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Modelling Building Renovation Using PERT

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Authors' contributions

This work was carried out in collaboration between both authors. Author NPA designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors NPA and GOA managed the analyses of the study. Author GOA managed the literature searches. Both authors read and approved the final manuscript.

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Abstract

Effective project management techniques are critical to managers and decision makers in handling projects in today's competitive environment. It is required that with such techniques, managers can carry out projects and complete them within specified time and resource constraint. This research considers the application of Program Evaluation and Review Technique (PERT). PERT was used to analyze data collected from Mega Star Technical and Construction Company in charge of the renovation/building construction of renovaworks at 48 Forces Avenue, Old GRA, Port Harcourt, Nigeria. The technique was used to obtain the network diagram, critical path, expected completion time for the project and the probability of completion within a required date. Ms Project version (2013) software was also used for the analyses. Results obtained revealed that the project can be completed within record time and possess a very high probability of completing the project within a stipulated date.

Keywords: Program Evaluation and Review Technique (PERT); project management; building construction; critical path; network diagram.

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1 Introduction

In recent years the concept of "project management" has taken center stage in the administration of most organizations in diverse fields. This is due to the fact that these organizations, no matter their sizes have at one time or the other planned and carried out certain activities or "projects" that were geared towards developing new products/services, rebranding, innovating etc, to achieve some organizational goals. These projects are short-term endeavors that seek to produce a distinctive product, service or outcome which has a distinct beginning and end; that is usually time-constrained, and to a large extent constrained by funding or deliverables [1]. [2] noted that projects are designed and implemented to address developmental needs or problems. The responsibility of managing a project (especially large scale) includes numerous tasks such as scheduling a number of activities throughout the entire process and planning their mode of execution, estimated time, each activity costs etc [3]. [4] described a project as an arrangement of interconnected activities in such a way that they are carried out in a definite order until the entire task is completed. These activities are interrelated in such a logical manner so that some activities must wait for others to finish before they can start. Such projects operate with in time, quality, cost constraints and also differ in scale and purpose [5]. In achieving these goals, it is therefore imperative that certain tools, management techniques and problem solving approaches be applied within the process to successfully complete these projects within a given time and estimated cost. These tools are imbedded in what is known as project management.

According to [6], project management is an area of study concerned with carefully projecting or planning, organizing, motivating and controlling resources to achieve specific goals and meet specific success criteria. In dealing with such projecting, scientific models that can aid planning, management, costing, and implementation of large-scale, temporary, complex projects were made available to managers/decision-makers as early as the 1900s. Among such models is the Gantt chart. The Gantt chart, attributed to Henry Gantt became a globally accepted scientific tool for project planning, scheduling, coordination and control [7,8]. Nevertheless, due the nature of some projects encountered in the mid/late 1950s, it became necessary to develop newer, more efficient and effective techniques. Two techniques offered by operations research methods were concurrently developed. These techniques are the Program (or Project) Evaluation and Review Technique (PERT) and Critical Path Method (CPM). Another method introduced was Work Breakdown Structure (WBS) [9]. A consulting firm originally developed PERT for the United States Navy. Their purpose was for planning the research and development activities for the Polaris Missile Program [10]. CPM on the other hand, was initially developed as an application for project construction by E.I. Du Pout de Nemours and company with emphasis on the tradeoff between the cost of the project and its overall completion time. More advances in the CPM were carried out later by Mauchly associates [3,4]. PERT and CPM are basically time-oriented methods; this means that both methods lead to estimating a time schedule. Though both methods were developed separately or independently, they are largely alike. The most significant difference is in the use of the time estimates for each technique. PERT assumes the time to be probabilistic while they were deterministic in CPM.PERT and CPM both offer appealing techniques to project managers to carry out their basic function of planning, scheduling and controlling. Therefore managers/decision-makers can;

1) Plan projects ahead of time and foresee possible sources of difficulties and challenges that may delay completion.
2) Schedule the project activities at the appropriate times to conform with proper job sequence so the project can be complete in record time,
3) Coordinate and control the project activities to stay within completion time schedule.

