1. ABSTRACT

LOB Against the EVM Analysis:

The Line of Balance Method (LOB) and Earned Value Management (EVM) analysis are simply variance techniques used in tracking the progress of a project. The LoB in the past was used to determine the variances in terms of cost and schedule which could occur on the project, whereas the EVM has gone further to determine the real situation by factoring in the actual work that was completed and predicting how much the project would spend if the work went on as at the time of carrying out the analysis. However, from the list of tables and figures below, the integrated LoB and EVM technique is more detailed in terms of determining the performance as well as forecasting what the end of the project could be.


2. INTRODUCTION

As a result of declining housing affordability in Nigeria due to prevalent economic recession, building and managing low-cost housing of identical apartment units has been adopted in order to make housing project delivery system seamless and affordable to low income earners. This multi-unit project scope of work is characterized by repeating activities, which in most instances comprises of a plan for a single apartment unit in an integrated system of project management and control using Line of Balance Scheduling Technique\(^1\) and Earned Value Management Best Practices\(^2\).

Some of major challenges associated with housing project execution and delivery system failure include;

- Deficiency in Planning and scheduling (PSD)

\(^1\) Editor’s note: Student papers are authored by graduate or undergraduate students based on coursework at accredited universities or training programs. This paper was prepared as a result of a course delivered by Dr Paul Giammalvo of PT Mitratata Citragraha in Jakarta, Indonesia. The paper was submitted to the Association for the Advancement of Cost Engineering International (AACEi) in 2013 in fulfillment of the certified cost engineering consultant (CCEC) requirements, for which the author was a successful applicant.

\(^2\)
Inadequate control procedure (ICP)
Deficiency in cost estimates preparation (DCE)
Poor contract management and supervision (PCM)
Contractors financial difficulties (CFD)
Shortage of technical and competent personnel (STP)
Delays in inspection and testing works. (DIW)
Frequent breakdown of construction plant and equipment (FBC)
Monthly payments difficulties (MPD)
Slow decision making (SDM)

Table 1: Project Failure Causes and Effects

Having identified these root causes and effects of housing project delivery system failure in Nigeria, the purpose of this study therefore is to find probable and workable mitigation, using LoB and Earned Value integrated management system.

Hence, the problem statement is to evaluate possibility of an integrated Line of Balance and Earned Value Management Techniques Best Practices to mitigate identified critical root causes of project failure;

- Deficiency in Planning and scheduling resulting in time overrun.
Inadequate cost control procedure resulting in budget overrun.
Inadequate Contractors financial cash flow.
To make recommendations in line with the findings of this work.

3. PROJECT PLANNING AND SCHEDULING USING LoB Method

3.1 Developing the Work Breakdown Structure (WBS)

A work breakdown structure is intended to assist better management of this project by providing a framework for the project scope, schedule and budget to be integrated. It allows for the logical subdivision of work scope into smaller, more manageable parcels which can more easily be defined and controlled.

- **Project Title:** Construction of 50 units of 3 Bedroom Flats for an Estate Development Project.
- **Project Duration:** 12 Months (48 weeks).
- **Proposed Project Budget:** N15,000,000.00 or $93,750.00 per unit (per flat) and totalling N750,000,000.00 or $4,687,500.00 overall for 50 units.
- **Project Tracking Schedule:** Every Quarter (3 months).
- **Project Objective:** The main objective of this project shall be the design and construction of a Model Housing Estate with fifty identical flats of 3-Bed rooms each.

Table 2iv: Work Breakdown Structure
3.2 Prepare a budget and schedule for accomplishing the work

Once the effort is identified through the WBS and OBS, a budget and schedule for accomplishing the work will be required, as shown below:
What is critical to being able to track earned value is that a portion of the budget is allocated for each work unit that comprises the WBS and that the WBS adequately defines all work necessary to meet the agreed-upon requirements for the project development and provides objective consistent measures that are useful in focusing attention on the “real” status of the project, as follows:

- Cost and schedule efficiency factors < 1 are cause for concern.
- Downward trend in CPI is consistent with government findings in monitoring projects since the 1970s (see below).
• Even with fluctuation, data reported early in the project is a good prediction of what will happen later.
• Frequent reporting of EV data supports trend analysis that can better communicate the direction of the project.

3.3 Line of Balance Historical Background

Line of Balance (LOB) was devised by the members of a group headed by George E. Fouch. During 1941, used by Goodyear Tire & Rubber Company to monitor production. It was successfully applied to the production planning and scheduling of the huge Navy mobilization program of World War II. LoB proved to be a valuable tool for expediting production visibility during the Korean hostilities. During this period, defense suppliers used LoB.

• LoB application has been further expanded, making it suitable now across a whole spectrum of activities ranging from research and development through job shop and process flow operations.
• Specific forms and reports will be found to differ in detail, but the basic pattern and symbols are quite uniform throughout industry.

