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Utilizing CPM/PERT Cost Function and Earned Value System in Monitoring and Controlling Building Projects (A Case Study of Recently Completed 5-Bedroom Detached Duplex at G.R.A, Maiduguri)

Nwakor A.A[*1], Ngita I[1], M.A Faringida[1], Dammo M.N[2], Aghidi, J. [2]

[1]Department of Building Technology, Ramat Polytechnic Maiduguri, Nigeria
[2]Department of Civil Engineering and Technology Ramat Polytechnic, Maiduguri, Nigeria

Abstract This paper x-rays the use of Critical Path Method-Project Evaluation Review Technique (CPM/PERT**)** cost function and Earned value system in monitoring and controlling civil and building engineering projects. The system culminates in the progressive generation of the CPI-SPI graphical contour which guides the project team in tracking projects. It is a simple step-by-step approach towards ensuring that what was executed is critically evaluated in the light of planned activities and providing indicators to project performance and an early warning system for corrective measures. Using the graphical explanation of the project under review, it was observed that a cost saving of 1.5% (N262, 488.13) from the scheduled cost of N21, 962,448.13 and the project was completed earlier than the scheduled period of 450 working days by approximately 15 days representing a savings of 3.33%. This implies that the use of CPI-SPI in monitoring and controlling construction projects is very important.

Keywords CPM, PERT, Cost Function, Earned Value, Control, Projects

Introduction

Many building and civil projects have been known to suffer several setbacks from their inception through completion. This phenomenon most frequently occurs as a result of improper coordination and control of the projects by the contractors, thus resulting in clients and contractors entangling themselves in webs of claims and counter-claims which more often than not become counter-productive [1]. Unpublished result of a survey of contract procurement methods conducted in Maiduguri Metropolis indicate that more than 80% of government-oriented projects are sold to would-be contractors, with the loot shared amongst some interest groups. This is a complete aberration of standard practice of contract acquisition. Contractors are invited to pay a certain percentage of the total project cost leaving them confused as to the cost, schedule and technical constraints of the projects. This practice has been observed to contribute to cash deficits, lost profits, project abandonment, buck passing, litigations, cost and time overruns.

It is equally observed that some Builders and Engineers engaged on construction sites lack adequate technical knowledge in project monitoring, coordination and control. Some still use the traditional bar chart to execute complex projects. The traditional methods of executing and monitoring projects can no longer hold water in the light of complex modern realities. This is because building and civil engineering projects involve so many complex interrelated and interdependent arrays of activities which require care and specialization in order to meet clients' objectives of time, cost, schedule and technical performance satisfactions [2]. Bar chart also has many flaws as it

fails to provide adequate information about the interrelationships of the voluminous interdependent tasks or operations [3]. It also carries the risk of schedule slippages, time overruns, improper decision and other contractual implications. Punmia et al (2008) reported that most building and civil engineering contracts where the traditional bar charts were used in India suffered several setbacks ranging from cost overruns, litigation with contractors, schedule slippages and misguided management decisions [4].

The network analysis technique has proved to be an effective management tool for planning, scheduling and controlling complex projects which involve interlinking activities. It has reduced some of the disadvantages of the bar chart, with improved coordination amongst the contract personnel, speed of execution and reduced cost overruns [3]. In Nigeria, nearly all intending building owners would require value for their facilities. This is true in the light of current economic and political crisis prevalent in almost every fabric of the society.

In this paper, an attempt is made to utilize CPM/PERT cost function and the Earned Value (EV) system in controlling and forecasting the progress of modern building projects, with particular emphasis to a recently completed 5-Bedroom detached Duplex located in G.R.A Maiduguri, Borno State, Nigeria.

Complex building projects can be effectively managed by defining the works to be performed, developing more realistic schedule and cost estimates based on resources planned to perform the work, determining where resources should be applied to best achieve the project objectives and identifying areas with potential delays or cost overruns in time to permit corrective actions [4]. Construction projects are usually faced with a lot of uncertainties, thus making its planning, scheduling and controlling a very tricky and complex task.

Willis (2015) [5] defined a network as a flow diagram consisting of activities and events connected logically and sequentially. The network diagram is an outcome of the *milestone* charts which is based on basic characteristics of all projects, that works must be performed in well-defined steps. The two most widely accepted network diagrams adopted in the construction industry are the *Critical Path Method (CPM)* and the *Program Evaluation Review Technique (PERT).* According to Punmia et al (2008) [4], the CPM network, which is activity- oriented, is generally adopted for repetitive-type projects and/or projects with fairly accurate time estimation. In the construction industry, it has wide application in bridges, dams, tunnels, buildings, highways, power plants, etc. The PERT system is an event-oriented network and is favoured for non- repetitive projects (once- through projects) and/or where precise time determination cannot be made such as Research and Development (R&D) projects. Chitkara (2006) [3] reported that the CPM uses the deterministic approach for activity duration where reasonably single time estimation is made, while the PERT employs a probabilistic approach where a three-time estimate is made with the activity duration being a weighted average of the three-time estimates.