PERT and CPM can both be applied in managing various projects like the construction of buildings, highways, bridges, refineries (including planning and maintenance) etc. They are also used for repairs of ships and other large operations, developing new arms, assembly of large items such as airplanes, ships etc. They may also be used for simple projects such as home modeling, cleaning and painting to moving into a new apartment.

This research will focus on the application of PERT to manage the renovation/building construction carried out at 48 Forces Avenue, Port Harcourt by Mega Star Technical and Construction Company.

2 Literature Review

PERT has gained much acceptance since it was first developed for the US Navy back in the 1950s. The technique has today become the standard for managing projects for many government contractors in various countries especially in the US. This is because of the success achieved by its implementation. PERT demonstrated its value, and was given credit for reducing the estimated time needed to develop the Polars Missile by two years [3,11]. A key feature in PERT is the incorporation of uncertainties in activity times in the analysis. It is a well-known fact that the time required to complete various activities in a research and development project are not quite known in advance. Therefore, to a large extent some level of uncertainty must be incorporated into the planning. PERT method offers this advantage because it is established on probability estimation of operation times and completion duration of the project [12,13,14].

Applying the Project Evaluation and Review Techniques for planning comprises of the steps outlined below:

1. Pinpoint specific activities and events: These activities are the individual jobs/tasks that are needed to complete the project. Events on the other hand are specific point in time which indicates the commencement and the completion of one or more activities.

2. Determine the appropriate order of the activities: In this case, the proper sequence of the activities must be put in place. This can be done alongside the above point. Ordering the sequence of some activities are obvious while others may require some kind of analysis to find out their proper order. For ease of analysis, the task could be listed in a tabular form to include information on sequence and duration.

3. Construct a network diagram: The network diagram consists of a set of nodes linked by arcs/arrows and serves as a good pictorial communication and planning tool for effective time management [11]. Each activity indicates a node and the arcs/arrows denote the connection between the activities. The network diagram is constructed using the activity sequence information and duration gotten from the table generated from points 1 and 2. Modern software packages can automatically translate these activity information tables into network diagrams.

4. Estimate the time required for each activity: Time estimates are usually measured in weeks, however, in some cases other consistent time units are considered. PERT is based on three time estimates; Optimistic time (O): shortest time required to complete an activity, most likely time (M): The time with the highest probability to complete the activity and Pessimistic time (P): the longest time that activity may require [15]. PERT is assumed to follow the beta probability distribution. Therefore, the expected time and variance for each activity are estimated using the following:

$$\text{Expected time} = \frac{(O + 4M + P)}{6} \tag{1}$$

$$\text{Variance} = \left(\frac{P - O}{6}\right)^2 \tag{2}$$

5. Determine the critical path: The critical path determines the total schedule time required for the project. This path is obtained by accumulating the individual times for the activities in each of the sequence and using it to obtain the lengthiest route in the entire project. The total project time does not change if any activity(ies) that falls outside the critical path changes (either speeds up or slows down). The amount of time that a non – critical path activity can be delayed such that the project is still within limits is called a slack time [16]. The activities within the critical path do not have any slack because a slack will mean a delay in the completion of the entire project. To determine the critical path there are certain activity time quantity that are needed especially if the critical path is not immediately known. These activity time quantities are the

Earliest Start time (ES), Earliest Finish time (EF), Latest Start time (LS) and Latest Finish time (LF). The ES and EF are calculated moving forward through the network while the LS and LF are calculated working backwards through the network. The difference between the LF and EF of each activity gives the slacks. In some cases, the total duration of the project can be shortened by adding the resources essential to shrink the time for the activities in the critical path. This process is known as project crashing.

6. Update the PERT chart as the project advances: The PERT network is constantly adjusted as the project advances. Also the actual times are used to replace the estimated times as the project develops. In managing project, consideration is given for eventual delays. When such delays occur, extra resources may become necessary to stay on course. The PERT chart can then be modified to reflect the new situation [15,17].

