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Project Crashing and its Implications on Quality of Work in Construction Firms: A Demonstration

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ABSTRACT

This study, project crashing and its implications on quality of work in construction firms was an attempt to explore the nitty-gritty of engendering network techniques via critical path methods in reducing the project duration thereby enhancing the quality performance of the project. The study employed quantitative research design and secondary data on elementary cost estimates on the construction of the proposed faculty of environmental sciences extension site in Enugu State University Science and Technology were collected. The data collected were analyzed using project crashing technique. From the findings, the study revealed that the project supposed completion time of 41 weeks were reduced to 27 weeks, while the indirect costs also reduced from ₦4, 440, 000 to ₦3, 240,000. In the light of the findings, the study concluded that project crashing is a veritable tool that can effectively reduce the project duration to barest minimum time frame without affecting the scope of the work.

Keywords: Project Crashing, Time overrun, Cost overrun, Performance specification

INTRODUCTION

Every project management is concerned with the optimization of time, cost and quality performance of the projects in meeting specific deadline at minimum cost. This, however, is predicated on the fact that complex project involving various interrelated activities, requiring a number of men, machines, materials and physical structures, whose effective coordination for optimum scheduling seldom be achieved by intuition based on the organizational dexterity and capabilities but have evolved certain techniques and methods for effective planning, scheduling and controlling of the projects [1]. According to [2] a further quest for a better management tool, begot network scheduling, which tends to give a rational and systematical allocation of man, materials, money and time to a project to avoid cost and time overrun. [3] have averred that ''network scheduling'' has become synonymous with project management since it is here that the greatest benefit of technique is well exploited. More so, many construction firms all over are characterized by cost overrun, time overrun and not meeting the client's specification (www. Clarityvillage.com). [4] noted, '' the characterized of a ''project'' can be summarized as a plane triangle (in which the angles represent cost, time and performance or '' duty specification'', circumscribed by regulatory constraints. This simple model called the theory of triple constraints) demonstrates an important feature: as with any (Euclidian) triangle, we cannot change one angle without affecting one or both of others. Hence any change in any of the variables will lead to project failure. [5] defines project management as ''the application of knowledge, skills, tools and techniques to a broad range of activities in order to meet the requirements of a particular project''. The criteria, for measuring the success of a project are contentious. While there are many criteria, such as the quality of work delivered and level of customer satisfaction, this paper focuses on factors that are clearly measured: time and cost. He further emphasis that project management generally is anchored on time and cost and it may be difficult to examine the influence of one without the other, yet no comprehensive methodology has been designed to deal with this twin problem. Trade–offs between activities duration and total cost are extensively discussed in the project scheduling literature because of its practical relevance. Time/cost trade is one of the very important issues in project accomplishment and has been well taken into consideration by operation/production or project managers. The impetus to shorten projects time may reflect on efforts to avoid late penalties (liquidated and ascertained damages), to take advantage of monetary incentives for timely or early completion of a project and/or to free resources for use on other projects. Suffice it to say that in new product developments, shortening the time may lead to strategic benefit; especially with regards to enhancing the competitiveness of the firm in the industry. Most construction firms heretofore have engendered network analysis through the application of Programme Evaluation and Review Technique (PERT) or Critical Path method (CPM) as operational technique in project planning and execution. The application of CPM in project scheduling and controlling utilizes activity-oriented network that consists a number of well recognized tasks or activities for which the activity times and costs are certainly known due to its deterministic nature [6].

Historically, Critical Path Method (CPM) as a project modeling technique was developed by Morgan R. Walker in the late 1950s, and was firstly used as skyscraper development in 1966 while constructing the former World Trade Center twin towers in New-York [7]. Since then, its usage has gained acceptance as most organizations especially construction firms have adopted it for effective sequencing and scheduling of their project activities, such that project completion time and cost would be balanced properly. However, the analysis and execution of this time change and its attendant impact on cost, is generally referred to as project crashing [8]. Therefore, project crashing is a systematic process of reducing the project duration by decreasing the time of one or more critical activities to less than the normal time [9]. Project crashing is achieved by effective allocation of additional resources to the activity at the least cost slope possible. Cost and schedule trade-offs are analyzed to determine how to obtain the greatest amount of compression for the least incremental cost [10]. However, since crashing a project will directly increase the project cost, it is therefore imperative to identify all critical paths tasks that have the potential to compress the project schedule for optimum results. In contrast, [11] maintained that construction firms should not allocate resources to non-critical paths because it will not have any multiplier effect on the project schedule.

