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Full Length Research Paper

Network analysis and building construction: Implications for timing and costing of activities

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The upsurge in building collapses in Nigeria recently has been a source of concern to builders, engineers, individuals and policy makers. Previous researches have observed many factors responsible for the menace, which includes; use of substandard product, poor design, and unskilled labour. None have adequately addressed the impact of timing and costing of stages in the building process as part of their key variables. This study was therefore informed to explore the cost and minimum expected time that will be required to complete the project. The data on the cost and duration of activities involved were obtained from ALMEGA, Nig. Ltd., a civil engineering company based in Lagos. Both critical path method (CPM) and project evaluation and review technique (PERT) were used for the analysis. The activities underwent crashing of both the time and cost, this paved way for the determination of critical path. Further analysis revealed that the shortest possible time for the completion of the analyzed building project is 55 days instead of the expected duration of 92 days. This means that through proper scheduling of activities, the expected completion time was reduced by 37 days. The additional cost associated with the reduction in timing is ₦830,000.00 ($5,355.00), which increases the initial expected cost required to complete the project from ₦3,290,000.00 ($21,226.00) to ₦4,120,000.00 ($26,581.00). Therefore, stringent adherence to the minimum possible time to complete a specific part of building process will trim down building collapses in Nigeria. Although, it may not be the only antidote, but when incorporated to building plan will make a difference.

Key words: Networking, building construction, crashing, time, cost, critical path method (CPM), project evaluation and review technique (PERT).

INTRODUCTION

The upsurge in building collapses in Nigeria recently has been a source of concern to builders, engineers, individuals and policy makers. The collapses, which occur at different stages of building construction or after buildings have been completed. Most factors, which the engineers, architects, builders and the population considered responsible for the menace are the use of substandard product, unskilled labour in terms of technicalities and so on. However, there is always neglect of the influence of duration and timing to complete the sub-section and the whole building project, this is the subject of this study.

Buildings are structures, which serve as shelters for man, his properties and activities. They must be properly planned, designed and erected to obtain desired satisfaction from the environment. A building project involves a single non-representative scheme typically undertaken to accomplish a premeditated result within a time bound and financial plan. However, because of the individuality of each project, its outcome can never be predicted with an absolute confidence (Ayininuola and Olalusi, 2010). It

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becomes imperative therefore, for the successful completion of the project, which perpetually depends on a large extent on carrying out essential activities in a sagacious sequence and deployment of resources to area of best gain and valuable importance.

The successful achievement and management of building project requires careful planning, scheduling and coordi-nation of numerous interrelated activities. Any building project will involve the completion of a number of smaller tasks. Some of these responsibilities can be started straight away while some need to await the completion of other tasks or done in parallel before they eventually commence. Therefore, the number of building collapses may arise if the specific tasks are completed before the minimum possible time expected to finish the tasks. One way of overcoming such problems is through the use of network models.

Network models are conventional means of finding the most skillful way to link a number of activities directly or indirectly in order to satisfy supply and demand requirements at different activity locations and project scheduling. The need for networking arises in building construction to programme and monitor the progress of the stages involved so that the building project is completed in the minimum time. In doing this, it pin-points the part of the project that are crucial which if delayed beyond the allotted time would increase the completion time of the project as a whole. It further assists in allocating resources, such as labour and equipment and thus helps to make the total cost of the building project a minimum by finding the optimum balance between various costs and time involved (Gueret and Sevaux, 2002). The earliest techniques for coping with project planning and scheduling challenges are the use of Gantt project planning charts and also the programme evaluation and review technique (PERT).

Beyond the challenges due to scheduling of project, the project manager is frequently faced with the problem of having to reduce the scheduled completion time of a project to meet the deadlines. Reducing the project duration time can be achieved by assigning more skilled labour into the project activities often in the form of overtime and by assigning more resources. However, additional labour and resources cost money and thus increases the overall project cost and as such, the decision to reduce the project duration by reducing the time of one or more of the critical path activities. This reduction in the critical path activities time is referred to as crashing. This can be achieved through deployment of more resources in terms of monetary value to the activities to be crashed using a procedure called project crashing and time cost analysis.

The present study determined the earliest and latest start times through identification of critical path. It revealed how time can be managed in a building project for best outcome. These were achieved in the first instance using critical path method (CPM) and PERT to provide analytical means for scheduling the activities by defining the project activities, their precedence relation-ships and their specific time requirements. Thereafter, the precedence relationships among the activities were represented by a network, which was used to develop the time schedule for the project.

