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NETWORK ANALYSIS ON PHASE 1B BUILDING OF THE UNIVERSITY HEALTH CENTRE, FUTA, USING CRITICAL PATH METHOD (CPM) AND PROGRAM EVALUATION REVIEW TECHNIQUE (PERT)

Oladimeji O.A.[1], Akomolafe M.A.[2], Lasisi T.A.[3*],

Oloja O.A.[4] and Oladimeji L.A.[3]

[1] Department of Statistics, Federal Polytechnic, Ile-Oluji, Nigeria.

[2]Department of Building Technology, Osun State Polytechnic, Ire, Nigeria.

[3]Department of Statistics, Ladoke Akintola University of Technology, Ogbomoso, Nigeria.

[4]Department of Curriculum and Instruction, Adeyemi College of Education,Ondo, Nigeria.

*Corresponding Author

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ABSTRACT: *Project planning and scheduling plays a vital role in estimating the time and cost angle of a project. Finalizing a project on time and within the budget is challenging. This study focused on finding the shortest possible time required to complete the phase 1B Building project of the University Health Centre, FUTA and also to evaluate the probability of completing the project within the stipulated time. This project work has been able to give a concise view about network analysis in building construction; definitions of some terms commonly used in network analysis was also stated. Also, an introduction to CPM and PERT was stated; assumptions of CPM, advantages and disadvantages of CPM were stated; assumptions, advantages and disadvantages of PERT were also stated. Data analysis was carried out and all the possible routes of the activities involved in the building project were found; the location of the critical path of the building project was also found; the expected duration for every activity in the building project was determined; the probability of completing the project within the stipulated time was also evaluated. The results showed that there is a 50% chance for the project to be completed within the stipulated time. With the information gathered on the building project, the project was delayed due to some factors such as low circulation of money, inadequate equipments, loss of some weeks due to a change in plan, and inadequate manpower; thus, there was a two month difference between the initial completion and the now actual completion time.*

KEYWORDS: Project, Cost Angle, Network, Critical Path, Manpower.

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INTRODUCTION

Network analysis in building construction refers to the use of mathematical models to analyse and optimize the flow of materials, information, and resources in a construction project. In Nigeria, network analysis is widely used in construction projects to improve efficiency and reduce costs. The use of network analysis tools such as PERT (Program Evaluation and Review Technique), CPM (Critical Path Method), and Gantt Charts can help project managers to identify critical activities, schedule and budget constraints, and potential risks. This information can then be used to allocate resources, set priorities, and make informed decisions to ensure the successful completion of the project within the specified time and budget constraints (6).

The advantage of these quantitative tools is the optimization of project duration, time minimization and project efficiency (11)(4). However, in comparing both techniques advantages to project management, PERT is event-oriented, probabilistic, and concern with time horizon is unknown. In contrast, CPM is activity-oriented and is a deterministic model and is used for projects that are repetitive in nature and are small in size (1)(7).

One of the key benefits of network analysis in construction projects is the ability to identify the critical path of a project. The critical path is the sequence of activities that determines the minimum duration of the project. By identifying the critical path, project managers can allocate resources and prioritize tasks in a manner that will minimize project delays and ensure timely completion (3).

Another advantage of network analysis is that it allows project managers to simulate different scenarios and evaluate the potential impact of changes in the project schedule. This can help project managers to identify potential risks and make informed decisions on how to mitigate them. For example, if a key resource becomes unavailable, network analysis can help project managers to determine the impact on the project schedule and to develop contingency plans (3).

It also plays a crucial role in building construction projects in Nigeria. By providing project managers with a comprehensive understanding of the project schedule and resources, network analysis helps to ensure that construction projects are completed on time, within budget, and to the highest quality standards (3).

Another aspect of network analysis in building construction projects in Nigeria is the importance of resource allocation. Network analysis allows project managers to determine the most efficient use of resources, such as labour, equipment, and materials, and to optimize their allocation based on the criticality of different activities. This helps to avoid overloading resources, which can lead to delays and cost overruns, and also helps to ensure that resources are available when they are needed most (6).

In addition, network analysis can also help to improve the accuracy of project cost estimates. By using network analysis tools, project managers can develop detailed cost estimates for each activity, taking into account the time required, the resources needed, and any potential risks. This information can then be used to create a comprehensive project budget, which can be updated and refined as the project progresses (6).