Today, CPM has been proven to be an essential technique for efficient planning and controlling of construction projects. CPM enables project managers to evaluate the early and late times at which activities can start and finish, calculating activity float (slack), to define critical activities, and to evaluate the impact of changes in duration and logical relations on the overall project duration [11]. Because of its benefits and the significant advancements that have been made in both computer hardware and scheduling software, the use of the CPM and its variation, the precedence diagram method (PDM), in all industries, including construction, has dramatically increased in the last three decades [12].

Statement of problem

Construction firms, especially the contracting firm handling the building of Faculty of Environmental Science extension site of Enugu State University of Science and Technology, Agbani, Enugu State are confronted with underbidding in terms of cost and duration. These problems, however, make it difficult for the contracting firm to create a convergence between the project cost and completion time. Though, [13] argues that a situation where the project completion time is delayed, as a result of underbidding and scheduling problems, the resultant effect is project abandonment, hence create problems between the contracting firm and the client. These problems arisen due to lack of efficient project management that has the potentiality of engendering critical path method as an off-shoot of network technique in establishing tasks that are critical and appropriate resources effectively through project crashing. Given the aforementioned problem, the study is designed to explore the effect of project crashing on quality performance of work in construction firms.

Objective of the Study

The general objective of the study is to determine the implications of project crashing on quality performance of work in the Faculty of Environmental Sciencesextension site in Enugu State University of Technology and Sciences, Agbani, Enugu. Specifically, the study seeks to reduce the project duration time through crashing of tasks on the critical paths for improved quality performance of tasks.

REVIEW OF RELATED LITERATURE

The Concept of Project Crashing

Project crashing is the name given to schedule compression techniques that are used when a person wants to shorten the duration of a project without changing the scope [14]. Project crashing should be calibrated, decided upon, and applied at the very start of a project for effective results. Crashing is the process of adding resources to one's project to be able to finish it faster. It involves a financial cost in most cases. Crashing is the technique to use when fast tracking has not saved enough time on the schedule [15]. More so, crashing analyzes and categorizes activities based on the lowest crash cost per unit time allowing the project team to identify those activities that will be able to deliver the most value at the least incremental cost. There are basically two techniques that can be use to shorten project duration while maintaining project scope. These techniques are fast tracking and crashing.

Fast tracking is a special case of crashing. In fast tracking activities that would have been scheduled in sequence are scheduled to be done with some overlap instead. The use of leads in the logical relationship between activities can be used to facilitate this all the relationships can be changed completely.Fast tracking is a duration compression technique to shorten the project schedule usually to meet the target dates. Normally, this is done by overlapping and compressing some of the project phases. And this will result in overall shorter project schedule. Most common method of fast tracking is to start two or more tasks at the same time that were originally planned to start on different time schedule [16].

Critical Path Method

CPM according to [17] is activity oriented network which consist of number of well recognized jobs, tasks or activities. It is often used for simple, repetitive types of projects for which the activity times and costs are known. [16] opined that for any contracting firm or contractors to effectively carry-out critical path analysis on a given project must firstly identify those activities that made-up the entire project. This will enable him/her introduce network analytical technique to represent the precedence relationship, according to which each activity can have a group of predecessors and can be followed by a group of successors.

