Project Evaluation Review Technique Model to Dredging Operations in Niger Delta

Barinyima Nkoi, Animia A. Wordu, and Fortune Worgu

Abstract—This research applies Project Evaluation and Review Technique (PERT) model to estimate acceptable duration for execution of each activity having random variable of time and some probability distribution for sand dredging operation in Niger Delta. The study takes into account proper planning, scheduling, controlling and allotment of dredging activities time using a project network model PERT. The model evaluated how acceptable time and saving cost could be achieved in a scenario of activities having random time variables. Readily available data of activities time from 2014 – 2017 were used to analyze the time estimate for various activities at a selected dredge site Aleto-Eleme in Port Harcourt metropolis Rivers State-Nigeria. The PERT was applied for the data analysis, to construct the PERT scheme for the dredging operations. Finally, parametric control for project evaluation and review techniques of acceptable time for the dredging activities were determined.

Index Terms—PERT Model; Dredging; Planning; Activities; Aleto-Eleme.

I. INTRODUCTION

Project evaluation and review techniques Program Evaluation and Review Technique (PERT) were constructed during the target to build nuclear – powered submarine, warships as they were expensive and required so much innovation and could not be governed by existing techniques.

Network diagrams are commonly called PERT diagrams, and PERT stands for program evaluation and review techniques one of the first formal methods developed for scheduling projects and programs [1]. PERT chart and network diagram as a term for many people are synonymous. As mentioned in the study, PERT has become synonymous with the schedules calculation with respect to network diagram [10].

Reference [2] posited PERT research to help in the planning a scheduling of the American Navy’s Polaris nuclear submarine missile project, which involves thousands of activities. The development of these technique PERT stressed on the aspect of planning and controlling of project where activities are subject to considerable degree of uncertainty in time of execution i.e the development of a resource allocation model for PERT/CPM analysis.

The objective of the study of project management 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 [2]. The main objectives before starting any project are to schedule the required activities in an efficient manner so as to complete it on or before a specified time limit at minimum cost of its completion [2].

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 comprehensive Dredge 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 [13]. 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 [14], [15].

Reference [16] 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 [17]. 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.

A. Project Evaluation and Review Technique (PERT)

The PERT technique big advantage is the kind of planning required to create a major network. Network development and critical path analyses reveal interdependence and problem areas that are neither obvious nor well defined by other planning method. The technique therefore determines where the greatest effort should be made for a project to stay on schedule. [3] discussed CPM and PERT technique usefulness for library management. [4] researched on a comparison between combinations of various network analysis approaches to accelerate engineering projects. He emphasizes on lack of holism in PERT and CPM techniques. Thus, to compete in critical and concurrent engineering environment, he provided integrated CPM approach.

Reference [5] presents an analysis of the Critical Path Method (CPM) and PERT in project planning. It highlighted the means by which a network diagram is constructed from a list of project activities and the computation involved for each method.

Reference [6] deals with time analysis and its application in practices. The researcher used PERT/CPM to provide the time analysis of two different projects and draw results from the analysis to help a company decide which project mode of execution to choose.

II. MATERIAL AND METHOD

A. Materials

The research data designed and collected from sand stockpile dredging project at Aleto-Eleme Rivers State-Nigeria [7].

<table>
<thead>
<tr>
<th>Activity</th>
<th>Description</th>
<th>Duration (Days)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A.</td>
<td>Project plan</td>
<td>7</td>
</tr>
<tr>
<td>B.</td>
<td>Equipment inspection</td>
<td>4</td>
</tr>
<tr>
<td>C.</td>
<td>MOU with concern parties</td>
<td>5</td>
</tr>
<tr>
<td>D.</td>
<td>Hydrographic survey (sand search)</td>
<td>7</td>
</tr>
<tr>
<td>E.</td>
<td>Survey the entire land</td>
<td>5</td>
</tr>
<tr>
<td>F.</td>
<td>Bush clearing</td>
<td>2</td>
</tr>
<tr>
<td>G.</td>
<td>Gov. Ministry Approval page</td>
<td>5</td>
</tr>
<tr>
<td>H.</td>
<td>Mobilization</td>
<td>7</td>
</tr>
<tr>
<td>I.</td>
<td>Bond wall preparation</td>
<td>2</td>
</tr>
<tr>
<td>J.</td>
<td>Piping to dredge</td>
<td>4</td>
</tr>
<tr>
<td>K.</td>
<td>Pumping commence and dozer stick pile material</td>
<td>30</td>
</tr>
<tr>
<td>L.</td>
<td>Quantity survey</td>
<td>1</td>
</tr>
<tr>
<td>M.</td>
<td>Handover</td>
<td>1</td>
</tr>
<tr>
<td>N.</td>
<td>Demobilization</td>
<td>5</td>
</tr>
</tbody>
</table>