The duration of an activity is the economical transaction time and activity duration estimation especially under PERT contributes to the numerous uncertainties in the network. Chitkara [6] therefore maintained that the Standard Deviation (SD) is used as a measure to estimate a project's uncertainty.

CPM and PERT use cost estimates along with the time estimates to provide a schedule for completing the activities at a minimum total cost as well as to assess the possibility of arriving at a feasible and desirable time-cost relationship [7].

The project cost consists of all direct and indirect costs associated with the project. Direct costs are those expenditures directly chargeable to and can be identified specifically with the activities of a project, such as cost of materials, labour, specific plant attached to the project, etc. Indirect costs are expenditures which are not apportioned or clearly allocated to individual activities of a project, but are assessed as a whole e.g. administrative and establishment charges, overhead, supervision, expenditure in central store organization, loss of revenue, lost profit and penalties [4]. Punmia et al, (2008) also maintained that the graph of indirect costs can show some form of curvature (instead of being linear) if the outage losses (loss in profit, loss due to penalty, due to inability to meet demand, etc) are added to the indirect cost (consisting only overheads and supervision) [4].

Spencer and Rahbar (1989) [7] maintained that the distribution of costs with respect to time must be known in order to successfully manage a project. They also suggested that a cost analysis be performed where activities span a range of time based on activities starting on an early start, late start and target schedule (mid point between the early and late starts). This means that for each day, the cost per day of each activity that is in progress is summed up to obtain

the total cost of project for that day. Cumulative project cost is divided by the total project cost to obtain percentage cost of each day. Likewise, the percentage time for each day is calculated by dividing the number of the working days by the total duration of the project.

Chitkara (2006) [3] maintained that effective project management requires planning, measuring, evaluation, forecasting and controlling all aspects of a project; which include quality of work, quantity of work, costs and schedules. An all-encompassing project must, therefore, be defined before starting the project; otherwise, there is no basis for control. This implies that project tracking cannot be accomplished without a well-defined work plan, budget and schedule, as they establish the benchmark that are necessary for comparing actual to planned accomplishments. Project control, therefore, measures the actual values of these variables and determines if the project is meeting its target of the work plan, and to make any necessary adjustments to meet project objectives. Project control involves a quantitative and qualitative evaluation of a project that is in a continuous state of change. Project tracking and control require careful and detailed record keeping of all cost and time elements on site. These records contain details of labour output, productivity, materials, labour, and plant costs expended on that particular project.

Moder et al (1983) [2] stressed that project control procedures should primarily be intended to identify deviations from the project plan rather than suggest areas of cost savings. Thus, this characteristic reflects the advanced stage at which project control becomes important. The time at which major savings can be achieved is during planning and design stages; changes during the construction stage can delay the project and lead to inordinate cost increases.

For cost control on a project, the construction plan and the associated cash flow estimates provide baseline reference for subsequent project monitoring and control. For schedules, progress on individual activities can be compared with the project schedule to monitor the progress of activities. Contract and job specifications provide the criteria by which to assess and assure the required quality of construction.

Chitkara (2011) [6] argued that the Works Breakdown Structure (WBS) is the starting point of an effective control system as it defines the work in sufficient details as to make it measurable, budgetable, schedulable and controllable. The WBS is a graphical display of the project that shows the division of work in a multi-level system; with the smallest unit being a work package (WP). In effect, every work package must be fragmented into scope, budget and cost.

Measurement of Construction Works

A construction project requires the completion of numerous tasks, beginning with initial clearing and site work through the final *punchlist* and clearing. Throughout the duration of a project, there should be a systematic reporting of the progress of work for each part of the project [3]. Several methods of measuring the project's progress include the units completed, incremental milestone, start/finish, supervisor opinion; cost ratio and weighted units methods.

The Units Completed Method

This is applicable to tasks that are repetitive and require uniform effort. Generally, the task is the lowest level of control, so only one unit of work is necessary to define the work. The percentage complete is given by:

$$\% \text{ complete} = \left(\frac{Number\ \ of\ units\ of\ tasks}{Total\ number\ \ of\ tasks}\right) 100\% \qquad 1$$

Incremental Milestone Method This is applicable to tasks that show subtasks that must be handled in sequence. For example, the installation of a major vessel in an industry facility may include the sequential tasks shown below: Completion of any subtask is considered a milestone, which represents a certain percentage of the total installation. The percentage may be established based upon the estimated work-hours to accomplish the work.