Basic terminologies

1. Activity: This is a time consuming effort required to perform a part of a project *Event:* This is an instant in time showing the end or beginning of an activity.
2. Restriction: This is the pre-requisite relationship which establishes the sequence of activities when one activity must be completed before a second activity begins.
3. Dummy activity: This is used to represent a restraint relationship which requires no time.
4. Pre-requisite activity: This is the one which immediately precedes the one being considered.
5. Post-requisite activity: It is the activity which immediately follows the one being considered.
6. Descendant activity: Is any activity restricted by the one under consideration.
7. A merge*:* This exists when two or more activities converge at a single event.
8. Pessimistic time: This is the amount of time if we encounter significant break down and/ or delays.
9. Most probable time: This is the most likely activity time under normal condition.
10. Optimistic time: This is the activity time if every task progresses in an ideal manner.
11. Free float: This is the amount of time activity can be delayed without affecting the commencement of a subsequent activity at its earliest start time but may affect timing of a previous activity.
12. Total float: The total float for an activity is the difference between the maximum time available for that activity and the duration of that activity.
13. Latest start time: This is the latest time an activity can begin without causing a delay in the overall duration of the project.
14. Earliest start time: It is the earliest time that an activity could begin assuming all the preceding activities are completed as soon as possible.
15. Critical path: of a network diagram gives the shortest time in which the whole project can be completed. It contains activities that do not have positive float and is the longest path (Ahuja and Orlin, 1993).

MATERIALS AND METHODS

Study location and data description

The data were collected from ALMEGA Nig. Ltd., a construction company based in Ketu, Lagos. The floor plan of the building is the first phase of the building project after clearing of the bush on the site. The project plan of the company has the various activities that would be carried out, as well as the duration (days) and cost of each activity in the construction of a bungalow building located at sub-urban part of Ibadan. The activities included planning, procurement of materials, excavation, plumbing and so on. The data contains the level of precedence among various activities, as well as the cost of each activity. To prevent clumsy analysis, activities were grouped.

This study focused on the cost and on the available duration (days) of the activities of carrying out the project. The duration is in multiple time estimates, that is, the optimistic time, the most likely time and the pessimistic time estimate. The network analysis procedures were used in analyzing the data; this involves the critical path method (CPM), project evaluation and review technique (PERT) and probability estimation. The aim of estimating probability is to find out the possibility that a node j in the network will occur by a pre-specified scheduled time, S_j, assuming that all the activities in the network are statistically independent. This probability was estimated in this study using

$$P(e_j \le S_j) = P\left(\frac{e_j - E(e_j)}{\sqrt{var(e_j)}} \le \frac{S_j - E(e_j)}{\sqrt{var(e_j)}}\right) = P(z \le K_j)$$

$$K_j = \frac{S_j - E(e_j)}{\sqrt{var(e_j)}}$$

where z is the normal random variable and. Justification for the use of the normal distribution is that e_j is the sum of independent random variables. Therefore, according to the central limit theorem e_j is approximately normally distributed.

In CPM networking, all the activities time estimates are single values with the assumption that activity time are known with certainty by using a single activity time estimate. In reality however, it is rare to have activity time estimate to be certain. This is because projects longest time is the activity required to be completed assuming everything went on normally. Therefore, the three time estimates were subsequently used to estimate the expected time (mean) and variance of the distribution. Expected time is the weight average of the three time estimates (optimistic (a), pessimistic (b) and most likely time (M)):

$$\text{Expected time (mean)} = \frac{a + b + 4M}{6} \text{ and Variance} = \frac{(\text{b} - \text{a})^2}{6}$$

Project crashing was done using:

$$\text{Cost slope} = \frac{Crash\ cost - Normal\ cost}{Normal\ time - Crash\ time}.$$

PERT analysis was used to obtain the cheapest cost by crashing as many activities as possible on the critical path.

PERT is a model designed to analyze and characterize the tasks involved in completing a given project. It is useful in the analysis of activities involved in completing a given project, particularly the time needed to complete each activity, and identifying the minimum time needed to complete the total project. PERT was developed primarily to simplify the planning and scheduling of large and complex projects. It was used to incorporate uncertainty by making it possible to schedule a project while not knowing precisely the details and durations of all the activities. It is more of an event-oriented technique rather than start- and completion-oriented, and is used more in projects where time, rather than cost, is the major factor. It is applied to very large-scale, one-time, complex, non-routine infrastructure and Research and Development projects.