Empirical Review

[15] studied scheduling project crashing time using linear programming approach. This study was aimed at developing a model that finds a proper trade-off between time and cost to expedite the execution process. Critical path method was used to determine the longest duration and cost required for completing

the project and then the time-cost trade-off problem was also formulated as a linear programming model. To implement the proposed model, necessary data were collected through interviews and direct discussion with the project managers of Chowdhury Construction Company, Dhaka, Bangladesh. The analysis reveals that through proper scheduling of all activities, the project can be completed within 120 days from estimated duration of 140 days. Reduction of project duration by 17% is achieved by increasing cost by 3.73%, which is satisfactory

In addition, the study on effect of project crashing in construction industry: An investigation of the strategies, challenges and impacts was studied by [13]. The objectives of thisstudy were to identify the strategies that can crash a project successfully, to identify thechallenges in project crashing and to examine the relationship between the strategiesused in project crashing and the impacts in terms of cost, time and quality. The data areobtained mainly from the primary data which is the survey questionnaires. Total sampleof 54 respondents were used in this study. The data collected were analyzed with correlation coefficient. The result of this study has identified thesuitable strategies to crash a project, the challenges faced in project crashing and alsosee the impact of the strategies used in terms of cost, time and quality.

[12] on the topic "expediting construction project management in Ebonyi state through time/cost trade-off analysis". The objective was to see the client complete the contract project within the contractual period; the reason for introducing penalty clause on the contract terms. A simplified representation of a small project with seven activities and linear programming model is formulated to represent this system. Procedures to solve these various problem formulations were cited and the solution is obtained using Microsoft excel (Solver parameter). Revealing Ebonyi state construction contract project, it is characterized with an obsolete technique of planning, scheduling and controlling project, which is using Bill of quantities and Gantt chart in implementing project. It recommends that the state should embrace change by using a better method of expediting construction contracts which time/cost trade-off analysis to reap the benefits of completing projects within the time schedule.

A study on construction scheduling using critical path analysis with separate time segments was also conducted by [11]. Project managers today rely on scheduling tools based on the Critical Path Method (CPM) to determine the overall project duration and the activities' float times. Such data provide important information about the degree of flexibility with respect to the project schedule as well as the critical and noncritical activities, which leads to greater efficiency in planning and control of projects. While CPM has been useful for scheduling construction projects, years of practice and research have highlighted a number of serious drawbacks that limit its use as a decision support tool. The traditional representation of CPM lacks the ability to clearly record and represent detailed as-built information such as slow/fast progress and complete representation of work interruptions caused by the various parties involved. In addition, CPM is based on two unrealistic assumptions: that the project deadline is not restricted and that resources are unlimited. With CPM, therefore, the most cost-effective corrective actions needed in order to recover delays and overruns cannot be determined. This research is based on the view that many of the drawbacks of CPM stem from the rough level of detail at which progress data is represented and analyzed, where activities' durations are considered as continuous blocks of time.

[14] studied project schedule compression considering multi-objective decision environment. This study aimed at presenting a new method to circumvent the limitations of current schedule compression methods, which reduce schedule crashing to the traditional time-cost trade-off analysis, where only cost is considered. The study utilized Heuristic methods of which the schedule

compression process was modeled as a multi-attributed decision making problem in which different factors contribute to priority setting for activity crashing. Critical path method was employed to identify the critical activities necessary for resource allocation and scheduling. The study found that CPM is the most and vital tool for effective reduction of project duration time for the improved performance without affecting the scope of the study.

Theoretical Framework

The underpinning theory of this study is anchored on Decision Theory propounded by Abraham W. in 1950. The theory assumes that decision making is essentially vital in efficient allocation of resources and utilization in meeting the demands of the environment. [10] argues that organizations are constrained given the limited resources of the relative utilities of a set of available alternatives so that the most preferred course of action can be selected for implementation. The decision to choose from various alternative course of action is fulcrum to the management of organization. The theory contends that for organization to entrench pertinent decisions with regard to available resources must have holistic (deterministic) understanding about the intervening variables of the environment.

Furthermore, [9] also believes that decision making is not done in a vacuum, but within the whims of limited resources that constrained the decision maker. Therefore, the application of various mathematical tools in decision making becomes absolutely imperative considering its pertinent role in providing optimal solutions to decision variables. The following are the assumptions of the theory:

1) The decision maker must have holistic understanding of the environment.
2) There must be various alternative courses of actions to enable the decision maker to choose the most preferred course of action.
3) The application of various mathematical techniques yields the realistic values that provide the optimal solution.