Since PERT gained popularity in the 1950s as a project management technique, several researchers have studied it extensively to improve on it and more are applying the technique in conjunction with the CPM to project tasks they undertake. Authors like [18] in their classic reported their investigation into the nature between project management practices in six industries and revealed the trends/development in the studied industries according to the use of these techniques. [19] also in a 10-year study reviewed project management literatures and emphasized the growing trends and changes experienced by the use of PERT/CPM as project management methods in a variety of fields. [20] presented the alternatives used in improving project management. They considered the Gantts chart along with network techniques (PERT and CPM) which allows graphs presentation showing projects schedule task. [21] analyzed the relevance of CPM and PERT when employed for planning, scheduling, controlling and implementing. They enumerated the advantages of the methods as they relate to minimizing troubles, delays, interruption by determining certain critical factor and various activities of the overall project management systems. [22] demonstrated how the PERT/CPM has fitted in for adequate use in the 21st century and further presented the importance the sequencing and crashing models developed under CPM, PERT allow their adaptation to scholastic reality. [23] suggested an improved methodology to estimate the mean project completion time using simulation. PERT analysis was used only for activities in the critical path [24].

Anderson and Hales [25] applied the CPM to research project development of Fire Economics Evaluation System (FEES). [26] studied the application of PERT in the management of health organization. The research revealed the benefits of PERT in obtaining an optimal solution. [15] applied both CPM and PERT to the furniture industry. [27] executed a project base company using PERT/CPM and concluded that the technique improves project management and provides better control over activities and project time. [28] and [29] used the optimum crashing method to minimize the required cost while attaining a specified completion time. [30] combined the CPM and PERT to determine the critical path and the expected duration for the startup of the bottling company unit. The PERT method gave the expected duration and CPM paid attention to the activities falling under the critical path. [31] proposed the use of PNs (Petri Nets) model which is analyzed through (PN based) scheduling techniques along with the PERT/CPM and used it to find the critical path as a basis to develop algorithms for resource constrained project management. [32] applied CPM scheduling techniques to research plan and management of graduate students' projects. In this case the CPM scheduling was without resource constraints. [33] analyzed data related to the project of the reactivation of line 1 for the production of iron ore concentrates of national iron ore mining company. Based on the methods of PERT, they wrote a MATLAB program to obtain the critical path and the probability of the project completion at a stimulated time. With advances in research and technology, PERT is analyzed using newer computer software.

Several authors [34] and [35] compared the PERT Method and Monte Carlo Method for probability analysis using a model of a project displayed by a network chart. The research demonstrated the different results that can be obtained using the methods. [36] also presented and compared probabilistic techniques of project management. Their comparative study was concerned with GERT, PERT and Monte Carlo simulation techniques and illustrated how each project network planning techniques are grouped and their properties. [37] reviewed and amplified the limitations of the classical scheduling techniques, the Gantt chart, the CPM and the PERT. The discussion of findings based on the case studies illustrates why limiting the contents of scheduling, education and teaching can be disadvantageous.

More recently, PERT and CPM are used simultaneously as a single technique with acronym PERT/CPM or CPM/PERT. [38] proposed a new method of sequencing of the network diagram into more realistic and constrained project management. They applied CPM as a standard method of network analysis of the activity and further included PERT analysis mechanism to determine the tasks that the project requires and the order in which they must be completed. [39] applied the PERT/CPM techniques in the production of the horizontal laminator (a machine used to cut polythene forum blocks in the mattresses industries).

Rama et al. [40] proposed a study on project planning using the deterministic and probabilistic models by network scheduling techniques. Using a building construction project as a case study and applying the two project scheduling methods namely PERT and CPM to determine numerically the different types of floating times of each activity and hence determined the central path which plays an important role in the project completion time. [41] developed a more realistic approach to solve project time cost optimization problem under certain conditions with fuzzy time periods. The proposed model used in the project leads decision makers to choose the desired solution under different risk levels. [42] used fuzzy PERT and fuzzy CPM logic techniques to plan, manage and improve an online internet business with fuzzy data.

3 Materials and Methods

Mega Star Technical and Construction Company Limited is a registered civil engineering company in Nigeria. It was incorporated in 1988 but started effective business in 1977. The company operations cover the Niger Delta Area. They service the government, public and private sectors in construction projects of all kinds ranging from building hotels to hospitals, institutions to residential apartments, office complexes to warehouses etc.

Data for the renovation/building construction project at Renovaworks at 48 Forces Avenue Port Harcourt, Rivers State, Nigeria (carried out by the company from August 2017 to December 2017) was used as the case study. Firstly, the raw data obtained were plotted and analyzed by the use of Gantt chart with the aid of the MS project (2013) software for project management. The schedule is as shown in Table 1. Details for the Gantt chart are given in the appendix.