Two key terminologies involved in PERT are PERT event and PERT activity. PERT event is a point that marks the start or completion of one or more activities. It consumes no time and uses no resources. When it marks the completion of one or more tasks, it is not "reached" (does not occur) until all of the activities leading to that event have been completed. Whereas, PERT activity is the actual performance of a task, which consumes time and requires resources, such as labor, materials, space, machinery. It is expedient to note that a PERT activity cannot be performed until the predecessor event has occurred. PERT has numerous advantages. For example, it enables building construction engineers to organize and quantify project information and provides them with a graphic display of the project. It also helps to identify which activities are critical to the project completion time and should be watched closely, and which activities involve slack time and can be delayed without affecting the project completion time.

RESULTS

Data presentation

Table 1 shows the description of activities involved for the construction process of a house construction project at Celica area, Ibadan. The construction activities begin with activity A and ends with activity O. Table 2 shows the distribution of the project activities relative to the actual number of days to complete individual activity and their respective cost implication in terms of naira and dollar of the building. The costs are basically labour costs based on the assumption that materials are already available for use. This is because, once the materials are available, the reduction in number of days to complete a particular activity will only be affected by the cost of hiring additional labour. Table 3 shows the project activity according to activities that must be performed before the next activity can begin, this is called the predecessor. The optimistic estimate (a), most likely estimate (m) and pessimistic estimate (b) of the building were determined to see the variations in the estimates as they affect the construction activities.

Using the formulae;

$$\text{Expected time (mean)} = \frac{\text{a} + \text{b} + 4\text{M}}{6} \text{ and Variance} = \frac{(\text{b} - \text{a})^2}{6}$$

were computed as shown in Table 4. The critical path calculations involve two passes: The forward pass determines the earliest occurrence times of the events, and backward pass calculates their latest occurrence times (Hamdy, 2007). The earliest time is calculated as follows:

$$ET_j = Maximum\ (ET_i + t_{ij})$$

where *i* is the starting node number for a particular activity; *j* is the ending node number for a particular activity; t_{ij} is the expected time to complete activity *i* to *j*

Table 1. Description of activities involved for the construction process of a house construction project at Celica area, Ibadan.

Activity		Description of activity
A		Site clearing
B		Excavating
C	A	Foundation
D	B	Rough wall
E	CD	Rough exterior plumbing
F	B	Roof
G	F	Rough electrical work
H	F	Rough interior plumbing
I	H	Exterior sliding
J	EG	Wall board
K	CD	Exterior painting
L	K	Flooring
M	IJ	Interior painting
N	H	Exterior fixtures
O	LMN	Interior fixtures

Table 2. Project activity, days (actual) and Cost (actual) of a house construction project at Celica area, Ibadan.

Activity		Days	Normal cost (₦)	Normal cost ($)
A		3	100,000.00	645.16
B		4	50,000.00	322.58
C	A	9	50,000.00	322.58
D	B	4	250,000.00	1,612.90
E	CD	5	400,000.00	2,580.65
F	B	6	200,000.00	1,290.32
G	F	8	420,000.00	2,709.68
H	F	7	400,000.00	2,580.65
I	H	8	300,000.00	1,935.48
J	EG	9	220,000.00	1,19.35
K	CD	4	180,000.00	1,161.29
L	K	6	200,000.00	1,290.32
M	IJ	4	190,000.00	1,225.81
N	H	8	160,000.00	1,03226
O	LMN	7	170,000.00	1,096.77

The costs in the table are labour cost excluding the cost of materials. It is assumed that materials are already in stock for the project. Therefore, crashing the time and labour does not affect cost of materials.

The backward pass is calculated as the latest time of occurrences of the last node, which is calculated as

$$LT_j = Minimum\ (LT_i - t_{ij})$$

The procedures are shown in the calculations below; the values of earliest and latest times are shown and arranged in Table 5. Figure 1 shows the network diagram of the project. In the diagram, all the activities are represented by alphabets A to O. The earliest and latest time required to complete an activity are shown in the circle (base) whereas, the top of the circles are identified by the activity number. The critical path is along activity BFGJMO where there is no redundancy and is the longest path.

The analyses of the paths are shown as:

PATHS

$$\text{ACKLO} \quad = 5.3 + 11.2 + 8.5 + 4.7 + 9.0 \quad = 38.7$$

Table 3. Project Activity, Predecessor, optimistic estimate (a), most likely estimate (m) and pessimistic estimate (b) of a building construction project at celica area, Ibadan.