The theory relates to the present study due to its advocacy on the need for decision makers to have holistic (deterministic) understanding about its environment. Also, the theory appreciates that a decision maker selects the best course of action amidst other alternatives for the optimum solution given resource constraints.

METHODOLOGY

The study employed a quantitative research design, of which,secondary data on cost estimate on the construction of the Faculty of Environmental Sciences extension site of Enugu State University of Science and Technology were collected. The data was spread-out cutting across every activity (task), and expected due date of completion, project cost, the indirect cost of the project etc. The data was analyzed with network technique via critical path method.

Table 1: Crash Costs estimation

Jobs	Activity	Duration Weeks	Project Cost	Crash Time	Crash Cost	Slope
(1-2)	Substructure	12	40,820,090	8	40,821,096	251.50 *
(2-3)	Frame	10	41,572,120	7	41,581,150	3,010 *
(2-4)	Staircase	2	2,587,020	1	3,587,020	1,000,000
(3-5)	External walls	2	11,750,340	2	11,750,340	0
(4-5)	Internal walls	3	8,097,900	2	8,198,940	101,040
(5-6)	Roof	5	23,882,150	3	23,889,162	3,506 *
(6-7)	Doors and window	2	16,348,000	1	16,445,210	97,210
(6-8)	Plumbing	3	9,230,000	2	9,331,250	101,250 *
(6-9)	Electrical install.	4	11,060,048	2	11,121,146	30,549
(7-9)	Fitting and Fixtures	3	9,421,000	2	9,481,000	60,000
(8-9)	Floor, wall and ceilin.	5	35,415,187.50	2	35,450,270	11,694.16 *
(9-10)	Painting and Decora.	2	3,683,600	1	3,705,333	21,733 *
(10-11)	Drainage works	2	2,440,000	1	2,441,160	1,160 *
			216,307,455.50			

The indirect cost is ₦120, 000.00 Source: Computed by the researcher:

Table 1 above shows a detailed number of activities with normal and crash durations and costs. Activity one to two has a normal duration of twelve weeks for the construction of the substructure of the environmental sciences extension site and crash duration of eight weeks. The building of the substructure cost is ₦40, 820,090 and the crash cost is ₦40, 821,090. This means that erecting the substructure (1-2) will cost ₦40, 820,090, working at planned speed and with planned resource. However, to reduce completion time from twelve to eight weeks, this will involve allocating additional resource on the tasks and this in turn, will lead to an increase in the cost of building the substructure to ₦40, 821,090. More so, the normal cost of building the frame is N41,572,120 whereas its normal duration will be ten weeks, while crash cost is 41,581,150 at seven weeks duration. The same process runs throughout the activities. Below is the network diagram showing the activity durations (weeks).

