American Journal of Engineering Research (AJER)
E-ISSN: 2320-0847 p-ISSN: 2320-0936
Volume-7, Issue-12, pp-150-165
www.ajer.org
Research Paper Open Access

Project Network Analysis Model to Dredging Operations In Niger Delta

[1]WORGU, F; & [2]WORDU, A. A;

1Mechanical Engineering Department Rivers State University, Nkpolu-Oroworukwo, Port Harcourt, Rivers State-Nigeria

2Chemical; Petrochemical Engineering Department Rivers State University, Nkpolu-Oroworukwo, Port Harcourt, Rivers State-Nigeria

Corresponding Author: WORGU, F

ABSTRACT: *The research work thrives to evolve proper planning, scheduling, controlling of dredging activities, timing and task allocations using well-known project management techniques. The whole essence of the research is applying the renowned network project model- critical path method [CPM]. The project activities time period 2014-2017 was scheduled for data collections. The CPM was applied for data analysis to decipher completely the usefulness of this work. Finally, the results obtained from the analysis of the events from node 1 to node 15 in figure 1 critical path method scheme for the project are zero slack time of each event determining critical activities for the two dredging sites [Aleto-Eleme and Rumu-opara-ali] in Port Harcourt metropolis Rivers State. The economics of this research work to the two dredging operations was cost of production was minimized for project designed for two months was achieved within 49 days and the extra days spent on new dredging operations.*

KEYWORDS: *Dredging operations, Critical path model, Network, Economics, Planning &Control*

Date of Submission: 01-12-2018 Date of Acceptance: 31-12-2018

I. INTRODUCTION

Dredging means excavation of materials by floating equipment mostly from below water level. This can be done by two different methods known as hydraulic (suction dredgers) and mechanical (bucket) grab dredgers [Fortranch Sea Tech. Services Ltd, 2017].

Literature showed that the dredging operations using project network analysis model is lacking in the existing project management. The relevant concepts on project management are not geared towards using network project analysis models in dredging execution in Niger Delta.

The utilization target on all dredging contracts is to get a M^3 of material from A to B in the most economical way[Dredge mechanical supervision and weekly reports 2010, Johnson].In most of the planning, network analysis is used in scheduling and controlling of project. Network analysis involves the representation of all activities as network. Successfully, completing a project of any size comprising of many related activities involve the use of Network analysis for accurate estimate of the time and resources required and a good understanding of the physical and logical interdependencies of every activities. Most commonly used project network analysis models are PERT and CPM but is not limited to the two as there are many other models applicable to different projects.

Research carried out in the area of dredging operation is limited. The existing algorithm assumes that in order to improve project operation, identification of each activity to be done in the project and estimation of time it will take to complete each activity must be known. Also, determination of the required sequence of activities must be listed. The objective of the technique (CPM) is the construction of a network reflecting the precedence relationships of the project activities.

Generally, the procedures operate in the following steps:
[Banga& Sharma, 2010] posited the following ***project network parametric controls:***

[1] In a sequential manner, draw the arrow diagram indicating the beginning and the ending events on a node, and the activity by an arrow **[2]** Show on the arrow the duration of each activity. **[3]** Starting from the left side of the arrow diagram for the initial activities in the project, time zero stands for the earliest start time (ES) for the activity on the beginning of the arrow. Continue the procedure for the entire network **[4]** Starting again from the end (right-hand side) of the project and using the latest finish time (LF) find the latest start time (LS) for each activity by deducting the duration of the activity. Continue the procedure for the entire network until the start of the project. **[5]** Determine the difference between the latest finish and earliest finish time for each activity to determine the slack (float) for each activity. **[6]** Where an activity start time is zero, then the activity is on the critical path. **[7]** The critical path for the project is where all the activities have a slack time of zero.

[Jacobs and Richard, 2010]stated that the two best known network planning models are CPM and PERT and were developed in the 1950s. Organizations exist for the objective of maximizing profits and providing better services to clients at the right time. Most organizations do not focus on what needs to be done in order to reach the project goal through project improvement. Not knowing or recognizing the set of activities,precedence relations and the responsibility of the various project subparts, this greatly affects operations and hence reducing on its performance. It's therefore necessary for an organization to have an effective and well-coordinated project management team to set up a comprehensiveDredge Management Plan (DMP) to improve its operations and profit because the business environment is rapidly changing, highly competitive and directly affects the performance of the organization. Since dredging operation is capital intensive, scheduling activities haphazardly in dredging operation affects the operations negatively by causing downtime, lack of maintenance at the right time and waste of resources and manpower.

Proper planning and management of dredging operations is a well-established method and techniques in operations research of [Fortranch Sea Tech Services, 2017]through network analysis which can successfully be used to optimize dredging operations, evaluate its performance and enhance production. All is targeted at reducing the time of dredging operation and avoiding delay in job handover. Efficient and effective project management technique in dredging industries is a major requirement for any dredging company as it will minimize the total time for a dredging activity and therefore prevent the cost incurred by delaying the project[Fortranch Sea Tech Services, 2017]; [Company dredging operation log book, 2018].

[Cohen, 2016] posited, that be it capital or maintenance dredging, remedial dredging, construction of airport, harbors, land reclamation or offshore projects, maritime infrastructure construction are more accurate description of the activities of modern dredging companies.

The method of project management has changed greatly in the past few years. In the past, project management only simplified the specification of each activity in the project, today it is a combination of factors [Cook, 1998].These factors affect the project positively and will even effect the implementation of the process within the company positively. New approaches in method and project management can save cost considerably, prevent potential problems in project execution and improve operations in the project.

Project management objective is to schedule the required activities in an efficient manner so as to complete it on or before a specified time limit at minimum cost. Two project management technique PERT and CPM are commonly used to show the logical sequence of activities to be performed in any project in order to achieve project objectives[Sharma, 2009].

Critical Path methodmodel lay its credence through the research Morgan R. Walker of El Dupont de Nemour& co and Kelli,J.E. of Remington and Rand Circa [Morgan, Kelli, Rand;1957] differently carried out researches in the companies on network analysis on the computational design for UNIVAC 1 computerand operationalized in 1958 and further applied the CPM to a maintenance shutdown at the Du-pontcompany works in Lousiville Kentuckyresulting in un-productive time was reduced drastically from 125hours to 93hours [Kerzner, 2003].

Furthermore,project evaluation review technique [PERT] was tested in 1958 for Polaris Missile program by program evaluation branch of the special project office of US Navy, facilitated by the Lockheed Missile systems division and Booz Allen &Hemilton consultant Firm.

