THE FUNDAMENTALS OF EARNED VALUE MANAGEMENT IN CONSTRUCTION PROJECTS: APPLICATIONS AND SIMULATIONS.

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ABSTRACT

Construction projects especially Mega Projects (MPs) are attributed with time and cost overruns which may be due to budget monitoring and evaluation processes, tools and or techniques etc. used in the project. There are many Project monitoring and control techniques such as Earned value management (EVM), Management Information Systems (MIS), Line of Balance (LOB), Site Man hour and Cost (SMAC), Work Breakdown Structure (WBS) etc. However, EVM is one of the most popular techniques with the widest use in construction projects because of its ability to measure project performance and progress in an objective manner by measuring scope, schedule, and cost in a single integrated system. EVM is notable for its ability to provide accurate forecasts of project performance problems due to its significant impact on the areas of Project planning and control; and similarly, using the methodology improves both scope definition as well as the analysis of overall project performance. More recent research studies have shown that the principles of EVM are positive predictors of project success. This paper presents a systematic approach to understanding the fundamentals of EVM by clearly defining the use and application of the EVM features and components in Project implementation. It also encompasses an in-depth analyses and simulations of EVM using Microsoft Excel and Microsoft Office Project software. Project Simulations provide options for decisions by simulating various courses of actions to provide information regarding the result of each intended decision or project scenario. The best option will be chosen after a thorough simulation results were obtained. These helps project managers to Track, analyse, solve budget and time deviation problems through the use of EVM evaluation technique in on-going projects before taking decisions especially in Microsoft Office Excel, and Microsoft Office Project software.

Keywords: Budget Monitoring, Cost and Time over-run, Evaluation, EVM, Project Control and Simulations etc.

1.0 INTRODUCTION

1.1 BACKGROUND AND RATIONALE FOR THE STUDY

Construction projects especially Megaprojects (MPs) are growing larger at an accelerating pace and are multiplying all around the world especially in developing countries. For instance, the high demand for new rail lines, high speed rail lines, multi-storey Hotels, offices, residential buildings and other sky-scrapers in the first two decades of this century cannot be under emphasize. The same phenomenon occurs in other industries such as oil and gas, mining, aerospace, ICT, supply chains, and defence. A conservative estimate for the global megaproject market is between US$6 and US$9 trillion per year (Flyvbjerg, 2014). Megaprojects have proved to be remarkably recession tolerant. Even during the downturn from 2008, the megaprojects business grew further. Never has it been more important to choose the most fitting projects and get their economic, social, and environmental impacts right. Never has systematic and valid knowledge about megaprojects been more critical (Ibid).
MPs are captivating to political leaders and the public because of their colossal size and the technical hurdles they overcome (Elgar and Frick, 2008). Such projects include skyscrapers, bridges, tunnels, large public transportation projects, seaports, power plants, dams, oil and natural gas extraction projects, large-scale sporting facilities, nuclear and other power plants etc.

Most Construction projects be it simple, complex, phase by phase and MPs are constrained by the available time and budget needed to execute the project. In most cases, such projects (especially MPs) go over budget due to the longer duration needed to deliver them (Dalibi, 2015). The more time between planning and delivery, the more likely that new challenges and complexities will arise (Ibid). As such, Project Time and cost challenges if not tackled or solved will lead to scope creeps and will ultimately bog down any project.

These enormous challenges posed by time and cost management in terms of project planning and delivery has left project managers and academicians in search and application of different solutions to the same problems (Flyvbjerg, 2003 and Dalibi, 2015). These problems may be due to budget monitoring and evaluation processes, tools and techniques used in the project.

However, several studies have examine such challenges and proposed solutions which include: Tracking of project performance and progress (Siu and Lu, 2011), trade-offs between competing project objectives and Simulation of project scenarios for proper decision making (Dalibi, 2015), Project Time-cost-trade-offs (Jian-xun and De-dong, 2012), The project performance measures to have minimal total duration, maximal profit, minimal cost, resource levelling, maximal quality, etc. (Jingwen et al., 2006, Wu and Yin, 2007), How to obtain the optimal total duration with maximal profit (Jian-xun and De-dong, 2012), Establishing a project plan and estimate the planned value over the life of the project (Kuhl and Graciano, 2014), Project simulation-based crashing methods (Bissiri and Dunbar 1999; Gutjahr et al., 2000; Haga and Marold 2004; Haga and Marold 2005; Kuhl and Tolentino-Pena 2008).