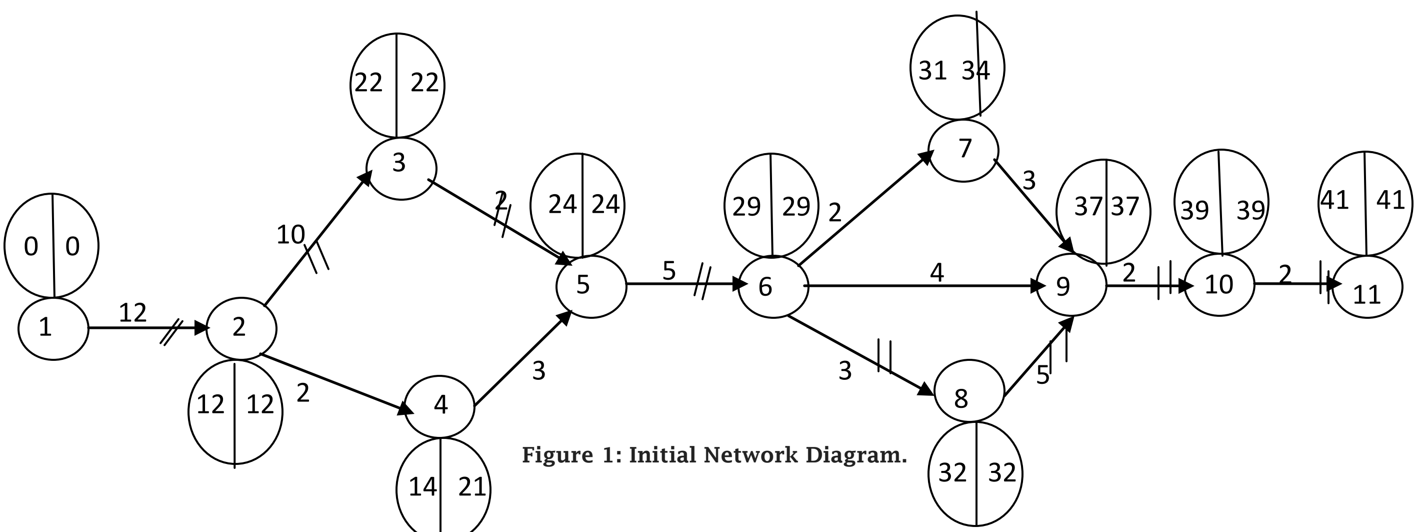


Figure 1: Initial Network Diagram.

Figure 1 above shows the network diagram of activity times (weeks) which are giving along the arrows. From the diagram, earliest start time (E) and latest finishing (L) for any activity represents the times at which an activity can begin at the earliest. It assumes that all the preceding activities start and finish at their earliest times. For instance, earliest start times of activity 1-2 is zero while the earliest occurrence time of activity 2 is obtained by adding activity time to earliest occurrence time of event 1. From the diagram above, the critical paths are 1 – 2 – 3 – 5 – 6 – 8 – 9 – 10 – 11 = 41. The normal completion period of the project is 41 weeks. Below is the critical paths computation.

1-2-3-5-6-8-9-10-11 = 41
1-2-3-5-6-7-9-10-11 = 38
1-2-3-5-6-9-10-11 = 37
1-2-4-5-6-7-9-10-11 = 31
1-2-4-5-6-9-10-11 = 30
1-2-4-5-6-8-9-10-11 = 34

Therefore, crashing from 41 weeks to 37 weeks becomes:

C_A = Total cost + 4(cost slope for activity 1-2) + 37 x 120,000 =

Direct cost =₦216, 307,455.50 + 4(251.50) = ₦216, 308,461.50
Indirect cost = 120,000 x 37 = ₦4, 440, 000,
Hence, the total cost of the project after crashing is ₦216, 308,461.50 + ₦4, 440,000 = ₦220, 748,461.50.