A comprehensive project team includes:Project manager,Contract experts,Site investigators, Scientist, Engineers, Dredge masters, Skippers, Financial planners and mechanics. Completing a project on time and within budget is not an easy task. The project scheduling phase plays a central role in predicting both the time and costs aspects of a project. Project consists of numerous activities involving consumption of resources. New approaches in methods and project management can save cost and avoid potential problems in project execution since many of the project tasks can be interdependent or independently executed in order to achieve the main objectives.

The present ***PROJECT B*** focus is creating a project network in dredging operation as an act of applying a formal procedure for planning, monitoring,controlling andidentifying each of the major activities required for the project and estimating how much time each activity will require.

A myriad of details must be considered in planning how to coordinate all these activities in developing a realistic schedule and in monitoring the progress of the project to improve operations.

II. MATERIALS AND METHOD

2.1MATERIALS

2.1.1 Research Data Collections

The data was mainly collected from the primary sources. Also, discussion and interview was carried out with the primary sources but no data was collected from them as the discussion centered on their operation and planning, strategies and performance for effective dredging operations. A formal and informal discussion was taken with staff and management of Sea Power Ventures Nigeria Ltd and Machineering Dredging Solutions Ltd. The discussion reveals that the courses of poor operation in the dredging industries include:

[1] Insecurity
[2] Lack of comprehensive MOU with concerned parties,
[3] Weather
[4] Insufficient funds.

Table 1 Reclamation Dredging project activities Machineering Dredging Solutions Ltd [Company dredging log book, 2017]

S/N	ACTIVITIES PLANNING	DURATION (DAYS)
1	MOU with various parties	5
2	Sand search (boreholes, 1,2,3…)	14
3	Bush clearing	5
4	Survey the entire land	2
5	Pre-survey	3
6	Ministry of solid, etc.	3
7	Decide which equipment to be used	1
8	Mobilization to site • Dredge • Personnel • Accommodation • Dry plant (bulldozer, wheel-loader, Generator) • Pipes • Securities • Tugboat • Speed boat • Diesel tank	14
9	Piping to dredge positioning in Borehole 1,2,3…	7
10	Pumping commence	
11	Dry plant (Bulldozer operates on the pre-survey level as it pushes the material to the required level.	
12	Leveling to specification	
13	Handing over	
14	Demobilization	

2.2 METHOD

In project management, the common methods are those of network analysis. These special analytical methods are used in cases where it is necessary to optimize and analyze a network of interconnected and related activities.

Methods of network analysis focus on calculating and optimizing the critical path between the activities.Fundamental project network analysis models***are: Critical path method [CPM],Critical chain method [CCM], Program evaluation and review technique [PERT],Graphical evaluation and review technique [GERT], Metra Potential Method [MPM]***

2.2.1 Critical Path Method[CPM]

The critical path is defined as the longest possible path from the starting point to the ending point on the graph chart. Each project has at least one critical path. The date of the last task completion is also the date of the project completion[Peter, *2009];*

[Langrova, 2003] stated two rules which are valid for critical path:

- The acceleration of work on the task that lies at the critical part reduces the duration of the project as a whole.
- Delayed task on the critical path is absolutely reflected in delays to the project as a whole.

Another definition of the critical path by [Rodriquez, 2011] is the path through the project network in which none of the activities have been delayed. i.e. ES = LS and EF = LF for all activities in the path.
Example of the network with activities nodes and critical path highlighted by a double line is shown in Figure 1 below.

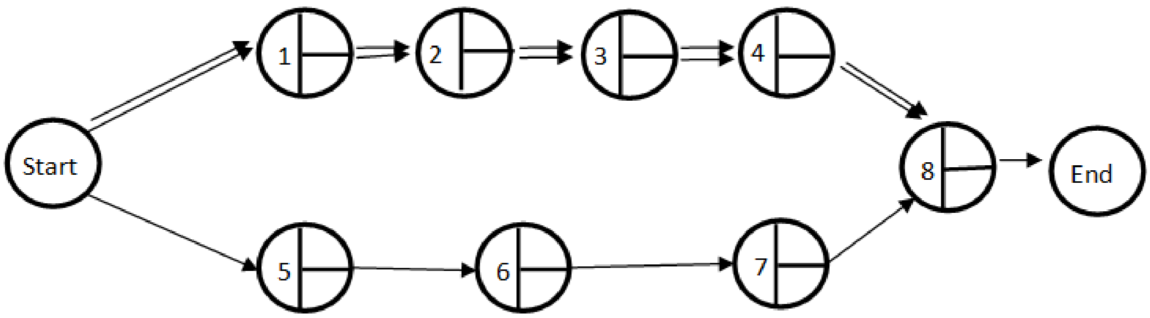


Figure 1 Network with Activities Nodes and Critical Path

2.2.2 Theory of Constrain [TOC]

The theory of constraint (TOC) is a thinking process that enables people to invent simple solution to seemingly complex problems"[Bates, 2006].

"The theory of constraint states that every system must have at least one constraint limiting its output" [Leach, 2000]. [Bates, 2006] also postulated that there is no choice in the matter; either you manage the constraints or they manage you. The constraints will determine the output of the system whether they are acknowledged and managed or not.
The TOC process looks for to identify the constraint and restructure the rest of the organization around it, through the use of five focusing steps.

2.2.3 Identify the constraint in a system

1. Decide how to exploit the constraint
2. Subordinate all process to the constraint: all level or system must adapt to support the weak link by accepting the decisions made above.
3. Elevate the constraint
4. The fifth step is to go back to the step number 1 and repeat whole process again according to definition that every system must have at least one constraint.

2.2.4 Critical Chain

The critical chain method which is also as well as in the theory of constraint [TOC] aims to determine the duration of a project based on the so-called critical chain length, which is a sequence of interdependencies of activities with the smallest advance [McGevna, 2011].

The critical chain is a superior network analysis technique. The method is based on CPM and includes accessibility and availability of resource. [Cook, 1998] while at the same time critical chain is an extension of TOC designed specifically for project environments.

Critical Chain method also takes into consideration the limitations caused by resources and the moving parts of the implicit reserve activities in so-called action buffer.

The idea of critical chain is replaced by the critical path of the CPM. The critical chain method allows for facilitating effective coordination of individual time. Critical chain method combines CPM and the TOC reduction theory that is seen as a shared resource with capacity constraint and sets the calculated time with some reserve. Therefore improves results by eliminating the shortcoming of CPM or PERT.

