Applying Project Evaluation and Review Techniques (PERT) And Critical Path Method (CPM) In Network Analysis (Evidence from The Building Practice Ltd at Badagry Local Government, Lagos)

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Abstract: Attaining the prompts and cost-effective execution of a project presents remarkable challenge, which is the key factors of adequate planning and scheduling of the project. This research categorically focus on finding a balance between the cost of project and the minimizing expected time needed for the conclusion of a construction project. Data were collected from the Building Practice Ltd., a construction firm situated in Lagos State, Nigeria. The finding adopted both the Programme Evaluation and Review Techniques (PERT) and Critical Path Method (CPM). Analysis was carried out, the possible routes of the activities involved in the building project, location of critical path and expected duration for every activity in the building project was determined. The probability of completing the project within the specific time was evaluated and the result indicated that there is a 50% chance for the projected to be executed within the specify period. The project was delayed due to inadequate equipment, loss of weeks as a result of changing in plan and insufficient manpower. The initial completion and actual completion time was estimated to be two months difference which actually reduce the time and increase cost efficiency of the project.

Keywords: Critical Path, Program Evaluation and Review Techniques, Probability Approach, project management, planning

I. Introduction

Coordinating and management of a project involves several activities, which varies from one organization to the others. This is because different organization has their own functions and objectives approach to actualize their goals. Network analysis makes use of mathematical models to analyse and optimize the flow of information, resources and materials which can be applied in a building construction project. As it was being practiced around the world, in which Nigeria is not exceptional, network analysis is generally used in construction project to improve productivity and efficiency in order to reduce the cost [6].

The use of network analysis tools like PERT (Program Evaluation and Review Techniques) help project managers to indicate critical activities, schedule and budget constraints in order to eliminate potential risks [7].

Network planning strategy make use of system to reduce cost by shortening the period of various activities, which make it possible to prepare road map of the action that will identify those programs in the plan that should be specifically analyzed [4].

PERT used on a network – based framework which accelerate the monitoring and programming of platform process to secure project completion time within the stipulated period. The techniques help in resources allocation like equipment and labour which contributes to minimizing the total cost of the construction project [9].

PERT integrate uncertainties in activity times into its analysis by estimating the probabilities of completing various project stages [5].

PERT models promote the fundamental functions of control, scheduling and planning for development and distribution of new products, turnaround maintenance of a plant and where the timing activities required of project activities [1].

Theory of Project Management

Project management is the organizing, planning, controlling and directing of resources in each activity of the project in order to optimizing the duration of the project activities, thereby minimizing the total cost and time. Every project involves human beings, materials, money, machines which are manageable factors, while the time of project completion is the uncontrollable factor in project analysis [11]. In the process of executing or implementing a project, several resources are engage which are restricted in supply. Therefore, it now the duty of the project manager to utilize these resources into project sub-activities by managing the project cycles in order to accomplish the projects result effectively and efficiently [2].

The stuff of project management is effectiveness, time saving and efficiency in order to fulfill this, project managers must employed and deploy a team of highly productive and determined workers who are committed to fulfilling the project objectives [3].

Pert in Project Management

The Project Evaluation Review Technique (PERT) is normally used by project managers to break large complex projects into sub-activities, deploying resources and managing the circles of the projects in order to minimize the total cost and time of the project[10].

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Hence, PERT is operational research tools used in driving project efficiency and effectiveness and it can be applied to several industries or sectors, such as construction, aviation, military, education as well as civil engineering. [12]..

Project Evaluaton and Review Techniques

PERT uses three time estimate for each activity, by assuming a beta probability distribution for the time estimates. When the mean and standard deviation of the completion time distribution, the probabilities of finishing the project at a given due date can be estimated.

a = optimistic time estimate implies that the minimum reasonable time taken to perform an activity.

b = pessimistic time estimates, mean the maximum reasonable time taken to perform an activity.

m = most likely time estimate, implies the most likely time estimate, implies that most likely time accepted to perform an activity.

An estimate of activity completion, time, the beta distribution is used, which is a reasonable approximate expression of activity duration.

The expected time t_e which approximate the mean, the standard deviation σ for the beta distribution is given as:

$$T_e = \frac{a + 4m + p}{6}$$

When the mean and standard deviation of the beta distribution is known, the probability of completing a project at a given time can be computed using normal distribution. It can be illustrated that determine the probability that a project would be completed in a due date K.

Then $Z = \frac{K - T_e}{\sqrt{\sigma^2 cp}}$

Where $\sigma^2 cp$ is the variance of individual activities on the critical path

Critical Path Method (CPM)

The critical path method is a project management tools applied to schedule and control the completion of a project within a stipulated period. Critical path deal with analysis of interdependent tasks of a project to determine the longest path of activities that must be completed on schedule for a particular project to be finished on time [4].