The key activity parameters used for analysis in PERT are:

- Expected duration $t_e$ – it is the weighted average of the three time estimates
  
  $$
  t_e = \frac{t_o + 4t_m + t_p}{6}
  $$

  where $t_o$ = Optimistic time
  $t_m$ = Most likely time
  $t_p$ = Pessimistic time

- $t_e$ = Standard deviation for expected duration

Standard deviation:

$$
\sigma_e = \sqrt{\frac{(t_p - t_o)^2}{6}}
$$

Variance of activity time:

The data for each activity was collected from the view of PERT three-time estimate for execution of every activity of the dredge operation. PERT model was used for the data to determine the expected activity time, draw the PERT diagram for network. Example of the network with activities nodes and critical path highlighted by a double line is shown in Fig. 1.

![Network activity diagram](http://example.com/network-diagram.png)

**Fig.1. Network activity nodes**

The PERT method is a non-deterministic extension of the CPM method. While CPM assumes each activity has a fixed duration, the PERT method understands each activity as a random variable of time and has some probability distribution. In practice, it was best represented by a beta-distribution. The beta distribution is generally used to describe the basic variability in time estimates. PERT differs from CPM in that it bases the duration of an activity on three estimations [8] shows:

- $t_o$ - Optimum time: The estimation of time required under optimum conditions.
- $t_m$ - Most likely time: the most probable amount of time required.
- $t_p$ - Pessimistic time: the estimation of time required under the worst conditions.

![Beta distribution in PERT](http://example.com/beta-distribution.png)

**Fig. 2. Beta distribution in PERT**

The data for each activity was collected from the view of
\[
\sigma_c^2 = \left[ \frac{6 \sigma_i^2}{t_i} \right]^2
\]

The expected project duration (EPD), which is the mean duration for completing the project, is the critical time of the project. Activities on the critical path define the EPD as:

\[
\text{EPD} = \sum t_c
\]

If we assume that the duration of the activities are independent random variables, then the variance of the total critical path’s duration is the sum of the variance on the critical path [2] shows:

\[
\sigma_c^2 = \sum \sigma_i^2 \quad \text{and} \quad \sigma_c = \sqrt{\sum \sigma_i^2}
\]

Where:
- \( \sigma_i^2 \) = Variance of activity time
- \( \sigma_i \) = Standard deviation of the duration of activity
- \( \sigma_c \) = Standard deviation of the critical path

The number of standard deviation, Z, of a normal distribution is given by the following formulas:

\[
Z = \frac{(TD - EPD)}{\sqrt{\sigma}}
\]

Where
- TD = Target duration
- EPD = Expected duration
- \( \sqrt{\sigma} \) = Standard deviation

Reference [2] example of the networks diagram for a project is shown in the picture below, with 3 times estimation for each activity. Left figure is optimistic time, middle figure is pessimistic time and right figure is most likely time.

![Networks diagram](image)

Fig. 3. The optimistic time, pessimistic time and most likely time

**TABLE II: PROJECT B ACTIVITY LIST [11]**

<table>
<thead>
<tr>
<th>Activity</th>
<th>Description</th>
<th>Immediate predecessors</th>
<th>Optimistic time</th>
<th>Most likely time</th>
<th>Pessimistic time</th>
</tr>
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<tbody>
<tr>
<td>A.</td>
<td>Project Plan</td>
<td>-</td>
<td>7</td>
<td>10</td>
<td>12</td>
</tr>
<tr>
<td>B.</td>
<td>Equipment inspection</td>
<td>-</td>
<td>4</td>
<td>7</td>
<td>9</td>
</tr>
<tr>
<td>C.</td>
<td>MOU with concerned parties</td>
<td>-</td>
<td>5</td>
<td>8</td>
<td>13</td>
</tr>
<tr>
<td>D.</td>
<td>Hydrographic survey (Sand search)</td>
<td>C</td>
<td>7</td>
<td>11</td>
<td>18</td>
</tr>
<tr>
<td>E.</td>
<td>Survey the entire land</td>
<td>D</td>
<td>5</td>
<td>9</td>
<td>10</td>
</tr>
<tr>
<td>F.</td>
<td>Bush Clearing</td>
<td>E</td>
<td>2</td>
<td>4</td>
<td>6</td>
</tr>
<tr>
<td>G.</td>
<td>Gov. Ministry Approval papers (Documentation)</td>
<td>A</td>
<td>5</td>
<td>7</td>
<td>12</td>
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<tr>
<td>H.</td>
<td>Mobilization</td>
<td>B</td>
<td>7</td>
<td>13</td>
<td>16</td>
</tr>
<tr>
<td>I.</td>
<td>Bond wall preparation</td>
<td>H</td>
<td>2</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>J.</td>
<td>Piping to dredge</td>
<td>I</td>
<td>4</td>
<td>8</td>
<td>14</td>
</tr>
<tr>
<td>K.</td>
<td>Pumping commence and dozer stock pile sand.</td>
<td>G</td>
<td>30</td>
<td>32</td>
<td>36</td>
</tr>
<tr>
<td>L.</td>
<td>Quantity Survey</td>
<td>K</td>
<td>1</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>M.</td>
<td>Handover</td>
<td>L</td>
<td>1</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>N.</td>
<td>Demobilization</td>
<td>M</td>
<td>5</td>
<td>8</td>
<td>11</td>
</tr>
</tbody>
</table>