Table 1. Activity list for the Renovaworks at 48 Forces Avenue Old GRA Port Harcourt, Nigeria

Activity	Activity description	Immediate predecessors	Estimated duration (Days)
1.	Renovation works	-	-
2.	**Main building**	1	89
3.	Start	2	0
4.	Demolition works	3	10
5.	New wall construction	4	14
6.	New roof trusses	5	9
7.	New roof covering	6	7
8.	Mep conduit piping	7	15
9.	Doors and windows sub frame	10	11
10.	Plastering(internal)	7	14
11.	Plastering(external)	10	14
12.	Handrails/burglary bars	10	10
13.	Electrical cabling	11	12
14.	Ceiling works	13	14
15.	Floor screeding / tilings	14	12
16.	Door and window panels	15	7
17.	Electrical/plumbering	15	10

Activity	Activity description	Immediate predecessors	Estimated duration (Days)
18.	A/c installation	17	7
19.	Internal painting	18	10
20.	External painting	19	7
21.	End of main building	20	0
22.	**Boys quarter**	1	60
23.	Demolition and alteration	5	3
24.	Substructure	23	7
25.	New block walls	24	7
26.	Roof trusses	25	7
27.	Roof covering	26	3
28.	Mep conduit piping	27	4
29.	Doors and window subframe	28	2
30.	Plastering (internal)	29	3
31.	Plastering (external)	30	2
32.	Electrical cabling	31	3
33.	Ceiling works	32	3
34.	Floor screening	33	3
35.	Doors and window panels	34	3
36.	Electrical/plumbing	35	3
37.	Internal painting	36	3
38.	External painting	37	2
39.	**Gate house**	1	32
40.	Demolition and alteration	28	2
41.	Substructure	40	4
42.	New wall block walls	41	3
43.	Roof trusses	42	3
44.	Roof covering	43	2
45.	Mep conduit piping	44	2
46.	Doors and window sub frame	45	2
47.	Plastering (internal)	46	2
48.	Plastering (external)	47	1
49.	Electrical cabling	48	2
50.	Ceiling works	49	2
51.	Floor screening	50	1
52.	Doors and window panels	51	1
53.	Electrical plumbing	52	2
54.	Internal painting	53	2
55.	External painting	54	1
56.	End of gate house	55	0

Table 2 shows the project analysis and time estimates/duration as required by PERT. The Project Evaluation and Review Technique (PERT) was used for the analysis. The steps for PERT were implemented as explained in the previous section.

Steps one and two are described in Tables 1 and 2. The network analysis for the project is as shown in Fig. 1. Table 3 shows the ES, EF, LS and LF for each activity in the project. When the LS and ES are the same, then that path in the project becomes a critical path. The critical path determines the total calendar time required for the project. The amount of time that a non-critical path can be delayed without affecting the project is referred to as slack time. It is obtained from the difference in the LF and EF of each activity.

Table 2. Expected duration, various time estimates and variance for the renovation project

