates were used to translate a monetary value into a time value:

Table 3.4- Formulas to Estimate planned duration of work

(Lipke, 2003)

Average Planned Value	$PV_{avg}=PV_{cum}/n$
Average Earned Value	$EV_{avg}=EV_{cum}/n$
Current period Planned Value	PV_{cp}
Current period Earned Value	PV_{cp}

Although this traditional method was applied for forty years, it deals with certain mathematical deficiencies (Lipke (2009). This induces that the method doesn't give reliable estimates for all projects and therefore adjusted methods have been developed. Recently three extensions to EVM were established: The Planned Value method (Anbari, 2003), the Earned Duration method (Jacob, 2003) and the Earned Schedule method (Lipke, 2003).

Table 3.5 provides an overview of the duration forecasting formulas of these three methods. Depending on the discount factor, three forecast formulas can be derived for each method.

Table 3.5- EAC (t) formulas for calculating EAC

(Vanhoucke, 2010)

Planned value Method (Anbari)	Earned value Method (Jacob)	Earned value method (Lipke)
$EAC(t)_{PV\,1}=PD-TV$	$EAC(t)_{ED\,1}=AD+(PD-ED)$	$EAC(t)_{ES\,1}=AD+(PD-ED)$
$EAC(t)_{PV\,2}=PD/SPI$	$EAC(t)_{ED\,2} = \mathrm{AD} + \frac{(\mathrm{PD}-\mathrm{ED})}{\mathrm{SPI}}$	$EAC(t)_{ES\,2} = \mathrm{AD} + \frac{(\mathrm{PD}-\mathrm{ED})}{\mathrm{SPI(t)}}$
$EAC(t)_{PV\,3}=PD/CR$	$EAC(t)_{ED\,3} = \mathrm{AD} + \frac{(\mathrm{PD}-\mathrm{ED})}{\mathrm{CR}}$	$EAC(t)_{ES\,3} = \mathrm{AD} + \frac{(\mathrm{PD}-\mathrm{ED})}{\mathrm{SPCR}}$

The Planned Value method (PV) relies on the Planned Duration for the entire project (PD), expressed in time units, to make forecasts about the future. This factor is then adjusted to the performance of the project (Lipke, 2003). In EAC (t) $_{PV1}$ the adjustment factor is the Time

Variance (TV). Which can be calculated by dividing the schedule variance by the planned value rate (PV_{rate}), this is the average planned value per time period?

$$TV = \frac{SV}{PV\ Rate} = \frac{SV * PD}{BAC} = \frac{(EV - PD) * PD}{BAC}$$

For the other two forecasting equations the SP1 respectively the CR (=SPI*CPI) are applied as discount factor to adjust the planned duration.

The **Earned Duration method** (ED) introduces a new variable named Earned Duration (ED). This variable can be calculated by multiplying the Actual Duration (AD) with the SPI.

ED = AD * SPI

The forecasting formulas differ from each other depending on the performance rate that is used as a discount factor. Performance rates equal to one, the SPI and the CR are assumed [Vanhoucke, 2010].

3.10 Earned Schedule

The Earned Schedule (ES) method can be seen as an expansion of EVM because the same basic EVM metrics are used and the ES performance measures are similar to those for EVM. ES was first introduced by Lipke (2003) and measures schedule performance in units of time instead of in costs, which is done in EVM. This approach solves the problem that the EVM schedule indicators SV and SPI encounter for late finish projects.

The method is based on two parameters: The Actual Time (AT) and the Earned Schedule (ES). The AT is the duration that has already been spent on the project. The concept of BS is similar to the one of EV in EVM. The value of BS is determined as can be seen in figure 4, by comparing the EV to the schedule (Lipke, 2003). In practice this is done by projecting the EV at a certain point in time (AT) onto the cumulative PV curve. By doing this, a point in time (E8) is obtained at which the current EV should actually have been realized. This can be before or after the current point in time, depending whether the project is behind or ahead of schedule.

With these two parameters, the Schedule Variance (SV(t)) and Schedule Performance Index. (SPI_t) at time t can be calculated. Now these metrics don't need to be translated from monetary units to time units. Similar as in EVM, the ES performance measures can be applied to make forecasts about the final duration of the project.

3.10.1 P-Factor

The P-factor (Lipke, 2004) is a recently proposed Earned Value measure that makes the direct connection between the schedule and EVM data. The P-factor is an indicator for schedule adherence, it measures whether the project is executed according to plan or not. This is important because projects that do not stick to the plan are mostly in trouble or might deal with a higher risk for rework. For example, Project A and Project B have the same PV and EV although they are executed differently. When schedule adherence is not taken into account this will result in similar forecasts for both projects although project B is confronted with a higher risk for possible rework Adhering to the plan assures that the predecessors to the tasks in progress are completed well and that no rework will be required for these tasks. If, however like in project B; certain tasks already started before some predecessors are finished, it might turn out that these tasks have to be redone and so the risk for rework increases. Figure 3.4 shows the P-factor graph.

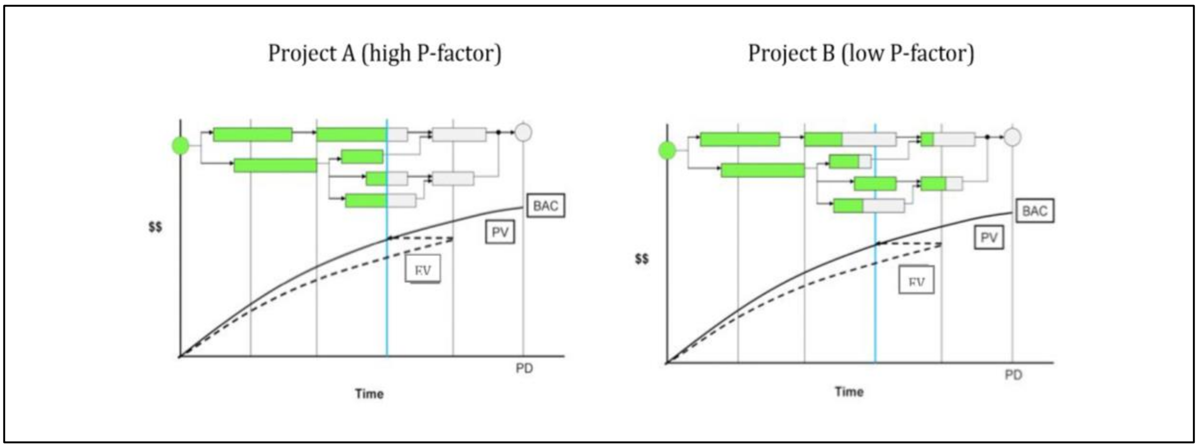


Fig 3.4- P-factor

(Source: Lipke W. 2004)

From Figure 3.4 the P-factor can be calculated by dividing the earned value corresponding to the baseline schedule at the actual time to the planned value at time ES. The P-factor lies between zero and one as the formula takes the minimum, of the planned value at time ES and the earned value accrued to the actual time.

3.10.2 Re-Baseline

The project baseline is a schedule consisting of all the activities of the project. As certain activities are difficult to forecast at the project start and depend heavily on other activities, the baseline is often established with a lot of uncertainty. During project execution, it might turn out that the original baseline becomes unrealistic as a basis for management control. This can be due to changes in scope, schedule, cost or a combination of these factors. To make the project manageable again, the project baseline can be changed. This is called re-base lining. An example is given in Figure 3.5 and 3.6 (Abba, 2006).

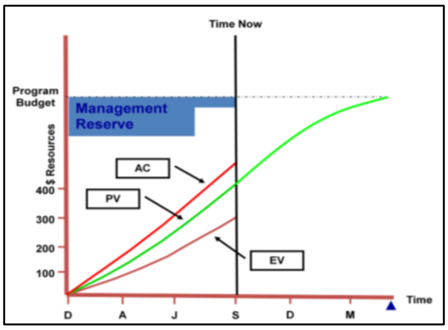


Fig 3.5- Project with current baseline

(Source: Abba, W, 2006)

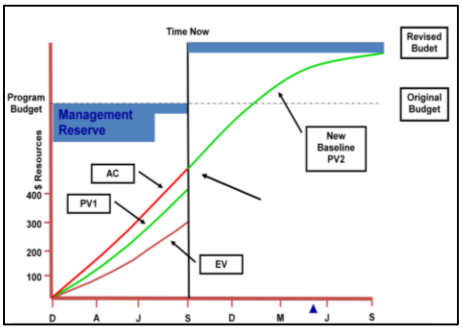


Fig 3.6- Project re-baseline

(Source: Abba, W, 2006)

From Figure 3.5, it can first be seen that there is a persistent trend of the actual cost being higher than the planned value. This explains a cost overrun for the performed work and a budget revision is required. Second the earned value in September (time S) is a lot lower than the planned value at that time. By performing less work than planned the project will be behind schedule and the end date of the project should be revised. Figure 3.6 shows the re-baseline schedule that continues on the Actual Cost curve (AC) of the project. Start dates, duration and budgeted cost of the different activities is adjusted to the new state of the project which results in a higher budget and longer duration of the project.

The question can be asked when the project baseline becomes so unrealistic that re-base lining is required. Unfortunately, there is no clear answer. The balance should be made between on the one hand sticking to the original baseline and making use of forecasting methods that take the original cost and schedule performance into account to make predictions about the future. On the other hand, setting up a new baseline restores the cost and schedule variance back to zero. Also the indices are reset to one. This allows future variances to become noticed more easily and will generally result in better forecasts. The negative side is that re-base lining requires extra effort for PMs (Abba W., 2006). The question can therefore be re-established into "is re-base lining worth the effort for PMs to control their project?”

3.11 Benefits of EVM

Following are some of the benefits of EVMS, described by Fleming and Koppelmen as the legacy of using the criteria on government contracts for three decades (Fleming and Koppelmen, 2002). Note that they do not separate benefits of earned value data {tom the benefits of the criteria, perhaps because the reliability of data depends on the disciplined application of the management practices described by the criteria.

1. It is a single management control system that provides reliable data.
2. It integrates work, schedule and cost using a work breakdown structure (WBS).
3. The associated database of completed projects is useful for comparative analysis.
4. The Cumulative cost performance index (CPI) provides an early warning signal.
5. The schedule performance index (SPI) provides an early warning signal.
6. The CPI is a predictor for the final cost of the project.
7. It uses an index-based method to forecast the final cost of the project.
8. The periodic (cg. weekly or monthly) CPI is a benchmark (Fleming and Koppelmen, 2002).
9. The “to-complete” performance index allows evaluation of the forecasted final cost.

3.12 EVM Summary

Since its introduction EVM has proven to be very valuable as project management control tool. This because of the different functions it fulfills. EVM provides a view on the current status of the project and also provides insight into the future of the project. As mentioned before, EVM focuses primarily on the costs of the project; this is why all parameter and analyzing the project’s cost performance. On the other hand, this led to some anomalies in the schedule performance measures.

As noted by lipke, the expression of the schedule performance measures in monetary units instead of units of time makes it counterintuitive and difficult to compare with other time based schedule indicators. Another problem incurred by the schedule indicators is that is that for a project which is behind schedule, at completion SV returns back to zero and the SPI equals unity. This may lead to biased conclusions about the final duration of the project.

Figure 3.7 shows an overview of all EVM key parameters, performance measures and forecasting indicators can be summarized, which was found in the book "Measuring Time" by Vanhoucke (2010) As the implementation of earned schedule overcomes these problems; the credibility of EVM is only rising. Especially with the insertion of the P-factor which closes the gap between schedule and EVM data, EVM can now control projects in a much extended way.