The difference between Critical Chain and Critical Path is that Critical Path is the longest possible path from start point to end point without taking into account the capacity constraints of the resources while Critical Chain takes into consideration the capacity constraints of the resources.
Two techniques developed to help manager Plan, Organize and Control project are;

1. Critical Path Method [CPM] and
2. Program Evaluation and Review Technique [PERT]

The focus of critical path method (CPM) is to determine when a project should be completed and to schedule when each activity in the project must begin in order to keep the project on schedule. While PERT was designed for projects where the time required to perform each activity is essentially a random variable.

PERT focuses on estimating the probability of completing a project by a given deadline. The major difference between CPM and PERT involves how the time element of the activities is determined [Ali & Selma, 2012].
Both CPM and PERT require a detailed network of the project that clearly indicates each of the main activities in the project and their precedence relationships.
Network analysis is used to design a formal procedure for planning, monitoring and controlling each activity in a project [Linda Main, 1989].
Identifying each of the major activities required for the project (dredging), along with the precedence relationships among the activities and estimating how much time each activity will require gives you an edge over the design of a formal project network analysis.

The activities in a project are represented as a network. A network is a set of activities in (nodes) that are connected in various ways by directed arcs (the arc in this network indicates the precedence relationship between nodes). In research studies, all projects have one unique start activity and one unique finish activity. However, some projects involve multiple starts and or finish activities.

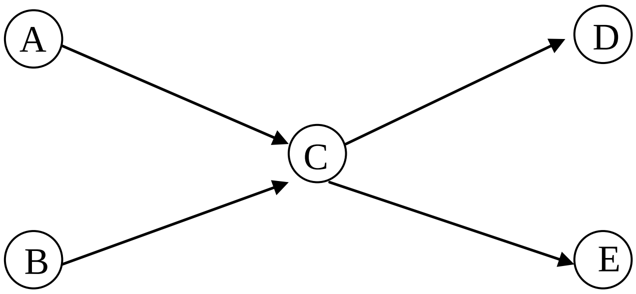


Figure2 Show multiple start and multiple finish activity

Using artificial start and finish activities to produce a network with unique start and finish points. See figure 3 below.

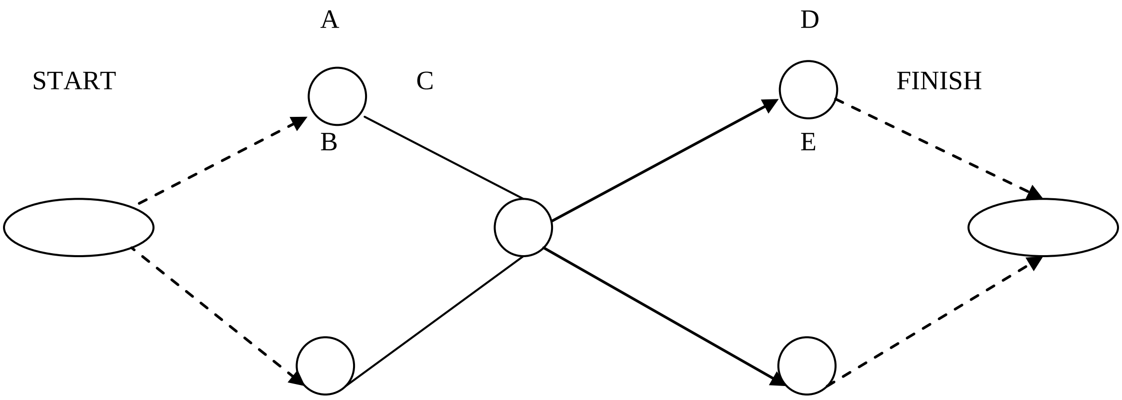


Figure 3 Shows artificial start and finish activity

Figure 5 Artificial Start and FinishActivities
Using artificial start and finish activities to produce a network with unique start and finish points.

It is necessary to create artificial start and or finish activities when a project does not have a unique start or finish activity. Artificial start activity was created to precede activities A and B above. Similarly, we inserted an artificial finish activity that allows the completion of activities D and E. These activities are artificial because they require no time to complete and merely serve to give a project a unique start and finish point. Thus, by using artificial start and finish activities, we can ensure that the network for any project has a unique start and finish point.

In order to apply either method of network analysis, you must:
a. Define the activities involved for each project
b. Define the precedence relation of activities.

2.2.5Activities in dredging operations
1. Reclamation dredging project involves the following activities:
a.MOU with the communities involved; b.Sand search operation. Boreholes drilling (borehole 1,2,3,..) c. Bush cuttingd. Surveying the entire land, e.Pre-surveying (pegging), f. Ministry of solid mineral, Ministry of

environment,EMA, inland waterwaysapproval etc.g. Mobilization to site, Dredge , Personnel, Accommodation, Dry Plants, Pipes, Securities, Tugboat, speed boat, Diesel tank, h.piping to dredge positioning in Borehole 1…..i.Pumping commence, j.Dry Plant (bulldozer) operates on the pre-survey level as it pushes the materials, k.leveling to specification and handing over, l.Demobilization

2.3 CONSTRUCTING RESEARCH PROJECT B NETWORK

Table 3Dredging Project Bdata was built from existing engineering experience data of table1 [Company dredging log book, 2017]at Aleto – Eleme, Rivers State-Nigeria.

Table 2 Project B Activity List and Data

Activity	Description	Immediate predecessors	Duration (days)
A.	Project Plan	-	7
B.	Equipment inspection	-	4
C.	MOU with concerned parties	-	5
D.	Hydrographic survey (Sand search)	C	7
E.	Survey the entire land	D	5
F.	Bush Clearing	E	2
G.	Gov. Ministry Approval papers (Documentations)	A	5
H.	Mobilization	B	7
I.	Bond wall preparation	H	2
J.	Piping to dredge	I	4
K.	Pumping commence and dozer stock pile sand.	G	30
L.	Quantity Survey	K	1
M.	Handover demobilization	L	1
N.	Demobilization	M	5

[Sharma, 2009] posited three rules for constructing the network for projects:

[1.] Each activity is represented by only one arc.
[2.] Each activity must be identified by two distinct end nodes.
[3.] Maintain correct precedence relationship as you add activities to network.