Activity	Optimistic time (t_o)	Pessimistic time (t_p)	Most likely time (t_m)	Expected mean duration (t_e) $\frac{to+4tm+tp}{6}$	Standard deviation (σ)	Variance $(\frac{tp-to}{6})^2$
2	75	91	89	87.00	2.67	7.11
3	0	0	0	0.00	0.00	0.00
4	8	12	10	10.00	0.67	0.44
5	12	16	14	14.00	0.67	0.44
6	8	11	9	9.17	0.50	0.71
7	4	9	7	6.83	0.83	0.69
8	10	17	15	14.50	1.17	1.36
9	8	13	11	10.83	0.83	0.69
10	9	16	14	13.50	1.17	1.36
11	10	16	14	13.67	1.00	1.00
12	8	12	10	10.00	0.67	0.44
13	10	14	12	12.00	0.67	0.44
14	11	16	14	13.83	0.83	0.69
15	9	14	12	11.83	0.83	0.69
16	3	9	7	6.67	1.00	1.00
17	7	12	10	9.83	0.83	0.69
18	4	9	7	6.83	0.83	0.69
19	6	12	10	9.67	1.00	1.00
20	5	9	7	7.00	0.67	0.44
21	0	0	0	0.00	0.00	0.00
22	40	62	60	57.00	3.67	3.44
23	3	7	5	5.00	0.67	0.44
24	4	9	7	6.83	0.83	0.69
25	4	9	7	6.83	0.83	0.69
26	3	9	7	6.67	1.00	1.00
27	2	5	3	3.17	0.50	0.25
28	2	6	4	4.00	0.67	0.44
29	1	4	2	2.17	0.50	0.25
30	2	5	3	3.17	0.50	0.25
31	3	4	2	2.50	0.17	0.028
32	4	5	3	3.50	0.17	0.028
33	3	5	3	3.33	0.17	0.028
34	3	5	3	3.33	0.33	0.11
35	4	5	3	3.50	0.17	0.028
36	1	5	3	3.00	0.67	0.45
37	2	5	3	3.17	0.50	0.25
38	1	4	2	2.17	0.50	0.25
39	24	34	32	31.00	1.67	2.79
40	1	4	2	2.17	0.50	0.25
41	3	6	4	4.17	0.50	0.25
42	2	5	3	3.17	0.50	0.25
43	2	5	3	3.17	0.50	0.25
44	1	4	2	2.17	0.50	0.25
45	1	4	2	2.17	0.50	0.25

Activity	Optimistic time (t_o)	Pessimistic time (t_p)	Most likely time (t_m)	Expected mean duration (t_e) $\frac{to+4tm+tp}{6}$	Standard deviation (σ)	Variance $(\frac{tp-to}{6})^2$
46	1	4	2	2.17	0.50	0.25
47	1	4	2	2.17	0.50	0.25
48	1	3	2	1.33	0.33	0.11
49	1	4	2	2.17	0.50	0.25
50	1	4	2	2.17	0.50	0.25
51	1	3	1	1.33	0.33	0.11
52	1	3	1	1.33	0.33	0.11
53	1	4	2	2.17	0.50	0.25
54	1	4	2	2.17	0.50	0.25
55	1	3	1	1.33	0.33	0.11
56	0	0	0	0.00	0.00	0.00

Table 3.Table showing the LS, ES, LF, EF and slacks of various activities

Activity	Durations	ES	EF	LS	LF	Slacks (LF-EF)
2	87.00	0.00	87.00	87.00	87.00	0.00
3	0.00	87.00	87.00	87.00	87.00	0.00
4	10.00	87.00	97.00	97.00	97.00	0.00
5	14.00	97.00	111.00	97.00	111.00	0.00
6	9.17	111.00	120.17	111.00	120.17	0.00
7	6.83	120.17	127.00	120.17	127.00	0.00
8	14.50	127.00	140.50	127.00	140.50	0.00
9	10.83	140.50	151.33	140.50	151.33	0.00
10	13.50	127.00	140.50	154.17	140.50	0.00
11	13.67	140.50	154.17	166.17	154.17	0.00
12	10.00	140.50	150.50	140.50	150.50	0.00
13	12.00	154.17	166.17	154.17	166.17	0.00
14	13.83	166.17	180.00	191.83	180.00	0.00
15	11.83	180.00	191.83	201.66	191.83	0.00
16	6.67	191.83	191.85	191.83	191.85	0.00
17	9.83	191.85	201.66	208.49	201.66	0.00
18	6.83	201.66	208.49	218.16	208.49	0.00
19	9.67	208.49	218.16	225.16	218.16	0.00
20	7.00	218.169	225.16	225.16	225.16	0.00
21	0.00	0.00	0.00	0.00	0.00	0.00
22	57.00	0.00	57.00	84.83	162.82	105.82
23	5.00	111.00	116.00	162.82	167.82	51.82
24	6.83	116.00	122.83	167.82	162.82	38.16
25	6.83	122.83	129.66	162.82	167.82	38.16
26	6.67	129.66	136.33	167.82	174.65	38.32
27	3.17	136.33	139.50	174.65	181.48	38.32
28	4.00	139.50	143.50	181.48	188.15	44.65
29	2.17	143.50	145.67	188.15	195.32	49.65
30	3.17	145.67	148.84	195.32	197.49	48.65
31	2.50	148.84	151.34	197.49	200.66	49.32
32	3.50	151.34	154.84	200.66	203.16	48.32