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Another benefit of network analysis in building construction in Nigeria is that it helps to improve project control and monitoring. Project managers can use network diagrams to monitor the progress of the project and identify any potential delays or deviations from the schedule. This information can then be used to make corrective actions and ensure that the project remains on track (6).

In conclusion, network analysis is a powerful tool that can help to optimize the flow of resources, information, and materials in building construction projects in Nigeria. By providing project managers with the information and insights they need to make informed decisions, network analysis helps to ensure that construction projects are completed on time, within budget, and to the highest quality standards (9). The aim of this paper is to analyse the phase 1B building project of FUTA Health Centre using CPM and PERT method, and the objectives of the paper are: to find all the possible routes of the activities involved in the building project, to locate the critical path of the building project, to determine the expected duration to complete each activity in the project, and to evaluate the probability of completing the project within the stipulated time.

LITERATURE REVIEW

Introduction to CPM and PERT

CPM (Critical Path Method) and PERT (Program Evaluation and Review Technique) are two commonly used network analysis methods in construction project management. They help project managers to understand the interdependencies between different activities and resources and to plan and execute construction projects more effectively.

CPM focuses on identifying the critical path of a project, which is the sequence of activities that determines the minimum duration of the project. By using CPM, project managers can allocate resources and prioritize tasks in a manner that will minimize project delays and ensure timely completion (6).

PERT, on the other hand, is a more flexible and adaptive approach to network analysis. It takes into account the uncertainty associated with individual activities and provides project managers with a range of possible project durations. This information can be used to evaluate different scenarios and make informed decisions about project risks and contingencies (6).

Both CPM and PERT are used to create network diagrams that graphically represent the relationships between activities and events in a construction project. These diagrams help project managers to understand the flow of resources, information, and materials and to identify any potential delays or deviations from the project schedule (8).

In conclusion, CPM and PERT are powerful tools that help construction project managers to plan, execute, and control projects more effectively. By providing a clear understanding of the project schedule, resources, and interdependencies, these methods help to ensure that construction projects are completed on time, within budget, and to the highest quality standards.

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CPM (Critical Path Method)

The Critical Path Method (CPM) is a project management technique used to schedule and control the completion of a project within a set deadline. It analyses the interdependent tasks of a project to determine the longest path of activities, called the "critical path," that must be completed on schedule for the project to be finished on time. The critical path is determined by calculating the earliest start and finish times for each task, taking into account the task durations and the dependencies between tasks. This information is then used to create a project network diagram and a project schedule, which can be used to monitor progress and identify potential delays (2).

The Critical Path Method is a powerful tool that helps project managers to ensure that their projects are completed on time and within budget. It is based on the principle of identifying the activities that must be completed in sequence and determining the minimum amount of time required to complete the entire project. This minimum time is then used as the basis for creating a project schedule that takes into account any delays, risks, or unforeseen events (10).

To use the Critical Path Method, a project manager first creates a list of all the tasks that must be completed for the project to be successful. These tasks are then grouped into activities that can be performed concurrently, or in parallel, and those that must be performed in sequence. The duration of each task is estimated, and the dependencies between tasks are identified, allowing the project manager to determine the critical path of the project (9).

The critical path is the sequence of tasks that must be completed on schedule in order for the project to be finished on time. This information is then used to create a project network diagram, which is a visual representation of the tasks and their dependencies. The network diagram is used to calculate the earliest start and finish times for each task, which helps the project manager to identify the critical path and to determine if the project is on track. (6).

The Critical Path Method can be used in a variety of project environments, including construction, engineering, software development, and more. It is a flexible tool that can be adapted to suit the specific needs of a particular project, and it is widely used due to its accuracy and efficiency in helping to manage complex projects (6).

Overall, the Critical Path Method is an essential tool for project managers who want to ensure that their projects are completed on time, within budget, and to the required quality standards.

PERT (Project Evaluation Review Technique)

PERT is a method for analysing and organizing complex projects and to help understand the tasks and dependencies involved in the project completion. It is a network diagram that helps in determining the critical path of a project, which is the longest sequence of activities that must be completed to finish the project on time. PERT is used in project management to manage time, resources and inter-dependencies between tasks and to determine the project's completion date (8).

