A Computer Based Approach for Determining the Probability of Completing a Project at a Certain Due Date [1]

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Abstract

This paper reports on a solution approach for determining the probability of completing a project at a certain due date via a computer-based approach. When estimating the expected completion probability of any construction project within a specified/certain due date/duration via program evaluation and review technique (PERT). This paper dwells on the computation of expected completion probability of a project within a specified/certain duration by using a computer-based program. The PERT-enabled software is designed using a C sharp programming code system to provide a unique capability such as viewing the expected project's probability of completion in line with the optimistic, most likely, and pessimistic times. In analyzing the project, provision was made by seamlessly integrating the project schedule computations into the system and implementing and developing the following modules viz; graphic user interface; the database; an iteration module; and a computing module. At the end of the exercise, an illustration of the entire process was presented by way of demonstrating and verifying the applications of the proposed computer-based software using stochastic computations of a case study construction project.

Keywords: Computer based approach, pert, project, probability of completing a project

1. Introduction

A Project can be viewed as a well-conscripted and a collection of tasks, jobs or activities that must be executed in some order and when all tasks are completed, the envisaged project objective is achieved (Thaeir & Ramadan, 2014). For instance, the construction of a building project consists of so many tasks like; preparation of site; pouring of footing and slab; the erection of walls; and finally roofing which must follow a sequence. One of the fundamental problems in project management is that of determining the minimum project duration/time and schedule. The Project Evaluation and Review Technique (PERT) is one of the fundamental tools for determining a schedule. As opined by Bregman (2009)**,** a network is a representation of projects and is comprised of activities with uncertain durations that appear as a probabilistic activity network. In actual fact, large-scale projects have numerous network paths that can share activities which include complex sub-paths, dependencies and share similar expected durations. Except for unusual special-case scenarios (Bregman, 2009), the probability of completing projects before the envisaged due dates and the anticipated benefits ensuing from expediting individual activities cannot be predetermined analytically. A lot of commercial scheduling software is readily available in the industry. According

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to Lee (2003), the software program are generally well articulated and does a good job by supporting scheduling functions, but it's unfortunate that they most often do not perform computations on probabilities of completing a project.

In a bid to complete a project on time and within budget has never been an easy task (Agyei, 2015). Despite all the recent advances in project management as a profession, most projects in Ghana today are still bedeviled with incidences of cost and time over-runs which invariably leads to an increase in the complex nature of the project. Agyei (2015) further reiterated that a large number of factors must have been responsible for the delays typically emanating from contractor related delays, delays from the client, consultant's delay, labour related delays and various other forms of external delays. These delays most times gives rise to schedule overrun, cost overrun, dispute, arbitration, complete abandonment and litigations of all sort. Bregman (2009) opined that although the use of simulation has been accepted as a method of evaluating probabilistic related issues in networks, Yang and Tsai (2008) were of the view that uncertainty associated with project duration often times leads to numerous schedule problems with regards to time-control, in as much as building project related activities are subject to considerable uncertainty which gives rise to the inability of projects to be delivered at the specified /planned or as contracted timelines.

In this paper, we concentrate on determining the due date for project completion using a computer-based approach. The objective of this paper is to determine the probability of completing a project at a certain due date using a computer-based approach. The contributions of this work is to provide an avenue for the effective use of the proposed program in determining the probability of completing a project at a certain due date at the click of a button without having to start computation manually. The other part of this paper is follows; Section 2 literature review, Section 3 materials and methods, Section 4 case study and Section 5 Conclusions.

2. Literature Review

According to Hajdu Malyusz and Vattai (2019) and Remon (2013), the history of network techniques came into being with the development of Critical Path Method (CPM) and the Program Evaluation and Review Technique (PERT) in 1957. They opined that the former (CPM) provides an optimal solution to problems of finding the minimum direct cost solution to a given project duration also known today as the time-cost-tradeoff problem, while the later (PERT) defines a stochastic problem with the sole aim of defining the distribution of the project duration assuming that the distribution of the duration of the activities are defined by the use of the so called PERT-Beta distribution. While the PMI (2017), reiterates that "the critical path is the sequence of activities that represents the longest path through a project, which determines the shortest possible project duration" p.210. Given the fact that activity times are stochastic variables, it then implies that the completion time for a project must also be a random variable. This invariably means that there is a potential variability in the project scheduling completion time. PERT is a project management tool and technique used to schedule, organize, and coordinate tasks within a given project **(**Suri & Ranjan, 2012)**.** It is a tool basically used to analyze the tasks (activities) involved in getting a given project completed, most specifically the time required to complete each task, as well as to identify the minimum time required to complete an entire project. In as much as the redefined project has an expected completion schedule, there is no guarantee that it will actually be completed within the specified duration. If per adventure, the various activities take longer than their expected time, the project might not be completed within the desired schedule period. In a nutshell, it would be useful to envisage the probability that the project will be completed within a specified time period.