It is a powerful technique that assist project managers to facilitate the project are completed on time and within budget. It primary aim, is to identify the activities that must be completed in sequential order by determining the minimum amount of time required to complete the entire project [10].

In the context of Critical Path Method (CPM), the time estimates for all activities are initially treated as single values by assuming a precise knowledge of each activity duration. The primary distinction lies in CPM assumption that activity times are directly proportional to the allocated resources, allowing for variations in activity time and overall project completion time by adjusting resources level [1],[8].

CPM is the actual time estimate of activities in a project and does not involve probability. The time estimates is determined by the estimator. For each activities there are four-time estimate:

Early Start (ES) is the earliest time it takes for an activity to begin. It assume that all preceding activities begin at their earliest possible start time; otherwise, a late start to the preceding activity will result in a late start to its succeeding activity. The ES of activity is the total of the time of all preceding activities on the path. And when activity has more than one preceding activity, the early start of the that activity depends on the early finish of the longest duration or the activitiy with the longest ES time, t.

Early Finish (EF) is an early start of an activity that will lead to an early finish. It assume that the activity begins with ES and end with t. EF = ES + t. The precedence relationship shows that the early start of activity depends upon the early finish of its immediate preceding activities. This implies that ES + t = EF.

Late start (LS) is a delay in the start of an activity. The latest time an activity can begin without delaying the project completion time.

Late Finish (LF): a late start to an activity will lead to a late finish. The delay in the late start of an activity resulting in the late finish of that activity must be such as not delay the project completion time. It is usually assume that for the last activity in the critical path, EF = LF and the LF – t = LS indicates a reverse process called backward moment. The LS of an activity is determined by the LF of the previous activities. However, when an activity has more than one preceding activity, that is, if two or more paths converge at a point in activity, the path with the shortest total LS time is taken as the LF of the preceding activity.

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II. Material and Methodology

The location of the site is the promises of Badagry Local Government Area of Lagos State. The project is the extension of the Administrative office, Block C. the building is design to be bungalow. The project was to start on the 10th of October, 2023 and the completion date 26th February, 2024. The project exceeded the initial time frame allotted due to some factors. The building construction was brought to completion on the 20th of April, 2024. Meanwhile at as the time of this research findings was carried and analysed, the building project was 80% completed. The source of date for this paper is purely primary. These estimates were provided by the project manager at the building practice limited, a construction company located in Lagos State of Nigeria. Table 1 proide the details breakdown of activities involved in the construction process. The construction site were visited and physical contact and interaction of site engineers and builders to facilitate the collection of the data process. The program of the work chart for the construction was provided with the assistant of a professional quantity surveyor. The chart was coded and interpreted. Activity duration was estimated on daily basis. The total of fifteen (15) activities were denoted as A, b, c, d ……………… and the days interval were provided.

The contractor for the building project was

The Building Practice Ltd.

Table I: Primary of activities involved for the construction process of Administrative Block C by the Building Practice Ltd.

Activity	Activity Code	Duration (days)
Mobilization	A	5
Site Clearing	B	6
Substructure	C	10
Frame	D	10
Walls	E	20
Roof and Roof Covering	F	5
Windows and Doors	G	10
Floors Finishes	H	15
Wall Finishes	I	15
Finishes Ceiling	J	10
Electrical Installation	K	15
Mechanical Installation	L	16
Painting and Decoration	M	10
External Works/Services	N	8
Cleaning and Handing Over	O	5

Network diagram will be drawn to indicates the activities relationship, the PERT and CPM will be carried out to show the critical path of the building project and the estimate of the project completion time.

Data Analysis and Result

The table below shows the activities description, activity code and their immediate predecessor, estimated duration of each activity on the program of work chart. The project was estimated to be completed in 120 days

Table II: Descriptions of Activities

Activity	Activity Code	Immediate Predecessor	Estimated Duration (in days)
Mobilization	A	-	5
Site Clearing	B	A	6
Substructure	C	B	10
Frame	D	C	10