PERT is a project management tool that helps in planning, organizing, and scheduling complex projects. It was initially developed by the U.S. Navy in the 1950s for managing the development of the Polaris submarine-launched ballistic missile system. PERT is used to

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determine the optimal sequence of activities required to complete a project, and it is based on the concept of a network diagram (8).

A network diagram is a visual representation of the project tasks and the relationships between them. In a PERT diagram, each task is represented by a node and the dependencies between tasks are represented by arrows. The length of each arrow represents the estimated time required to complete the task it represents. The critical path is determined by finding the longest sequence of tasks that must be completed to finish the project on time (8). PERT is particularly useful for projects that are complex and involve multiple inter-dependencies between tasks. By creating a network diagram, project managers can identify potential bottlenecks and make adjustments to the schedule to ensure that the project is completed on time. Additionally, PERT helps project managers understand the impact that changes to one task may have on the entire project timeline (3).

In conclusion, PERT is a valuable tool for project management and can help ensure that projects are completed on time and within budget. It is widely used in various industries, including construction, engineering, software development, and more (3).

The site is situated on the campus of the Federal University of Technology, Akure. The project is an extension of the University Health Centre phase 1B. The building is to be constructed with no storey (bungalow). The project was scheduled to commence on the 3rd of November, 2021 and the completion date 24th of March, 2022. The project exceeded the initial expected time allotted due to some factors. The building construction was brought to completion on the 23rd of May, 2022, but at the time this research was carried out and analysed, the building project was not yet completed. The source of data for this paper is purely primary. I visited the construction site and made physical contact with the site engineers and builders to facilitate the data collection process and to get more understanding about the project, and the program of the work chart for the construction was provided. With the help of a professional quantity surveyor and a builder, the chart was decoded and interpreted. Activity duration was estimated on a daily basis. A total of fifteen (15) activities were denoted as A, B, C, …, O. The day's interval for each activity would be provided as well.

The contractor for the building project was **SHON – NIGERIA LIMITED**.

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METHODOLOGY

A network diagram would be drawn to show the activities relationship, and also CPM AND PERT would be performed/carried out to show the critical path of the building project and to estimate the project completion time.

Materials:

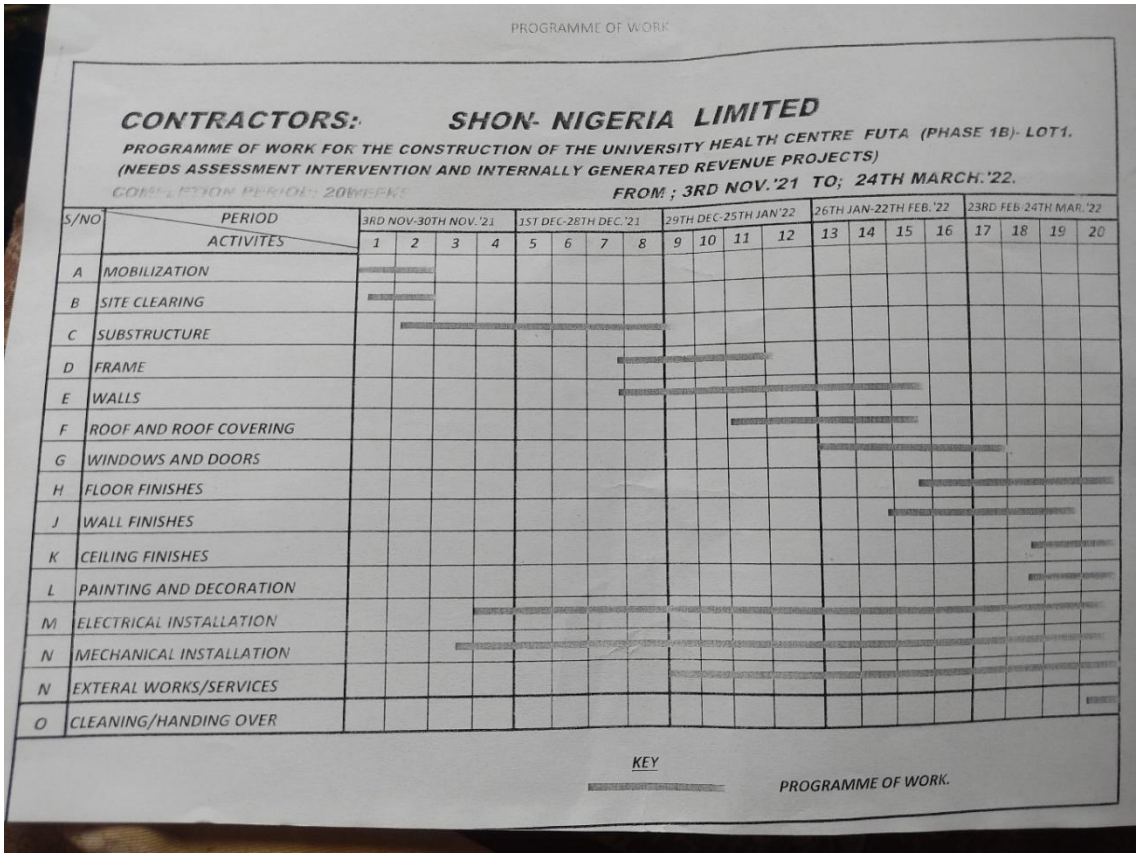

Fig 1: Shows the program of work for the building project.

ACTIVITY	ACTIVITY CODE
MOBILIZATION	A
SITE CLEARING	B
SUBSTRUCTURE	C
FRAME	D
WALLS	E
ROOF AND ROOF COVERING	F
WINDOWS AND DOORS	G
FLOOR FINISHES	H
WALL FINISHES	I
CEILING FINISHES	J
PAINTING AND DECORATION	K
ELECTRICAL INSTALLATION	L

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MECHANICAL INSTALLATION	M
EXTERNAL WORKS / SERVICES	N
CLEANING AND HANDING OVER	O

Fig 2: Shows all the activities and the activities code.

DATA ANALYSIS AND RESULT

From the program of the work chart, all compound activities were extracted for the analysis of this study. Table 1 below shows the activity description, activity code and their immediate processor, estimated duration and days interval of each activity on the program of work chart. The project was estimated to be completed in 100 days.

Activity Description	**Activity Code**	**Immediate Predecessor**	**Estimated Duration (In days)**	**Days Interval**
MOBILIZATION	A	-	10	1 – 10
SITE CLEARING	B	A	8	2 – 10
SUBSTRUCTURE	C	B	35	7 – 42
FRAME	D	C	22	34 – 56
WALLS	E	C,D	40	34 – 74
ROOF AND ROOF COVERING	F	D,E	23	51 – 74
WINDOWS AND DOORS	G	E,F	24	60 – 84
FLOOR FINISHES	H	G	25	74 – 99
WALL FINISHES	I	F,G	25	69 – 94
CEILING FINISHES	J	I	12	88 – 100
PAINTING AND DECORATION	K	H,I,J	13	87 – 100
ELECTRICAL INSTALLATION	L	C	83	15 – 98
MECHANICAL INSTALLATION	M	C	87	13 – 100
EXTERNAL WORKS/SERVICES	N	L,M	60	40 – 100
CLEANING AND HANDING OVER	O	K,N	4	96 – 100