According Remon (2013), one of PERT's most powerful concept is its ability to manage stochastic tendencies. It's a technique for estimating and planning large projects. It (PERT) makes use of simple statistical notations in arriving at a probability distribution for purposes of completing the due dates of project's milestones. Remon (2013), further reiterated that PERT was designed to provide:

1) Information to management on the actual and impending problems associated with completing a project;
2) continuous release of status reports on active projects for purposes of achieving established objectives, completion/due dates, as well as the probability of realizing both; and;
3) Information on the most and least critical component activities within each project.

While Trietsch and Baker (2011) opined that PERT focuses more on the creation and control of project schedules in stochastic-based environments. It relies on a stochastic analysis approach named engine.

Several studies in the past have investigated and designed programs for determining the probability of computing a project in one way or the other. For instance, Suri and Ranjan (2012), estimated the probability of project completion by using SIM_DEL estimator in India, Nafkha (2016),uses stochastic PERT method to estimate ERP project implementation duration, Trietsch and Baker (2011), designed PERT 21 as a means of offering a radically different stochastic analysis for projects, Remon (2013), designed a Repetitive-Projects Evaluation and Review Technique (RPERT) using Line of Balance technique (LOB) in case of single or multiple number of crews which is a simplified software in Egypt, Lee, Arditi and Son (2013) did an automated study on the probability distribution of project completion times in simulation-based scheduling in Korea, Hsiau and Lin (2009) designed a fuzzy PERT approach to evaluate plant construction project scheduling risk under uncertain resources capacity in Taiwan, Lee (2003) designed a software, Stochastic Project Scheduling Simulation (SPSS), for measuring the probability to complete a project in a certain time specified by the user in Illinois, Chicago, Lee and Shi (2004) did a study on statistical analyses for simulating schedule networks in Illinois, Chicago. It is imperative to note that from the aforementioned studies, none has been conducted with Nigerian context, hence the essence of this work.

Therefore, this study is different from the previous study in terms of the description on the application of a computer based approach in determining the probability of completing a project at a certain due date.

3. Materials and Methods

The method deployed for this study is as depicted in the flowchart shown in figure 1. The algorithm was used in running the iteration-based experiment with the aid of activity durations modeled with PERT. Computing the probability of completing a project at a certain due date consist of: (1) determining the activity durations, (2) carrying out the iteration and compute the events time with a view to determining the critical path in the network, (3) identify the critical (longest) path, and (4) conduct the iteration process by repeating steps 1 to 3, and (5) calculate the mean project duration, standard deviation, variance and the probability of completing the project at a certain due date. However, the computer program will calculate the minimum number of iterations needed based on the given values. If the number of iterations is provided, the system will return an expected time, T_e, variance V^2 as well as the mean project duration.

The three time estimates (optimistic, most-likely, and pessimistic times) are used in PERT. For purposes of comparison, the same three time estimates are used for the activities in the schedule network under iteration. The program will run the iterated results with a view to collecting the results from each point. Hence, the mean project duration and its confidence interval are computed for the samples in the runs. In computing the Z score, the followings are required, that is, the mean, standard deviation and the expected due date of completion of the project. Thereafter, values of the Z-table stored in the program is extracted based on the Z score value and thereafter the percentage is computed.

See flow diagram on next page.