Activity	Durations	ES	EF	LS	LF	Slacks (LF-EF)
33	3.33	154.84	158.17	203.16	206.66	48.49
34	3.33	158.17	161.67	206.66	209.99	48.32
35	3.50	161.67	164.64	209.99	213.32	48.68
36	3.00	164.67	167.84	213.32	216.82	48.98
37	3.17	167.84	170.01	216.82	219.82	49.81
38	2.17	170.01	170.01	225.16	222.99	52.98
39	31.00	0.00	31.00	31.00	162.30	131.30
40	2.17	31.00	145.67	162.30	193.30	47.63
41	4.17	145.67	149.84	193.30	197.47	47.63
42	3.17	149.84	153.01	154.47	153.01	0.00
43	3.17	153.01	156.18	197.47	200.64	44.46
44	2.17	156.18	158.35	200.64	203.81	45.46
45	2.17	158.35	160.52	203.81	205.98	45.46
46	2.17	160.52	162.69	205.98	208.15	45.46
47	2.17	162.69	164.86	208.15	210.32	45.46
48	1.33	164.86	166.19	210.32	212.49	46.30
49	2.17	166.19	168.36	212.49	213.82	45.46
50	2.17	168.36	170.53	213.82	215.99	45.46
51	1.33	170.53	171.86	215.99	218.16	46.30
52	1.33	171.86	173.19	218.16	220.33	47.14
53	2.17	173.19	177.53	220.33	221.66	44.13
54	2.17	177.53	178.86	221.66	222.99	1.33
55	1.33	178.86	178.86	222.99	225.16	46.30
56	0.00	0.00	0.00	0.00	0.00	0.00

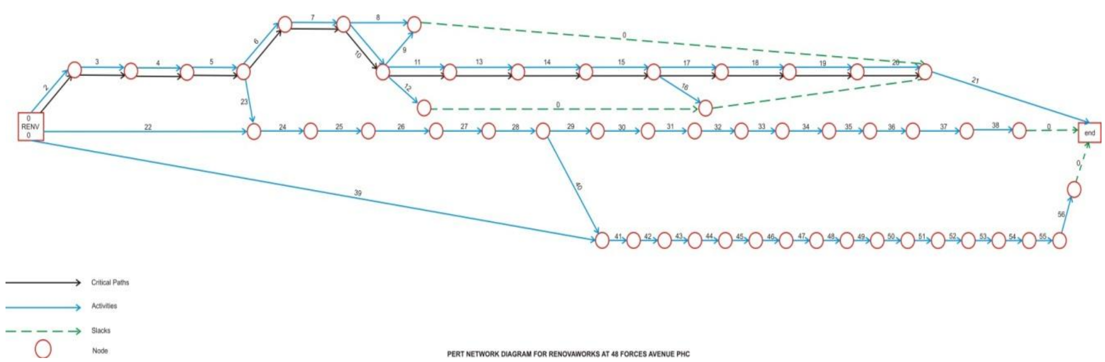

Fig. 1. PERT network diagram for Renovawork at 48 Forces Avenue Port Harcourt, Nigeria

4 Results and Discussion

From the construction of the network diagram seven paths were identified. These paths are as shown below.

1. 2→3→4→5→6→7→8→21
2. 2→3→4→5→6→7→10→11→13→14→15→17→18→19→20→21
3. 2→3→4→5→6→7→8→9→10→11→13→14→15→17→18→19→20→21
4. 22→23→24→25→26→27→10→15→28→29→20→31→32→33→34→35→36→37→38
5. 22→23→24→25→26→27→28→29→30→31→32→33→34→35→36→37→38
6. 39→28→40→41→42→43→44→45→46→47→48→49→50→51→52→53→54→55→56
7. 39→40→41→42→43→44→45→46→47→48→49→50→51→52→53→54→55→56

The second path was further identified as the critical path. This path consists of activities;