Start/Finish Method

This is ideal for tasks without well-defined intermediate milestones or for which the time required is difficult to estimate. For example, the alignment of a piece of equipment may take a few hours to few days, depending on the situation. The worker may know when the work will start and when it is finished, but never the percentage completion in between. For this method, an arbitrary percentage complete is assigned at the start of the task and a

100% complete when it is finished. A starting of 20-30% might be assigned for tasks that require long duration, while 0% may be assigned for tasks with a short duration.

Supervisor Opinion Method

This is basically a subjective approach used for minor tasks such as construction support facilities, where development of a more discrete method cannot be used.

Cost Ratio Method

This is applicable to administrative tasks such as project management, quality assurance, contract administration or project control. These tasks involve a long period of time or are continuous throughout the duration of the project. Generally, these tasks are estimated and budgeted as lumpsum *Naira* and work-hours, rather than measurable quantities of production work. The percentage complete is gotten as follows:

$$\% \text{ complete} = \left(\frac{Actual\ \ cost\ or\ work\,hours\ \ to\ date}{Forecast\ \ at\ completion}\right) 100\% \qquad 2$$

Weighted Unit Method

This is ideal for tasks that involve major efforts of works that occur over a long duration of time. Generally, the work requires several overlapping sub-tasks that each has a different unit of measurement. A weight is assigned to each subtask to represent the estimated level of effort. 'Work-hours' is usually a good measure of the required level effort. As quantities are completed for each task, these quantities are converted into equivalent units and percentage complete is calculated.

Earned Value (EV) System

After determining the progress of different work tasks, the next step is to develop a method that combines the different work tasks to determine the overall percentage complete for the project. Chitkara (2006) []3 suggested the use of the *Earned Value (EV)* system which can be used to define overall percentage complete for the entire project. The EV can be linked to the project budget, which is expressed as work-hours or *Naira*. Thus, for a single account, the **earned** value can be calculated by:

$$EV = (\% \text{ complete}) \text{ X Budget for that account} \qquad 3$$

A budget is "earned" as the task is completed up to the total amount in that account. For example, an account may be budgeted at N100,000 and 60 work-hours. If the account is reported as 25% complete, as measured by one of the previously described methods, then the Earned Value is defined as N25,000 and 15 work-hours.

EV = 0.25 X N100,000 = N25,000 (and 0.25 X 60 WHs = 15 work-hours)

Thus, progress in all accounts can be reduced to earned work-hours and *Naira* which provides a method for summarizing multiple accounts and calculating the overall progress for the total project. The equation for determining the overall project percentage complete is given as:

$$\% \text{ complete} = \frac{\left(Earned\ \ work\,hours \big/ Naira\ \ all\ accounts\ \right)}{\left(Budgeted\ \ work\,hours \big/ Naira\ \ all\ accounts\ \right)} \text{ X } 100 \qquad 4$$

The concepts discussed above provide a system for determining the percentage complete of a single work task or combination of tasks. This provides the basis for analysing the result to determine how well work is progressing, as compared to what was planned. The EV system provides a method for evaluating the performance of the project. Actual work-hours and *Naira* must also be included to prepare the 'performance evaluation report'.

Basic Definitions for EV System Analysis

The following definitions are provided to describe the procedure for evaluating cost and scheduling performances.

(i) **Budgeted work-hours or Naira to date** -This represents what is planned to do and is defined as the Budgeted Cost for Work Scheduled (BCWS).

(ii) **Earned work-hours or Naira to date** - This represents what was done, and is defined as the Budgeted Cost for Work Performed (BCWP).

(iii) **Actual work-hours or Naira to date -** This represents what has been paid and is defined as the Actual Cost of Work Performed (ACWP).

(iv) **Performance against schedule -**This is a comparison of what was planned against what was done, i.e. a comparison of budgeted and earned work-hours. If the budgeted work-hours are less than the earned work-hours, it means more was done than planned, and the project is ahead of schedule. The opposite would indicate the project is behind schedule.

(v) **Performance against budget -**This is measured by comparing what was done to what was paid. This compares earned work-hours to actual work-hours or cost. If more was paid than is done, then the project would have a cost overrun of the budget.

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The following variance and index equations can be used to calculate these values:

(a) SV = Earned work hours or Naira – Budgeted work hours or Naira

$$= \text{BCWP} - \text{BCWS} \qquad 5$$

(b) $$\text{SPI} = \frac{Earned\ \ work\ hours\ \text{ or Naira to date}}{Budgeted\ \ work\ hours\ \ or\ Naira\ \ to\ date} = \frac{BCWP}{BCWS} \qquad 6$$

(c) CV = Earned workhours or Naira – Actual workhours or Naira

$$= \text{BCWP} - \text{ACWP} \qquad 7$$

(d) $$\text{CPI} = \frac{Earned\ \ work\ hours\ \ or\ Naira\ \ to\ date}{Actual\ \ work\ hours\ \ or\ Naira\ \ to\ date} = \frac{BCWP}{ACWP} \qquad 8$$

Where,

SV = Schedule variance SPI = Schedule Performance Index

CV = Cost Variance CPI = Cost Performance Index

A positive variance and index of ≥ 1.0 is indicative of favourable performance.