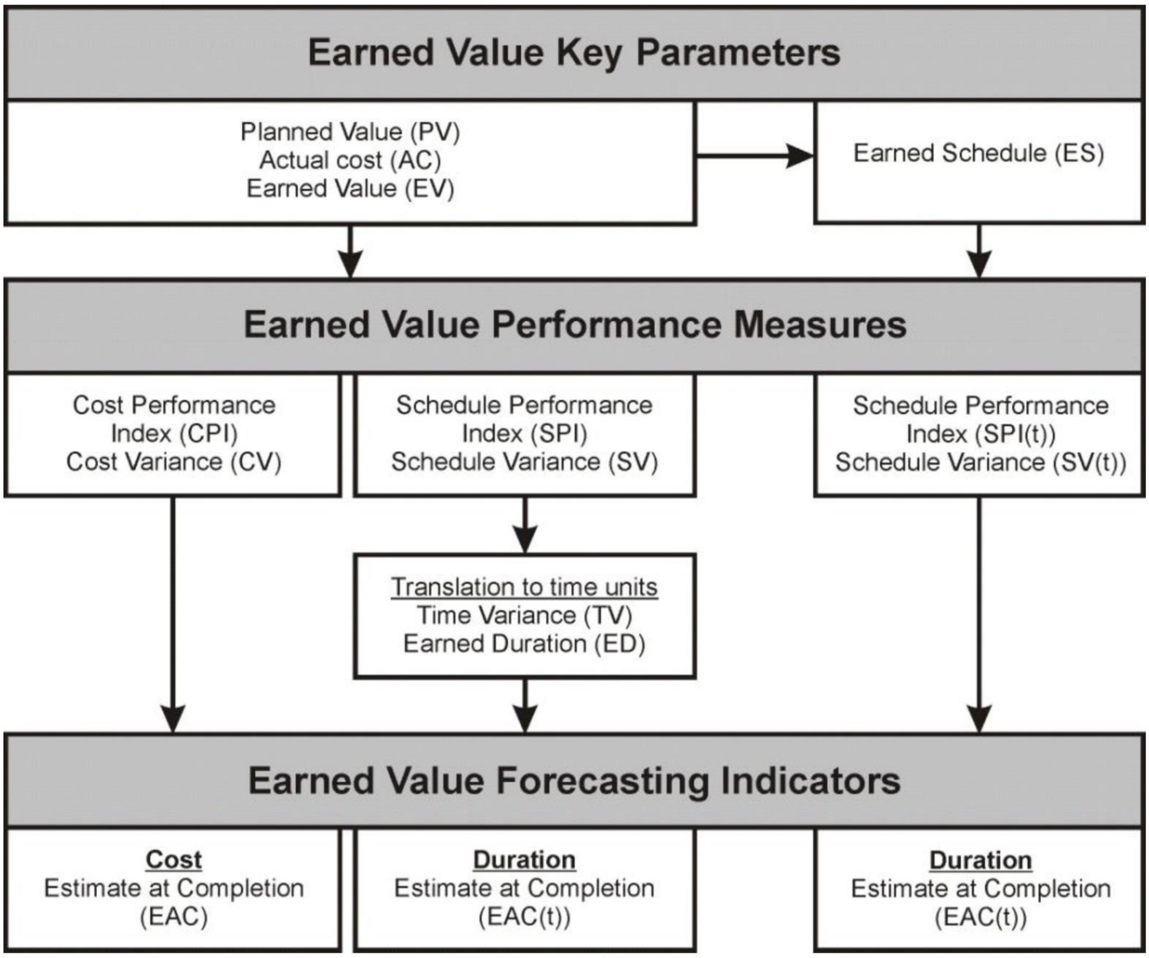


Fig 3.7- Overview EVM metrics

(Source: Vanhouke Mario, 2010)

3.13 Causes of Cost & Time Overrun in Construction Project

A cost overrun. also known as a cost increase or budget overrun, is an unexpected cost incurred in excess of budgeted amount due to an underestimation of the actual cost during meeting Cost overrun should be distinguished from cost escalation which is used to express an anticipated growth in a budgeted cost due to factors such as inflation.

Time overruns occur when projects or tasks within a project is not completed by the time the project plan specifics. This can occur when materials to complete a project are back ordered and work cannot be completed until the materials arrive. Sometimes, labor shortages can cause work to be completed slower than anticipated (Christensen. 2002).

3.13.1 Factors Influencing Time and Cost Overrun

Financial Factors (Christensen, 2002).

The financial factors resulting in cost overrun are:

1. Market conditions
2. Fluctuation in money exchange rate
3. Inflation
4. Payments delay
5. Availability of finance management and plans
6. Estimating method used

Factors Related to Construction Parties (Christensen, 2002).

The consultants View indicates that the most severe cost overrun and time overrun causes under the group are:

1. Experience in contracts
2. Lack of information and coordination between construction parties
3. Experience in the line of work.
4. Poor financial control
5. Lack of qualified project manager
6. Poor quality of project management
7. Lack of application of risk management process
8. Knowledge of clients and consultants
9. Lack of coordination between designers
10. Financial status of owner
11. Government requirements

Factors Related to Construction Items (Christensen, 2002).

The consultants input shows that the most severe factors are:

1. Insufficient time for estimate.
2. Size of contract.
3. Incomplete drawings.
4. Period of contract
5. Inadequate labor productivity.
6. Frequent design changes
7. Lack of raw material sources
8. Relationship between labor and management team
9. Type and content of contract
10. Inadequate specifications.
11. Lack of skilled labor
12. Labor and equipment required
13. Unclear arbitration process

Environmental Factors Group (Christensen, 2002).

The factors under this group are:

1. Materials price fluctuation
2. Lack of historical data
3. Number of competitors.
4. Location
5. Supplier manipulation
6. Laws and regulations
7. Rock and soil suitability
8. Terrain conditions
9. Weather
10. Ground conditions
11. Public exposure of the project
12. Social and cultural impacts

Political Factors (Christensen, 2002).

1. Political situation
2. Difficulties on importing equipment's and materials
3. Dealing with suppliers and traders
4. Monopoly of material suppliers.

One important step of a project is to compare the budgeted/estimated project compares with the completed actual project. Cost overruns need a constructive analysis. Once the project is completely finished, and the project costs are paid, a postmortem meeting with significant individuals of the project team to discuss what went right and what went wrong is highly recommended (Christensen, 2002).

Chapter 4

Methods and Methodology

4.1 General

"If you can’t measure if you can’t manage". Whether one trusts the validity of this common phrase most of the time or all of the time, measuring the true progress of a project presents a formidable task. Given a baseline plan, projects typically report a moon: of the completed work and compare it to that scheduled. Similarly, most projects can and do mason the current cost and compare it to the planned spending. But for a more comprehensive view, how does one measure the progress of a project against the triple constraint of cost, schedule, and scope? The two simple measures above separate schedule and cost and include scope only indirectly, as function of schedule. In this framework, the more contemplation of rho budgeted cost of work performed cries out for an immediate comparison to the actual cost. Earned value analysis next brings the schedule into this common comparison basis by asking how much Spending next brings it should have occurred, i.e., according to a project’s schedule, at the specific time of any comparison. The major objectives of applying earned value to a contract are to encourage contractors to use effective’s internal technical, cost and schedule management control systems for better management insight (Lipke, 2003).

This data is in turn used for determining product-oriented contract status, and projecting future performance based on trends to date. In addition, EVM allows better and more effective management decision making to minimize adverse impacts to the project. The aim is to demonstrate that earned value management (EVM) is a program management technique that integrates technical performance requirements, resource planning, with schedules, while taking risk into consideration as shown in figure 4.1.

Fig 4.1- Project management component circle

(Lipke, 2003)

Earned value provides an objective measurement of how much work has been accomplished on a project. Using the earned value process, the management team can readily compare how much work has actually been completed against the amount of work planned to be accomplished. All work is planned. Budgeted, and scheduled in time-phased "planned value" increments constituting a Performance Measurement Baseline (PMB). Earned Value differs from the usual budget verses actual costs incurred model, in that it requires the cost of work in progress to be quantified. This allows the project manager to compare how much work has been completed against how much he expected to be completed at a given point. Earned Value is also known as Performance Measurement. Management by Objectives, Budgeted Cost of Work Performed and Cost Schedule Control Systems. Earned value (EV) is one of the most; sophisticated and accurate methods for measuring and controlling project schedules and budgets. Earned value has been used extensively in large projects, especially in government projects. Project Management Institute is a strong supporter of the earned value approach because of its ability to accurately monitor the schedule and cost variances for complex projects (Lipke. 2003).

There are three primary advantages to Using earned value:

- Accuracy in reporting.
- Ability to deal with the uneven rate of project expenditures and work.
- The early warning it provides project managers, allowing them to take the necessary corrective action should the project be spending more money than it is physically accomplishing (Lipke. 2009).

4.2 Data Collection

In order to perform EVM analysis information about estimated and actual cost, planned and actual duration for different construction activities is necessary. In the present study the information was collected of a high rise structure constructed my Mahindra life space developers. Table 4.1 gives the clear details of the entire project along with the start and finish time and also the total area of the project and the total cost of the high rise.

Table 4.1- Actual Project Details

Client	Mahindra Lifespace Developer Ltd.	Total Duration	909 days
Contractor	RSB Infrastructure Ltd.	Start date	30/03/2012
Name of the project	Mahindra Aura	Planned finish date	24/09/2015
Contract amount	₹ 302,814,361.74	Total floor area	1244487sft
Contract amount for Tower H	₹ 270000000	Total floor area of Tower H	139943 sft
Start date of tower H	1/11/2012	Finish date of tower H	22/05/2015

4.3 Earned Value Analysis

Earn Value Management (EVM) technique was used to track the progress and Status Project and to predict future performance of the Project (Lipke, 2004). EVM technique integrates the scope, schedule and cost of project. EVM technique answers a lot of questions to the stakeholders in a project related to the performance of the project. EVM technique can be used to show past performance of the project, current performance of the project and predict the future performance of the project by use of statistical techniques. Proper planning coupled with effective use of the EVM technique will reduce large amount of issues arising out of schedule and cost overruns (Lipke, 2004). The basic elements of EVM are mentioned below

a. Planned Value (PV)
b. Actual Cost (AC)
c. Earned Value (EV)

These elements are calculated for different activities at regular interval during progress of work.

4.3.1 Planned Value (PV)

This is also referred to as Budgeted Cost of Work Scheduled (BCWS). Planned Value (PV) or BCWS is the total cost of the work scheduled /Planned as of a reporting date. This is calculated as shown in Eq.1 (Lipke, 2004):

PV or BCWS = Hourly Rate * Total Hours Planned or Scheduled........... (1)

4.3.2 Actual Cost (AC)

This is also referred to as Actual Cost of Work Performed (ACWP). Actual Cost (AC) or ACWP is the total cost taken to complete the work as of a reporting date.

This is calculated as shown in Eq.2 (Lipke, 2004):

AC or ACWP = Hourly Rate * Total Hours Spent........... (2)

4.3.3 Earned Value (EV):

This is also referred to as Budgeted Cost of Work Performed (BCWP). Earned Value (EV) or BCWP is the total cost of the work completed/performed as of a reporting date. This is calculated as shown in Eq.3 (Lipke, 2004):

EV or BCWP = Baseline Cost * % Complete Actual........... (3)

All these three elements can be derived from Work Breakdown Structure by associating the costs to each of the tasks. For a big project it will be a tedious task to calculate these elements manually. Scheduling Software's like Microsoft Project is used to calculate these three elements.

4.3.4 Cost Variance (CV)

It is a very important factor to measure project performance. Cost Variance (CV) indicates how much over budget or under budget the project is. Cost Variance can be calculated as in (4) (Lipke, 2004):

Cost Variance (CV) = Earn value (EV) - Actual Cost (AC) = BCWP- ACWP........... (4)

a. The formula mentioned above gives the variance in terms of cost which will indicate how less or more cost has been to complete the work as of date.
b. Positive Cost Variance Indicates the project is under budget.
c. Negative Cost Variance Indicates the project is over budget.

4.3.5 Cost Variance Percentage

Indicates how much over or under budget the project is in terms of percentage. Cost Variance Percentage can be calculated as in (5) (Lipke, 2004):

CV % = Cost Variance (CV) / Earned Value (EV) = CV / BCWP............ (5)

The formula mentioned above gives the variance in terms of percentage which will indicate now much less or more money has been used to complete the work as planned in terms of percentage.

a. Positive Variance % indicates project. Under Budget.
b. Negative Variance % indicates project over Budget.

4.3.6 Cost Performance Indicator (CPI)

Cost Performance indicator is an index showing the efficiency of the utilization of the resources on the project. Cost Performance Indicator can be calculated as shown in Eq.6 (Lipke, 2004):

CPI = Earned Value (EV) /Actual Cost (AC) = BCWP / ACWP........... (6)

a. The formula mentioned above gives the efficiency of the utilization of the resources allocated to the project.
b. CPI value above 1 indicates eminency in utilizing the resources allocated to the project is good.
c. CPI value below 1 indicates efficiency in utilizing the resources allocated to the project is not good.