These have led to the use of various project monitoring and control techniques to enable tracking and measuring of project performance and progress. There are many Project monitoring and control techniques such as Earned value management (EVM), Management Information Systems (MIS), Line of Balance (LOB), Site Man hour and Cost (SMAC), Work Breakdown Structure (WBS) etc. However, among all these, EVM is one of the most popular techniques with the widest use in construction projects because of its ability to measure project performance and progress in an objective manner by measuring scope, schedule, and cost in a single integrated system. EVM is notable for its ability to provide accurate forecasts of project performance problems due to its significant impact on the areas of Project planning and control; and similarly, using the methodology improves both scope definition as well as the analysis of overall project performance (Siu and Lu, 2011; Kuhl and Graciano, 2014).

This paper presents a systematic approach to understanding the fundamentals of EVM by clearly defining the use and application of the EVM features and components in Project
implementation. It also encompasses an in-depth analyses and simulations of EVM using Microsoft office Excel and Microsoft Office Project softwares.

2.0 EARNED VALUE MANAGEMENT (EVM).

2.1 THE EMERGENCE OF EVM

EVM emerged as a financial analysis specialty in United States Government programs in the 1960s especially within their defence sector. It has since become a significant branch of project management and cost engineering. Project management research works investigating the contribution of EVM to project success suggests a moderately strong positive relationship. Implementations of EVM can be scaled to fit projects of all sizes and complexities (DSMC1997; Wayne 2000; Fleming and Koppelman 2005 and 2010; Marshall 2006).

The genesis of EVM occurred in industrial manufacturing at the turn of the 20th century, based largely on the principle of "earned time" popularized by Frank and Lillian Gilbreth, but the concept took root in the United States Department of Defence (DoD) in the 1960s. The original concept was called PERT/COST, but it was considered overly burdensome (not very adaptable) by contractors who were mandated to use it, and many variations of it began to proliferate among various procurement programs. In 1967, the DoD established a criterion-based approach, using a set of 35 criteria, called the Cost/Schedule Control Systems Criteria (C/SCSC). In 1970s and early 1980s, a subculture of C/SCSC analysis grew, but the technique was often ignored or even actively resisted by project managers in both government and industry. C/SCSC was often considered a financial control tool that could be delegated to analytical specialists (Fleming and Koppelman 2010).

In the late 1980s and early 1990s, EVM emerged as a project management methodology to be understood and used by managers and executives, not just the EVM specialists. By 1989, EVM leadership was elevated as an essential element of program management and procurement. In 1991, some defence projects and programs were cancelled because of performance problems detected by EVM (Marshall, 2006). This demonstrated how EVM mattered to successful projects, programs and portfolios.

In the 1990s, many U.S. Government regulations were eliminated or streamlined. However, EVM not only survived the acquisition reform movement, but became strongly associated with the acquisition reform movement itself. Most notably, from 1995 to 1998, ownership of EVM criteria (reduced to 32) was transferred to industry by adoption of ANSI EIA 748-A standard (Marshall, 2006).

The use of EVM quickly expanded beyond the Defence sector. It was adopted by many organizations and technology-related agencies. Many industrialized nations also began to utilize
EVM in their own procurement programs. An overview of EVM was included in first Project Management Body of Knowledge (PMBOK) Guide in 1987 and expanded in subsequent editions. The construction industry was an early commercial adopter of EVM. Closer integration of EVM with the practice of project management accelerated in the 1990s. In 1999, the Performance Management Association merged with the Project Management Institute (PMI) to become PMI’s first college, the College of Performance Management. The United States Office of Management and Budget began to mandate the use of EVM across all government agencies and, for the first time, for certain internally-managed projects (not just for contractors). EVM also received greater attention by publicly-traded companies in response to the Sarbanes-Oxley Act of 2002 (Marshall, 2006, Fleming and Koppelman 2010; PMBOK, 2013).