Project Forecasting

Ratios are used in the earned value system to predict the cost to complete a project. The CPI is used to predict the magnitude of a positive cost overrun or underrun and it adjusts the budget based on past performance. The SPI is used to predict the magnitude of a possible time advance or delay and it adjusts the schedule based on past performance.

BAC = Original project estimate (Budget at completion)

$$\text{ETC} = \frac{BAC - \text{BCWP}}{CPI} \qquad \text{(Estimate to complete)} \qquad 9$$

$$\text{EAC} = (\text{ACWP} + \text{ETC}) \qquad \text{(Estimate at completion)} \qquad 10$$

Project Measurement and Control

For project control, Project Managers should focus attention on items indicating substantial deviation from budgeted amounts. Overruns in cost might be due to lower than expected productivity, higher than expected material costs, or other factors. Low productivity might be caused by inadequate training, lack of required resources such as equipment/tools or inordinate amount of rework to correct quality problems.

The purpose of project plan is to successfully control the project to ensure completion within budget and schedule. The S-curve, which plots cost (or work-hours) and time, provides a measure of schedule performance. Project elements of labour, materials and equipment are usually evaluated in common units of Naira. Schedule performance indicates the rate at which these project elements are occurring at budgeted expenses. Performance measurements are based on earned-value concepts and S-curve analysis. The earned value concept provides a quantitative measure of the scheduled budget value of the work compared to the actual budgeted value of the work accomplished.

Measuring the progress of a project supports management in establishing a realistic plan for executing a project and provides the Project Manager and client with a consistent analysis of project performance.

The CPI provides a comparison of the number of work-hours (WHs) being spent on the work tasks to hours budgeted and is an indicator of productivity. For Equation 9 to be a true indicator of productivity, only those tasks for which budgets have been established should be included in the summation. All actual WHs need to be properly reported to establish accurate historical records for subsequent projects of similar nature.

SPI relates amount of work performed to that scheduled to a point in time. Scheduled WHs are summarized from task schedules. While SPI for total project (or a work package) is somewhat of an indicator of schedule performance, it only compares volume of work performed to that scheduled. Project managers must expend more efforts on critical activities to avoid the danger of not meeting milestones and final completion dates. The SPI does not indicate that work is completed in proper sequence. Thus, as part of schedule control, the schedules of all included tasks in each work package need to be regularly examined so that any item behind schedule can be identified and corrective action taken to bring them back to schedule.

The CPI and SPI provide quantitative measurements of the progress of the work. Values of CPI or SPI > 1.0 indicate good performance whereas values < 1.0 show poor performance. A graph of CPI Vs SPI is plotted to show the trend of their performance throughout the project. A project begins with CPI and SPI = 1.0 and varies due to the dynamisms that can affect its costs and schedule. SPI>1.0 indicates project is ahead of schedule. This may be due to original production rates being low, working conditions on sites being better than expected, more staffing than expected, etc. SPI<1.0 indicates project is behind schedule. This schedule slippage may be due to weather delay, understaffing, disorganised work, undue bottlenecks affecting production.

CPI>1.0 indicates good project cost performance which may arise due to actual productivity being better than planned, measured % complete is too high, etc. CPI<1.0 indicates poor project cost performance which may arise due to poorer than planned productivity, under estimate of % complete, etc.

Project Managers should not overreact to slight changes in these performance indices. However, although minor deviations are expected, major ones should alert the PM to investigate the reasons for the significant change in the project performance. Concerns should be raised if the trends of CPI and SPI are progressing towards poor performance. Thus, CPI and SPI provide information needed to ensure the project is progressing towards successful completion.