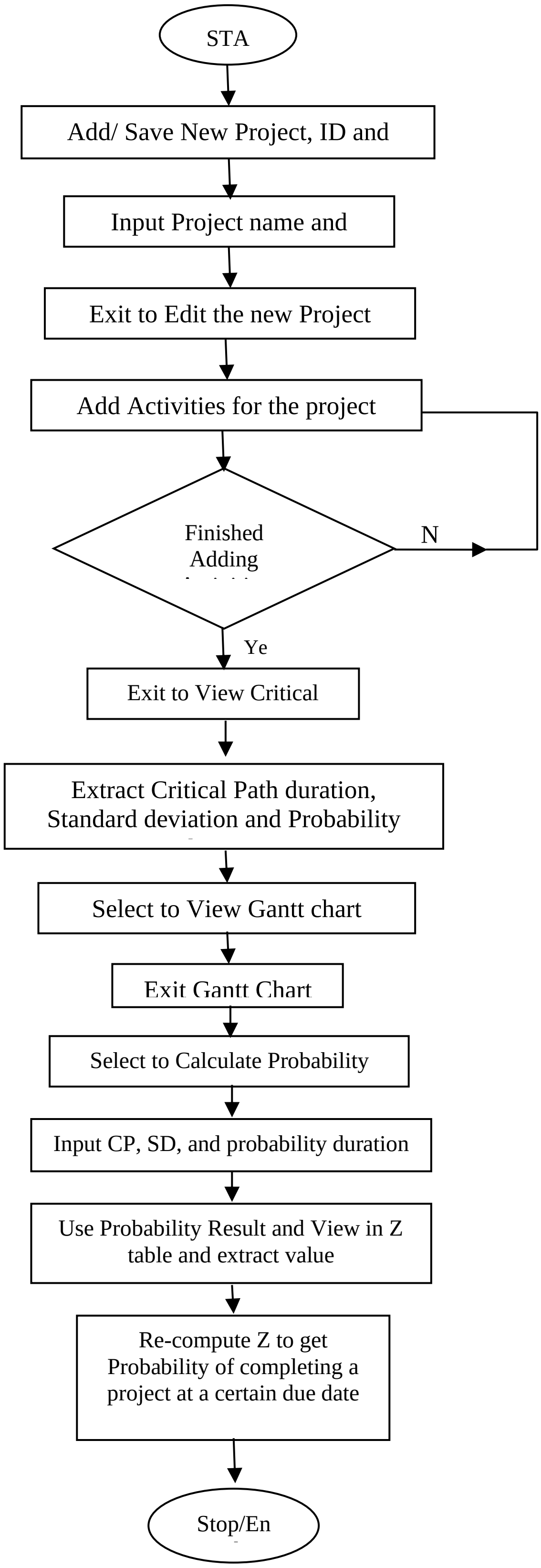

Figure 1: Algorithm of proposed computer-based algorithm

4. Case Study

To demonstrate the procedure for the iteration properly, the network diagram in figure 2 was drawn from the data available in table 1. The network diagram is made up of an activity-on-arrow or activity-on-arc network consisting of 7 nodes and 11 activities. All the eleven (11) activities were assigned the optimistic, most likely and pessimistic time estimates. The durations were used directly in computing the PERT model the activity durations.
Based on the details in tables 1 and figures 1, the network diagram in figures 2 was constructed using the underneath procedure.

Table 1: Data on Activities and events time

Title	Activity	Events time			Te	Variance
		to	tm	tp		
A	1-2	2	4	7	7	0.69
B	1-3	3	5	8	8	0.69
C	1-4	1	3	6	6	0.69
D	1-7	2	3	7	7	0.69
E	2-6	2	5	9	9	1.36
F	3-5	1	2	4	4	0.25
G	3-6	2	2	4	4	0.11
H	3-7	3	3	5	5	0.11
I	4-5	4	2	6	6	0.11
J	5-7	5	5	7	7	0.11
K	6-7	3	2	5	5	0.11

Given that the critical path method (CPM) is very efficient in scheduling projects, its activities become handy in solving an envisaged project management scheduling problem. The earliest start time and the earliest finish time of an activity bearing in mind the absence of any delays occurring anywhere in the project are called the starting time and the finishing time of the activity.

If EST_J is the earliest time an activity J can commence, and EST_J is the earliest time an activity J can end, then the earliest time an activity would end is the earliest time it would commence plus its duration. For instance, if the earliest time activity ‘A’ can commence is say 4 weeks and its duration is 7 weeks, then the earliest A can finish is at 11 weeks. In a nutshell, if G_J is the duration of activity J, then we have

$$EFT_J=EST_J+G_J \text{.................. (1).}$$

In a situation where activity i is the immediate predecessor of activity$j$, then activity$j$ cannot commence until activity i is completed. By the rule of precedence relationship, activity$j$ cannot commence until all of its immediate predecessors have been concluded, hence the earliest time activity j can commence is the highest value of the earliest finish times of its immediate predecessors, that is,