4.3.7 Schedule Variance (SV)

Indicates how much ahead or behind schedule the projects. Schedule Variance can be calculated as shown in Eq.7 (Lipke, 2004):

Schedule Variance (SV) = Earned Value (EV) Planned Value (PV) = BCWP- BCWS.......... (7)

a. The formula mentioned above gives the variance in terms of cost which will indicate how much cost of the work is yet to be completed as per schedule or how much cost of work has been completed over and above the scheduled cost.
b. Positive Schedule Variance Indicates we are ahead of schedule.
c. Negative Schedule Variance Indicates we are behind of schedule.

4.3.8 Schedule Variance Percentage

Schedule Variance % indicates how much ahead or behind schedule the project is in terms of percentage. Schedule Variance % can be calculated as shown in Eq.8 (Lipke, 2004)

SV%= Schedule Variance (SV)/planned value (PV) =SV/BCWS…………….. (8)

- The formula mentioned above gives the variance in terms of percentage which will indicate how much percentage of work is yet to be completed as per schedule or how much percentage of work has been completed over and above the scheduled cost.
- Positive Variance % indicates project ahead of schedule.
- Negative Variance % indicates project behind of schedule.

4.3.9 Schedule Performance Indicator (SP1)

Schedule Performance Indicator is an index showing the efficiency of the time utilized on the project. Schedule Performance Indicator can be calculated as shown in Eq.9 (Lipke, 2004):

SPI= Earned Value (EV)/Planned Value (PV) = BCWP/BCWS .... (9)

- The formula mentioned above gives the efficiency of the project team in utilizing the time allocated for the project.
- SPI value above l indicates project team is very efficient in utilizing the time allocated to the project.
- SPI value below 1 indicates project team is less efficient in utilizing the time allocated to the project.

4.3.10 Budget at Completion (BAC)

Budget at Completion (BAC) is the total budget allocated to the project (Lipke, 2004).

- Budget at Completion (BAC) is generally plotted over time. Say like periods of reporting (Monthly, Weekly etc.).
- BAC is used to compute the Estimate at Completion (BAC).
- BAC is also used to compute the TCPI and TSPI. BAC is calculated as in (10):

  BAC = Base lined Effort-hours * Hourly Rate........... (10)

4.3.11 Estimate to Complete (ETC):

- Estimate to Complete (ETC) is the estimated cost required to complete the remainder of the project (Lipke, 2004).
- Estimate to Complete (ETC) is calculated and applied when the past estimating assumptions become invalid and a need for fresh estimates arises.
- ETC is used to compute the estimation at completion (EAC).

4.3.12 Estimate at Completion (EAC): Estimate at Completion (BAC) is the estimated cost of the project at the end of the project (Lipke. 2004):

There are three methods to calculate BAC:

- Variances aretypical this method is need when the variances at the current stage are typical and are not expected to occur in the future.
- Past Estimating Assumptions are not valid- This method is used when the past estimating assumptions are not valid and fresh estimates are applied to the project.
- Variances will be present in the future - This method is used when the assumption is that the current variances will be continued to be present in the future. Different way to calculate EAC as shown below (Lipke, 2004):

1. BAC = AC + (BAC-EV)
2. EAC = AC+ETC
3. EAC = AC + (BACEV) / CPI.

4.3.13 Variance at Completion (VAC)

It is the variance on the total budget at the end of the project. This is the difference between what the project was originally expected (baseline) to cost, versus what it is now expected to cost. VAC is calculated as show in Eq.11 (Lipke, 2004):

VAC = BAC-EAC........... (11)

4.3.14 Percentage Completed Planned

The percentage of work which was planned to be completed by the Reporting Date. This is calculated as shown in Eq. 12 (Lipke, 2004):

% Completed Planned = PV / BAC........... (12)

4.3.15 Percentage Completed Actual

The percentage of work which was actually completed by the Reporting Date. This is calculated as shown in Eq. 13 (Lipke, 2004):

% Completed Actual = AC / BAC. .... (13)

4.4 Earned Value Analysis Using Microsoft Project software

Microsoft Project is an important tool to track project performance using Earned Value. The following steps were carried out to obtain the EV for the project under case study,

Step 1: Create project plan

Base line project is a feature used to describe the project plan. It contains two tasks called "User Interface" and "Database design" which are represented in Gantt chart and resource sheet as shown in Figure 4.2 and Figure 4.3 respectively,

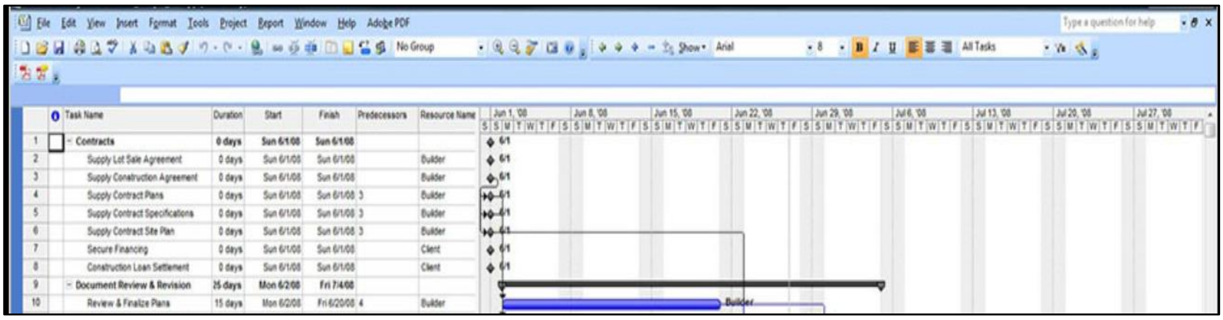


Fig 4.2- Gantt chart

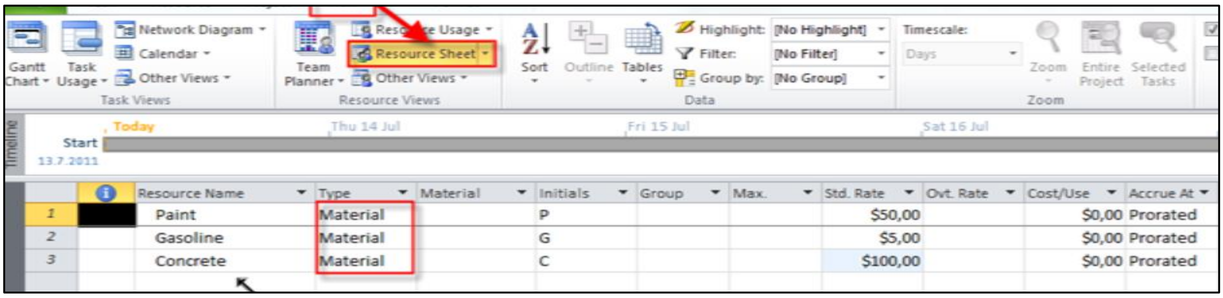
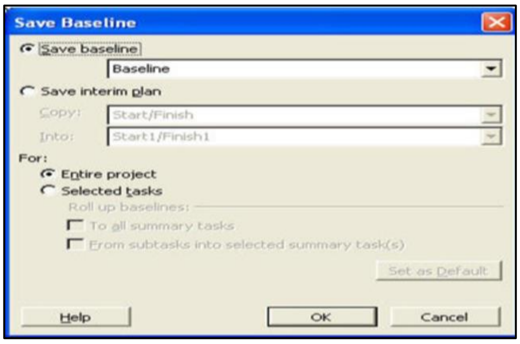


Fig 4.3- Resource Sheet

Step 2: Save Baseline

To measure status of the project, 'save base line' plan function was used depending upon the frequency of measurement (Figure 4.4). In the present study, this was performed on quarterly basis. Similarly, project statistics was used to check the EVM parameters for next cycle of measurement as shown in Figure 4.5.



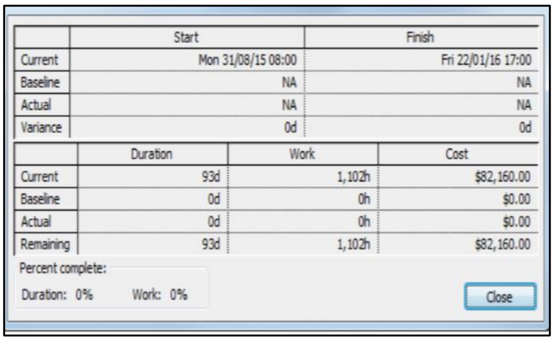


Fig 4.4- Save Baseline

Fig 4.5- Project Statistics

Step 3: Update project plan

After entering the necessary details for activity, project status can be tracked through update project plan".

Step 4: Set status date

This step is performed to set the desired date according to the progress of work. This will help to monitor the project performance as per requirement. For example 05/02/20l4 indicates the status date of the project as shown in Figure 4.6.

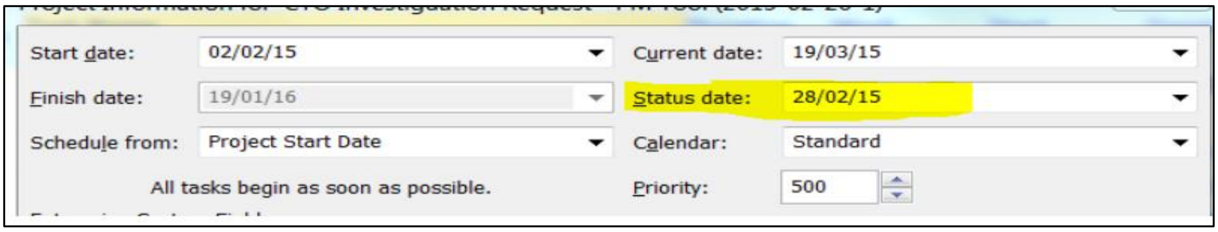


Fig 4.6- Set Status Date

Earned value calculations also based on following settings on Microsoft Project (Figure 4.6).

Baseline Number: If project contains multiple base lines, it is possible to specify particular baseline to perform EV calculation.

EV Calculation Method: Earned value calculations always based on % Complete or Physical % Complete. Steps are: Under Tools menu, select Options; Click on Calculation tab and Click on Earned Value; select Default task Earned Value method and Baseline for Earned Value calculations from dropdown and click OK; Save Project Plan. In the present study, EV calculation method was adopted to calculate different EV parameters.

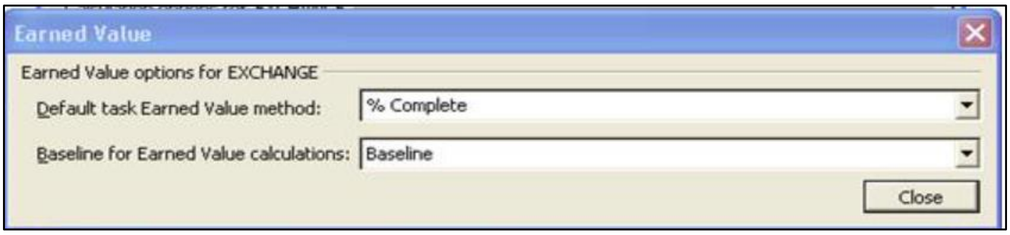


Fig 4.7- Settings for EV calculation method

Step 5: Analyze Earn Value

This function will enable to measure the Project performance in terms of EVM parameters.

Step 6: Cash Flow Analysis and Cost Overview

Incomings and outgoings of cash represent the operating activities of an organization. In accounting, cash flow is the difference in amount of cash available at the beginning of a period and the amount at the end of that period. This function is used for graphical representation of earn value analysis in terms cost and duration; It can help in future planning of the project. Steps are: Under Tools menu, select Options; Click on report and Click on visual report; select Default Task Cash flow or cost overview click OK.

4.5 Summary

The data collected during field visit was processed using MS Project software to estimate the earned value parameters. Thus, EVM parameters such as AC, EV, PV, CV, SV, CPI, and SPI were obtained for project by adopting the procedure as explained above.

Chapter 5

Results and Discussion

5.1 General

The Earned Value Analysis helps project managers to track the performance of the project. In this chapter, the EVM parameters required for performing the earned value management are discussed in details. Also the detailed cost calculation is shown in the following chapter. The performance of project in terms of their indices are explained in detail below. Table 5.1 shows the overall costing of building H. Along with the duration mentioning the start and finish time of every activity which has been carried out in the building.