$2 \rightarrow 3 \rightarrow 4 \rightarrow 5 \rightarrow 6 \rightarrow 7 \rightarrow 10 \rightarrow 11 \rightarrow 13 \rightarrow 14 \rightarrow 15 \rightarrow 17 \rightarrow 18 \rightarrow 19 \rightarrow 20 \rightarrow 21$

The expected project completion time is the addition of the activity times on the critical path, that is;

=87.00+0.00+10.00+14.00+9.17+6.83+13.50+13.67+10.00+12.00+13.83+11.83+9.83+6.83+9.67+7.00+0.00= 235.16 days

The project variance of the critical path is also estimated to be;

7.11+0.00+0.44+0.44+0.71+0.69+1.36+1.00+0.69+0.69+0.69+0.69+1.00+0.44+0.00=15.95

To determine the probability that the project has a duration less than or equal to 243 days we use $Z = \frac{X-\mu}{\sigma}$ for the approximation;

where the mean (μ) = 235.16 and standard deviation (σ) = 3.99,

$$P(T \leq 243) = P\left(\frac{243-235.16}{3.99}\right) = p(z \leq 0.712) = 0.7653 \text{ or } 76.53\%$$

Therefore given the above results, it is clear that the expected project completion time of the project is 235.16 days and project variance is 15.75. By determining the mean and variance of the entire project, it is therefore possible to find the probability that the project can be completed within a stipulated date. In this instance we used a duration of less than or equal to 243 days. It was seen that there is a probability of 0.7653 or a 76.53% chance of completing the entire project within 243 days or less.

5 Conclusion

PERT can be applied to obtain solution for many project management problems. These can be either large or small scale projects. PERT offers important analytical tools and techniques to project managers who are constantly faced with increasing project demands that require high quality standards under serious time and resource constrains. As is the case with this study, PERT was used to analyze the renovation/building construction carried out by Mega Star Technical and Construction Company. The method was used to identify the critical path, slacks time, construct a network diagram, estimate the expected project completion time, the project variance of the critical path and probability of completing the project on or before a stipulated date.

PERT/CPM technique can bring immense value to project managers in any field of endeavor. The technique offers models that can reduce cost, help managers know/estimate the completion date for projects and also guide in scheduling projects, the amount of project they can undertake within a given period and consequently increase in competitiveness.

Competing Interests

Authors have declared that no competing interests exist.

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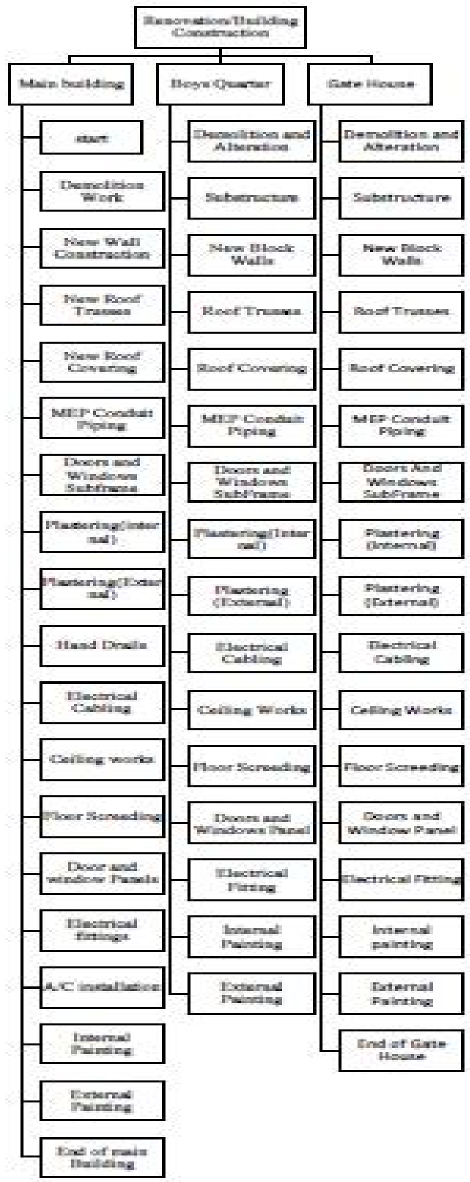
Appendix

Work Breakdown Structure of Renovation Works At 48 Forces Avenue Old GRA, Port Harcourt, Rivers State, Nigeria.



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