EVM establishes the analytical relationships between the budget cost, actual cost and the work done to allow better assessment of activity time and budget requirements (McConnell 1985). EVM techniques integrate the project scope, schedule and cost in order to indicate project performances at a particular time or any chosen time for the purpose of ascertaining the time and cost performance of the project within the outlined scope.

2.1.1 Definitions

The earned value technique measures performance of the project as it moves from project initiation through project closure. The earned value management methodology also provides a means to forecast future performance based upon past performance. The earned value technique (EVT) compares the value of the budgeted cost of work performed (earned) at the original allocated budget amount to both the budgeted cost of work scheduled (planned) and to the actual cost of work performed (actual). This technique is especially useful for cost control, resource management, and production (PMBOK, 2008).

Earned value management (EVM) is a methodology that combines scope, schedule, and resource measurements to assess project performance and progress. It is a commonly used method of performance measurement for projects. It integrates the scope baseline with the cost baseline, along with the schedule baseline, to form the performance baseline, which helps the project management team assess and measure project performance and progress. It is a project management technique that requires the formation of an integrated baseline against which performance can be measured for the duration of the project. EVM develops and monitors three key dimensions for each work package and control account:

i. Planned value (PV),
ii. Earned value (EV),
iii. Actual cost (AC).

The principles of EVM can be applied to all projects in any industry (PMBOK, 2013).
2.2 THE EVM TERMINOLOGY

Three parameters, planned value (PV), earned value (EV) and actual cost (AC) laid the EVM foundation (Siu and Lu, 2011). But, EVM has other components and fundamentals (as cited by Anbari, 2003; Fleming and Koppelman 2010; Siu and Lu, 2011; PMBOK, 2013; Kuhl and Graciano, 2014) which include but not limited to:

- **Actual Cost**: As used in a typical business setting, the actual costs recorded on the books, expended and sometimes incurred, against a given project. The AC is the actual cost of completed work.
- **Actual Cost of Work Performed (ACWP)**: The total costs incurred in accomplishing the work performed.
- **Baseline**: The approved time phased project plan.
- **Baseline Review (BR)**: A review conducted to determine with a limited sampling that a contractor is continuing to use the previously approved performance management system and is properly implementing a baseline on the contract or option under review.
- **Budget at Completion (BAC)**: The sum of all authorized budgets allocated to a project. It is synonymous with the earned value term “Performance Measurement Baseline” (PMB). The term BAC can have different meanings from organization to organization depending on what management has authorized for the project: sometimes direct labor hours only, direct labor dollars, other direct costs, burdens, profit, etc. The precise authorized BAC depends on management’s expectations. It is also total budget available for the execution of the project or, in other words, the sum over the planned values of all activities.
- **Budgeted Cost for Work Performed (BCWP)**: The sum of the authorized work which has been completed, and partially completed, plus management’s budget for the completed work. BCWP has been replaced with the term “earned value.”
- **Budgeted Cost for Work Scheduled (BCWS)**: The sum of the work which has been authorized, plus management’s budget for the authorized work. The total of the authorized work equals the Budget at Completion (BAC). The term BCWS has been replaced with the term “planned value.”
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- **Compliance Evaluation Review (CER):** A term which has replaced an earlier term, “Demonstration Review” (DR). The CER is the initial formal review of a contractor’s management control system and the process to determine whether or not it satisfies the requirements of the earned value management system criteria.

- **Contract Budget Base (CBB):** The negotiated contract cost value, plus the estimated value of authorized but unprized work.

- **Contract Work Breakdown Structure (CWBS):** A customer prepared breakout or subdivision of a project typically down to WBS Level 3, which: (1) subdivides the project into all its major hardware, software, and service elements; (2) integrates the customer and contractor effort; and (3) provides a framework for the planning, control and reporting of the project.

- **Control Account Plan (CAP):** A management control unit or subproject in which earned value performance measurement will take place. It was formerly called a “Cost Account Plan.”