This programming technique guarantees continuity and maintenance of required tasks which promotes effective management, learning effect, wastes reduction and increased quality. Each team crew is responsible only for one kind of service, doing that activity repeatedly in all identical units.
### Table 5: Activity Based LoB Table

<table>
<thead>
<tr>
<th>Activity id</th>
<th>Activity Name</th>
<th>Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><strong>Foundation</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Pegging and Digging works</td>
<td>5</td>
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<tr>
<td></td>
<td>Cement Casting of foundation</td>
<td>6</td>
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<td></td>
<td>Block work to DPC level</td>
<td>5</td>
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<tr>
<td></td>
<td>Sand filling</td>
<td>6</td>
</tr>
<tr>
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<td>Internal Partitioning</td>
<td>3</td>
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<tr>
<td></td>
<td>Mixing of Cement</td>
<td>2</td>
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<tr>
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<td>Carpentary works</td>
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<td>Glazed tiling works</td>
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<td>Installation of internal external doors</td>
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<td>Installation of windows</td>
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<td>Boarding of windows and doors</td>
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<td>Installation of electrical pipping, and cabling fittings</td>
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<td><strong>Roofing</strong></td>
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<td>Installation of PVC ceilings</td>
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<td><strong>Finishing</strong></td>
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<td>Installation of pipes, and fittings</td>
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<td></td>
<td>Construction and installation of kitchen cabinet</td>
<td>2</td>
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<td></td>
<td>Procurement and installation of bathroom baths and accessories</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Procurement and installation of WC and accessories</td>
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</tr>
<tr>
<td></td>
<td>Procurement Installation of electrical piping, cabling and fittings</td>
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<tr>
<td></td>
<td>Cement mixing and plastering works</td>
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<td></td>
<td>Layout and Digging</td>
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<td>1</td>
</tr>
<tr>
<td></td>
<td>Tilling works</td>
<td>5</td>
</tr>
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</table>

**Total for quarterly cost of buildings (ie. 13 flats per quarter)**
3.4 Benefits of Line of Balance

- Line of Balance (LoB) is a simple diagram showing location and time at which a certain crew will be working on a given operation. It focuses on balancing the time taken for individual activities by either re-distribution of resources or by reducing process wastes. It is a planning methodology to optimize resources used.

- The LoB process is employed when repetitive activities exist within the contract’s work scope. The manufacturing of parts and the assembly of units in the factory are two candidates for the use of LoB.

- LoB is a management control process for collecting, measuring and presenting facts relating to time, cost and accomplishment - all measured against a specific
plan. It shows the process, status, background, timing and phasing of the project activities, thus providing management with measuring tools that help in:

a. Comparing actual progress with a formal objective plan.
b. Examining only the deviations from established plans, and gauge their degree of severity with respect to the remainder of the project.
c. Receiving timely information concerning trouble areas and indicating areas where appropriate corrective action is required.
d. Forecasting future performance.

- The "Line of Balance" itself is a graphic device that enables a manager to see at single glance which of many activities comprising a complex operation are "in balance" - i.e., whether those which should have been completed at the time of the review actually are completed and whether any activities scheduled for future completion are lagging behind schedule. The Line of Balance chart comprises only one feature of the whole philosophy which includes numerous danger signal controls for all the various levels of management concerned.

- The LoB learning curve depicts an Improvement in productivity by 20% and saves money and time, faster planning process and superior visual control, due to its repetitive tasks schedules, where a certain defined delivery schedule of similar item must be maintained chronologically.

Fig 2: LoB Learning Curve:

<table>
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<th>No of Units</th>
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<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
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<th>9</th>
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<td>6.0</td>
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4. EARNED VALUE PROJECT MANAGEMENT

4.1 Historical Background

EVM is a project management methodology for measuring financial and project performance. A basic form of EVM can be traced back to industrial engineers on the factory floor in the late 1800s. In 1967, EVM was introduced by the U.S. federal government as an integral part of the Cost/Schedule Control System, Criteria to understand the financial aspects of programs and to be used in large acquisition programs in an attempt to establish a consistent methodology based on best practices.

The method and its variations have been used under several names, such as earned value project management, earned value method, earned value analysis, and cost/schedule summary report (Fleming & Koppelman, 2003, 2010; Kim, 2000; Kim et al., 2003).

4.2 Earned Value Management Best Practices

To encourage wider use of EVM, the federal government decided to discard C/SCSC by the end of 1996 and turned toward a more flexible EVM system (EVMS). The American National Standards Institute (ANSI)/Electronic Industries Alliance (EIA) Standards published guidelines for EVMS initially in 1998.

Earned value management is an integrated system of project management and control that enables a Contractor and their customer to monitor the progress of a project in terms of integrated cost, schedule, and technical performance measures. It provides a measure of cost and schedule performance against plan, allowing early visibility into anticipated final cost.