Table 5.1- Construction Cost Data

Task Name	Duration	Start	Finish	Cost
Tower-H	**203 days**	**Sat 11/1/14**	**Fri 5/22/15**	**₹ 25,412,049.00**
Civil Work	**201 days**	**Sat 11/1/14**	**Wed 5/20/15**	**₹ 18,383,318.50**
WIP	0 days	Thu 1/1/15	Thu 1/1/15	₹ 0.00
Brick Work	**14 days**	**Mon 12/1/14**	**Sun12/14/14**	**₹ 1,108,740.00**
Full Brick Work	7 days	Mon 12/1/14	Sun 12/7/14	₹ 554,370.00
Half Brick Work	7 days	Mon 12/8/14	Sun 12/14/14	₹ 554,370.00
Internal Plaster	**10 days**	**Mon**	**Wed 12/24/14**	**₹ 606,812.00**

Flats	10 days	Mon 12/15/14	Wed 12/24/14	₹ 303,406.00
Common area	7 days	Mon 12/15/14	Sun 12/21/14	₹ 303,406.00
Tiling	**59 days**	**Sat 11/1/14**	**Mon 12/29/14**	**₹ 1,629,362.90**
Room Tiling	**56 days**	**Sat 11/1/14**	**Fri 12/26/14**	**₹ 802,262.90**
1st Floors	3 days	Sat 11/1/14	Mon 11/3/14	₹ 401,131.45
Ground Floor	5 days	Mon 12/22/14	Fri 12/26/14	₹ 401,131.45
Toilet Tiling	**8 days**	**Mon**	**Mon 12/29/14**	**₹ 582,500.00**
Wall Tile	3 days	Mon 12/22/14	Wed 12/24/14	₹ 291,250.00
Floor Tile	5 days	Thu 12/25/14	Mon 12/29/14	₹ 291,250.00
Kitchen Tiling	**5 days**	**Mon**	**Fri 12/26/14**	**₹ 244,600.00**
Floor Tile	3 days	Mon 12/22/14	Wed 12/24/14	₹ 122,300.00
Wall Tile	5 days	Mon 12/22/14	Fri 12/26/14	₹ 122,300.00
Stone Work	**64 days**	**Sat 11/1/14**	**Sat 1/3/15**	**₹ 714,210.00**
Toilet Counter stone	**2 days**	**Mon**	**Tue 12/23/14**	**₹ 86,820.00**
Kitchen Counter stone	2 days	Mon 12/22/14	Tue 12/23/14	₹ 86,820.00
Common area Stone Work	**64 days**	**Sat 11/1/14**	**Sat 1/3/15**	**₹ 627,390.00**
Lift Lobby Flooring	**56 days**	**Sat 11/1/14**	**Fri 12/26/14**	**₹ 297,030.00**
1st Floor	3 days	Sat 11/1/14	Mon 11/3/14	₹ 148,515.00
Ground Floor	5 days	Mon 12/22/14	Fri 12/26/14	₹ 148,515.00
Lift lobby Cladding	**61 days**	**Tue 11/4/14**	**Sat 1/3/15**	**₹ 330,360.00**
1st Floor	4 days	Tue 11/4/14	Fri 11/7/14	₹ 110,120.00
Ground Floor	4 days	Sat 12/27/14	Tue 12/30/14	₹ 110,120.00
Balcony Tiling	4 days	Wed 12/31/14	Sat 1/3/15	₹ 110,120.00
Door Shutter	**12 days**	**Sat 11/1/14**	**Wed 11/12/14**	**₹ 321,120.00**
Door hardware	**105.2 days**	**Sat 11/1/14**	**Sat 2/14/15**	**₹ 1,665,723.60**
Internal Painting- Putty Final Coat	**72 days**	**Sat 1/3/15**	**Sun 3/15/15**	**₹ 0.00**
Internal Painting- 1st Coat	**71 days**	**Wed 1/7/15**	**Wed 3/18/15**	**₹ 0.00**
Internal Painting- 2nd Coat	**54 days**	**Sat 3/28/15**	**Wed 5/20/15**	**₹ 8,384,004.00**
External Painting	**163 days**	**Sat 11/1/14**	**Sun 4/12/15**	**₹ 2,311,746.00**
Wooden Flooring	**36 days**	**Tue 3/31/15**	**Tue 5/5/15**	**₹ 1,641,600.00**
Services	**200 days**	**Tue 11/4/14**	**Fri 5/22/15**	**₹ 7,028,730.50**
Electrical Wiring	**106.2 days**	**Tue 11/4/14**	**Wed 2/18/15**	**₹ 1,447,491.50**
Chinaware & CP fitting	**72 days**	**Sat 1/10/15**	**Sun 3/22/15**	**₹ 725,634.00**
Plumbing Testing	**20 days**	**Mon 3/23/15**	**Sat 4/11/15**	**₹ 305,952.00**
Electrical fixture	**53 days**	**Tue 3/31/15**	**Fri 5/22/15**	**₹ 2,949,653.00**
SHWS	15 days	Sun 2/1/15	Sun 2/15/15	₹ 1,600,000.00

The cost considered in the above mentioned table is being taken from the Appendix-I from the BOQ sheet of the project.

Table 5.2 shows the distribution of all the values as Actual value (AV), Earned value (EV) and Planned value (PV).

Table 5.2- Cumulative PV, EV and AC

Task Name	Planned Value -	Earned Value - EV	Actual Value-AC
Tower-H	**₹ 10,022,974.73**	**₹ 5,175,738.82**	**₹ 5,175,738.82**
Civil Work	**₹ 10,022,974.73**	**₹ 5,175,738.82**	**₹ 5,175,738.82**
WIP	₹ 0.00	₹ 0.00	₹ 0.00
Brick Work	**₹ 1,108,740.00**	**₹ 1,108,740.00**	**₹ 1,108,740.00**
Full Brick Work	₹ 554,370.00	₹ 554,370.00	₹ 554,370.00
Half Brick Work	₹ 554,370.00	₹ 554,370.00	₹ 554,370.00
Internal Plaster	**₹ 606,812.00**	**₹ 606,812.00**	**₹ 606,812.00**
Flats	₹ 303,406.00	₹ 303,406.00	₹ 303,406.00
Common area	₹ 303,406.00	₹ 303,406.00	₹ 303,406.00
Tiling	**₹ 1,629,362.90**	**₹ 1,629,362.90**	**₹ 1,629,362.90**
Room Tiling	**₹ 802,262.90**	**₹ 802,262.90**	**₹ 802,262.90**
1st Floors	₹ 401,131.45	₹ 401,131.45	₹ 401,131.45
Ground Floor	₹ 401,131.45	₹ 401,131.45	₹ 401,131.45
Toilet Tiling	**₹ 582,500.00**	**₹ 582,500.00**	**₹ 582,500.00**
Wall Tile	₹ 291,250.00	₹ 291,250.00	₹ 291,250.00
Floor Tile	₹ 291,250.00	₹ 291,250.00	₹ 291,250.00
Kitchen Tiling	**₹ 244,600.00**	**₹ 244,600.00**	**₹ 244,600.00**
Floor Tile	₹ 122,300.00	₹ 122,300.00	₹ 122,300.00
Wall Tile	₹ 122,300.00	₹ 122,300.00	₹ 122,300.00
Stone Work	**₹ 714,210.00**	**₹ 714,210.00**	**₹ 714,210.00**
Toilet Counter stone	**₹ 86,820.00**	**₹ 86,820.00**	**₹ 86,820.00**
Kitchen Counter stone	₹ 86,820.00	₹ 86,820.00	₹ 86,820.00
Common area- Stone Work	**₹ 627,390.00**	**₹ 627,390.00**	**₹ 627,390.00**
Lift Lobby Flooring	**₹ 297,030.00**	**₹ 297,030.00**	**₹ 297,030.00**
1st Floor	₹ 148,515.00	₹ 148,515.00	₹ 148,515.00
Ground Floor	₹ 148,515.00	₹ 148,515.00	₹ 148,515.00
Lift lobby Cladding	**₹ 330,360.00**	**₹ 330,360.00**	**₹ 330,360.00**
1st Floor	₹ 110,120.00	₹ 110,120.00	₹ 110,120.00
Ground Floor	₹ 110,120.00	₹ 110,120.00	₹ 110,120.00
Balcony Tiling	₹ 110,120.00	₹ 110,120.00	₹ 110,120.00

Door Shutter	**₹ 321,120.00**	**₹ 321,120.00**	**₹ 321,120.00**
Door hardware	**₹ 1,665,723.60**	**₹ 333,144.72**	**₹ 333,144.72**
Internal Painting- Putty Final Coat	**₹ 0.00**	**₹ 0.00**	**₹ 0.00**
Internal Painting- 1st Coat	**₹ 0.00**	**₹ 0.00**	**₹ 0.00**
Internal Painting- 2nd Coat	**₹ 2,018,371.33**	**₹ 0.00**	**₹ 0.00**
External Painting	**₹ 1,502,634.90**	**₹ 462,349.20**	**₹ 462,349.20**
Wooden Flooring	**₹ 456,000.00**	**₹ 0.00**	**₹ 0.00**

Table 5.3 gives the total earned value report for the study.

Table 5.3 - Earned Value Report

Month	Planned value (BCWS) (in Cr)	Actual cost (ACWP) (in Cr)	Earned value (BCWP) (in Cr)
November 2014	19.85	18.50	18.00
December 2014	21.35	20.00	19.50
January 2015	22.25	20.90	20.40
February 2015	23.25	21.90	21.30
March 2015	24.75	23.40	22.70
April 2015	26.00		
May 2015	27.00		

From Table 5.3 we have following Values:

- Planned value (BCWS) = 24.75 Cr
- Earned value (BCWP) = 22.70 Cr
- Actual cost (ACWP) = 23.40 Cr
- Budget at completion (BAC) = 27.00 Cr