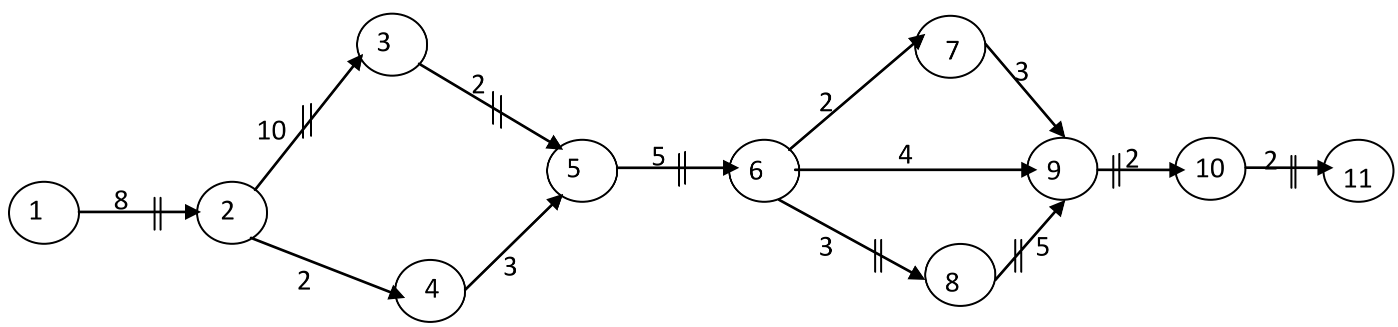
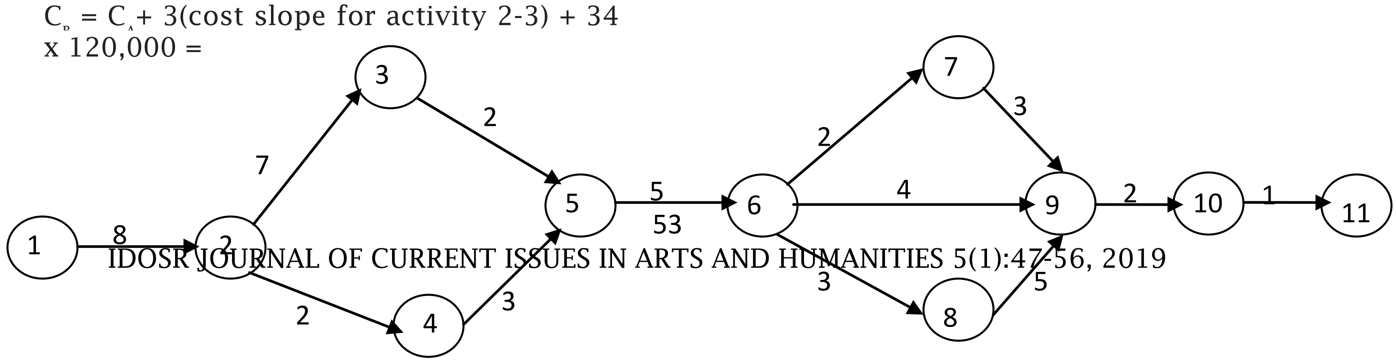


Figure 2. Network after crashing from 41 to 37 weeks

1-2-3-5-6-8-9-10-11 = 37
1-2-3-5-6-7-9-10-11 = 33
1-2-3-5-6-9-10-11 = 34
1-2-4-5-6-7-9-10-11 = 27
1-2-4-5-6-9-10-11 = 26
1-2-4-5-6-8-9-10-11 = 30

Figure 2 above shows the preceding diagram of all the activities of erecting the structure. From the aforementioned, the critical paths were 1 – 2 – 3 – 5 – 6 – 8 – 9 – 10 – 11 = 37. Therefore, crashing from 37 weeks to 34 weeks, it becomes:
C_B = C_A+ 3(cost slope for activity 2-3) + 34 x 120,000 =

Direct cost = ₦216, 308,461.50 + 3(3,010) = ₦216, 317,491.50
Indirect cost = 120,000 x 34 = ₦4, 080,000
Hence, the total cost of the project after crashing is ₦216, 317,491.50 + ₦4, 080,000 = ₦220, 397,491.50. From a careful observation on the diagram, theproject duration after crashing has reduced from 37 weeks to 34weeks. Also, the indirect cost varies proportionately with time.



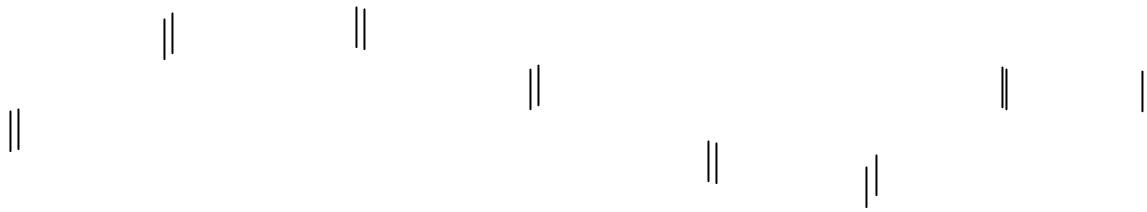


Figure 3. Network after crashing from 37 to 34 weeks

From a careful observation in figure 3 above, the duration time after crashing has reduced from 34weeks to 33weeks. The critical paths were 1 – 2 – 3 – 5 – 6 – 8 – 9 – 10 – 11 = 34. Therefore, crashing from 34 weeks to 33weeks, it becomes: $C_C = C_D$ + 1(cost slope for activity 10-11) + 33 x 120,000 =