2.3.1CPM MODEL COMPUTATION

Activities in critical path are activities that has no variation in determining its start and finish time. If a critical activity runs late, then the entire project will run late.
Since the objective of critical path analysis is to estimate the total project duration and to assign starting and finishing times to all activities involved in the project, the researcher will hold onto the critical path method technique to improve the dredging operation.

In order to prepare the project scheduling, the researcher must consider the following factors.
1. Total completion time of the project.
2. Earliest and latest start time of each activity.
3. Critical activities and critical path
4. Float for each activity i.e. the amount of time by which the completion of a non-critical activity can be delayed, without delaying the total project completion time.

The critical path calculation involves two passes forward pass and backward passes method for calculating the earliest event occurrence and latest allowable times of events occurrence.

2.3.2Determination of the Slacks (Sij)

Slack also called float of an event is the difference between its latest occurrence time (Li) and its earliest occurrence time (Ei)
That is:

$$\text{Event float} = Li – Ei \qquad \textbf{[1]}$$

Slack is the amount of time an activity can run late without delaying the project. A slack time of zero (o) identifies a critical activity

$$Sij = Lj - Ei - Dij \qquad [2]$$

Taking the basic concepts of project management as a framework for implementations

- A project consists of interested activities which are to be executed in a certain order before the entire task is completed.
- The activities are interrelated in a logical sequence which is known as precedence relationship.
- Project is represented in the form of network for the purpose of analytical treatment to get solutions for scheduling and controlling it activities.

Two basic major technique uses in project management.

(i) CPM – Critical Path Method
(ii) PERT – Project Evaluation and Review Technique

2.3.3 Phase of Project Management

(i) Planning;-

(a) Dividing the project into distinct activities
(b) Estimating time requirement for each activity
(c) Establishing precedence relationship among the activities
(d) Construction of the arrow diagram (Network)

(ii) Scheduling: Determining the start and end time of each and every activity

(iii) Controlling: Use the arrow diagram and time chart for continuous monitoring and progress reporting.

From table 3.3 Critical Path thick lines in the diagram for the project "B" are shown below.

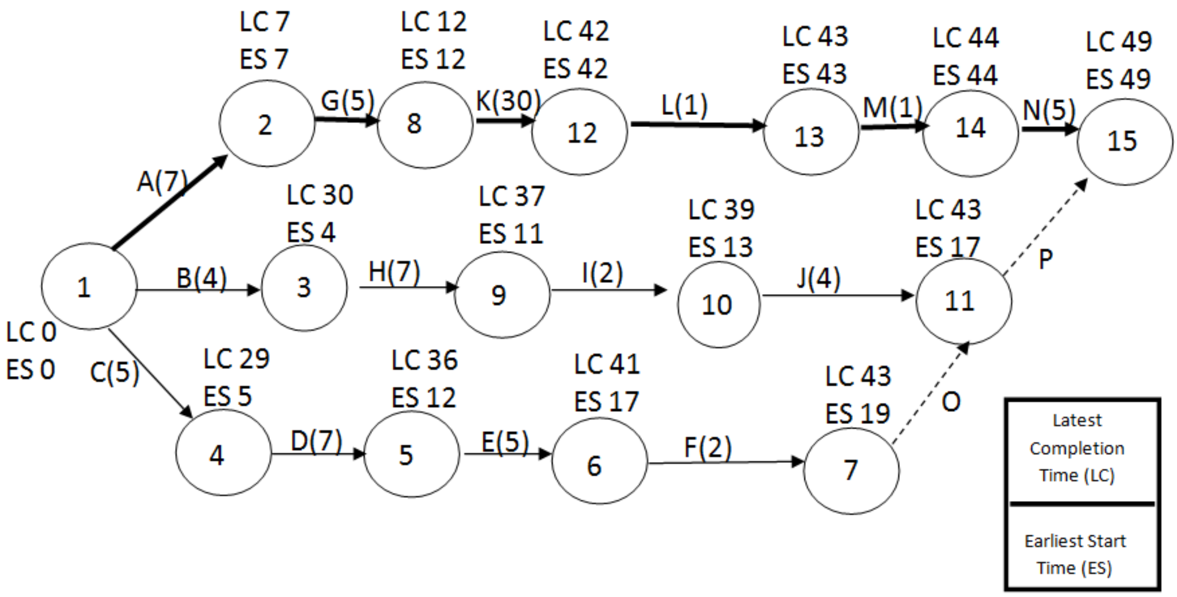


Figure 4 Critical Path Method CPM for project B

Using the forward pass formula, equation 3.1 for computation and discussion of the ES result for each event in figure 4

Event 1: This is the start event. Hence its Earliest Start is zero. ES (of event – 1) = 0

Event 2: Event 2 is the end of activity "A" as well as the beginning of activity "G". activity G can start at the same time when activity "A" comes to completion. Hence, the Earliest Start Time of event – 2 is given by ES (of events – 2) = ES (of event – 1) + Duration of activity A.

= 0 + 7 = 7

Event - 3: Event 3 represents the end of activity "B" as well as the beginning of activity "H" Activity H can start at the same time when activity B comes to completion, Hence the Latest Start time of event – 3 is given by ES (of event- 3) = ES (of event-1) + Duration of activity B

= 0 + 4 = 4

Event -4: Event 4 represents the end of activity "C" as well as the beginning of activity "D". Activity D can start immediately activity C comes to completion. Hence, the earliest start time event 4 is given by ES (of event – 4) = ES (of even -1) + Duration of activity C

= 0 + 5 = 5

Event – 5: Event 5 represents the end of activity D as well as the beginning of activity E. Activity E can start immediately activity D comes to completion. The earliest start time of event 5 is given by ES(of event -5) = ES(of event -4) + Duration of activity D

= 5 + 7 = 12

Event -6: Event 6 represents the end of activity E as well as the beginning of activity F. Activity F can start immediately activity E comes to completion. The earliest start time of event 6 is given by ES (of event -6) = ES(of event -5) + Duration of activity E

= 12 + 5 = 17

Event -7: Event 7 represents the end of activity F. ES(of event -7) =ES(of event -6) + Duration of activity F

= 17 + 2 = 19

"O" is a dummy activity.