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Network Diagram

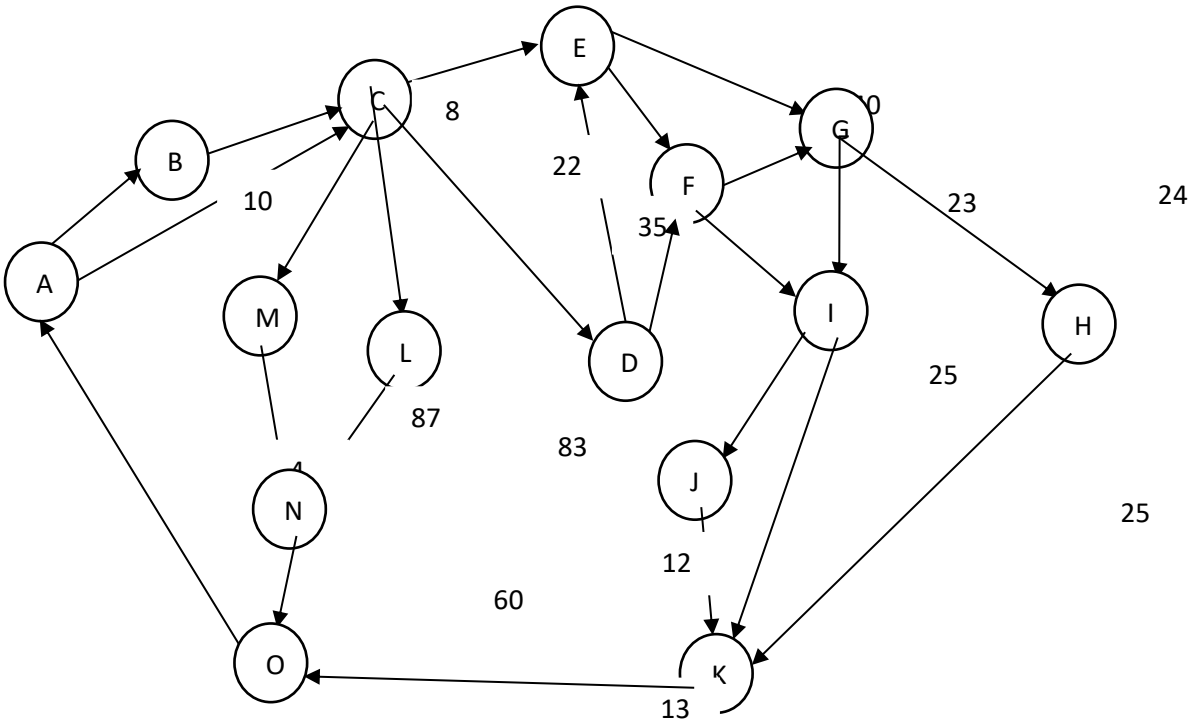

Fig 3: A network diagram showing all activities involved in the process of construction for the University Health Centre phase 1B.

The Result of the Critical Path

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

With Activity Description: Mobilization, Site Clearing, Substructure, Frame, Walls, Roof and Roof Covering, Windows and Doors, Wall Finishes, Ceiling Finishes, Painting and Decoration, Cleaning/Handing Over.

Note: Some activities are not present on the critical path. This means that with or without some activities on the critical path, the project will still come to completion.

Also, we would notice that there are overlaps in the work program, which means that before some activities end, another activity has already begun in order to save time; therefore, in finding our critical path, the days interval between our first activity and last activity, taking the overlapping time of all activities in the critical path into consideration, is still 100 days.

Thus, our critical path: A – B – C – D – E – G – H – I – J – K – O

With days interval, (1 – 10) (2 – 10) (7 – 42) (34 – 56) (34 – 74) (51- 74) (60 – 84) (69 – 94)

. (88 – 100) (87 – 100) (96 – 100).

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Total days in the critical path is 100 days, which means the shortest possible time to complete the project is 100 days.

Table 2: Shows the Project Activity, Immediate Predecessor, Normal Time (m), Optimistic time (a), and Pessimistic Time (p) for the Building Project

S/N	Activity code	Immediate Predecessor	Normal Time (days) (m)	Optimistic time(days) (a)	Pessimistic time(days) (p)
1	A	-	10	8	12
2	B	A	8	6	10
3	C	B	35	33	37
4	D	C	22	20	24
5	E	C,D	40	38	42
6	F	,D,E	23	21	25
7	G	E,F	24	22	26
8	H	G	25	23	27
9	I	F,G	25	23	27
10	J	I	12	10	14
11	K	H,I,J	13	11	15
12	L	C	83	81	85
13	M	C	87	85	89
14	N	L,M	60	58	62
15	O	K,N	4	2	6

Result of the Expected Duration for Every Activity

To calculate the expected duration for every activity for the building project, we use the formula: $te = \frac{a + 4m + p}{6}$

a = optimistic time (the minimum time to complete an activity in project)

m = normal time (the most likely time to complete an activity in a project)

p = pessimistic time (the estimate of the maximum time to complete an activity in a project)

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

1. $ta = \frac{8+4(10)+12}{6} = 10\ days$

2. $tb = \frac{6+4(8)+10}{6} = 8\ days$

3. $tc = \frac{33+4(35)+37}{6} = 35\ days$

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4. $td = \frac{20+4(22)+24}{6} = 22\ days$