- **Cost Performance Index (CPI):** The cost efficiency factor representing the relationship between the physical work performed plus management’s budget for the completed work (the earned value), divided by the actual costs expended and or incurred to complete such work. The CPI is likely the most critical metric provided by earned value management. Formula: earned value divided by actual costs.

- **Cost to Complete Forecast:** A time-phased forecast for the completion of all project work. It is typically synonymous with “Estimate to Complete.”

- **Cost Variance (CV):** The numerical difference between the earned values less the actual costs.

- **Contract Budget Base (CBB):** The negotiated contract cost value, plus the estimated value of authorized but unprized work.

- **Demonstration Review (DR):** A former term which has been replaced by a new term “Compliance Evaluation Review” (CER). The DR was the initial formal review of a contractor’s management control system and processes to determine whether or not they satisfied the requirements of the earned value management system criteria.

- **Earned Value (EV):** The authorized work physically accomplished, plus management’s budget for the completed work. Earned Value and per cent complete are synonymous terms.

- **Earned Value Management (EVM) System and Earned Value Project Management (EVPM):** A project management technique which focuses on the completion of authorized work and its authorized budget, called the “earned value,” for the purpose of monitoring performance and predicting the final required costs and time necessary to finish the project.

- **Estimate at Completion (EAC):** A forecasted value expressed in Naira / Dollars and/or hours, to represent the projected final costs of a project when all work is completed. The EAC equals the actual costs incurred, and liabilities, plus the estimated costs for completing all the remaining project work.

- **Estimate to Complete (ETC):** Forecasts which are expressed in either dollars or hours, developed to represent the value of the work remaining to complete a task or a project.
• **Integrated Baseline Review (IBR):** A form of earned value process verification in which the technical project management staff leads the effort to verify that the entire project baseline has been budgeted with realistic values to accomplish all the planned work. The IBR is intended to expose the front-loading of baselines.

• **Level of Effort (LOE):** LOE is one of the three approved methods to measure earned value performance (discrete, apportioned, and level of effort). LOE represents work that does not result in a final product. Examples are field engineering, liaison, coordination, follow-up or other support activities which are not associated with a definable end product. LOE simply measures the passage of time. LOE is the least desirable method of measuring earned value.

• **Network Schedule:** This is a logic flow diagram consisting of the activities and events which must be accomplished in order to reach project objectives, showing their planned sequence, interrelationships, and constraints.

• **Organizational Breakdown Structure (OBS):** A functionally oriented organizational hierarchy used as the framework for the assignment of project task performance responsibilities.

• **Over Target Baseline (OTB):** A project baseline which results from the acknowledgement of an overrun, and actually incorporates the forecasted overrun into the performance baseline for the remainder of the work. OTBs should only be used with the approval of senior management and the customer.

• **Planned Value (PV):** budget that is projected to be spent up to a given period of the project. It is sometimes referred to as budgeted cost of work scheduled (BCWS).

• **Planned Start (PS):** time at which each activity is planned to start.

• **Planned Duration (PD):** this is the amount of time over which each activity is planned to be completely executed.

• **Planned Completion (PC):** it refers to the time at which each activity is expected to complete.

• **Percent Complete:** A measured estimate, typically expressed as a percentage, of the amount of work completed on a total project, or on specific tasks within the project. Percent complete estimates are often used to measure discrete earned value performance, but in a subjective manner.

• **Performance Measurement Baseline (PMB):** On earned value projects, the PMB is a time-phased budget plan against which project performance will be measured. It is formed by the summation of the budgets assigned to control account plans (CAPs), plus their applicable indirect budgets. For future effort, not planned to the control account level, the Performance Measurement Baseline also includes budgets assigned to higher-level WBS elements. The PMB should not include any management or contingency reserves, which are controlled budgets above the PMB.

• **Planned Value (PV):** This is the baseline measurement plan for an earned value project. It is also the sum of the budgets for all authorized work, scheduled to be accomplished within a given time period. The Planned Value consists of the authorized work and authorized budget for the Work; previously called the “Budgeted Cost for Work Scheduled.” The PV is the planned budget cost serving as a baseline to guide project execution; the EV is the budget cost
based on the work performed which is calculated by multiplying activity budget and the percentage of work completed. The sum of all PV equals the Budget at Completion (BAC).