Activity	Predecessor	Optimistic estimate (a)	Most likely estimate (m)	Pessimistic Estimate (b)
A	-	4	3	16
B	-	4	4	18
C	A	6	9	25
D	B	7	5	27
E	CD	4	6	21
F	B	9	8	20
G	F	13	7	28
H	F	15	9	29
I	H	14	6	22
J	EG	20	5	33
K	CD	11	4	24
L	K	2	3	14
M	IJ	7	3	18
N	H	6	8	20
O	LMN	9	6	20

Table 4. Mean and variances of activities of a building construction project at Celica area, Ibadan.

Activity	Predecessor	Mean	Variance	Standard deviation
A	-	5.3	4.0	2
B	-	6.3	5.4	2.3
C	A	11.2	10.0	3.2
D	B	9.0	3.4	1.8
E	CD	8.1	8.0	2.8
F	B	10.1	3.4	1.8
G	F	11.5	6.3	2.5
H	F	13.3	5.4	2.3
I	H	10.0	1.8	1.3
J	EG	12.2	4.7	2.2
K	CD	8.5	4.7	2.2
L	K	4.7	4.0	2.0
M	IJ	6.2	3.4	1.8
N	H	9.7	5.4	2.3
O	LMN	9.0	3.4	1.8

$$\text{ACEJMO} = 5.3 + 11.2 + 8.1 + 12.2 + 6.2 + 9.0 = 52.0$$

$$\text{BDEJMO} = 6.3 + 9.0 + 8.1 + 12.2 + 6.2 + 9.0 = 50.8$$

$$\text{BDKLO} = 6.3 + 9.0 + 8.5 + 4.7 + 9.0 = 37.5$$

$$\text{BFGJMO} = 6.3 + 10.1 + 11.5 + 12.2 + 6.2 + 9.0 = 55.3$$

$$\text{BFHIMO} = 6.3 + 10.1 + 13.3 + 10.0 + 6.2 + 9.0 = 54.9$$

$$\text{BFHNO} = 6.3 + 10.1 + 13.3 + 9.7 = 39.7$$

Table 6 shows the Means and Variances of Activities along the Identified Critical Path. In actual fact, many project work are full of uncertainties, in this project however, the longest path is BFGJMO (critical activity), which means the completion time is approximately 55.3 days. Then, it becomes necessary to know how realistic this will be by estimating the probability of achieving this scheduled date.

Therefore, in order to know whether this project time can be completed at this time, we assumed a completion number of days say 60. Thereafter, we computed the

Table 5. Procedures for calculating forward pass and backward pas.

Forward pass (Earliest start time)	Backward pass (Latest event time)
$\mathrm{ET(A)} = \mathrm{Max}(0 + 5.3) = 5.3$	$\mathrm{LT(O)} = \mathrm{Min}(55.3 - 0) = 55.3$
$\mathrm{ET(B)} = \mathrm{Max}(5.3 + 11.2) = 16.5$	$\mathrm{LT(N)} = \mathrm{Min}(55.3 - 9) = 46.3$
$\mathrm{ET(C)} = \mathrm{Max}(0 + 6.3) = 6.3$	$\mathrm{LT(M)} = \mathrm{Min}(55.3 - 9) = 46.3$
$\mathrm{ET(D)} = \mathrm{Max}(6.3 + 9.0) = 15.3{,}16.3 = 16.3$	$\mathrm{LT(L)} = \mathrm{Min}(55.3 - 9) = 46.3$
$\mathrm{ET(E)} = \mathrm{Max}(16.6 + 8.1) = 24.7{,}27.9 = 27.9$	$\mathrm{LT(K)} = \mathrm{Min}(46.3 - 4.7) = 41.6$
$\mathrm{ET(F)} = \mathrm{Max}(6.3 + 10.1) = 16.4$	$\mathrm{LT(J)} = \mathrm{Min}(46.3 - 6.2) = 40.1$
$\mathrm{ET(G)} = \mathrm{Max}(16.4 + 11.5) = 27.9$	$\mathrm{LT(I)} = \mathrm{Min}(46.3 - 6.2) = 40.1$
$\mathrm{ET(H)} = \mathrm{Max}(16.4 + 13.3) = 29.7$	$\mathrm{LT(H)} = \mathrm{Min}(40.1 - 10) = 30.1$
$\mathrm{ET(I)} = \mathrm{Max}(29.7 + 10.0) = 39.7, 40.1 = 40.1$	$\mathrm{LT(G)} = \mathrm{Min}(40.1 - 12.2) = 27.9$
$\mathrm{ET(J)} = \mathrm{Max}(27.9 + 12.2) = 40.1$	$\mathrm{LT(R)} = \mathrm{Min}(27.9 - 11.5) = 16.4$
$\mathrm{ET(K)} = \mathrm{Max}(16.6 + 8.5) = 25.1$	$\mathrm{LT(E)} = \mathrm{Min}(40.1 - 12.2) = 27.9$
$\mathrm{ET(L)} = \mathrm{Max}(25.1 + 4.7) = 29.8$	$\mathrm{LT(D)} = \mathrm{Min}(27.9 - 11.5) = 19.8, 33.1 = 19.8$
$\mathrm{ET(M)} = \mathrm{Max}(40.1 + 6.2) = 46.3$	$\mathrm{LT(C)} = \mathrm{Min}(27.9 - 8.1) = 19.8$
$\mathrm{ET(N)} = \mathrm{Max}(29.7 + 9.7) = 39.4, 46.3 = 46.3$	$\mathrm{LT(B)} = \mathrm{Min}(16.4 - 10.1) = 6.3$
$\mathrm{ET(O)} = \mathrm{Max}(46.3 + 9) = 55.3$	$\mathrm{LT(A)} = \mathrm{Min}(19.8 - 11.2) = 3.2, 3.6 = 8.6$