4.2 Benefits of Earned Value Project management Best Practices

Successful implementation of Earned Value Management principles can result in:

- **Better Visibility into Program Performance.**
  The combination of advanced planning, baseline maintenance, and earned value analysis yields earlier and better visibility into program performance than is provided by non-integrated methods of planning and control.

- **Reduced Cycle Time to Deliver a Project**
  Earned value management is premised on careful detailed planning – task decomposition, scheduling and budgeting. This planning often addresses/prevents problems from surfacing later in the effort that result in rework. Thus, as rework is prevented cycle time may, in fact, be reduced.
- **Fosters Accountability**
  When the developer, at the personal level, understands how their pieces fit into the overall project effort they tend to focus on delivery of a quality product. Additionally, over time they are better able to estimate the work required to complete a task, thereby improving the overall accuracy of the budget/estimating process for future efforts.

- **Reduced Risk**
  Because earned value measures enable realistic estimates of completion (for both cost and schedule) to be derived early in the project, it is possible to make adjustments and take corrective action to mitigate the risk of cost overruns and schedule slippage.

5. **EVM AND LoB INTEGRATED PROJECT MANAGEMENT APPROACH**

   Earned value management (EVM) is an integrated system of project management and control that enables a Contractor and their customer to monitor the progress of a project in terms of integrated cost, schedule, and technical performance measures.

   Earned value project management involves planning work to a manageable level of details such that it is feasible to allocate a portion of the budget to each planned work unit (13 flats per quarter), and then tracking progress by the accumulated “value” of completed work units quarterly. As work is performed, it is “earned” on the same basis as it was planned, in dollars or other quantifiable units. As the work units are completed, the project earns the budgeted value associated with those work units.

   This method associates a dollar value with work completed so that it can be compared with the actual spending (to determine cost variance – potential cost overruns), and the planned spending (to determine schedule variance – potential schedule slippage). In this manner, planned and actual spending is integrated with actual work performed.

   The integration provides greater visibility into the real project status for all stakeholders and thus creates a scenario for better management of risks, for early determination of whether a project is in trouble, and for estimating what will be needed to complete it.
6. ANALYSIS AND COMPARISON

Table 6\textsuperscript{xvi}: Activity Integration Table

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<th>Activity of Activity Name</th>
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</table>

Fig 3\textsuperscript{xvii}: Overall Project Status S-Curve:
According to DAU\textsuperscript{xviii} in Projects, EVM is a management methodology for integrating scope, schedule and resources for objectively measuring, monitoring, controlling and reporting project performance and progress against the baseline. These criteria were first released by the U.S. DoD\textsuperscript{xx} in Dec 1967. EVM is calculated by using formulas to determine variances related to time and cost for progress analysis purposes and forecasting. Some major EVM acronyms applicable in this analysis include;

**CPI:** Cost Performance Index indicates the efficiency with which work has been accomplished. A CPI greater than 1 is favorable as demonstrated below:
Fig 4: CPI vs Project Duration Curve

Where CPI = EV/AC (EV= Earned Value = Actual % Complete * BAC; AC = Actual cost)

SPI: Schedule Performance Index compares how much work has been accomplished against how much work had been planned to be accomplished. An SPI > 1 (positive) is favorable.

Fig 5: SPI vs Project Duration Curve

Where SPI = PV/EV = (PV = Planned Value = Planned % Complete *BAC; EV = Earned Value)
EAC: Estimate at Completion represents Project Manager’s estimate of what the final cost of the project or task will be.

BAC: Budget at Completion represents total budget for the project or unit.

Fig 6: EAC vs BAC Curve

Where EAC = BAC/CPI = (BAC = Budgeted at Completion; CPI = Cost performance index)

7. CONCLUSION AND RECOMMENDATION

Based on above analysis the integration of Line of Balance and Earned Value variance techniques best fits this project development and guarantee timely and economical project development and delivery.

The learning curve depicts an Improvement in productivity by 20% and saves money and time, faster planning process and superior visual control, due to its repetitive tasks schedules, where a certain defined delivery schedule of similar item must be maintained chronologically.

The integration provides greater visibility into the real project status for all stakeholders and thus creates a scenario for better management of risks, for early determination of whether a project is in trouble, and for estimating what will be needed to complete it.

Based on the yardstick for measuring project performance; timelines, cost savings accuracy and consistency, hence, the user friendly integrated LoB and EVM measurement, monitoring, controlling and reporting system is implemented with an
average SPI of 1.06 and CPI of 0.96 as shown above, and therefore recommended for future project development and delivery systems.

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xvii Fig 3: Overall Project Status S-Curve
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EAC vs BAC Curve: By Author: (Dec 2012)

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Retrieved from http://owl.english.purdue.edu/owl/resource/560/19/

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