- **Project Master Schedule (PMS):** Typically the highest summary level schedule for a project, depicting the overall phasing and all major interfaces, critical milestones, and key elements.

- **S-Curve:** A graphic display of cumulative costs, hours, percentage of work, or other items, plotted over a horizontal time scale, often used to track cost performance for management. Such curves start slowly; accelerate in the middle, and then taper off slowly at the end. The S-Curve is considered to be the normal distribution for such work, and represents essentially one-half of a statistical “bell-shaped” curve.

- **Schedule at Completion (SAC):** Total expected project duration that results from the traditional Critical Path Method (CPM).

- **Schedule Performance Index (SPI):** The baseline schedule efficiency factor representing the relationship between the earned values achieved, versus the planned value. The formula: earned value divided by planned value.

- **Schedule Variance (SV):** The numerical difference between the earned value less the planned value.

- **Statement of Work (SOW):** A description of a product or service to be procured under a project; a statement of requirements.

- **Surveillance:** A term used in earned value oversight to mean the monitoring of continued compliance with an approved and validated management control system.

- **To Complete Performance Index (TCPI):** The forecasted future performance levels, expressed as a CPI, which must be achieved on all remaining work in order to meet some financial goal as set by management. The financial goals are typically two: (1) management’s current authorized budget, and (2) the project manager’s current estimate at completion.

- **Total Allocated Budget (TAB):** Sometimes also called the Project Cost Base, it is the sum of all budgets allocated to a project. The TAB consists of the performance measurement baseline (PMB) plus any management or contingency reserves. The TAB will relate directly to the Contract Budget Base.

- **Validation:** A term used in earned value to mean the “approval” or compliance with the criteria.

- **Variance:** The difference between the expected or budgeted or planned values and the actual results.

- **Variance at Completion (VAC):** Any numerical difference between Budget at Completion (BAC) and the latest Estimate at Completion (EAC).

- **Work Breakdown Structure (WBS):** A deliverable-oriented family tree display of the hardware, software, services and project-unique tasks which completely defines, organizes, and graphically portrays the project.
The EVM fundamentals and components are graphically illustrated below:

![Figure 1: Earned value Parameters](image)

Source: Siu and Lu, 2011; Kuhl and Graciano, 2014

The following formulas, forecasts, assumptions and trends are mostly used in EVM computations.

| Table 1: Basic Formula |
|------------------------|------------------|
| Indicator              | Formula          |
| Cost Variance (CV)     | \( EV - AC \)    |
| Schedule Variance (SV) | \( EV - PV \)    |
| Cost Performance Index (CPI) | \( \frac{EV}{AC} \) |
| Schedule Performance Index (SPI) | \( \frac{EV}{PV} \) |

| Table 2: Forecasting Formula |
|-----------------------------|------------------|
| Forecasting Indicator       | Formula          |
| Estimate At Completion (EAC) | \( AC + ETC \)   |
| Estimate To Completion (ETC) | \( EAC - AC \)   |
| Variance At Completion (VAC) | \( BAC - EAC \)  |
2.3 THE EVM METHODOLOGY

EVM establishes the analytical relationships between the budget cost, actual cost and the work done to allow better assessment of activity time and budget requirements (McConnell 1985). EVM techniques integrate the project scope, schedule and cost in order to indicate project performances at a particular time point.

A major construction project usually spans for years, effective time and cost tracking is important to successful project delivery. Preventive and corrective actions are required to tackle any adverse situations in time. Though previous research pointed out that EVM could be successfully applied and beneficial to the industry (Christensen 1993, 1998), its effective applications in construction have been limited. Previous research works found that the EVM techniques fail to obtain accurate indicators to reflect project performance status, especially when the scope, schedule and cost estimates are imprecise or subjected to changes (Eldin 1989; Vargas 2003; Solomon and Young 2007; Lukes 2008; Kim and Reinschmidt, 2010). Thus, EVM techniques are difficult to be applied to dynamic construction projects and do not add much value to project execution, especially when:

i. There is absence of adequate project planning and documentation,

ii. The construction schedule is compounded by considering the resource constraints such as resource availability limits and multiple calendars,

iii. Activity and project delays encountered during project executions,

iv. There is no EVM analyst or specialist within the project team.
Realistically, no new project will ever be defined with absolute precision. But one must make some educated assumptions about a new project in order to quantify and then decompose the work with sufficient confidence that the effort can then be planned, scheduled and budgeted with some degree of certainty. Anything less, and management will be committing to a new project by providing essentially a “blank check.” Vague scope definition invites scope creep (Fleming and Koppelman 2010).

Nevertheless, there is no standard EVM implementation methodology for coping with changing scope definitions in connection with complicated activity-project delay scenarios. Though, Anbari (2003) suggested “time estimate to complete” which is defined in EVM to a certain extent factors in delayed project time, the extended duration is roughly predicted without any quantitative scheduling analysis.

3.0 SIMULATION IN PROJECT MANAGEMENT

Simulation is the imitation of the operation of a real-world process or system over time (Banks et al., 2001). Project management simulation for training is an interactive learning activity, frequently practiced as a group exercise. The purpose of the simulation is to impart to audience or project management practitioners the competencies such as knowledge, skills, and attitudes that will ultimately improve their performance (Salas et al., 2009). It confronts trainees with the situations and problems that arise in real world projects. Trainees see the consequences of the decisions they make by tracking the evolution of the project parameters: scope, costs, schedule, and quality, as well as human factors. The simulation provides an opportunity for learners to analyse, solve typical project problem before taking decisions (Ibid).

There are several Project management softwares that enable simulations such as WinQSB© (Chang and Desai 2003), LINDO Optimization Software (El-kholy, 2011), Sim-Project, Fissure, Turbo-project, MS office Excel, MS Office Project and @risk© etc. This paper will focus on EVM Practice and Simulations using MS office Excel and MS Office Project softwares developed by Microsoft©.

All project simulations in computer attempt to model a real-life project or a hypothetical situation of the project on a computer so that it can be studied to see how the planned project scenario will work. In the process of executing any Project, time and cost related problems or other challenges may bog down the project or affect the project negatively. This is due to the inherent nature of MPs (larger durations of and huge budget). As such, problems regarding time and cost will be addressed severally at the execution stage. This is where simulations and decision analysis softwares come into play (Dalibi, 2015). The truth is that there is no entirely satisfactory way to account for complex deals that extend over several years (Fusaro and Miller, 2002).

An EVM application in any software is carried out by inputting the planned values of the project time and cost. This allows the following:
i. By changing the variables (time and cost data) in the simulation; all predictions can be made about the behaviour of the project under study.

ii. By recording the daily, weekly and monthly data against the planned data; any deviation can be detected which can be against the project or for the project (earned value for the project).

iii. So also, any Such Simulations provide many options in the decision making process from which the best simulated option/scenario will be chosen after a thorough or repetitive simulation results were obtained.

3.1 EVM SIMULATION

EVM application and simulation is broken down in to the following steps:

1. Use the Drawings and Bill of Quantities (BOQ) to break down activities and tasks required to execute the project.

2. Using the BOQ, Compute the estimated cost of each activity based on the expected profit margin.

3. Determine and allocated duration for activities based on precedency relationships.

4. Draw up the Project Plan (in any project plan software, preferably MS Office Project)

5. Plan the Budget for each activity over its duration (days, weeks, months etc.). - Planned values

6. Execute, Monitor and control while keeping record of the budget performance for each activity over its duration to ascertain the Actual Cost for each activity executed. Compute the cumulative values obtained. – Actual costs

7. Determine the progress of work based on the duration (days, weeks, months etc.) using percentages to determine finished and unfinished work.