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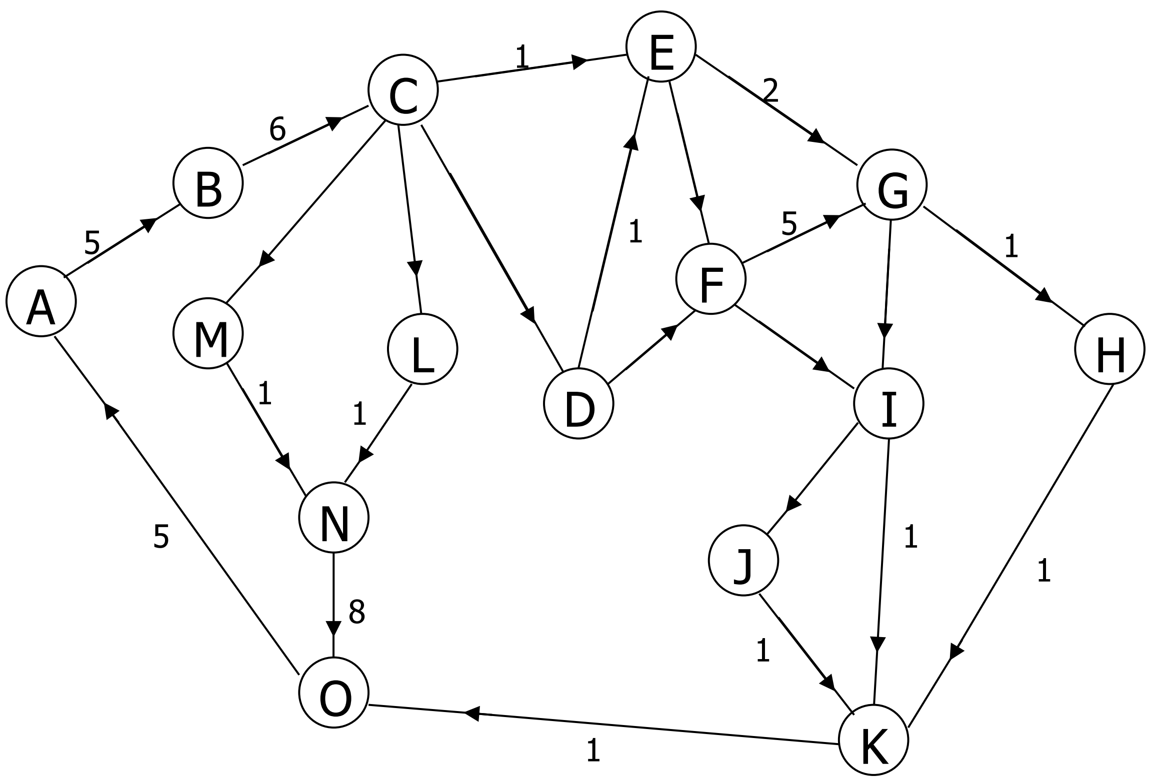
Walls	E	C, D	20
Roof and Roof Covering	F	D, E	5
Windows and Doors	G	E, F	10
Floors Finishes	H	G	15
Wall Finishes	I	F, G	15
Finishes Ceiling	J	I	10
Electrical Installation	K	H, I, J	15
Mechanical Installation	L	C	16
Painting and Decoration	M	C	10
External Works/Services	N	L, M	8
Cleaning and Handing Over	O	K, N	5

Fig 1: Network Diagram



The Result of The Critical Path

From the above network diagram, the critical path of the building project is the route:

A. Critical Path: A – B – C – D – E – F – G – I – J – K – O

Duration: 5 + 6 + 10 + 10 + 20 + 5 + 10 + 15 + 10 + 15 + 5 = 111 days

That is, the activity with description: mobilization site clearing, substructure, frame, walls, roofs and roof covering, window and doors, wall finishes, electrical installation, cleaning and handing over. Therefore, the total days in the critical path is 111 days, which means the shortest possible time to complete the project is 111 days.

It is important to note that some activities are not present on the critical path. It implies that with or without some activities on the critical path, the project will still come to conclusion.

The following table indicate the project activity, immediate predecessor, optimistic time (days) (a), normal time (m) and pessimistic time (p) for the building project.

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Table III: Estimation

S/N	Activity	Immediate Predecessor	Optimistic Time (days) (a)	Normal Time (days) (m)	Pessimistic Time (days) (p)
1	A	-	4	5	7
2	B	A	4	6	8
3	C	B	8	10	12
4	D	C	7	10	11
5	E	C, D	18	20	22
6	F	D, E	3	5	7
7	G	E, F	8	10	12
8	H	G	14	15	17
9	I	F, G	13	15	16
10	J	I	8	10	12
11	K	H, I, J	13	15	17
12	L	C	14	16	18
13	M	C	9	10	12
14	N	L, M	6	8	10
15	O	K, N	3	5	7

Expected Duration Result for Every Activity

The formula: $t_e = \frac{a + 4m + p}{6}$ is apply to compute the expected duration for every day activity for the project.