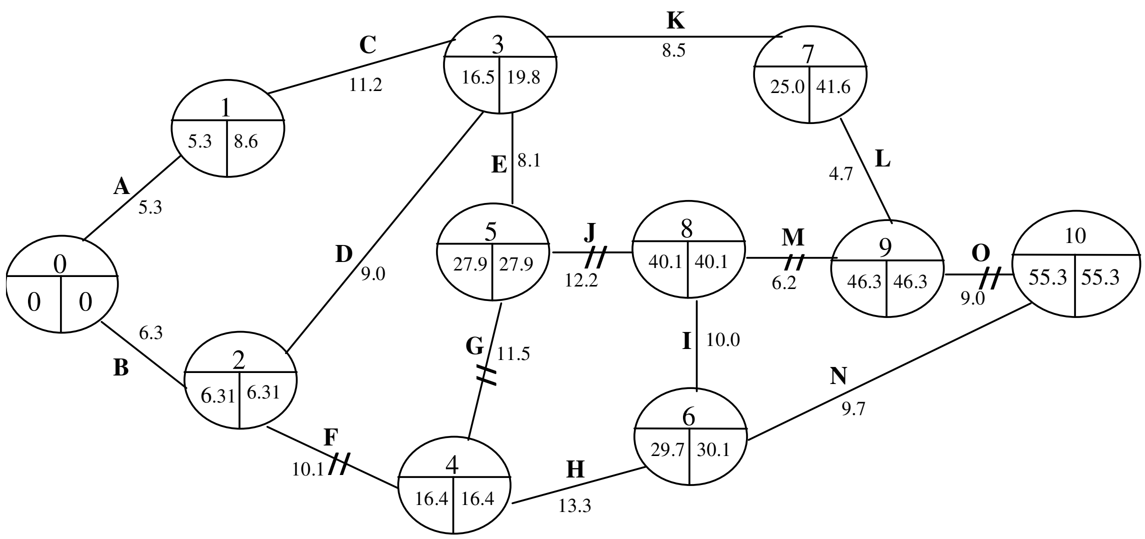

Figure 1. Network diagram.

probability that the project will be completed in less than 60 days as:

$$Z = \frac{\bar{x} - \mu}{\sigma} = \frac{60 - 55.3}{5.09} = 0.9234$$

Therefore, the probability that project will be completed in less than 60 days:

$$= P(Z < 0.9234) = 0.5 + \Phi(0.9234)$$
$$= 0.5 + 0.3212$$
$$= 0.8212$$

Cost analysis

This building project analyses will be incomplete if the cost associated with its monetary terms is not worked out. The essence of cost analyses is to determine the optimum cost of the project using the method of least cost scheduling. This was done by reducing the time of activities on the critical path with the lowest cost slope. If the time is reduced this will in turn increases the cost. This could result to extending the hours of work per day or hiring more labour:

$$Cost\ slope = \frac{Crash\ cost - Normal\ cost}{Normal\ time - Crash\ time}$$

Table 6. The earliest time, latest time and slack activities of a building construction project at Celica Area, Ibadan.