Methodology

This section discusses the details of the project's cost and time scheduling processes as well as the controlling, forecasting and analysis of the project's life span

Table 1 - Summary of Project Activity Duration, Constraints & Cost Data

Activities	Description	Imm Pred	Duration	% Duration	Budgeted Cost (N)			
	Substructure		**Days**		**Labour**	**Labour cost/day**	**Materials**	**Material cost/day**
1	Site clearing and carting away	Nil	7	1.1	17250	2464.3	0	0.0
2	Excavate topsoil	1	3	0.5	24150	8050.0	0	0.0
3	Setting Out	2	2	0.3	17825	8912.5	17250	8625.0
4	Trench Excavation	3	7	1.1	72234.38	10319.2	0	0.0
5	Column pit excn	3	3	0.5	18112.5	6037.5	0	0.0
6	Septic tank excn & construction	3	14	2.2	74980	5355.7	247250	17660.7
7	Lev & com bottom of excns	4,5	4	0.6	15525	3881.3	0	0.0
8	Anti-termite treatment	7	3	0.5	17250	5750.0	48645	16215.0
9	Column & col base rebar	8	14	2.2	39100	2792.9	161575	11541.1
10	Col bases & trench concreting	9	10	1.6	165600	16560.0	553150	55315.0
11	Curing concrete	10	3	0.5	11500	3833.3	6325	2108.3
12	Blockwork to DPC level	10	14	2.2	77625	5544.6	383525	27394.6
13	Formwork to fdn cols & bases	11,12	7	1.1	26500	3785.7	92000	13142.9

14	Concreting fdn cols	13	7	1.1	23575	3367.9	40250	5750.0
15	Striking formwk to fdn cols	14	3	0.5	20700	6900.0	0	0.0
16	Backfilling trench & filling to make up lev-	15	7	1.1	25645	3663.6	0	0.0
17	Hardcore filling, watering & compaction	15	7	1.1	62100	8871.4	326600	46657.1
18	Formwk to edges of ground floor slab	15	5	0.8	18400	3680.0	74405	14881.0
19	Damp-proofing bed & blockwk	16	3	0.5	18400	6133.3	92575	30858.3
20	Fabric rebar to oversite concrete	17	3	0.5	20125	6708.3	143750	47916.7
21	Oversite concrete	18,19,20	7	1.1	172500	24642.9	575000	82142.9
22	Striking formwk to edges of O/S concre	21	4	0.6	13800	3450.0	0	0.0
23	Curing oversite concrete	21	7	1.1	5750	821.4	5750	821.4
	Superstructure							
24	Concrete starters to g/f cols	22	7	1.1	12075	1725.0	10925	1560.7
25	Blockwk to lintel lev	22	20	3.1	169050	8452.5	844100	42205.0
26	Col & lintel formwk	24,25	14	2.2	63250	4517.9	218500	15607.1
27	Col & lintel rebar	26	14	2.2	51750	3696.4	193200	13800.0
28	Col & lintel concrete	27	7	1.1	58650	8378.6	195500	27928.6
29	Striking formwk to cols & edges of lintels	28	7	1.1	23000	3285.7	0	0.0
30	Blockwk to first floor lev	23,29	14	2.2	730250	52160.7	304750	21767.9
31	Fwk to cols, beams, staircase & 1st floor slab	30	21	3.3	154100	7338.1	862500	41071.4
32	Rebar to cols, beams, slab & staircase	31	14	2.2	116955	8353.9	725075	51791.1
33	Concreting cols,beams,slab & staircase	32	10	1.6	161000	16100.0	836050	83605.0
34	Striking formwk to edges of slab& staircase	33	5	0.8	13800	2760.0	0	0.0
35	Electrical Services	31	21	3.3	181700	8652.4	518075	24670.2
36	Curing cols,beams,slab & staircase	33	7	1.1	12075	1725.0	5750	821.4
37	First floor column starters	34	7	1.1	17250	2464.3	15525	2217.9
38	Blockwk to first floor up to lintel	34,36	21	3.3	173075	8241.7	844100	40195.2
39	Formwk to cols & lintels	37,38	14	2.2	70150	5010.7	218500	15607.1
40	Rebar to cols & lintels	38	14	2.2	63825	4558.9	193200	13800.0
41	Concreting cols & lintels	39,40	7	1.1	75325	10760.7	195500	27928.6
42	Striking formwk to cols & edges of lintels	41	7	1.1	28750	4107.1	0	0.0
43	Blockwk to roof level	41	14	2.2	70725	5051.8	352446.25	25174.7
44	Roof Beam formk and rebar	42,43	24	3.8	75325	3138.5	281750	11739.6
45	Concreting roof beams and slab	44	14	2.2	80500	5750.0	247250	17660.7
46	Striking formwk to first floor conc, beam, lintel	45	14	2.2	72450	5175.0	0	0.0
47	Roof work	46	30	4.7	166750	5558.3	3225750	107525.0
48	Scaffold errection	45	14	2.2	34500	2464.3	62100	4435.7
	Finishes & Associated Works							
49	Fixing doors & windows	47	14	2.2	80500	5750.0	529000	37785.7
50	Burglar proofing	49	12	1.9	41400	3450.0	303600	25300.0
51	Floor screeding to receive tiling	47	14	2.2	51750	3696.4	294975	21069.6
52	Plastering & rendering	47	21	3.3	172500	8214.3	747500	35595.2