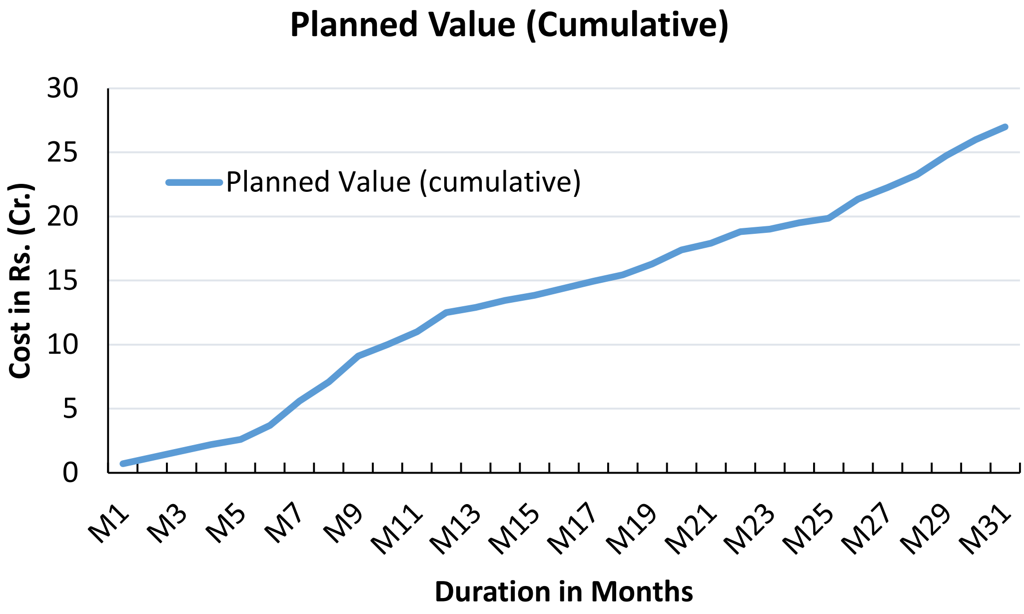


Fig 5.1- Cumulative S Curve {Duration (months) *V/s* Cost (Cr)}

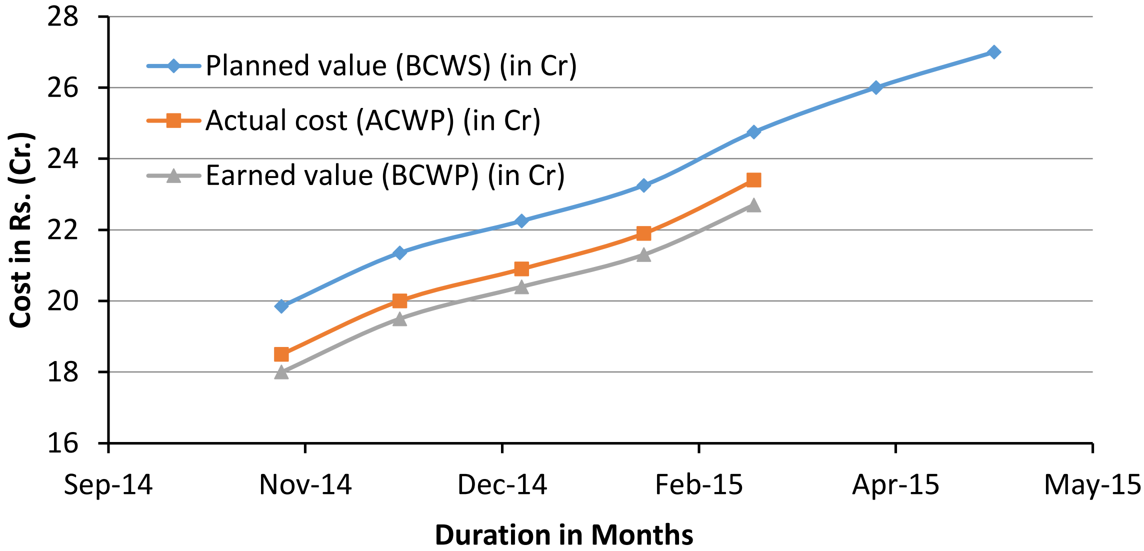


Fig 5.2- Cumulative PV, EV and AC for the Project

Graph shows the S-Curve for cumulative planned value, earned value and actual cost of the project for a period of 5 months. The graphs are the time v/s cost representation of the values. From Figure 5.1, it is clear that the earned value line is below the planned value line, which indicates that the work has not been accomplished as per the planned value. From Figure 5.2, it is also clear that the earned value line is below the actual cost line, which indicates that the work has been going as a cost overrun.

Table 5.4- Project Performance Indicators

To Calculate	Formula	Value (In Cr)	Questions for Project Management	Interpretation
1. How are we doing time-wise? Schedule analysis and forecasting				
Schedule Variance (SV)	SV = EV−PV	-2.05	Are we ahead or behind of schedule?	Behind the schedule
Schedule Performance Index (SPI)	SPI = EV/PV	0.917	How efficiently are we using time?	Behind the schedule
Time Estimate at Completion	(BAC/SPI) / (BAC/Months)	(27/0.917) / (27/31) = 34	When are we likely to finish work?	Behind the scheduled date
2. How are we doing cost-wise? Cost analysis and forecasting				
Cost Variance (CV)	CV = EV−AC	-0.7	Are we under or over our budget?	Over the budget
Cost Performance Index (CPI)	CPI = EV/AC	0.97	How efficiently are we using resources?	Over the budget
Estimate at Completion (EAC)	EAC = BAC/CPI	27.83	What is the project likely to cost?	Continuation of current performa tend leading to over budgeted cost.
Variance at Completion (VAC)	VAC = BAC−EAC	-0.83	Are we under or over budget?	Over the budget
Estimate to Complete	(BAC−EV)/ CPI	27.835	What will be the remaining work cost?	Continuation of current performa tend leading to over budgeted cost

The calculation of various project performance indicators is shown in the above table. It is clear that,

1. The Schedule Variance (SV) of the project is -2.05 resulting in project to be behind the schedule. The Schedule Performance Index (SPI) tells that the project is progressing with the rate of 91.7% of the original planned value. The rate at which the project is progressing is indicated by SPI.
2. The original estimated completion time for the project was 31 months. But, at this stage we found that if this continues at this current rate, then the project will take 3 months more than the original planned date leading to the final work completion in 34 months.
3. The cost variance of the project is -0.7 which is very unfavorable for the project resulting in project to be over the budget. The Cost Performance Index (CPI) of 0.97

tells the project is currently running over the budget by 3% for the total cost we spend, leading to attaining the value of rupees 0.97 for every 1 rupee spent.

4. The Estimate at Completion (EAC) shows that expected total cost of Project at Completion is based on the performance of data 27 Cr (i.e. BAC) divided by 0.97 (ie. CPI) is 27.83 Cr. Thus, EAC is 27.83 Cr. In other words, as the project is getting only 0.97 rupee for every 1 rupee, resulting in project to cost 27.83 Cr instead of 27 Cr that was planned.
5. The Variance at Completion (VAC) shows variance of total cost of the project work and the expected cost. Here the value of VAC is -0.83. That means, by the date the project is over budget by 0.835 Cr. The Estimate to Complete (EAC) shows the expected cost required finishing all the remaining work, here it is 27 Cr. This is the real amount needed to complete the work.

5.2 Summary

The project performance indicators show that the project is behind the original schedule as per the SPI calculations. The is approximately 3 months behind the schedule. The project is also over budgeted as the CPI has become negative as shown in the above table 5.4.

Chapter 6

Conclusions and Future Scope

6.1 General

EVM is a project performance evaluation technique that has application in project management. EVM is widely recognized as a core project management technique with many advantages, however, its utilization is not widespread beyond a few specific industries, notably the defense and aerospace organisations. Limited studies have been reported in construction sector. Therefore, the purpose of this study is to investigate the impact of different project characteristics in relation to influence on earned value predictors and EVM in general.

6.2 Conclusions

1. As project managers, all are aware of earned value management to help control costs. Using this concept to track a real-time project is extremely useful and gives an instant feel about the performance of the project.
2. The expected outcome of the project will show the difference in scheduled performance and actual performance of the project for a particular period of observation. Based on

the performance, we can find the reasons for variance of schedule and variance of cost; also we can predict the future of the project.

3. Although EVA (Earned Value Analysis) may be most easily associated with the monitoring and evaluation of project cost that are undertaken within an organization, it can also be readily applied, with some adjustment, to the control of project cost that are performed by contractors and vendors. In those circumstances, however, it must be recognized that the client and contractor will have differing perspectives on actual and budgeted costs.
4. This study also indicated that EVA has significant value and presents unique features that can benefit clients, consultants and contractors involved in the wide range of construction industries.
5. EVM keeps the project managers on alert on any mishaps to take corrective actions on the right time.
6. It also provides an efficient way to manage risks in a construction projects and try to avoid them in future projects.
7. As, EVA requires a lot of proper integration of planning, effective costing and monitoring systems of different project activities to ascertain the input figures needed for calculating earned value. Therefore, the project managers have to use a proper accounting system that would help in making earned value work effectively for the project.

6.3 Scope for Future Work

This study has emphasized on the performance of a residential building and provided useful understandings on different aspects related to EVM methodology. Despite the sample size being small, it is assumed that the study gives a fair overview of construction projects. Similar studies can be performed to evaluate the project performance of Infrastructure projects. There is wide scope for developing a project management software which could produce pictorial representation of EVM parameters for different activities based on the variances and indices directly without involving complexity of variables and can be interpreted by lower management.

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Appendix I

BOQ for Tower H

Sr. No.	Description of Items	Unit	Qty.	Rate	Amount
1.01	Excavation over areas from existing natural ground level. Earth work in excavation by mechanical means over areas, clearing the site from bushes, vegetation etc. and stacking the excavated material complete at site including providing required slopes to vertical sides, shoring, strutting, dewatering and back filling (under OMC condition and rolled in layers of not more than 20 cm thickness) with the suitable excavated soil and disposal surplus excavated earth inside the premises including rehandling, transporting, royalties, loading at all levels, depths and height all complete as directed, all leads and lifts, incidentals, etc. complete. Excavation shall be payable only for vertical cut up to the outer edge of foundation lean concrete as indicated on drawings throughout the pit depths. Cost of extra excavation required for working space, supporting side shuttering of foundations and that required for making slopes for stability of excavation shall be deemed to be included in the rate quoted. (Note: - The Line & levels in the drawings shall be strictly followed and excess excavation if any shall be made good by the contractor free of cost as per the instructions of the Project Manager, to include stacking of excavated earth inside the premises and disposal of excess excavated earth. The item also to include final dressing as (required) at bottom level 0.3 m depth manually to reach PCC level of foundation).				
A	Depth upto 1.5 mtr.	Cum	56	130	7280
B	Depth between 1.5 mtr to 3.0 mtr (To final dressed level)	Cum	8	145	1160
1.02	Transportation, handling and filling with already available excavated earth in trenches, around sides of foundation, behind retaining walls, under floors etc. at all depths and levels as per drawings, in layers, not exceeding 20cm in depth. & consolidating each deposited layer by ramming and watering as per specifications (within a lead upto avg. 500 mtr.) Note: Filling will be done with available excavated earth already stacked at site by the other Contractor.	Cum	2000	100	200000
1.03	Providing and filling with fine river sand in plinth and under floor, above raft, including watering, ramming and consolidation, dressing complete.	Cum	200	1235	247000
1.04	Earth work in excavation in foundation trenches or drains (not exceeding 1.5m in width or 10sqm on plan) including back filling, dressing of sides and ramming of bottoms, lift upto 1.5m, including getting out the excavated soil and disposal of surplus excavated soil as directed within site				
A	All kinds of soil.	Cum	50	120	6000

1.05	Providing and injecting chemical emulsion for pre-constructional anti-termite treatment and creating a chemical barrier under and all-round the column pits, wall trenches basements excavation, top surface of plinth filling, junction of wall and floor along the external perimeter of building, expansion joints, surroundings of pipes and conduits etc. complete (Plan area at Ground floor level shall be measured)				
A	CHLOROPYRIPHOS emulsifiable concentrates 1.0%	Sqm	1400	90	126000
2.01	Providing and laying in position cement concrete of specified grade including the cost of centring shuttering - All work for all heights.				
A	1:2:4 (1 cement: 2 coarse sand: 4 graded stone, aggregate 20mm nominal size) / (M - 15)	Cum	17	5550	94350
B	1:4:8 (1 cement: 4 coarse sand: 8 graded stone, aggregate 40mm nominal size) / (M - 7.5)	Cum	158	4000	632000
3.01	Providing & laying cast - in - place structural controlled cement concrete of grade M-20 using weigh batching plant (Fully Computerised) with fly ash as per I.S.code & upto extent permitted by I.S.code with cement of O.P.C. grade and using pump with 20mm down coarse aggregates excluding cost of centering & shuttering, & reinforcement steel but including making shear keys and provision of construction / contraction / control joints in various locations, laid, consolidated and cured, Item to include all structural items like base raft, ramp, column, wall, footings, equipment foundations, fins, mullions, beams, lintels, pergola, chajja, facia, parapet, railing, slab, trenches, drains, U/G & O.H. water tanks and sumps etc. of any shape and sizes. The rates of concrete to include the cost of admixtures / plasticisers to achieve specified strength and to facilitate pumpable concrete, for all heights and lifts below or above G.L. as shown in the drawings.				
A	Foundation, raft slab, raft beams, plinth beam, pedestals/ bases or column, grade slab of U/G tank etc.	cum			
B	Suspended floors, roofs, balconies, shelves / counters, stair waist slabs, folded plate stairs and landings, lintel and floor beams, girders (deep beams), RCC bands, cantilever projections, slab of tank etc.	cum	60	5800	348000
C	Columns, pillars, piers, abutments, posts and struts, offset and projection of columns, water tank walls, lift walls, shear wall etc.	cum	40	5800	232000
D	Parapets, planters, facins, fins, cornices, coping, vertical projection of balconies, pergolas, copings, sills etc. (for all heights below or above ground level as shown in the drawings)	cum	30	6200	186000
3.02	Providing & laying cast - in - place structural controlled cement concrete grade M-20 using weigh batching plant and pump with 20mm down coarse aggregates excluding cost of centring & shuttering & reinforcement steel but including				