**TABLE III: CALCULATION FOR TO, TM AND TP**

<table>
<thead>
<tr>
<th>Activity</th>
<th>( t_o )</th>
<th>( t_m )</th>
<th>( t_p )</th>
<th>( \sigma^2 = \frac{(6\sigma_i^2)}{t_i} )</th>
<th>( \sigma^2 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>7</td>
<td>10</td>
<td>12</td>
<td>9.8</td>
<td>0.694</td>
</tr>
<tr>
<td>B</td>
<td>4</td>
<td>7</td>
<td>9</td>
<td>6.8</td>
<td>0.694</td>
</tr>
<tr>
<td>C</td>
<td>5</td>
<td>8</td>
<td>13</td>
<td>8.3</td>
<td>1.777</td>
</tr>
<tr>
<td>D</td>
<td>7</td>
<td>11</td>
<td>18</td>
<td>11.5</td>
<td>3.361</td>
</tr>
<tr>
<td>E</td>
<td>5</td>
<td>9</td>
<td>10</td>
<td>8.5</td>
<td>0.694</td>
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<tr>
<td>F</td>
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<td>4</td>
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<td>4.0</td>
<td>0.444</td>
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<tr>
<td>G</td>
<td>5</td>
<td>7</td>
<td>12</td>
<td>7.5</td>
<td>1.361</td>
</tr>
<tr>
<td>H</td>
<td>7</td>
<td>13</td>
<td>16</td>
<td>12.5</td>
<td>2.25</td>
</tr>
<tr>
<td>I</td>
<td>2</td>
<td>3</td>
<td>5</td>
<td>3.2</td>
<td>0.25</td>
</tr>
<tr>
<td>J</td>
<td>4</td>
<td>8</td>
<td>14</td>
<td>8.3</td>
<td>2.777</td>
</tr>
<tr>
<td>K</td>
<td>30</td>
<td>32</td>
<td>36</td>
<td>32.3</td>
<td>0.1</td>
</tr>
<tr>
<td>L</td>
<td>1</td>
<td>2</td>
<td>4</td>
<td>2.2</td>
<td>0.25</td>
</tr>
<tr>
<td>M</td>
<td>1</td>
<td>3</td>
<td>4</td>
<td>2.8</td>
<td>0.25</td>
</tr>
<tr>
<td>N</td>
<td>5</td>
<td>8</td>
<td>11</td>
<td>8.0</td>
<td>1.0</td>
</tr>
</tbody>
</table>

\[
\text{Activity} = \begin{cases}
- & \text{Earliest occurrence time of an event} \\
\text{Li} & \text{Latest allowable time of an event} \\
\text{ES} & \text{Early start time activity } (ij) \\
\text{LS} & \text{Latest start time of an activity} \\
\text{EF}_i & \text{Early finish time of an activity } (ij) \\
\end{cases}
\]

\[
\text{LF}_ij = \text{Latest finish time of an activity } (ij) \\
\text{T}_ij = \text{Duration of an activity } (ij)
\]

**B. Determination 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:

\[
\text{Event float} = Li - Ei
\]

Slack is the amount of time an activity can run late without delaying the project. A slack time of zero \((0)\) identifies a critical activity.

\[
Sij = Lj - Ei - Dij
\]
This diagram for the research exhibits critical activities and non-critical activities. The activities with zero slack time from the diagram shows the critical activities of the dredging project B. The critical activities are: A, G, K, L, M, N with expected durations of 9.8 + 7.5 + 32.3 + 2.2 + 2.8 + 8.0 = 62.6 days.