Event -8: Event 8 represents the end of activity G as well as the beginning of activity R. activity K can start immediately activity G comes to completion. The earliest start time of event 8 is given by ES(of event -8) = ES (of event -2) + Duration of activity G

= 7 + 5 =12

Event -9: Event 9 represents the end of activity H as well as the beginning of I. activity I can start after the completion of activity H. the earliest start time of event 9 becomes

ES(of event 9) = ES(of event 3) + Duration of activity H = 4 + 7 = 11

Event -10: Event to represents the end of activity I as well as the beginning of activity J. activity J starts immediately after the completion of activity I. the earliest start time of event 10 becomes ES(of event -10) =ES(of event 9) + Duration activity I

= 11 + 2 = 13

Event -11: Event 11 represents the end of activity J. Earliest start time of event 11 becomes

ES(of event 11) = ES(of event 10) + Duration of activity J = 13 + 4 =17

"P" is a dummy activity.

Event -12: Event 12 represents the end of activity K as well as the beginning 8 of activity L. activity L can start immediately activity K comes to completion. The earliest start time of the event "12" becomes ES(of event 12) = ES(of the event 8) + Duration of activity K

= 12 + 30 = 42

Event -13: Event 13 represents the end of activity L as well as the beginning of activity M. activity M can start only when activity L is complete. Earliest start time for event 13 becomes

ES(of event 13) = ES(of the event 12) + Duration of the activity L

= 42 + 1 = 43

Event 14: Event 14 represents the end of activity M as well as the beginning of activity N. Activity N can commence after the completion of activity M. Hence, the earliest start time of the event 14 is given by ES(of event 14) = ES(of event 13) + Duration of activity M

= 43 + 1 = 44

Event – 15: Event 15 represents the end of activity N as well as the end of the project. Hence, the earliest start time of the event 15 is ES (of event 15) = ES(of event 14) + Duration of activity N

= 44 + 5 = 49

Backward Pass Computation: A method of computation of the finishing time of events. The computation begins from the final event and moves toward the initial event.

Using the backward pass formula, equation 3.2 for computation and discussion of the LC result for each event in figure 4.1:

Event -15: Earliest start time of event -15 is 49. Since this is the last event, for completing the project without delay the latest completion time (LC) for the last event should be equal to the earliest start time (ES) of that event.

Hence, LC (of event -15) = ES (of event 15) = 49

See Appendix B for the computation of the latest completion time of the events (events 15 – 1) using backward pass.

From figure 4.1 the bold line on the arrow diagram shows the critical path. The critical path duration is 49 days. Therefore, project completion time is 49 days.
Finding the Critical Path, this can be identified by simply finding out all the possible paths from the starting node of the project to the end node of the project and then selecting the path with the maximum sum of activity times on that path.
To highlight the CP, just darken the line from the network diagram, the critical path is
1 – 2 – 8 – 12 – 13 – 14 – 15
A – G – K – L – M – N
7 + 5 + 30 + 1 + 1+5 = 49 Days

The total critical path duration is 49days. Therefore, project completion time is 49 days.
7 days = 1 week
49days $=\frac{1\ Week}{7\ day}$ = 7 weeks

Using Critical Path Method to execute project "B" the contract was delivered in less than 2 months.

Table 3 Summary of Total Floats and Free Floats

S/N	Activity (i,j)	Duration (Dij)	Total Float (TF_{ii})	Free (FF_{ij})
A.	1 – 2	7	0	0
B.	1 – 3	4	26	0
C.	1 – 4	5	24	0
D.	4 – 5	7	24	0
E.	5 – 6	5	24	0
F.	6 – 7	2	24	0
G.	2 – 8	5	0	0
H.	3 – 9	7	26	0
I.	9 – 10	2	26	0
J.	10 – 11	4	26	0
K.	8 – 12	30	0	0
L.	12 – 13	1	0	0
M.	13 – 14	1	0	0
N.	14 – 15	5	0	0

Every critical activity will have zero total float and zero free float, based on this properties we can determine critical activities.

Applying network analysis in the project (B) improved the operations by delivering the project before deadline. One of the advantages of project planning is the possible reduction in the total time necessary for completion of the project.

Table 4 The Calculation for Critical and Non-Critical Activity for Total and Free Float.

Activity (i, j)	Duration (D_{ij})	Earliest Time		Latest time		Float	
		Start (E_i)	Finish (E_i +D_{ij})	Start (L_j - D_{ij})	Finish L_j	Total (L_i – D_{ij}) - E_i	Free (E_j – E_i) – D_{ij}
1 – 2	7	0	7	0	7	0	0
1 – 3	4	0	4	26	30	26	0
1 – 4	5	0	5	24	29	24	0
4 – 5	7	5	12	29	36	24	0
5 – 6	5	12	17	36	41	24	0
6 – 7	2	17	19	41	43	24	0
2 – 8	5	7	12	7	12	0	0
3 – 9	7	4	11	30	37	26	0
9 – 10	2	11	13	37	39	26	0
10 – 11	4	13	17	39	43	26	0
8 – 12	30	12	42	12	42	0	0
12 – 13	1	42	43	42	43	0	0
13 – 14	1	43	44	43	44	0	0
14 – 15	5	44	49	44	49	0	0

Table 5 Calculation for Non-Critical Activity Total Float and Free Float.

Activity (i, j)	Duration (D_{ij})	Earliest Time		Latest time		Float	
		Start (E_i)	Finish ($E_i + D_{ij}$)	Start (L_jD_{ij})	Finish L_j	Total $(L_i – D_{ij})$ - E_i	Free. $(E_j – E_i) – D_{ij}$
1 – 3	4	0	4	26	30	26	0
1 – 4	5	0	5	24	29	24	0
4 – 5	7	5	12	29	36	24	0
5 – 6	5	12	17	36	41	24	0
6 – 7	2	17	19	41	43	24	0
3 – 9	7	4	11	30	37	26	0
9 – 10	2	11	13	37	39	26	0
10 – 11	4	13	17	39	43	26	0

The network diagram is essential in calculating the schedule. Gantt charts display both the schedule information and the task relationships.

Figure 4.2 Shows the Gantt Charts for the dredging project (project B).
It has the same schedule dates as the network in Figure 4.1. Notice that all task are currently scheduled at their early start date.