Direct cost = ₦216, 317, 491.5 + 1(1,160) = ₦216, 318, 651.50
Indirect cost = 120,000 x 33 = ₦3, 960,000. Hence, the total cost of the project after crashing is ₦216, 318, 651.50+ ₦3, 960,000 = ₦220, 278,651.50

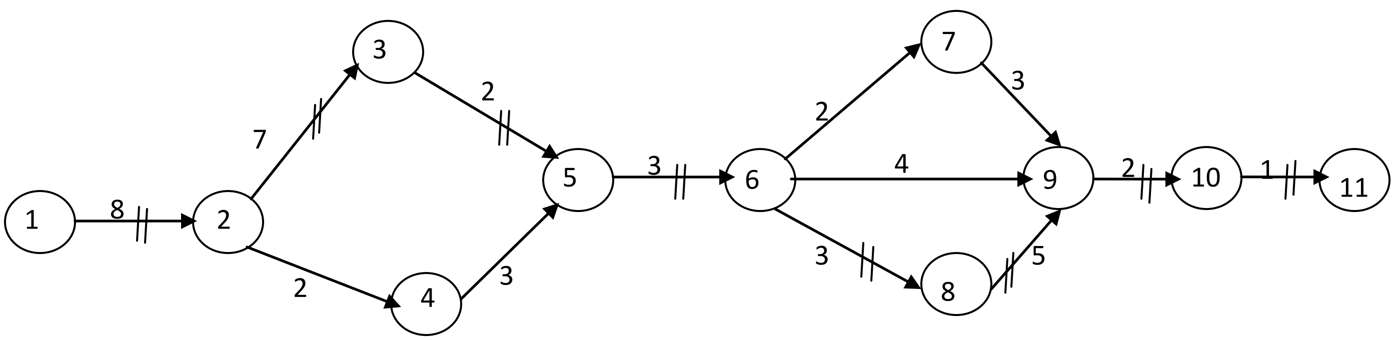


Figure 4. Network after crashing from 34 to 33 weeks

Figure 4 above also showed the preceding diagram of all the activities crashed on the critical paths resulting to attendant decrease on the duration periods (weeks). The critical paths were 1 – 2 – 3 – 5 – 6 – 8 – 9 – 10 – 11 = 31. Crashing from 33 weeks to 31 weeks, it becomes: $C_D = C_C$ + 2(cost slope for activity 5-6) + 31 x 120,000 =

Direct cost = ₦216, 318,651.50 + 2(3,506) = ₦216, 325, 662.50
Indirect cost = 120,000 x 31 = ₦3, 720,000. Hence, the total cost of the project after crashing is ₦216, 314,467.50 + ₦3, 720,000 = ₦220, 045,663.50.