Activity	Earliest time	Latest time	Slack
A	5.3	8.6	3.3
B	6.3	6.3	0
C	16.5	19.8	3.3
D	16.6	19.8	3.3
E	27.9	27.9	0
F	16.4	16.4	0
G	27.9	27.9	0
H	29.7	30.1	0.4
I	40.1	40.1	0
J	40.1	40.1	0
K	25.1	41.6	16.5
L	29.8	46.3	16.5
M	46.3	46.3	0
N	46.3	46.3	0
O	55.3	55.3	0

Applying this model on each of the activity gives:

$$A(0-1) = \frac{120-100}{3-2} = 20$$

; $$B(0-2) = \frac{10-50}{4-2} = 10$$;

$$C(1-3) = \frac{80-50}{9-6} = 10$$;

$$D(2-3) = \frac{270-250}{4-3} = 20$$;

$$E(3-5) = \frac{440-400}{5-3} = 20$$;

$$F(2-4) = \frac{290-200}{6-4} = 15$$

$$G(4-5) = \frac{460-420}{8-4} = 10$$;

$$H(4-6) = \frac{450-400}{7-3} = 12.5$$

$$I(6-8) = \frac{550-300}{7-3} = 12.5$$;

$$J(5-8) = \frac{310-220}{9-6} = 30$$;

$$L(7-9) = \frac{250-200}{6-3} = 16.7$$;

$$M(8-9) = \frac{200-190}{4-2} = 5$$;

$$N(6-9) = \frac{180-160}{4-2} = 5$$;

$$O(9-10) = \frac{210-170}{7-5} = 20$$

The path duration of all the activities is as shown in Table 7 below. For each crashing process, there must be an activity belonging to the initial critical path. This means we did not crash non-critical path alone and we crashed at least one activity along the critical path. Also, crashing of the activities from critical path could be done in any order provided that the initial critical path is eliminated to generate a zero critical path entirely. In Table 8, we have utilized all the possible chares available to the crashing of the critical activities, further crashing will not be economically viable, and will not reduce the project completion number of days. However, only crashed activities will attract extra cost over the normal cost as earlier

Table 7. Means and variances of activities along the identified critical path.

Critical activity	B	F	G	J	M	O
Mean	6.3	10.1	13.5	12.2	6.2	55.3
Variance	5.4	3.4	6.3	4.7	3.4	25.9

Table 8. Path duration from activity A to O.

Activity	Path 1	Path 2	Path 3	Path 4	Path 5	Path 6	Path 7	Crash time	Slope ₦'000	Slope $'000
A(0 − 1)	5.3	5.3						1	20.00	0.129
B(0 − 2)			6.3	6.3	6.3	6.3	6.3	2	10.00	0.065
C(1 − 3)	11.2	11.2						3	10.00	0.065
D(2 − 3)			9.0	9.0				1	20.00	0.129
E(3 − 5)		8.1	8.1					2	20.00	0.129
F(2 − 4)					10.1	10.1	10.1	2	45.00	0.290
G(4 − 5)					11.5			4	10.00	0.065
H(4 − 6)						13.3	13.3	4	12.50	0.081
I(6 − 8)						10.0		4	62.50	0.403
J(5 − 8)		12.2	12.2		12.2			3	30.00	0.194
K(3 − 7)	8.5			8.5				2	30.00	0.194
L(7 − 9)	4.7			4.7				3	16.70	0.108
M(8 − 9)		6.2	6.2		6.2	6.2		2	05.00	0.032
N(6 − 9)							9.7	4	05.00	0.032
O(9 − 10)	9.0	9.0	9.0	9.0	9.0	9.0	9.0	2	20.00	0.129
Total duration	38.7	52.0	50.8	37.5	55.3	54.9	48.4			

explained.

Tables 9 and 10 shows the project Activity, days (actual and crash) and cost (actual and crash) of the house construction. In the tables, crashing activity A for one day for instance will attract N20, 000.00 extra costs. Also, crashing of activity from 4 days to 2 days will increase the activity cost from N50,000.00 to N70,000.00. The process of crashing continues till the building is completed. Activity (0-1) has been crashed by 1 day at an extra cost of 1 × N 20 = N20 and reducing the period by 1 day.Activity (0-2) has been crashed by 2 days at an extra cost of 2 × N10 = N20 and reducing the period by 2 days. Activity (1-3) has been crashed by 3 days at an extra cost of 3 × N10 = N30 and reducing the period by 3 days. Activity (2-3) has been crashed by 1 day at an extra cost of 2 × N20 = N40 and reducing the period by 2 days. And so on.