a = optimistic time

m = normal time

p = pessimistic time

$t_e = \frac{a + 4m + p}{6}$

1. $t_a = \frac{4 + 4(5) + 7}{6}$ = 5 days
2. $t_b = \frac{4 + 4(6) + 8}{6}$ = 6 days
3. $t_c = \frac{8+ 4(10) + 12}{6}$ = 10 days
4. $t_d = \frac{7 + 4(10) + 11}{6}$ = 10 days
5. $t_e = \frac{18 + 4(20) + 22}{6}$ = 20 days
6. $t_f = \frac{3 + 4(5) + 7}{6}$ = 5 days
7. $t_g = \frac{8 + 4(10) + 12}{6}$ = 10 days
8. $t_h = \frac{14 + 4(15) + 17}{6}$ = 15 days
9. $t_i = \frac{13 + 4(15) + 17}{6}$ = 15 days
10. $t_j = \frac{8 + 4(10) + 12}{6}$ = 10 days
11. $t_k = \frac{13 + 4(15) + 17}{6}$ = 15 days

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12. $t_l = \frac{14 + 4(16) + 18}{6}$ = 16 days

13. $t_m = \frac{9 + 4(10) + 12}{6}$ = 10 days

14. $t_n = \frac{6 + 4(8) + 10}{6}$ = 8 days

15. $t_o = \frac{3 + 4(5) + 7}{6}$ = 5 days

Project Completion Time Estimate

It is certain that some activities take longer than their expected time, this could lead to project delay within the stipulated schedule time. Therefore, it is important to know that the probability deadline that a project can be completed. To determine this, the variance and standard deviation of the total time along the critical path, which is equal to the sum of the variance of activity on the critical path. The variance formula:

$$\sigma = \left(\frac{p - a}{6}\right)^2$$

Each activity on project critical path

Table IV: Probabilistic Computations

Critical Path	Optimistic Time (a)	Most likely time (m)	Pessimistic Time (p)
A	4	5	7
B	4	6	8
C	8	10	12
D	7	10	11
E	18	20	22
F	3	5	7
G	8	10	12
I	13	15	16
J	8	10	12
K	13	15	17
O	3	5	7

p = pessimistic time

a = optimistic time

1. $\sigma = \left(\frac{7-4}{6}\right)^2 = 0.25$

2. $\sigma = \left(\frac{8-4}{6}\right)^2 = 0.444$

3. $\sigma = \left(\frac{12-8}{6}\right)^2 = 0.444$

4. $\sigma = \left(\frac{11-7}{6}\right)^2 = 0.444$

5. $\sigma = \left(\frac{22-18}{6}\right)^2 = 0.444$

6. $\sigma = \left(\frac{7-3}{6}\right)^2 = 0.444$

7. $\sigma = \left(\frac{12-8}{6}\right)^2 = 0.444$

8. $\sigma = \left(\frac{16-13}{6}\right)^2 = 0.25$

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9. $\sigma = \left(\frac{12-8}{6}\right)^2 = 0.444$

10. $\sigma = \left(\frac{17-13}{6}\right)^2 = 0.444$

11. $\sigma = \left(\frac{7-3}{6}\right)^2 = 0.444$

Therefore, the project variance total = 0.25 + 0.444 + 0.444 + 0.444 + 0.444 + 0.444 + 0.444 + 0.25 + 0.444 + 0.444 + 0.444 = 4.495

Standard deviation = $\sqrt{4.495}$ = 2.1

Probability that the project will be completed on the scheduled time is given by:

P (Z ≤ K)

➔ Probability (Z ≤ $\frac{Ts - Te}{\sigma}$)

Where K = $\frac{Ts - Te}{\sigma}$

Where Ts = Scheduled Time

Te = Expected time of the critical path

Ts = 110 Te = 110

K = $\frac{Ts - Te}{\sigma} = \frac{110 - 110}{2.1} = \frac{0}{2.1} = 0$

P (Z ≤ 0) = 0.5

This means that the probability of completing the project in 110 days is 0.5, implies that there is a 50% chance that the project can be completed in 110 days.

III. Summary

This research paper was able to determine all the possible routes of various activities connected to the building project. By heating the critical path, find the expected duration for every activities and evaluate the probability of completing the project within the estimated period. The results indicate that there is a 50% chance for the project to be completed with the time frame. From this findings, the project was delayed because of some factors like insufficient funds, shortage of facilities and manpower shortcoming. The actual completion time and the initial completion period has about two months intervals.

IV. Conclusion

Large-scale project management involves managing activities across the organization. PERT and critical path mode techniques are employed to solve the stages by stages activities in a priority relationship for optimum minimization of the total cost of the project efficiency. Inadequate planning and poor analysis of good project management, the project work will experience a lot of difficulties.

V. Recommendation

As regard this findings, project manager should check all the required resources to cover every activity, must be assembled and prioritized to remove what could bring delay and unavoidable cost implications. Also policies makers should focused on improving project execution implementation in developing nations like Nigeria to minimized the many cases of failed and delay projects, in order to limit or avoid these difficulties and problems.

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