5. $te = \frac{38+4(40)+42}{6} = 40\ days$

6. $tf = \frac{21+4(23)+25}{6} = 23\ days$

7. $tg = \frac{22+4(24)+26}{6} = 24\ days$

8. $th = \frac{23+4(25)+27}{6} = 25\ days$

9. $ti = \frac{23+4(25)+27}{6} = 25\ days$

10. $tj = \frac{10+4(12)+14}{6} = 12\ days$

11. $tk = \frac{11+4(13)+15}{6} = 13\ days$

12. $tl = \frac{81+4(83)+85}{6} = 83\ days$

13. $tm = \frac{85+4(87)+89}{6} = 87\ days$

14. $tn = \frac{58+4(60)+62}{6} = 60\ days$

15. $to = \frac{2+4(4)+6}{6} = 4\ days$

Estimation of Project Completion Time

Although the project is said to be completed within days, realistically, it is not guaranteed that it will be completed within the stipulated time frame. If some activities take longer than their expected time, the project will not be completed within the desired schedule time. Thus, it is useful to know the probability that the project deadline will be met. The first step to take is to find the variance and standard deviation of the total time along critical path, which is equal to the sum of the variances of activity on the critical path. Therefore, the variance formula:

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

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Table 3: Shows the Project Critical Path, Each Activity in the Critical Path Optimistic Time, Most Likely Time and Pessimistic Time

Critical Path	Optimistic Time (a)	Most likely time (m)	Pessimistic Time (p)
A	8	10	12
B	6	8	10
C	33	35	37
D	20	22	24
E	38	40	42
F	21	23	25
G	22	24	26
I	23	25	27
J	10	12	14
K	11	13	15
O	2	4	6

p = Pessimistic time

a = Optimistic time

1. $\sigma = \left(\frac{12-8}{6}\right)^2 = 0.444$
2. $\sigma = \left(\frac{10-6}{6}\right)^2 = 0.444$
3. $\sigma = \left(\frac{37-33}{6}\right)^2 = 0.444$
4. $\sigma = \left(\frac{24-20}{6}\right)^2 = 0.444$
5. $\sigma = \left(\frac{42-38}{6}\right)^2 = 0.444$
6. $\sigma = \left(\frac{25-21}{6}\right)^2 = 0.444$
7. $\sigma = \left(\frac{26-24}{6}\right)^2 = 0.444$
8. $\sigma = \left(\frac{27-23}{6}\right)^2 = 0.444$
9. $\sigma = \left(\frac{14-10}{6}\right)^2 = 0.444$
10. $\sigma = \left(\frac{15-11}{6}\right)^2 = 0.444$
11. $\sigma = \left(\frac{6-2}{6}\right)^2 = 0.444$

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Project Length Variance = 0.44 + 0.44 + 0.44 + 0.44 + 0.44 + 0.44 + 0.44 + 0.44 + 0.44 + 0.44 + 0.44 = **4.884**

Standard Deviation = $\sqrt{4.884}$ = **2.2s**

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

$$p(z \leq D)$$

$$= Probability\left(z \leq \frac{Ts - Te}{\sigma}\right)$$

$D = \frac{Ts-Te}{\sigma}$ where:

Ts = Scheduled time

Te = Expected time of the critical path

Ts = 100

Te = 100

$$D = \frac{Ts - Te}{\sigma} = \frac{100 - 100}{2.2} = \frac{0}{2.2} = 0$$

$$p(z \leq 0) = 0.5$$

This implies that the probability of completing the project in 100 days is 0.5, that is, there is a 50% chance that the project would be completed in 100 days.

SUMMARY

This paper has been able to find all the possible routes of the activities involved in the building project, locate the critical path of the building project, determine the expected duration for every activity in the building project, and evaluate the probability of completing the project within the stipulated time.

The result shows that there is a 50% chance for the project to be completed within the stipulated time. With the information gathered on the building project, the project was delayed due to some factors such as low circulation of money, inadequate equipment, loss of some weeks due to a change in plan, and inadequate manpower; thus, there was a two month difference between the initial completion and the now actual completion time.

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CONCLUSION

In conclusion, a project is a task with a specific beginning and end, aimed at producing a unique product, service, or result. Without proper planning and analysis and good project management, project work might experience so many difficulties, such as time loss (which would lead to delay in project completion time), loss of focus and concentration of the labourers, money cost in materials, and inadequate manpower.

RECOMMENDATION

I recommend that construction companies need to employ qualified project managers that would be able to apply these project management techniques and other techniques to building projects and other construction projects, in order to limit or avoid these difficulties and problems.

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