Therefore, the crash duration will be 53 days and at a total cost of (summation of the total cost after crashing and their over head cost) N4120 + N 500 × 53 = N30 620.00 ($197.55). This means that the cost after the crashing plus over head cost for 53 days is N30 620.00 ($197.55). This result was better than the result under normal situation, which is cost before crashing plus overhead cost for 55 days. That is equal to N3290 + 500 × 55 = N30 790.00. ($198.65)

DISCUSSION

Networking is a planning technique for projects that are sequential in nature. The basis of the technique is to find the required resources for each stage or operation so that the subsequent stages are not interfered with and the target output can be achieved (Robinson et al., 1993). The network analysis technique has been applied in construction work mainly to house building and highway construction. The method as used in this study helped at reducing the number of days expected to complete a building project located at Celica Area, Ibadan. The building was designed by ALMEGA Nig. Ltd., Ketu Lagos. The company gave the expected number of days and cost that will be required to complete each activity involved till the project is done.

The researchers with aim of trying to explore how networking model can be perfectly applied to this building without breaking standing rules of National Building Codes. Data analysis was done using CPM and PERT

Table 9. Path duration from activity A to O.

Activity	Path 1	Path 2	Path 3	Path 4	Path 5	Path 6	Path 7
Initial Duration	38.7	52.0	50.8	37.5	55.3	54.9	48.4
Crashing A(0 – 1) by 1	(1)	(1)	(1)	(1)	(1)	(1)	(1)
Revised duration	37.7	51.0	49.8	36.5	54.3	53.9	47.4
Crashing B(0 – 2) by 2	(2)	(2)	(2)	(2)	(2)	(2)	(2)
Revised Duration	36.7	50.7	48.8	35.5	53.3	52.9	46.4
Crashing C(1 – 3) by 3	(3)	(3)	(3)	(3)	(3)	(3)	(3)
Revised Duration	34.7	48.0	46.8	36.5	51.3	50.9	44.4
Crashing D(2 – 3) by 1	(1)	(1)	(1)	(1)	(1)	(1)	(1)
Revised duration	35.7	49.0	47.8	34.5	52.3	51.9	45.4
Crashing E(3 – 5) by 2	(2)	(2)	(2)	(2)	(2)	(2)	(2)
Revised duration	33.7	46.0	41.8	34.5	41.3	41.9	42.4
Crashing F(2 – 4) by 2	(2)	(2)	(2)	(2)	(2)	(2)	(2)
Revised duration	34.7	48.0	46.8	33.5	51.3	49.9	44.4
Crashing G(4 – 5) by 4	(4)	(4)	(4)	(4)	(4)	(4)	(4)
Revised duration	30.7	44.0	42.8	29.5	47.3	45.9	40.4
Crashing H(4 – 6) by 4	(4)	(4)	(4)	(4)	(4)	(4)	(4)
Revised duration	30.7	44.0	42.8	29.5	42.3	46.9	40.4
Crashing I(6 – 8) by 4	(4)	(4)	(4)	(4)	(4)	(4)	(4)
Revised duration	26.7	40.0	38.8	25.5	43.3	41.9	40.4
Crashing J(5 – 8) by 3	(3)	(3)	(3)	(3)	(3)	(3)	(3)
Revised duration	27.3	41.0	39.8	26.5	44.3	42.9	37.4
Crashing K(3 – 7) by 2	(2)	(2)	(2)	(2)	(2)	(2)	(2)
Revised Duration	33.7	47.0	45.8	32.5	50.3	49.9	43.4
Crashing L(7 – 9) by 3	(3)	(3)	(3)	(3)	(3)	(3)	(3)
Revised Duration	30.7	44.0	42.8	29.5	47.3	46.9	40.3
Crashing M(8 – 9) by 2	(2)	(2)	(2)	(2)	(2)	(2)	(2)
Revised duration	25.3	39.0	37.8	24.5	42.3	40.9	35.0
Crashing N(6 – 9) by 4	(4)	(4)	(4)	(4)	(4)	(4)	(4)
Revised duration	26.7	40.0	38.8	25.5	43.3	41.9	40.7
Crashing O(9 – 10) by 2	(2)	(2)	(2)	(2)	(2)	(2)	(2)
Revised duration	28.7	42.0	40.8	27.5	45.3	43.9	42.0

methods to reduce both the timing (days) and costing (‘N000). It is normal that if number of days to complete a project is reduced, then the associated cost will increase. Timing reduction was done by identification of critical path by searching for the tasks that their earliest and latest start times are identical. Thereafter, we determine which path between such tasks that has no slack. This is the critical path. On the diagram (Figure 2), the critical path is indicated by striking the connected lines with two bars.