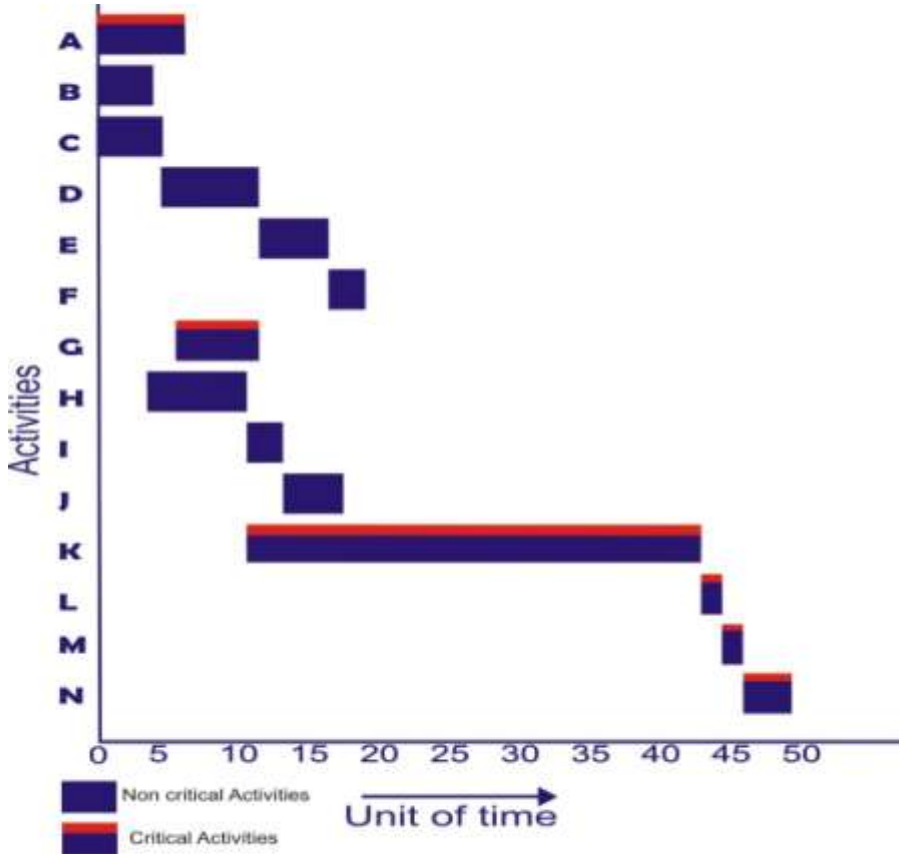


Figure 4.2. Gantt chart for project (B)

Table 6 Project B activities and durations

Activities	A	B	C	D	E	F	G	H	I	J	K	L	M	N
Preceding Activities	-	-	-	C	D	E	A	B	H	I	G	K	L	M
Durations (days)	7	4	5	7	5	2	5	7	2	4	30	1	1	5

As shown in figure 4.2. The total time required for the completion of the dredging project "B" is 49 days. The dredging project has 14 activities (A, B, C, ….N). The time required for each of the fourteen activities and the precedence relationships between the activities are shown in Table 4.4.

Activity A, B and C have no preceding activities i.e., they do not depend on any other activity for their commencement. They start at the same time and proceed concurrently though they take different time intervals for execution.

Activity D cannot be started until activity C is over. The bar representing C, D, E and F, therefore, run serially. Activity G cannot be started until activity A is over. Activity H cannot be started until activity B is completed. The bar representing H, I and J, therefore, run serially. Activity K cannot be started until activity G is over. The bar representing activities K, L, M and N run serially to the end of the project duration.

Figure1Critical Path Method (CPM)
1 – 2 – 8 – 12 – 13 – 14 – 15
A – G – K – L – M – N = 7+5+30+1+1+5=49 DAYS

The bold line on the arrow diagram shows the critical path. The critical path duration is 49 days.Therefore,project completion time is 49 days.

Finding the Critical Path, thiscan be identified by simply finding out all the possible paths from the starting node of the project to the end node of the project and then selecting the path with the maximum sum of activity times on that path.

Using the two rules in finding the critical Path
(i) Determine earliest start time (ES) of all the nodes. This is called forward pass.
(ii) Determine latest completion time (LC) of various nodes. This called backward pass.

Formula to determine earliest start time
ESj = Max (ESi + Dij)
J = Ending activity
I = Starting activity

Forward Pass
For node 1 $ES_1 = 0$
Node 2 $ES_2 = D_{1,2} = 0 + 7 = 7$
Node 3 $ES_3 + D_{1,3} = 0 + 4 = 4$
Node 4 $ES_4 + D_{14} = 0 + 5 = 5$
Node 5 $ES_5 + D_{4,5} = 5 + 7 = 12$
Node 6 $ES_6 + D_{4,5} = 12 + 5 = 17$
Node 7 $ES_7 + D_{6,7} = 17 + 2 = 19$
Node 8 $ES_8 + D_{2,8} = 7 + 5 = 12$
Node 9 $ES_9 + D_{3,9} = 4 + 7 = 11$
Node 10 $ES_{10} + D_{9,10} = 11 + 2 = 13$
Node 11 $ES_{11} + D_{10,11} = 13 + 4 = 17$
Node 12 $ES_{12} + D_{8,12} = 12 + 30 = 42$
Node 13 $ES_{13} + D_{12,13} = 42 + 1 = 43$
Node 14 $ES_{14} + D_{13,14} = 43 + 1 = 44$
Node 15 $ES_{15} + D_{14,15} = 44 + 5 = 49$
Finding the latest completion time of each node. This calculation is called a backward pass.
Determination of the latest completion time (LCi)
$LC_i = \text{Min} (LC_j – D_{ij})$

Backward pass
Starting from the last node being the 15th nodeending node latest completion time is always equal to earliest start time.

Node 15 = 49
Node 14 = $LC_{15} – D_{14,15} = 49 – 5 = 44$
Node 13 = $LC_{14} – D_{13,14} = 44 – 1 = 43$
Node 12 = $LC_{13} – D_{12,13} = 43 – 1 = 42$
Node 11 = $LC_{13} – D_{11,13} = 43 – 0 = 43$
Node 10 = $LC_{11} – D_{10,11} = 43 – 4 = 39$

Node 9 = $LC_{10} – D_{9, 10}$ = 39 – 2 = 37
Node 8 = $LC_{12} – D_{8, 12}$ = 42 – 30 = 12
Node 7 = $LC_{11} – D_{3, 11}$ = 43 – 0= 43
Node 6 = $LC_{7} – D_{6, 7}$ = 43 – 52= 41
Node 5 = $LC_{6} – D_{5, 6}$ = 41 – 5 = 36
Node 4 = $LC_{5} – D_{4, 5}$ = 39 – 3 = 29
Node 3 = $LC_{9} – D_{3, 9}$ = 37 – 7 = 30
Node 2 = $LC_{8} – D_{2,8}$ = 12 – 5= 7
Node 1 = $LC_{2} – D_{1, 2}$ = 7 – 7 = 0
= $LC_{3} – D_{1, 3}$ = 30 – 4 = 26
= $LC_{4} – D_{1, 4}$ = 29 – 5 = 24

Taking the minimum value, being 0 (zero) as the latest completion time of node 1
To find the critical path we consider the following conditions for critical path.
ES_i = LC_i
ES_j = LC_j
ES_j = $ES_i = LC_j = D_{ij}$

To highlight the CP, just darken the line from the network diagram, the critical path is 1 – 2 – 8 – 12 – 13 – 14 – 15
A – G – K – L – M – N
7 + 5 + 30 + 1 + 1+5 = 49 Days

The total critical path duration is 49days. Therefore, project completion time is 49 days.
1 month = 30 days
49days $= \frac{1 month}{30 day}$ = 1.6 months

Using Critical Path Method to execute project "B" the contract was delivered in less than 2 months.