53	Tiling	51,52	21	3.3	201250	9583.3	937250	44631.0
54	Painting & decoration	50,53	16	2.5	86825	5426.6	368000	23000.0
55	Plumbing /Sanitary fitting & testing	6,46	14	2.2	92000	6571.4	652050	46575.0
56	Kitchen &wardrobe cabinets	47	14	2.2	138000	9857.1	460000	32857.1
57	Scaffold dismantling & making good damaged walls	54	14	2.2	17250	1232.1	0	0.0
58	Site clearing ,cleaning and handing over	57	10	1.6	35075	3507.5	0	0.0
	Total	**Total**	**635**	**100**	**4551476.88**	**7167.7**	**17410971.25**	**27418.9**
		GRAND TOTAL			**N21962448.13**			

Table 1 shows the summary of the project's duration, constraints and cost data. This table was used to prepare the project's network diagram using the critical path method. The network diagram with the associated Event times and the Critical Path for the 5-Bedroom Duplex is not shown here because of space limitations. The total estimated project duration was found to be 450 working days, making a saving of 41% out of the 635 nominal working days. The project, on the Calender Date Plan, was scheduled to start form Wednesday, 1st February, 2014 and end on Friday, 10th July, 2015

Project Measuring and Controlling Analysis

For ease of coordination, the Project Manager decided to control the project on a monthly basis. The workers were conditioned to work for 8 hours daily (8.00am – 1.00pm, then 2.00 – 5.00pm) and 6 days per week (Mondays through Saturdays), making a total of 48 hours per week except on holidays and unexpected emergencies.

Figure 1 shows the graph of cumulative scheduled material, labour and total project costs. This graph was generated using the table of scheduled cumulative labour, material and project target costs based on the earliest and latest starting times of activities respectively.