	making shear keys and provision of construction / contraction / control joints in various locations, laid, consolidated and cured, Item to include all structural items like base raft, ramp, column, wall, footings, equipment foundations, fins, mullions, beams, lintels, pergola, chajja, facia, parapet, railing, slab, trenches, drains, U/G & O.H. water tanks and sumps etc. of any shape and sizes. The rates of concrete to include the cost of admixtures / plasticisers to achieve specified strength and to facilitate pumpable concrete, for all heights and lifts below or above G.L. as shown in the drawings.				
A	Foundation, raft slab, raft beams, plinth beam, pedestals/ bases or column, grade slab of U/G tank etc.	Cum		6100	
B	Suspended floors, roofs, balconies, shelves / counters, stair waist slabs, folded plate stairs and landings, lintel and floor beams, girders (deep beams), RCC bands, cantilever projections, slab of tank etc.	Cum	25	6000	150000
C	Columns, pillars, piers, abutments, posts and struts, offset and projection of columns, water tank walls, lift walls, shear wall etc.	Cum		6500	
D	Parapets, planters, facias, fins, cornices, coping, vertical projection of balconies, pergolas, copings, sills etc. (for all heights below or above ground level as shown in the drawings)	Cum	5	6200	31000
3.05	**Centring and shuttering**				
	Approved Marine plywood or 3mm thick steel plate shuttering and centring for structural concrete work in locations called for including strutting, propping, bracing, bolting, wedging, casing, striking, removal of form etc. complete for any size, section, thickness. Props shall consist of well-designed steel pipes adequately braced (wooden ballies as props shall not be permitted). The item to include centring and shuttering at all heights and levels, below or above ground level.				
A	Foundation, raft slabs, raft beams, plinth beam, pedestals/ bases of columns etc.	Sqm	33	290	9570
B	Retaining walls (any thickness)	Sqm		330	
C	Suspended floors, roofs, shelves in kitchen & toilet, landings, balconies, stairs and landings, slabs of water tank, ramp slabs etc.	Sqm	450	330	148500
D	Lintels, beams, floor beams, girders, cantilever beams, deep beams, ramp beams etc.	Sqm	750	350	262500
E	Columns, pillars, piers, abutments, posts and struts, off sets & projection of columns, transfer columns, lift walls, water tank walls, shear wall, ramp walls etc.	Sqm	150	330	49500
F	Parapets, Planters, vertical fins, balcony facias, projections, pergolas as per the shape and profiles indicated in the drawings.	Sqm	125	395	49375

	1) Nothing extra shall be paid for circular, semi-circular in shape, irregular shuttering, additional height in shuttering and it is assumed to be included in the quoted rates.				
	2) It should be ensured that all joints between the shuttering plates is not exceeding 3 mm.				
	3) The plates shall have fairly flat surface with undulations not exceeding + 3 mm				
	4) The pattern of shuttering including the deployment of various sizes of plates shall be got approved in advance from owners.				
3.06	Laying of reinforcement for RCC work including straightening, cutting, bending, binding with necessary binding wire (including cost of binding wire) and placing in position complete, in all shapes, size and sections etc. at all floors and all heights / depths as per design and drawings:				
A	HYSD (High yield strength deformed bars) / Thermo Mechanical Treated bars (TMT)	MT	50	9500	475000
3.07	Extra for using richer mix in place of (M-20) cement concrete for RCC work above item no. 3.08				
A.	Extra for using (M-25) concrete in place of (M-20) cement concrete for RCC work.	cum	135	400	54000
B.	Extra for using (M-30) concrete in place of (M-20) cement concrete for RCC work.	cum	10	800	8000
C.	Extra for using (M-35) concrete in place of (M-20) cement concrete for RCC work.	cum	25	1000	25000
4.01	Supplying and fixing in position insert plates, bolts, angles, tees, plates, anchor bolts, anchor plates, cleats, column guards and grillage beams etc. in reinforced cement concrete work including cost of cutting, bending, drilling, threading and welding lugs etc. with all tools tackles and labour as per design or as directed including a coat of approved primer and making good the concrete surface if required.	Kg	3550	110	390500
4.08	Steel Work welded in built-up sections / framed work with MS square / round bars, pipes, tubes and like including cutting, hoisting, fixing in position by suitable means and applying 2 or more coats of synthetic enamel paint of approved colour and brand over zinc chromate steel primer on structural steel etc. as required.				
A	In railings, grills, ladders, louvers, guard bar, brackets, gates and similar. (Staircase railing & Balcony railing)	KG	16237	105	1704885
4.09	Providing and fixing ISI marked steel glazed doors, windows and ventilators of standard rolled steel sections, joints mitred and welded with 15x3mm lugs, 10cm long, embedded in cement concrete blocks15x10x10cm of 1:3:6 (1 cement : 3 coarse sand : 6 graded stone aggregate 20mm nominal size) or with wooden plugs and screws or rawl plugs and screws or with fixing clips or with bolts and nuts as required, including providing and fixing of 5mm thick glass panes with glazing				

	clips and special metal sash putty of approved make complete including applying a priming coat of approved steel primer and two coats of approved make & shade of synthetic enamel paint, excluding the cost of metal beading and other fitting except necessary hinges or pivots as per required.				
A	Fixed windows	Sqm	7	2800	19600
B	Extra for side hung / top hung portions	Sqm	7	200	1400
4.10	Providing and fixing angle / T iron frames for doors / windows and ventilators of MS angle, T sections, joints mitred and welded with 40x4 mm lugs 15cm long embedded in cement concrete block of size 20 x10 x10 cm, mix 1:3:6 (1 cement :3 coarse sand :6 graded stone aggregate 20 mm nominal size) or with wooden plugs and screws or rawl plugs and screws or fixing clips or with bolts and nuts as required including fixing of necessary butt hinges and screws and applying a priming coat of approved steel primer & applying two coats of synthetic enamel paint.	Kg	633	100	63300
4.11	Providing and fixing in position MS door shutter made out with 1 mm thick MS sheet welded with Iron frame and diagonal bracing of 40 x40 x6 mm and 3 mm MS gusset plate at the junctions and corners including door frames (chowkhat)made out with Tee of size 40 x40 x6 mm including hinges, hold fast , MS sliding bolt , MS tower bolt , handles with necessary cutting , grinding , welding etc. including cost of providing and applying two coats of approved make and shade of synthetic enamel paint over a coat of approved steel primer complete.	Sqm	10	3100	31000
	(Quoted Rates are for all heights, depths, levels, leads and lifts) The operations describe below are only indicative & the item is to be executed as per technical/ manufacturer's specification. Testing shall be done by pounding water (150mm depth) for 72 hours.				
	Note: (The Water proofing work must be executed by an approved specialised Agency. The Contractor shall give a 10 years guarantee including sealing of sleeves as per instruction of the Project Manager).				
5.01	**Tapecrete water proofing**				
	Providing, applying & testing water proofing treatment of RCC sunken slabs (toilets, kitchens and balconies) comprising of the following operations.				
	Cleaning RCC surfaces and plastering of RCC and brick wall surface with 12mm cement mortar 1:4 (1 cement : 4 coarse sand) mixed with CICO admixture as per manufacturer's specifications.				
	Three coats of tapecrete - (first layer of tapecrete to be @ 0.253kg/ sqm, the second & third layer to be @ 0.126kg/ sqm) each admixed with grey cement over a coat of neat cement slurry admixed with chemical CH - 9 and sealing all corners,				

	joints, junction of pipes and masonry etc. with Epoxy putty all complete as per manufacturer's specification and drawing.				
	12mm thick protective plaster 1:4 (1 cement: 4 coarse sand) over treated surface etc. complete. (Quoted rate to include grouting of RCC surface for any cracks/ fissures)	Sqm	945	495	467775
5.02	**Brick bat coba waterproofing**				
	Providing and laying water proofing treatment for terrace with the following including cleaning the RCC slab top surface.				
	Providing on top of slab surface cement slurry mixed with water proofing compound thereafter providing cement mortar 1:4 (1 cement : 4 coarse sand) 20mm thick with polymer based water proofing compound and layer of new half broken bricks (coba) giving gaps of 15-20mm between broken bricks, providing necessary gradient for proper flow of water and providing cement slurry with water proofing compound spread over brick bat coba in cement mortar 1:4 (1 cement : 4 coarse sand) with water proofing compound filled in gaps of broken bricks and 20mm plaster in cement mortar 1:4 (1 cement : 4 coarse sand) mixed with polymer based water proofing compound, top finished smooth with neat cement and providing rope chequers including extending the water proof plaster 300mm on vertical surfaces with necessary chasing / treating of walls including providing and making gola as per drawing etc. Average thickness of the brick bat coba to be 125mm.				
	The item also include providing and making khurrahs 450mm x 450mm/ 300mm x 300mm with average minimum thickness of 50mm cement concrete 1:2:4 (1 cement: 2 coarse sand: 4 graded stone aggregate of 20 mm nominal size) finished with aluminium foil and 12mm cement plaster 1:3 (1 cement: 3 coarse sand) and a coat of neat cement rounding the edges and making and finishing the outlet complete. (Plan area will be measured and paid)	Sqm	1264	875	1106000
5.03	Extra / less thickness				
	Add or deduct for extra or less thickness over item no. 5.02	Cum	10	4000	40000
5.04	Sunken area filling				
	Providing and laying in position brick bat cement concrete 1:4:8 (1 cement: 4 coarse sand: 8 graded Brick bat aggregate 40 mm nominal size) at all level including the cost of centring and shuttering.	Cum	53	3285	174105
5.05	Injection Waterproofing				
	Providing and applying Injection water proofing treatment for underground / overhead tank, retaining wall and other RCC structure with the following operations				
A	FOR VERTICAL WALLS (post construction)				
	Providing and laying water proofing treatment by chemical injection grout process in water tank (Underground and Overhead), retaining wall or other areas using 20 mm dia MS nozzles of minimum 25mm deep in walls placed and fixed	Sqm	168	550	92400

	@1.2m distance in both direction in the wall and @ 0.75m c/c along construction joints, consisting of injecting cement slurries of different viscosities under pressure by pump using acrylic based water proofing chemical mixed with neat cement slurry and sealing off nozzles after the injection operation with suitable admixture including providing and applying two coats of acrylic based water proofing chemical mixed with neat cement slurry as per manufacturers specifications and providing 12-15mm thick neat finished cement plaster 1:3 (1 cement : 3 coarse sand) added with acrylic based water proofing chemical as per manufacturers specification and direction of Project Manager.				
B	FOR HORIZONTAL SURFACES				
	Providing and laying water proofing treatment by chemical injection grout process on base of over head water tank or other area as per specifications comprising of two layers of Cement mortar 1:3 mixed with Acrylic water proofing compound, providing and fixing 20 mm pipe sleeves at 1.2m C/C and grouting acrylic based water proofing chemical mixed with neat cement slurry through the pipes with, complete with cutting & sealing of the pipes as per specification and direction of Project Manager. (OH tanks)	Sqm	44	600	26400
5.06	Providing & Laying Vapour barrier of Polyethylene sheet of 1.4mm thickness & 55 minimum density having tensile strength of 10 (M.D.) and 4.5 (T.D.) Kg/sq.cm. The tensile elongation of 50 % (M.D.) & 40 %(T.D.) and water vapour transmission rate should not exceed 5g / m² / Day. The item should be complete as per Manufacture's specification and as directed by P.M. The horizontal surface area shall be measured and paid, however the edges having upturn of min. 200mm.on all side. (Under Raft)	Sqm		120	
6.01	Providing and constructing Brick masonry with bricks of class designation 75 [Crushing strength not less than 75 kg/sqcm] and thickness specified at all heights and levels in foundations, plinth and superstructure for any shapes, fins, projections, in shafts etc. including providing scaffolding, raking out joints, curing, dewatering etc., complete as per drawing.				
A	In foundation & plinth 230 mm thick and above in cement mortar 1:6 mix (1 cement: 6 coarse sand).	Cum	10	5200	52000
B	230 mm thick and above (nominal dimension) in super structure in cement mortar 1:6 mix (1 cement: 6 coarse sand).	Cum	108	5300	572400
C	230 mm thick and above (nominal dimension) in cement mortar 1:4 mix (1 cement: 4 coarse sand)	Cum		5600	
D	Brickwork in staircase steps with brick class designation 75 in cement mortar 1:3 (1 cement: 3 coarse sand) at all heights and levels.	Cum	1	5800	5800
E	Half brick masonry using selected quality burnt brick of class designation 75 in basement and super structure laid in cement	Sqm	1097	670	734990