Computing Total Floats and Free Floats for Non-Critical Activities.

TOTAL FLOATS:
It is the amount of time that the completion time of an activity can be delayed without affecting the project completion time.
Formula to find the Total Float
TF_{ij} = $LC_j – ES_i – D_{ij}$

Where
TF_{ij} = Total Float of Activity
LC_j = latest completion time for ending activity
ES_i = Earliest start time for starting activity
D_{ij} = Duration of the activity.

Table 7 Summary of Total Floats and Free Floats

S/N	Activity (i,j)	Duration (Dij)	Total Float (TF_{ii})	Free (FF_{ij})
O.	1 – 2	7	0	0
P.	1 – 3	4	26	0
Q.	1 – 4	5	24	0
R.	4 – 5	7	24	0
S.	5 – 6	5	24	0
T.	6 – 7	2	24	0
U.	2 – 8	5	0	0
V.	3 – 9	7	26	0
W.	9 – 10	2	26	0
X.	10 – 11	4	26	0
Y.	8 – 12	30	0	0
Z.	12 – 13	1	0	0
AA.	13 – 14	1	0	0
BB.	14 – 15	5	0	0

Total Float = $LC_j - ES_i - D_{ij}$
For activity A 1 – 2 = $LC_2 - ES_1 - D_{1,2}$ = 7 – 0 – 7 = 0
For activity B 1 – 3 = $LC_3 - ES_1 - D_{1,2,}$= 30 – 0 – 4 = 26
For activity C 1 – 4 = $LC_4 - ES_1 - D_{1,4}$ = 29 – 0 – 5 = 24
For activity D 4 – 5 = $LC_5 - ES_4 - D_{4,5}$ = 36 – 5 – 7 = 24
For activity E 5 – 6 = $LC_6 - ES_5 - D_{5,6}$ = 41 – 12 – 5 = 24
For activity F 6 – 7 = $LC_7 - ES_6 - D_{5,7}$ = 43 – 17 – 2 = 24
For activity G 2 – 8 = $LC_8 - ES_2 - D_{2,8}$ = 12 – 7 – 5 = 0
For activity H 3 – 9 = $LC_9 - ES_3 - D_{9,3}$ = 37 – 4 – 7 = 26
For activity I 9 – 10 = $LC_{10} - ES_9 - D_{9,10}$=39 – 11 – 2 = 26
For activity J 10 – 11 = $LC_{11} - ES_{10} - D_{10,11}$ = 43 – 13 – 4 = 26
For activity K 8 – 12 = $LC_{12} - ES_8 - D_{8,12}$ = 42 – 12 – 30 = 0
For activity L 12 – 13 = $LC_{13} - ES_{12} - D_{12,13}$ = 43 – 42 – 1 = 0
For activity M 13 – 14 = $LC_{14} - ES_{13} - D_{13,14}$ = 44 – 43 – 1 = 0
For activity N 14 – 15 = $LC_{15} - ES_{14} - D_{14,15}$ = 49 – 44 – 5 = 0

For the Free Float; FF_{ii}

Free float is the amount of time that the activity completion time can be delayed without affecting the earliest start time of immediate successor activities in the network.

$FF_{ij} = ES_j - ES_i - D_{ij}$
Free Float for the project B. = $ES_i - ES_i - D_{ij}$
For activity A 1 ---- 2 = 7 – 0 – 7 – 0
For activity B 1 ---- 3 = 4 – 0 – 4 = 0
For activity C 1 ---- 4 = 5 – 0 – 5 = 0
For activity D 4 ---- J = 12 – 5 – 7 = 0
For activity E 5 ---- 6 = 15 – 12 – 5 = 2
For activity F 6 ---- 7 = 17 – 15 – 2 = 0
For activity G 2 ---- 8 = 12 – 7 – 5 = 0
For activity H 3 ---- 9 = 12 – 5 – 7 = 0
For activity I 9 ---- 10 = 14 – 12 – 2 = 0
For activity J 10 ---- 11 = 18 – 14 – 4 = 0
For activity K 8 ---- 12 = 42 – 12 – 30 = 0
For activity L 12 ---- 13 = 43 – 42 – 1 = 0
For activity M 14 ---- 15 = 49 – 44 – 5 = 0

Every critical activity will have zero Total Float and zero Free Float, based on this criteria we can determine Critical Activities.

The critical Path from total seen by company the critical path
A – G – K – L – M – N

Applying network analysis in the project (B) improved the operations by delivering the project before deadline. One of the advantages of project planning is the possible reduction in the Total Time necessary for completion of the project.