Thus, schematically critical path activities are:

The probability that the project would be completed in 61.5 days goes through the extent of noting the project critical path variance of the entire project. From table 2, the variance for the project is 15.902.

\[ \sigma^2 = \text{Variance} = 13.902 \]

Reference [2] states that

\[ Z = \frac{T_s - T_e}{\sigma} \text{ and } \sigma = \sqrt{15.905} = 3.98 \]

Where:

- \( T_s \) = Schedule time
- \( \sigma \) = standard deviation
- \( T_e \) = Expected completion time of the project
- \( Z \) = Number of standard deviation the schedule time lies away from the mean or expected date.

\[ \sigma^2 = \sigma_1^2 + \sigma_2^2 + \sigma_3^2 \ldots \ldots \sigma_n^2 \text{ sum of variance} \]

The preferred completion time of dredging project can be calculated as:

\[ T_s = Z \sigma + T_e. \]

\[ Z = \frac{61.5 - 62.6}{3.98} = -\frac{1.10}{3.98} = 0.276 \neq -0.3 , Z = -0.3 \]
The probability for 62.6 days is 50%. The probability for the project being completed in 61.5 days is 37.07%. The probability that the project will get delayed beyond 62.6 days is 0.6293=62.93%.

Given that $P \left( Z = \frac{T_2 - T_3}{\sigma} = 0 \right)$

$T_s = \text{scheduled time}$

The duration of the project will have 97 percent chance of being completed

Given that $P \{ Z = \frac{T_2 - T_3}{\sigma} = 0.97 \}$

$Z_{0.97} = 0.3$, from normal distribution table

$-0.3 = \frac{T_2 - T_3}{\sigma}$

$1.119 = T_3 - 62.6$

$T_s = (1.119 \times 62.6) = 63.719$ days

III. RESULTS AND DISCUSSION

Results from data evaluations shows that 62.6 days was used to complete the dredging and stockpile project of 100,000 m³ of sand under uncertain activities completion time.

For dredging project where activity time is stochastic PERT consider the average weighted mean of the three-time estimate of every activity; optimistic time, pessimistic time and most likely time. Further evaluation and analysis of the three time estimate to find the expected time of activity lead to finding of the critical path of the project which amount to total of 62.6 days for critical activities to be complete. The probability for completing the project within 62.6 days is probability of 50 percent.

The variance of the dredging project activities evaluated give 13.902, through which the probability for completing the project within 61.5 days was known to be 37.07% from this point we find the probability that the project will be delayed beyond the expected time of 62.6 days by 62.93%.

Finally, calculations of duration of the project would take to completion by 97% in 64 days.

ACKNOWLEDGMENT

This research project was made possible by the good efforts of the two dredging companies, Fortranch Sea Tech. Services Ltd and Machineering Dredging Solutions Limited who gave the consultancy of putting their project into research back-up to enable them proffer best methods of operating to strike profit in an environment where militancy is prevalent.

REFERENCES


NOMENCLATURE

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Definition</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>EF</td>
<td>Earliest finish time</td>
<td>Days</td>
</tr>
<tr>
<td>LF</td>
<td>Latest finish time</td>
<td>Days</td>
</tr>
<tr>
<td>$t_o$</td>
<td>Optimistic time</td>
<td>Days</td>
</tr>
<tr>
<td>$t_m$</td>
<td>Most likely time</td>
<td>Days</td>
</tr>
<tr>
<td>$t_p$</td>
<td>Pessimistic Time</td>
<td>Days</td>
</tr>
<tr>
<td>$t_e$</td>
<td>Expected duration</td>
<td>Days</td>
</tr>
<tr>
<td>$\sigma$</td>
<td>Standard deviation for expected duration</td>
<td>Days</td>
</tr>
<tr>
<td>$\sigma^2$</td>
<td>Variance of activity time</td>
<td>Days</td>
</tr>
</tbody>
</table>

EPD | Expected project duration |
$\sigma_c$ | Standard deviation of the critical path |
$\sigma_t^2$ | Variance of activity time |
$\sigma_i$ | 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 |
$E_t$ | Earliest occurrence time of an event |
$L_t$ | Latest allowable time of an event |
ES | Early start time activity |
LS | Latest start time of an activity |
EF | Early finish time of an activity |
LF | Latest finish time of an activity |
$T_d$ | Duration of an activity |
$S_t$ | Slack time |
$D_t$ | Duration |
$T_s$ | Scheduled time |
$T_e$ | Expected completion time of the project |

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