With the proper identification of the critical path, we were able to track down the total time of the project and we know how much slack there is in the non-critical tasks. We have a structured plan that is logical and ordered. All the company would have to do now is how to assign resources and put them into action.

Further analysis revealed that the shortest possible time for the completion of the building project in this study is 55.3 days instead of the expected duration of 92 days. This means that through proper planning and scheduling of activities, the expected completion time was reduced by 36.7 days. Also, the cost associated with the reduction in timing to complete the project is N830,000.00 ($5,354.84). This is the additional cost required to complete the project. Therefore, the initial cost of N3,290,000.00 ($21,225.81) will increase to N4,120,000.00 ($26,580.65) to recruit more skilled labour to complete the project.

In order to know whether this project time can be completed at this time, we assumed a completion number of days say 60. Thereafter, the probability that the project will be completed in less than 60 days was estimated at 0.8212. This means, the probability of achieving the scheduled time of less than 60 days is 82.12%. This is a

Table 10. Project Activity, Days (actual and crash) and cost (actual and crash) of a house construction project at Celica area, Ibadan.

Acivity	Duration (days)		Cost (₦'000)		Cost ($)	
	Actual	Crash	Actual	Crash	Actual	Crash
A(0 – 1)	3	2	100	120	645.16	774.19
B(0 – 2)	4	2	50	70	322.58	451.61
C(1 – 3)	9	6	50	80	322.58	516.13
D(2 – 3)	4	3	250	270	1,612.90	1741.94
E(3 – 5)	5	3	400	440	2,580.65	2838.71
F(2 – 4)	6	4	200	290	1,290.32	1870.97
G(4 – 5)	8	4	420	460	2,709.68	2967.74
H(4 – 6)	7	3	400	450	2,580.65	2903.22
I(6 – 8)	8	4	300	550	1,935.48	3548.39
J(5 – 8)	9	6	220	310	1,19.35	2000.00
K(3 – 7)	4	2	180	240	1,161.29	1548.39
L(7 – 9)	6	3	200	250	1,290.32	1612.90
M(8 – 9)	4	2	190	200	1,225.81	1290.32
N(6 – 9)	8	4	160	180	1,03226	1161.29
O(9 – 10)	7	5	170	210	1,096.77	1354.84
	Total		3290	4120	21,225.81	26,580.65

Activity (0-1) has been crashed by 1 day at an extra cost of 1×₦ 20 = ₦20 and reducing the period by 1 day; Activity (0-2) has been crashed by 2 days at an extra cost of 2×₦10 = ₦20 and reducing the period by 2 days; Activity (1-3) has been crashed by 3 days at an extra cost of 3×₦10 = ₦30 and reducing the period by 3 days; Activity (2-3) has been crashed by 1 day at an extra cost of 2×₦20 = ₦40 and reducing the period by 2 days. And so on.

Figure 2. The front view of the building.

high probability and it implies that the assumption that the project will be completed in less than 60 days is plausible. However, if the management of the company considers this probability not too good enough, more efforts must be geared towards attaining an acceptable probability okay for the project completion. Further crashing of activities may be the solution where more resources will be employed. The architectural design of the front view of the building is as shown in Figure 2.

Conclusion

The problem of poor project execution, non completion and behind schedule, which are rampant in our society today will be a thing of the past if network analysis tools are employed and incorporated into the project plan at the onset of work activities. Also, the task of building project management can be improved if network analysis technique is adopted, this will identify minimum time a building project can take before completion. It will eliminate any sort of redundancy or dangling of activities, so that the developer can meet the needs of other clients who need its services at other building sites. We recommend that stringent adherence to the minimum possible time to complete a specific part of building process will check the effects of building collapses in Nigeria. Although it may not be only antidote, but when incorporated to building plan will make a difference.

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