Table 8 Calculation of Critical and Non-Critical Activity to Float and Free Float

Activity (i, j)	Duration (D_{ij})	Earliest Time		Latest time		Float	
		Start (E_i)	Finish ($E_i + D_{ij}$)	Start ($L_j - D_{ij}$)	Finish L_j	Total $(L_i - D_{ij}) - E_i$	Free $(E_j - E_i) - D_{ij}$
1 – 2	7	0	7	0	7	0	0
1 – 3	4	0	4	26	30	26	0
1 – 4	5	0	5	24	29	24	0
4 – 5	7	5	12	29	36	24	0
5 – 6	5	12	17	36	41	24	0
6 – 7	2	17	19	41	43	24	0
2 – 8	5	7	12	7	12	0	0
3 – 9	7	4	11	30	37	26	0
9 – 10	2	11	13	37	39	26	0
10 – 11	4	13	17	39	43	26	0
8 – 12	30	12	42	12	42	0	0
12 – 13	1	42	43	42	43	0	0
13 – 14	1	43	44	43	44	0	0
14 – 15	5	44	49	44	49	0	0

Table 9 Calculation of Non-Critical Activity Total Float and Free Float

Activity (i, j)	Duration (D_{ij})	Earliest Time		Latest time		Float	
		Start (E_i)	Finish ($E_i + D_{ij}$)	Start (L_jD_{ij})	Finish L_j	Total ($L_i – D_{ij}$) - E_i	Free. ($E_j – E_i$) – D_{ij}
1 – 3	4	0	4	26	30	26	0
1 – 4	5	0	5	24	29	24	0
4 – 5	7	5	12	29	36	24	0
5 – 6	5	12	17	36	41	24	0
6 – 7	2	17	19	41	43	24	0
3 – 9	7	4	11	30	37	26	0
9 – 10	2	11	13	37	39	26	0
10 – 11	4	13	17	39	43	26	0

III. PRESENTATION OF RESULTS CUM DISCUSSIONS

The activities, job description, duration for task completion and predecessor activities for a dredging project carried out by Machineering Dredging Solutions Ltd. at AletoEleme, Rivers State and Rumu-opara-ali, Obio/Akpor Rivers State with a 14 x 14 dredger capacity for the time span [2014 – 2017].

The activities, job description, durations for task completion and predecessor activities for a dredging project carried out by Machineering Dredging Solutions Ltd at AletoEleme, and Rumu-opara-ali, Obio/Akpor Local Government Area, Rivers Statewith a 14 x 14 dredger capacity for the time span [2009 – 2014].

Project A was carried out earlier at Rumuopara-Eli, Obio/Akpor Local Government Area, Rivers State, without the application of a network analysis technique for a 100,000m^3 of sand stock pile project and was agreed by both parties that job is to be delivered in two (2) months' time.

Since there was noplan on how the project should be executed, it resulted to the contract running for over 2 months and incurred more cost and penalty.

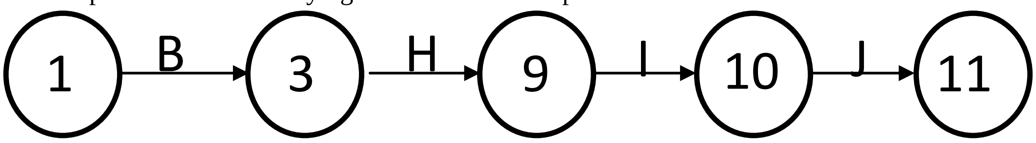
Table 3is data presentation for the dredging project B. Dredging of 100,000m^3 of sand with a 14 x 14 capacity dredger and stock pile at Aleto – Eleme, Rivers State. The table shows the activities description, immediate predecessors' activities and duration for each activity execution. The dredging operation starts with activity A and ends with activity N as listed in table 2. The Earliest Start Time and Latest Completion time for the activities of the project are shown in table 4. These Earliest Start Time and Latest Completion time of each activity was calculated using the forward pass and backward pass algorithm. The activities on the critical path were obtained from the time spend on each activity as shown in table 2 and data used for calculating the Earliest Start Time, Latest Completion Time, Total float and Free float of each activity as shown in figure 4. And those nodes (events) in which the ES and LC are the same giving difference of zero are called the critical activities. From the critical path where there are critical activities, the amount of time the dredging project could take is 49 days.

On the critical path, since the two time estimates of all the nodes are the same, it means that a succeeding activity in a critical path shall commence immediately after its proceeding activity is completed. This reduced the number of days for the dredging operation from 60 days to 49 days. The dredging could be reduced by 11 days through which cost is saved.

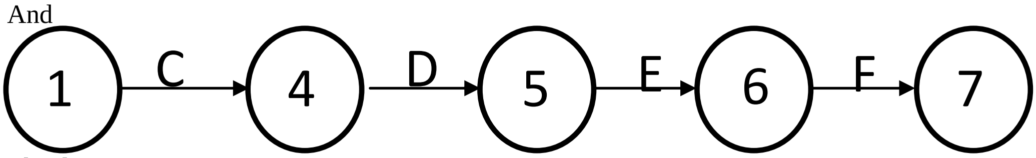
Figure 4 shows all the activities of the dredging project represented with an arrow diagram called project ne twork diagram. In the diagram, the critical path is shown with thick lines joining all those events that have zero slack time. From the data collected and from the computations; the critical path of the dredging operation is represented in nodes as

1 – 2 – 8 – 12 – 13 – 14 – 15 as well as in activities A – G – K – L – M – N.

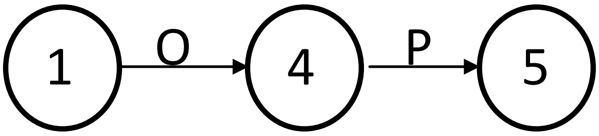
Activities that are not in the critical path are called non – critical activities. From the Network Diagram, non-critical path with activities lying on the non-critical path are:



And



The dummy activities are



Total Time Duration along the Critical Path is 49 days which represents the overall time for the project completion time which is 7 weeks.

IV. CONCLUSION

This study enhanced engineering management practice model in area of project management using project network analysis model techniques to improve dredging operations and other related industrial activities in the Niger Delta, Rivers State-Nigeria.

The research serve as specification for future private sector partnership information consultations in effective dredging project planning, activities scheduling and controlling and other construction project.

Finally, the economics of the project is assured from onset of the embarking on project because underutilization of equipment and waste of resources in project is strictly avoided.

NOMENCLATURE

Symbols	Definitions
EF	Earliest finish time
LF	Latest Finish time
t_0	Optimistic time
t_m	Most likely time
t_p	Pessimistic Time
t_e	Expected duration
σ_e	Standard deviation for expected duration
σ_e^2	Variance of activity time
EPD	Expected project duration
σ_c	Standard deviation of the critical path
σ_c^2	Variance of activity time
σ_i	Standard deviation of the duration of activity
I	Standing activity node
J	Ending activity node
Z	Number of standard deviation of a normal distribution.
TD	Target duration
$\sqrt{\sigma}$	Standard deviation
E_i	Earliest occurrence time of an event
L_i	Latest allowable time of an event
ES	Early start time activity
LS	Latest start time of an activity
EF_{ij}	Early finish time of an activity
LF_{ij}	Latest finish time of an activity
T_{ij}	Duration of an activity (ii)
S_{ij}	Slack time
D_{ij}	Duration

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