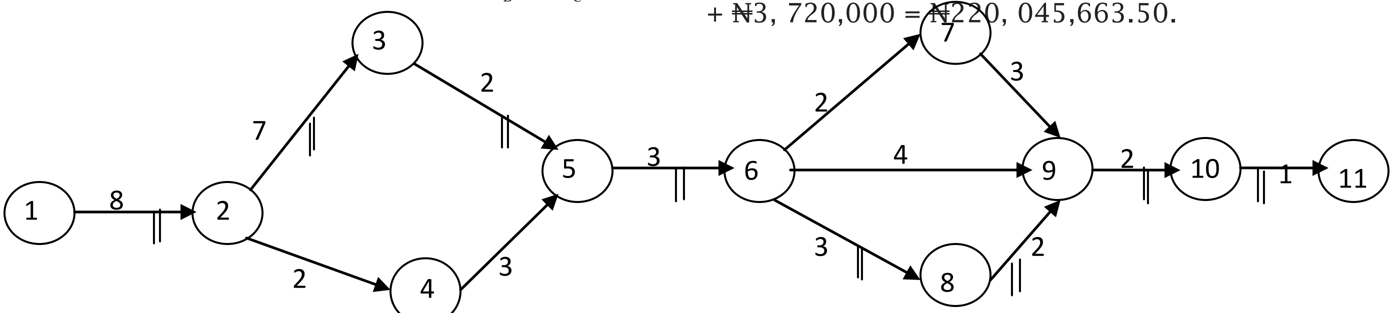


Figure 5. Network after crashing from 33 to 31 weeks

However, figure 5 showed the preceding diagram of all the activities crashed on the critical paths resulting to attendant decrease on the duration periods (weeks). The critical paths were 1 – 2 – 3 – 5 – 6 – 8 – 9 – 10 – 11 = 28. Crashing from 31 weeks to 28 weeks, it becomes: $C_E = C_D +$ 2(cost slope for activity 8-9) + 28 x 120,000 =
Direct cost = ₦216, 325, 663.50 + 3(11,694.16) = ₦216, 360, 745. 98
Indirect cost = 120,000 x 28 = ₦3, 360,000. Hence, the total cost of the project after crashing is ₦216, 360, 745. 98+ ₦3, 360,000 = ₦219, 720, 745. 98.

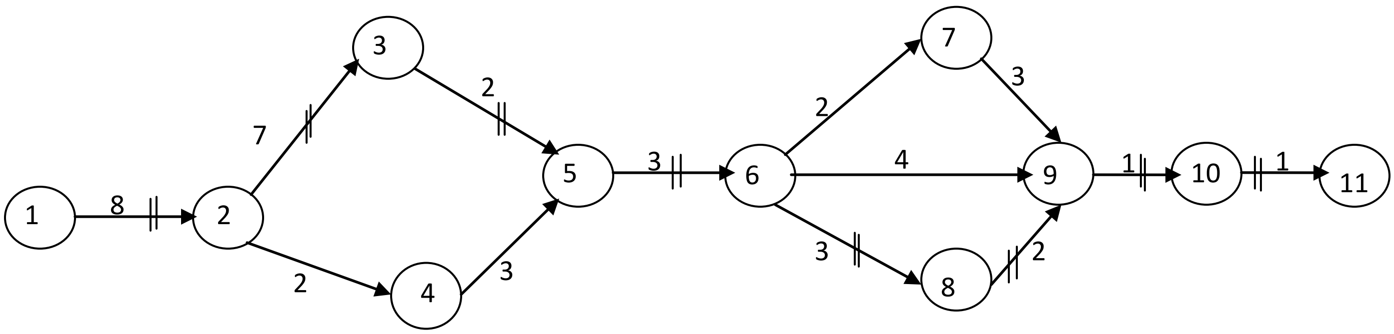


Figure 6. Network after crashing from 31 to 28 weeks

The critical paths in figure 6 were 1 – 2 – 3 – 5 – 6 – 8 – 9 – 10 – 11 = 27. Crashing from 28 weeks to 27 weeks, it becomes: $C_E = C_E$ + 1 (cost slope for activity 9-10) + 27 x 120,000 =Direct cost = ₦216, 360, 745.98 + 1(21,733) = ₦.216, 382, 478. 98
Indirect cost = 120,000 x 27 = N3, 240,000. Therefore, the total cost of the project after crashing is ₦.216, 382, 478. 98 + ₦3, 240,000. = ₦219, 622, 478. 98

CONCLUSION

From the findings of this study, it is logical to conclude that network technique plays pertinent role in the reduction of project completion time through project crashing via critical path methods. Project crashing allows the project manager to offer re-planning advice based on the functional relationship between time and cost. Objectively, the project manager can generate alternative cost and time scenarios. Furthermore, project crashing provides the client with feasible options. At a glance they can review and accept a range of time saving alternatives and their cost implications.From the foregoing, knowing the critical path in the project is sacrosanct in project completion because it will carefully guide the contractor on the activity to allocate considerable resources with little or no wastages. By assessing the associated costs of reducing the critical activities, it is possible to select the most cost effective crash sequence.

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