	mortar 1:4 (1 cement: 4 coarse sand) as per specification including one no. 16 gauge 25 mm wide MS plate at every fourth course and drawing or as directed by Project Manager.				
F	Brick work 70 mm thick with bricks of class designation 75 in cement mortar 1:3 (1 cement: 3 coarse sand) in super structure.	Sqm	21	670	14070
7.01	Providing and laying 20 mm thick mirror polished Kota stone slab in flooring, landing of staircase with slabs of approved size and shade with machine cut edges laid to required pattern over a bed of 20 mm (approx.) thick cement mortar 1:4 (1 cement: 4 coarse sand) including laying slabs in cement slurry pigmented to match the shade of slabs, grinding, rubbing, chamfering, making holes and polishing etc. complete. (staircase and elect., panel rooms)	Sqm	111	1050	116550
7.02	Providing and laying 20 mm thick mirror polished Kota stone slab in dado, skirting, pillars with slabs of approved size and shade with machine cut edges laid to required pattern over a bed of 12 mm (approx.) thick cement mortar 1:3 (1 cement: 3 coarse sand) including laying slabs in cement slurry pigmented to match the shade of slabs, grinding, rubbing, chamfering, nosing etc. and polishing complete. (staircase and elect., panel rooms)	Sqm	19	1530	29070
7.03	Providing and laying 20mm thick mirror polished Kota stone slab in treads and risers in single piece with machine cut edges laid over 20mm cement mortar 1:4 (1 cement: 4 coarse sand) including laying slabs in cement slurry pigmented to match the shade of slabs grinding, chamfering, rubbing, chamfering, nosing, polishing etc. complete. (staircase steps)	Sqm	257	1530	393210
7.04	Providing and fixing 5-6mm thick white glazed tiles approved make, size and shade in floors and walls over 15 mm thick cement mortar 1:4 (1 cement: 4 coarse sand) jointed with white cement slurry mixed with pigment to match the shade of tiles, complete as per detail & as shown in the drawing only. (Tiles shall be supplied by owner free of cost) (UG/OH tanks)	Sqm	213	475	101175
7.05	Providing and laying 30mm thick cement concrete flooring 1:2:4 (1 cement: 2 coarse sand: 4 graded stone aggregate 20mm nominal size) including finishing with floating coat of neat cement, nosing of steps, PVC strips 30x6mm @1200mm c/c both ways and finishing etc.	Sqm	278	300	83400
7.06	Providing and laying 18mm thick cement plaster skirting with cement mortar 1:3 (1 cement: 3 coarse sand) finished with a floating coat of neat cement including rounding of junctions with floor etc. complete.	Sqm	71	275	19525
7.07	Providing and Laying 40mm thick marble chips flooring, skirting, treads of staircase, rubbed and polished to granolithic finish, under layer 31mm thick cement concrete 1:2:4 (1 cement : 2 coarse sand : 4 graded stone aggregate 12.5 mm and down) and top layer 9mm thick with white, black,	Sqm		600	

	chocolate, grey, yellow or green marble chips of sizes 4mm to 7mm nominal sizes laid in cement marble powder mix 3:1, (3 cement : 1 marble powder) by weight in proportion 4:7 (4 cement marble powder : 7marble chips) by volume including cement slurry for all heights and lifts including cost of forming nosing in treads etc. complete.				
7.08	Providing and laying flooring with 18 to 20mm thick Udaipur Green marble stone of approved quality in specified size of stone slab as per drawings and pattern laid over 20mm thick CM 1:4 (1 cement: 4 coarse sand) jointed with white cement slurry mixed with pigment to match the shade of slab including mirror polishing, edge chamfering, surfaces pointing etc. complete as per specification & drawing. (Unpolished Random Marble stone slabs of varying sizes shall be supplied by owner free of cost) (Lift Lobby)	Sqm	1127	800	901600
7.09	Providing and laying with 18 to 20mm thick Udaipur Green marble stone of approved quality in specified size of stone slab as per drawings and pattern laid over 20mm thick cement mortar 1:3 (1 cement: 3 coarse sand) jointed with white cement slurry mixed with pigment to match the shade of stone slab including making and polishing of edge chamfering, moulding half or full round etc. complete as shown in the drawings and as per specifications or as directed by the project manager of MLDL. (Unpolished Random Marble stone slabs of varying sizes shall be supplied by owner free of cost) (Lift Lobby)				
A	In Skirting	Sqm	87	2400	208800
B	In Dado / Cladding with SS cramps / pins / dash fasteners etc.	Sqm	229	995	227855
7.10	Providing and laying 18-20mm thick Udaipur Green Marble stone of approved quality in back splash, facia, ledge of bath tub/ shower area, window sill etc. fixed in cement mortar 1:3 (1 cement: 3 coarse sand) with approved SS Clamps, Pins in single piece as per details including chamfering and mirror polishing of edges Complete as per Drawing. (Unpolished Random Marble stone slabs of varying sizes shall be supplied by owner free of cost)	sqm	244	1500	366000
7.11	Providing & laying 18-20 mm thick mirror polished granite Stone in required size of approved quality in counters, back splash, facia, ledge of bath tub/ shower area, window sill etc fixed over average 20 mm thick cement mortar 1:4 (cement : 4 coarse sand) and joints neatly finished with cement paste mixed with matching pigment including edge chamfering, moulding, making opening / holes for sink wash basin, mixer soap dispenser, ledge / surrounding of bath tub, back splash, facia ledges of shower area etc. as required and mirror polishing of mouldings and cut edges, filling of silicon at junctions with sanitary fixtures and corners with wall wherever required complete as per drawings. (kitchen and	Sqm	714	1350	963900

	toilets counters) (Prepolished Random Granite stone slabs of varying sizes shall be supplied by owner free of cost)				
7.12	Providing and laying polished vitrified floor tiles of approved shade, size and manufacturer laid over 20mm to 30mm thick 1:4 cement mortar (1 cement : 4 sand consisting 50% fine and 50% coarse sand) and joining tiles with non-shrink epoxy tile grout matching with the shade of tiles including 3mm thick PVC tiles spacer embedded in adhesive mortar including making proper uniform grooves at top of joint as shown all from approved manufacturer (Living/ Dining Internal passage/ Bed rooms) (Tiles shall be supplied by owner free of cost)	Sqm	7991	495	3955545
7.13	Specification as above in skirting on 12mm to 20mm thick cement mortar 1:3 (1 cement : 3 coarse sand) & fixed with chemical adhesive and filling grooves with non-shrink tile grout matching with the shade of tile complete. (Living/ Dining Internal passage/ Bed rooms) (Tiles shall be supplied by owner free of cost)	Sqm	1005	855	859275
7.14	Providing and laying in floors Anti-Skid Ceramic Tiles of 7-8 mm thickness or as per manufacturer specifications of approved make, shade size and quality laid on 20 to 30 mm thick cement mortar 1:4 (1 cement : 4 coarse sand) including grouting the jointed using plastic spacers for uniform alignment and grooves with non-shrink epoxy tile grout matching with the shade of tile including cleaning the surface complete and providing uniform grooves (kitchen) (Tiles shall be supplied by owner free of cost)	Sqm	1165	525	611625
7.15	Providing and fixing 7-8 mm thick or as per manufacturers specifications Anti-Skid Ceramic Tiles of approved make, shade, size and quality in skirting / dado laid on 15/20 mm thick cement mortar 1:3 (1 cement: 3 sand, consisting of 50% fine and 50 coarse) and jointed using plastic spacers for uniform alignment and grooves with non-shrink epoxy tile grout matching with the shade of tiles including cleaning the surface complete. (Kitchen) (Tiles shall be supplied by owner free of cost)	Sqm	1561	580	905380
7.16	Providing and laying in floors Ceramic Tiles of 7-8 mm thickness or as per manufacturer specifications of approved make, shade size and quality laid on 20 to 30mm thick cement mortar 1:4 (1 cement: 4 coarse sand) and jointed using plastic spacers for uniform alignment and grooves with non-shrink epoxy tile grout matching with the shade of tile including cleaning the surface complete and providing uniform grooves (Tiles shall be supplied by owner free of cost) (Toilets)	Sqm	1031	525	541275
7.17	Providing and fixing 6-7 mm thick or as per manufacturers specifications Ceramic Tiles of approved make, shade, size and quality in skirting / dado laid on 15/20 mm thick cement mortar 1:3 (1 cement: 3sand, consisting of 50% fine and 50 coarse) and jointed using plastic spacers for uniform alignment and grooves with non-shrink epoxy tile grout	Sqm	4167	525	2187675

	matching with the shade of tiles including cleaning the surface complete. (Tiles shall be supplied by owner free of cost) (Toilets)				
7.18	Providing and laying in floors Textured Ceramic Tiles of 7-8 mm thickness or as per manufacturer specifications of approved make, shade size and quality laid on 20 to 30mm thick cement mortar 1:4(1 cement: 4 coarse sand) and jointed using plastic spacers for uniform alignment and grooves with non-shrink epoxy tile grout matching with the shade of tile including cleaning the surface complete and providing uniform grooves (Tiles shall be supplied by owner free of cost) (Balconies)	Sqm	2188	525	1148700
7.19	Providing and laying minimum 18 to 20 mm thick Rough Kota stone slab of uniform shade in plinth protection laid over base of cement mortar of specified thickness in 1:4 (1 cement:4coarse sand) jointed with grey cement slurry mixed with pigment to match the shade of slab, making grooves, pointing etc. complete as per drawing and pattern.				
A	Horizontally laid with 20 mm thick mortar	Sqm	311	900	279900
B	Vertically laid with 12 mm thick mortar	Sqm	311	950	295450
8.01	Providing & laying 6 mm thick cement plaster to ceilings/balcony ceiling in cement mortar 1 :3 (1 cement: 3 fine sand) on R.C.C. surface including curing, drip course was ever required scaffolding etc. complete for all levels and heights. (On ceiling of flats)	Sqm	4644	210	975240
8.02	Providing & laying 12 - 15mm thick cement plaster to walls columns, piers etc. in cement mortar 1 :3:3 (1 cement: 3 fine sand: 3 coarse sand) on plain side of wall or R.C.C. surface including curing, racking joints, hacking scaffolding GI chicken wire mesh, groove all around the corner of wall & ceiling etc complete for all levels and heights. (Internal walls of flats)	Sqm	3788	230	871240
8.03	Providing and applying 15mm thick cement plaster 1:5 (1 cement:5coarse sand) mixed with waterproofing compound in proportion as recommended by the manufacturer in shafts etc including racking joints hacking, curing, scaffolding, GI chicken wire mesh etc complete for all heights & levels. (Shafts and lift walls etc.)	Sqm	835	240	200400
8.04	Providing and applying 18-20 mm thick cement plaster in two coats under layer 12 mm thick cement plaster 1 : 5 (1 cement : 5 coarse sand) mix with approved waterproofing compound added in proportion as recommended by the manufacturer with a top layer of 6-8 mm thick cement plaster 1 : 6 (1 cement : 50% sand & 50% coarse sand) on outside brick wall and concrete surfaces including racking, joints, hacking, curing, scaffolding, GI chicken wire mesh, making grooves, bands, drip coarse wherever required etc. all complete. (External walls)	Sqm	16252	370	6013240