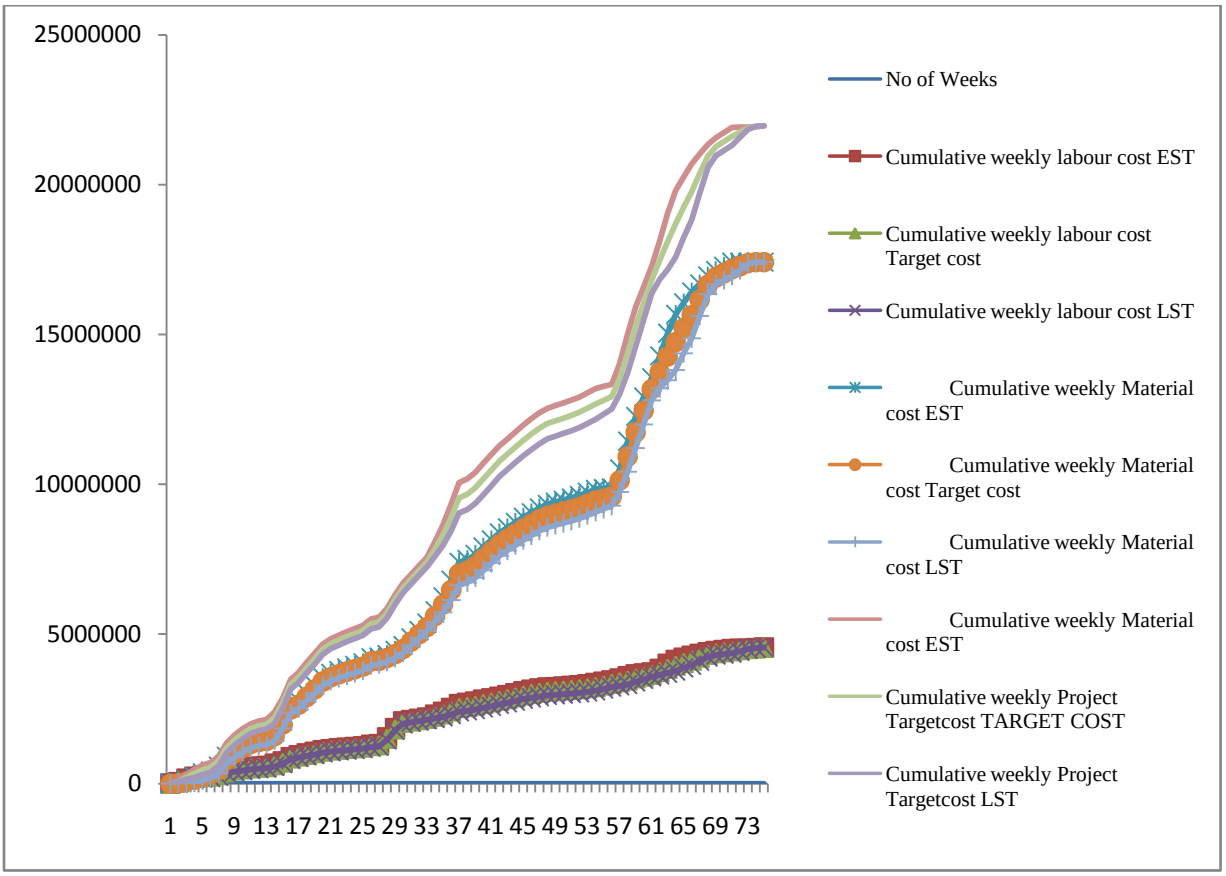

Figure 1: Cumulative scheduled weekly material, labour and Total Project target cost graph

Table 2: Project Status Report Analysis for 5-Bedroom Detached Duplex at GRA, Maiduguri

MONTH	DATE	BCWP	ACWP	BCWS	BAC	CV	SV	CPI	SPI	ETC	EAC
01	07/03/2014	263,490.88	275,500	360,159.88	21,962,448	-12009.12	-96669	0.9564097	0.731594	22687930	22963430
02	06/04/2014	880,500.00	754,450	1,250,500.00	21,962,448	126050	-370000	1.1670754	0.704118	18063913	18818363
03	03/05/2014	2,028,121.90	1980500	2,075,521.90	21,962,448	47621.9	-47400	1.0240454	0.977162	19466253	21446753
04	02/06/2014	3,028,646.90	3246000	3,626,646.90	21,962,448	-217353.1	-598000	0.9330397	0.835109	20292600	23538600
05	30/07/2014	4,661,531.90	4825000	4,661,531.90	21,962,448	-163468.1	0	0.9661206	1	17907615	22732615
06	27/08/2014	5,167,071.90	4988000	5,216,061.90	21,962,448	179071.9	-48990	1.0359005	0.990608	16213310	21201310
07	25/09/2014	5,562,096.90	5543800	6,433,863.80	21,962,448	18296.9	-871766.9	1.0033004	0.864503	16346401	21890201
08	22/10/2014	7,618,296.90	7,950,000	7,618,296.90	21,962,448	-331703.1	0	0.9582763	1	14968700	22918700
09	19/11/2014	9,354,250.60	9,160,500	9,134,715.60	21,962,448	193750.6	219535	1.0211507	1.024033	12347049	21507549
10	18/12/2014	11,238,727	11,155,500	11,035,292	21,962,448	83,227	203435	1.0074606	1.018435	10644308	21799808
11	15/02/2015	11,784,402	11,805,000	11,729,834.50	21,962,448	-20598	54567.5	0.9982551	1.004652	10195836	22000836
12	13/03/2015	12,295,562.63	12,350,000	12,507,148	21,962,448	-54437.37	-211585.4	0.9955921	0.983083	9709685	22059685
13	24/04/2015	12,739,246.75	12,800,500	12,864,223	21,962,448	-61253.25	-124976.3	0.9952148	0.990285	9267549	22068049
14	21/05/2015	13,361,032	13,328,000	12,744,680.50	21,962,448	33032	616351.5	1.0024784	1.048361	8580151	21908151
15	21/06/2015	17,558,523	17,518,400	16,479,823	21,962,448	40123	1078700	1.0022903	1.065456	4393862	21912262
16	19/07/2015	18,573,448	17,933,500	18,905,748	21,962,448	639948	-332300	1.0356845	0.982423	3272232	21205732
17	17/08/2015	21,455,298	21,095,675	20,142,573	21,962,448	359623	1312725	1.0170472	1.065172	498649.5	21594325
18	14/09/2015	21,962,448	21,700,000	21,922,198	21,962,448	262448.13	40250.13	1.0120944	1.001836	0	21700000
19	05/10/2015	21,962,448	21,700,000	21,922,198	21,962,448	262448.13	40250.13	1.0120944	1.001836	0	21700000

Analysis of CPI-SPI Project Contour for the 5 Bedroom Duplex under Review

Figure 2 shows the progressive CPI-SPI contour from inception to completion of the project. The graph was prepared using the data generated from Table 2. The analysis of the project's performance was based on the model adopted by Chitkara, (2006). From this figure, the project suffered an initial setback in the early months of its life. During the status report of the first month (7/3/2014), the project was found to be behind schedule and over budgeted. On analysis, several factors were found responsible for this phenomenon. These included inaccurate estimates, delays caused due to inclement weather and civil disturbances, lower than planned productivity and difficult or disorganised work. The same fate was discovered during the fourth status report analysis (2/6/2014). However, during the second status report conducted on 6/4/2014, the project was seen to be behind schedule, caused by such factors as was than estimated productivity, delays in starting activities, poor productivity offset by fewer than planned quantities and unforeseen working conditions.