8. Compute the earned values from the progress of work in percentages. Compute the cumulative values obtained. – Earned values

9. Use the computed values in step 5-6-7-8 to compute the EVM performance metrics of the Project (with a graphical representation) as shown below:

   **Project Performance Metrics**
   
   Cost Variance (CV = EV - AC)
   Schedule Variance (SV = EV - PV)
   Cost Performance Index (CPI = EV/AC)
   Schedule Performance Index (SPI = EV/PV)
   Estimated Cost at Completion (EAC)

10. Draw up the EVM report using step 1-9 with an EVM graphical representation.
## 4.0 APPLYING THE EVM SIMULATION IN 9-STEPS

**Step 1-3:**

### 4.0.1 PROJECT: NEW NIQS SECRETARIAT COMPLEX - SOUTH BANK MAKURDI, BENEUE STATE

**Summary From BOQ with Breakdown for Project Planning**

<table>
<thead>
<tr>
<th>S/N</th>
<th>Elements Summary</th>
<th>BOQ Amount</th>
<th>Estimated Planned Spending or Total Budget</th>
<th>Duration</th>
<th>Task Relationship</th>
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<td>17</td>
<td><strong>Profit Margin</strong></td>
<td>₦18,445,621.25</td>
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<tr>
<td>18</td>
<td><strong>Profit Margin %</strong></td>
<td>21.54%</td>
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</table>
Step 4: The Project Plan using MS Office Project

Step 5: the Budget Plan for each activity over its duration
**Step 6:** Execute, Monitor and control while keeping record of the budget performance for each activity over its duration to ascertain the Actual Cost for each activity executed. Compute the cumulative values obtained. – *Actual costs*

<table>
<thead>
<tr>
<th>WBS</th>
<th>SUBSTRUCTURE</th>
<th>N 11,481,274.00</th>
<th>Wk 1</th>
<th>Wk 2</th>
<th>Wk 3</th>
<th>Wk 4</th>
<th>Wk 5</th>
<th>Wk 6</th>
<th>Wk 7</th>
<th>Wk 8</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1</td>
<td>Task 1</td>
<td>N 1,230,000.00</td>
<td>N 471,900</td>
<td>N 481,700</td>
<td>N 211,870</td>
<td>N 399,120</td>
<td>N 387,320</td>
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<tr>
<td>1.2</td>
<td>Task 2</td>
<td>N 1,160,000.00</td>
<td>N 201,350</td>
<td>N 403,900</td>
<td>N 399,410</td>
<td>N 387,320</td>
<td>N 387,320</td>
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<tr>
<td>1.3</td>
<td>Task 3</td>
<td>N 1,943,210.00</td>
<td>N 493,900</td>
<td>N 493,900</td>
<td>N 372,700</td>
<td>N 387,320</td>
<td>N 311,500</td>
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<tr>
<td>1.4</td>
<td>Task 4</td>
<td>N 1,246,370.00</td>
<td>N 218,700</td>
<td>N 310,000</td>
<td>N 111,100</td>
<td>N 91,700</td>
<td>N 174,000</td>
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<tr>
<td>1.5</td>
<td>Task 5</td>
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<td>N 846,600</td>
<td>N 90,500</td>
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<tr>
<td>1.6</td>
<td>Task 6</td>
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<td>N 935,600</td>
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</tbody>
</table>

**Step 7 & 8:** Determine the progress of work based on the duration (days, weeks, months etc.) using percentages to determine finished and unfinished work and Compute the earned values from the progress of work in percentages. Compute the cumulative values obtained. – *Earned values*

<table>
<thead>
<tr>
<th>WBS</th>
<th>SUBSTRUCTURE</th>
<th>N 11,481,274.00</th>
<th>Wk 1</th>
<th>Wk 2</th>
<th>Wk 3</th>
<th>Wk 4</th>
<th>Wk 5</th>
<th>Wk 6</th>
<th>Wk 7</th>
<th>Wk 8</th>
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</thead>
<tbody>
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<td>13%</td>
<td>56%</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
</tr>
<tr>
<td>1.2</td>
<td>Task 2</td>
<td>N 1,160,000.00</td>
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<td>39%</td>
<td>68%</td>
<td>75%</td>
<td>90%</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
</tr>
<tr>
<td>1.3</td>
<td>Task 3</td>
<td>N 1,943,210.00</td>
<td>25%</td>
<td>40%</td>
<td>50%</td>
<td>100%</td>
<td>100%</td>
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</tr>
<tr>
<td>1.4</td>
<td>Task 4</td>
<td>N 1,246,370.00</td>
<td>25%</td>
<td>30%</td>
<td>68%</td>
<td>75%</td>
<td>90%</td>
<td>100%</td>
<td>100%</td>
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</tr>
<tr>
<td>1.5</td>
<td>Task 5</td>
<td>N 921,640.00</td>
<td>25%</td>
<td>30%</td>
<td>68%</td>
<td>75%</td>
<td>90%</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
</tr>
<tr>
<td>1.6</td>
<td>Task 6</td>
<td>N 2,280,636.00</td>
<td>25%</td>
<td>30%</td>
<td>68%</td>
<td>75%</td>
<td>90%</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
</tr>
</tbody>
</table>