8.05	Providing and applying on walls distempering with oil bound washable distemper of approved brand, shade and manufacturer to give an even shade on new work, two or more coats over and including preparation of surface with birla putty including scaffolding, cleaning and curing etc. complete as per specifications and as directed by the Engineer-in-charge. (Internal walls of flats)	Sqm	35477	80	2838160
8.06	Providing and applying on ceilings distempering with dry distemper of approved brand, shade and manufacturer to give an even shade on new work, two or more coats over and including preparation of surface with birla putty including scaffolding, cleaning and curing etc. complete as per specifications and as directed by the Engineer-in-charge. (Internal Ceiling of flats)	Sqm	16655	80	1332400
8.07	Providing and finishing two or more coats of synthetic enamel paint of approved manufacture and shade to new wood work and steel work applied evenly to give a uniform finish as approved including preparation of surface and a coat of approved primer, scaffolding etc. (Internal doors)	Sqm	5707	100	570700
8.08	Providing and finishing two or more coats of French Polish of approved manufacture and shade to new wood work and steel work applied evenly to give a uniform finish as approved including preparation of surface and a coat of approved primer, scaffolding etc. (Main doors)	Sqm		495	
8.09	Providing & applying three or more coats of white wash with whiting to plastered surfaces of walls, ceiling etc. as called for applied and brought to uniform finish as approved. (Shafts and lift shafts).	Sqm	2441	30	73230
8.10	Providing and painting at all levels three or more coats of water proofing cement paint (SUPER SNOWCEM) of approved colour and shade including the cost of preparing the surface, curing, scaffolding, at all levels, heights, leads and lifts etc. complete. (Parapet)	Sqm	505	80	40400
8.11	Providing and applying Texture Paint Wall finish as per manufacturer's specifications. Texture paint of approved make and shade of exterior grade including the cost of scaffolding and preparatory works as required to complete the work. (Basic rate Rs.140/- per sqm) (External walls)	Sqm	22994	259	5955446
8.12	Providing and fixing metal tile ceiling systems, comprising of tile size 600mm x 600mm manufactured of 0.5mm thickness pre-coated galvanised steel. The tile shall be powder coated with matt finish coat of silicon polyester 20-micron powder coating (Metallic silver or white colour as approved) and shall be laid exposed grid system with 24mm wide T-section flanges, main runners of size 24mm x 33mm x 0.33mm thick and cross runners 24mm x 25mm x 0.25mm thick & 600mm long and perimeter wall angle 19mm x 19mm x 0.45mm thick.				
	All exposed faces shall be powder coated in approved colour and supported from slab by means of 4mm dia rigid	Sqm	1684	1150	1936600

	suspension rod and 0.7mm thick ceiling bracket including provision of AC grill, diffusers and fire protection system, light fixtures etc. complete as per standard specification of the manufacturer. The item also includes black acoustical fleece to be glued over the perforation for sound absorption. The work shall be got done through recommended contractor of manufacturer. (Toilet Ceiling)				
8.13	Providing and fixing 12.5 mm thick gypsum board false ceiling in horizontal/vertical and curved surfaces, coffers etc. fixed with screws to underside of GI suspension system comprising of G.I. angle of size 0.55 mm thick having one flange of 20mm and another flange of 30mm and a web of 27mm flanges along with perimeter of ceiling, screws fixed to brick/RCC /partition wall with the help of nylon sleeves and				
	screws at 610 mm centres both sides. Then suspending GI intermediate channels of size 45mmx 0.9mm thick with two flanges 15mm each from the soffit at 1220mm centres with ceiling angle of width 25mmx10mmx0.55mm thick fixed to soffit with G.I. cleat and steel expansion fastener. Ceiling section of 0.55 mm thickness having knurled web of 51.5 mm and two flanges of 26mm each with lips of 10.5mm are then fixed to intermediate channel with the help of connecting clip and in direction perpendicular to the intermediate channel at 457mm centre and Gyp Board fixed to the ceiling section with 25 mm drywall screws at 230mm centres complete in all respect as per recommendations of India Gypsum Ltd. and approval including making and cutting for electrical / AC / fire fighting fixture and providing and fixing MS angle/tee/flat/ perforated edge bead for suspended ceiling and GI angle beads, edge beads wherever AC/Light fittings are to be installed, trap door in ceiling where directed. (lobby on ground floor)	Sqm	271	850	230350
8.14	Specification same as above but instead of gypsum board providing and fixing 4mm thick veneer over 9mm thick MDF board of approved make treated with anti-termite and fire retardant paint including making groove, leaping, polishing etc. complete.	Sqm	5	1600	8000
9.02	Fixing of wooden Door frames of different width varies from 720 mm to 2000 mm, 2150 mm height including the cost of necessary fasteners & screws and fixing arrangement etc. complete in all respect. (Wooden frame shall be supplied by owner free of cost)	Each	46	500	23000
9.03	Fixing of door shutter of different width varies from 720 mm to 1200 mm of 2150 mm height with heavy duty 3 nos. 125 mm size Brass with chrome finish butt hinges etc. as per drawing complete. (Only door shutter shall be supplied by owner free of cost)	Sqm	2265	450	1019250

9.04	Providing and fixing wooden moulded architrave to door frames with necessary screws, plugs etc. complete as per drawing.				
A	For seasoned champ wood of size 60 mm x 25 mm	Rmt	896	115	103040
B	For seasoned champ wood of size 50 mm x 12 mm	Rmt	5610	90	504900
C	For seasoned champ wood of size 19 mm x 19 mm	Rmt	6506	70	455420
9.05	Providing and fixing in position 6 mm thick bevelled edge mirror fixed on 6mm thick water proof ply backing with self-adhesive tape and screws with SS cap as per design and drawing.	Sqm	196	2450	480200
9.06	Providing and fixing 65mm wide PVC strip for handrail cover of approved shape, fixed to existing M.S. flat as required for proper complete work as per drawing specification and as directed.	Rmt	444	195	86580
9.07	Hardware’s to door shutters				
A	Fixing of Mortice lock with handle in door including necessary screws etc. complete. (Mortise lock shall be provided by owner free of cost)	Each	1252	200	250400
B	Fixing of 200 mm Tower bolt in door including necessary screws etc. complete. (Tower bolt shall be provided by owner free of cost)	Each	1252	50	62600
C	Fixing of 75 mm long Baby latch in door including necessary screws etc. complete. (Baby latch shall be provided by owner free of cost)	Each	418	100	41800
G	Fixing of door stoppers/ door buffers in door including necessary screws etc. complete. (Stopper/ Buffer shall be provided by owner free of cost)	Each	2504	50	125200
9.08	Providing and fixing Access panel in shaft including minimum three or more coats of synthetic enamel paint over a coat of primer etc. complete as per drawing.				
	Outer frame is made of hard wood of section 60x40 mm grouted in brick work with hold fast of 6" long MS flat of size 25x5 mm.				
	A shutter is made of 19 mm thk. Marine ply panel fixed with 75 mm long brass with chrome finish butt hinges, screws etc. complete as per drawing.	Sqm	115	3500	402500
9.09	Providing and fixing Loft shutter with frame including minimum three or more coats of synthetic enamel paint as per approved shade over a coat of primer etc. complete as per drawing.				
	Outer frame is made of hard wood of section 60x40 mm grouted in brick work with hold fast of 6" long MS flat of size 25x5 mm.				
	A shutter is made of 19 mm thk. Marine ply panel fixed with 75 mm long brass with crome finish butt hinges, screws etc. complete as per drawing. (LV Shaft)	Sqm	47	3000	141000
9.10	Specification as above with glass shutter of 6mm thick plain glass instead of 19 mm thick commercial board including style made of hard wood of size 75 mm x 40 mm with all	Sqm	40	2550	102000

	required fittings and hardware's etc. complete as per drawing. (hose real shutter)				
10.01	Providing and placing in position suitable PVC water stops fix pan or approved equivalent for construction / expansion joints between two RCC members and fixed to the reinforcement with binding wire before pouring concrete etc.				
A	Dumb bell with central bulb (150mm wide, 6mm thick)	Rmt	200	480	96000
B	As above but 230 mm wide , 9mm thick)	Rmt		500	
10.05	Providing and fixing aluminium strips as per IS 737 covering over expansion joints with stainless steel screws as per design to match the colour/shade of wall treatment.				
A	300 mm wide X 3 mm thick	Rmt	250	1035	258750
10.06	Supplying and fixing in position precast CI manhole cover with frame of 500 mm dia (weight of covers & frame should not be less than 55 kg.)	Each	6	3500	21000
10.08	Providing and fixing heavy duty MS puddle flange to Water tank complete as per drawing				
A	50 mm dia	Each	10	950	9500
B	65 mm dia	Each	10	1700	17000
C	80 mm dia	Each	10	2000	20000
D	100 mm dia	Each	10	2500	25000
E	150 mm dia	Each	10	4000	40000
10.09	Providing orange colour safety foot rest of minimum 6mm thick plastic encapsulated as per IS: 10910 on 12mm dia steel bar conforming to IS: 1786 having minimum cross section as 23 mm x 25mm and over all minimum length 263mm and width as 165mm with minimum 112mm space between protruded legs having 2mm tread on top surface by ribbing or chequering besides necessary and adequate anchoring projections on tail length on 138mm as per standard drawings and suitable to with stand the bend test and chemical resistance test as per specifications and having manufacturer's permanent identification mark to be visible even after fixing, including fixing in manholes with 30 x 20 x 15cm cement concrete block 1:3:6 (1 cement : 3 coarse sand : 6 graded stone aggregate 20mm nominal size) complete as per design.	Each	60	390	23400
12.01	Dismantling of brick work in cement mortar, (full brick) with plaster on both sides stacking of serviceable material and disposal of unserviceable material to dumping area as directed by Project Manager.	Cum	40	800	32000
12.02	Dismantling of brick work in cement mortar, (half brick) with plaster on both sides stacking of serviceable material and disposal of unserviceable material to dumping area as directed by Project Manager.	Sqm	100	400	40000
12.03	Dismantling of RCC works in beams, columns, slabs etc. including sub-base, cutting and removal of reinforcement, stacking of serviceable material and disposal of unserviceable material to dumping area as directed by Project Manager.	Cum	10	5600	56000

12.04	Chipping of Plaster/Brick work and disposal of malba outside the premises as directed by Project Manager.	Sqm	200	200	40000
12.05	Dismantling of existing all types of flooring/subbase and stacking the removed material in proper way or dumping the same as directed Project Manager including disposal of the same out of premises.	Cum	20	2200	44000
12.06	Rectification/ refixing / grindings if required of Steel Work welded in built-up sections / framed work with MS square / round bars, pipes, tubes in S/case & Balcony Railings and applying 2 or more coats of synthetic enamel paint of approved colour and brand over zinc chromate steel primer on structural steel etc. as required.	Kg	22000	20	4,40,000
12.07	Grinding & mirror polishing of existing Kota stone slab in flooring, landing of staircase, skirting & Steps etc., grinding, cement slurry pigmented to match the shade of slabs, rubbing, chamfering, making holes etc complete.	Sqm	850	375	3,18,750
12.08	Grinding & mirror polishing of existing Udaipur marble stone slab in flooring, landing of staircase, skirting & Steps etc., grinding, cement slurry pigmented to match the shade of slabs, rubbing, chamfering, making holes etc complete.	Sqm	600	280	1,68,000
12.09	Grouting & cleaning of existing Vitrified/ Ceramic tiles in Flooring/ dado/ skirting including joining tiles with non-shrink epoxy tile grout matching with the shade of tiles 7 removal of PVC spacers etc.	Sqm	7300	200	14,60,000
12.10	Providing and applying external cement plaster with a top layer of 6-8 mm thick cement plaster 1: 6 (1 cement: 50% sand & 50% coarse sand) on external surfaces including racking, joints, hacking, chipping, curing, scaffolding, GI chicken wire mesh, making grooves, bands, drip coarse wherever required etc. all complete.	Sqm	2500	250	6,25,000
12.11	Providing and applying on walls distempering with oil bound washable distemper of approved brand, shade and manufacturer to give an even shade on new work, two or more coats over and including scaffolding, cleaning and curing etc. complete as per specifications and as directed by the Engineer-in-charge.	Sqm	11000	60	6,60,000
12.12	Providing and applying on walls distempering with dry distemper of approved brand, shade and manufacturer to give an even shade on new work, two or more coats over and including scaffolding, cleaning and curing etc. complete as per specifications and as directed by the Engineer-in-charge.	Sqm	5000	60	3,00,000
12.13	Providing & applying one coats of white wash with whiting to plastered surfaces of walls, ceiling etc. as called for applied and brought to uniform finish as approved.	Sqm	4000	20	80,000
	TOTAL				**5,26,52,466**

Publications

[1] Manojkumar Shukla, Dr. R.B.Magar and Dr. Abdul Razak H, “Use of Earn Value Management in Indian Construction Industry. A State of Art.”, International Journal of Engineering Research ISSN: 2319-6890(online), 2347-5013(print) Volume No.5, Issue Special 1 pp: 262-264, 8th and 9th January 2016.

[2] Manojkumar Shukla and Dr. R.B.Magar , “Earn Value Management a Boon to Indian Construction Industry” TECH-CHRONICLE An international e-journal on emerging trends in science, technology and management ISSN NO: 2454-1958 Special issue Tech-Ed 2016 pp: 26-28, 23rd January 2016.

[3] Manojkumar Shukla and Dr. R.B.Magar, “Cost and Schedule analysis of a Structure using Earn Value Management”, NICMAR. **(Paper Communicated)**