In general, there were progressive and systematic corrective measures which culminated in an early completion of the project with a cost saving of N262, 448.13 from the originally budgeted cost of N21, 962,448.13 representing 1.5% savings.

Conclusion and Recommendations

In conclusion, the 'PERT/CPM cost function and earned value system' provide very effective monitoring and evaluation techniques for building and civil engineering projects. It is therefore recommended as follows:

(i) Project managers who may want to adopt these methods must be very realistic in assessing both the durations and costs of the activities. This can be achieved by constantly updating the performances of his labour force as well as cost of building materials and plants.

(ii) To achieve success, periodic evaluation of the cost-time graph must be done in order to reflect the realities of the project.

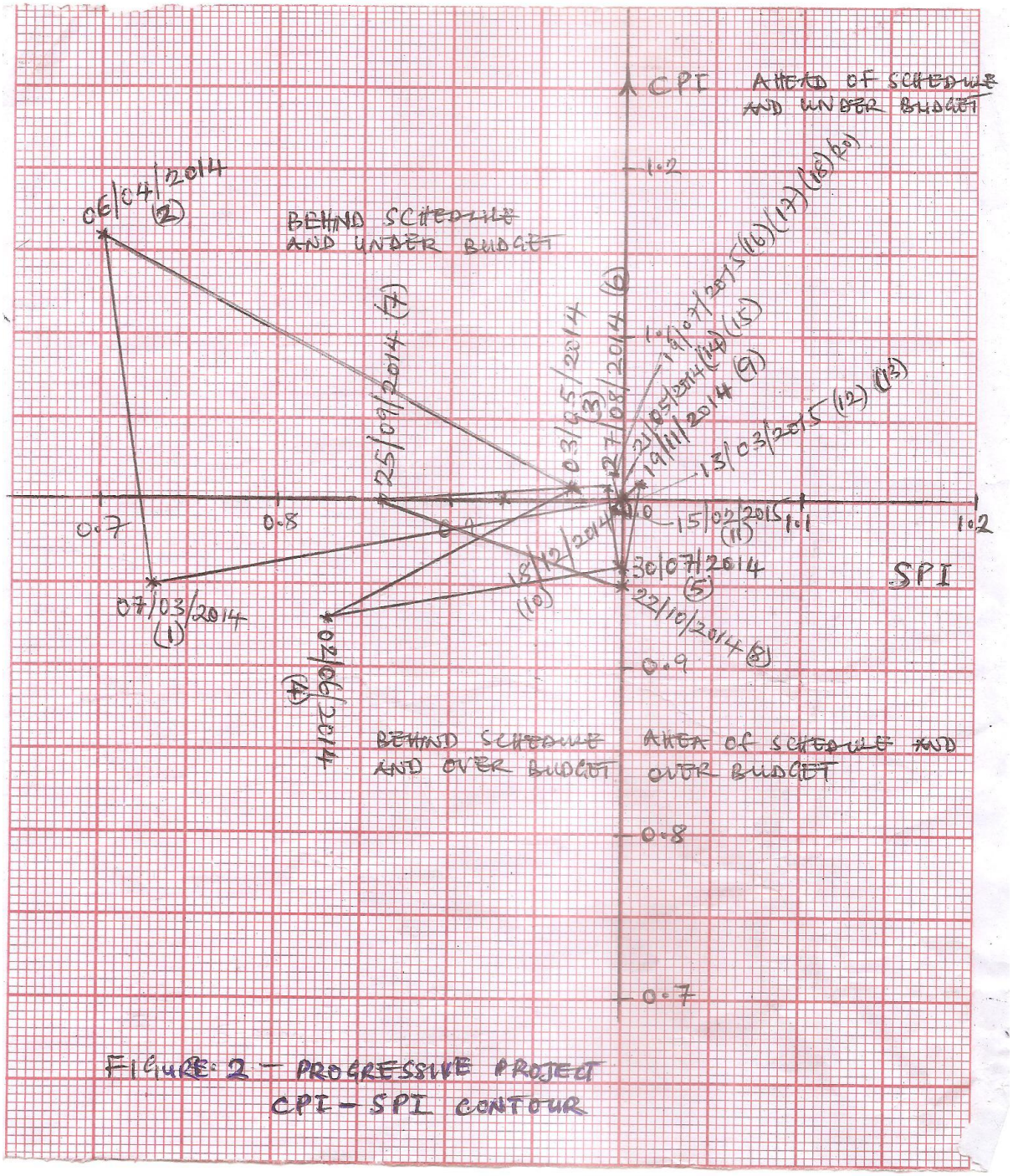

Figure 2: Progressive Project CPI_SPI Contour

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