**Cumulative Earned Value (EV)**

|       | N 1,835,500.00 | N 1,837,000.00 | N 2,206,302.00 | N 4,220,374.00 | N 5,399,300.00 | N 7,899,988.00 | N 9,979,116.00 |
Step 9: Use the computed values in step 5-6-7-8 to compute the EVM performance metrics of the Project

### Project Performance Metrics

<table>
<thead>
<tr>
<th></th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>G</th>
<th>H</th>
<th>I</th>
<th>J</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cumulative Planned Values</td>
<td>₦675,980</td>
<td>₦2,304,680</td>
<td>₦5,321,210</td>
<td>₦6,247,990</td>
<td>₦7,823,638</td>
<td>₦9,476,238</td>
<td>₦11,128,874</td>
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<td></td>
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</tr>
<tr>
<td>Cumulative Actual Cost (AC)</td>
<td>₦475,980</td>
<td>₦2,982,210</td>
<td>₦4,786,580</td>
<td>₦6,027,370</td>
<td>₦7,134,065</td>
<td>₦8,441,065</td>
<td>₦9,504,705</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Cumulative Earned Value (EV)</td>
<td>₦193,500</td>
<td>₦1,587,000</td>
<td>₦2,906,203</td>
<td>₦4,328,084</td>
<td>₦5,399,300</td>
<td>₦7,859,966</td>
<td>₦9,978,116</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- **Cost Variance (CV = EV - AC)**: -282480, -1402210, -1880377.5, -1699286, -1735605, -581609
- **Schedule Variance (SV = EV - PV)**: -482480, -717680, -2425007.5, -1919906, -2424338, -1616242, -1150758
- **Cost Performance Index (CPI = EV/AC)**: 0.41, 0.53, 0.61, 0.72, 0.76, 0.93, 1.04
- **Schedule Performance Index (SPI = EV/PV)**: 0.29, 0.69, 0.55, 0.69, 0.69, 0.83, 0.90
- **Estimated Cost at Completion (EAC)**: ₦28,242,154, ₦21,625,670, ₦18,909,913, ₦15,989,035, ₦15,171,930, ₦12,330,843, ₦11,051,610
5.0 CONCLUSION

All project simulations in computer attempt to model a real-life project or a hypothetical situation of the project on a computer so that it can be studied to see how the planned project scenario will work. In the process of executing any project of any scale, time and cost related problems or other challenges may bog down the project or affect the project negatively if not properly planned, monitored, controlled and responded for whenever there are deviations, changes or challenges at the execution stage. This is where decision analysis soft wares and simulations come into play.

EVM technique especially its computer simulation will guide the project professionals with accurate forecasts of project performance problems due to its significant impact on the areas of Project planning and control; and similarly, using the methodology improves both scope definition as well as the analysis of overall project performance as a positive predictors of project success.

The MS office Excel© and Project© softwares are suitable for simulating EVM with many options and different results to guide project practitioners. By changing variables (time and cost data) in the simulation, predictions can be made about the behaviour of any project under study. Such Simulations provide many options in the decision making process from which the best simulated option/scenario will provide insights to the pitfalls and the pratfalls of a given project after a thorough or repetitive simulation results were obtained.
REFERENCE


The Fundamentals of Earned Value Management (EVM) in Construction Projects: Applications And Simulations.