$$EST_J=\max EFT_i \text{.....................(2).}$$

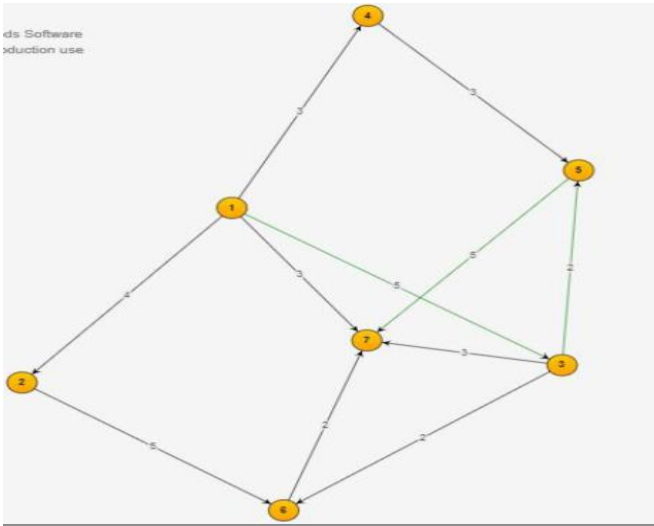

Figure 2: Graphic user interface of the Network diagram

Where the highest value is greater than all immediate predecessors i of activity$j$, we use equations 1 and 2 to find the earliest start time (EST) and earliest finish time (EFT) of all activities bearing in mind that the EST of the initial node is 0. The end product of these computations leads to the realization of the project completion time, which is the earliest start of the ending node. Hence, project completion time will be =EST +$Finish$…………….(3).

As soon as one is closer to the ending node it's an indication that the entire project has been consummated. This process of computation of the EST and EFT via equations 1 through to 3 is usually called the forward pass of the CPM algorithm as propounded by Fulkerson's rule (Akpan, 1987). To be able to compute the critical activities and critical path, two more equations needs to be identified. Let say LSTj and LFTj be the latest time activity j can commence and the latest time it can end without affecting the project completion time. Hence, equation 4 would be LSTj=LFT$j-tj$………(4).

If per adventure activity$j$ is an immediate successor of activity$i$, then activity i must be completed before activity j can commence. If the latest time activity i can end is the lowest value of the latest start times (LST) of all its successors, then LFTI=min LSTj……………….(5)

In a situation where the lowest value is over all immediate successors of$j$ of activity$i$, then equations 4 and 5 will be used to compute the latest start times (LST) and latest finish times (LFT) for all activities, reasons been that the latest finish time for the ending node is the project completion time. This process of computation is known as the backward pass of the CPM algorithm obeying the Fulkerson's rule. The slack also known as float of each activity j is the difference between the latest start time and earliest start time of activity$j$ can be computed. For instance, slack or float of activity j=LSTj−ESTj …………………(6).

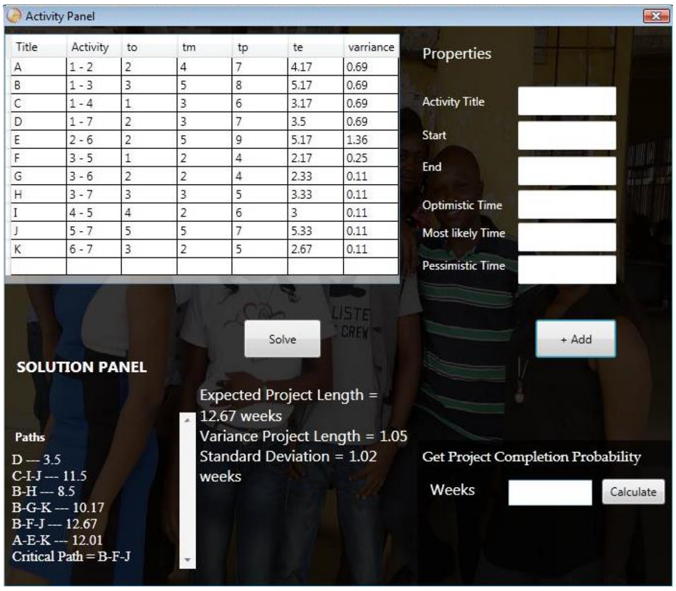

Figure 3: Graphic user interface of the activity panel indicating the solution panel

The reasons underlying the float or slack is that if an activity has a positive slack, then that activity has some free time to play around with, that is, it could commence a little bit later without disrupting the entire project. In a nutshell, its duration could increase by the proportion of its float without jeopardizing the entire project (Akpan & Chizea, 2013). On the other hand, if an activity has a zero float, then any addition in its duration jeopardizes the entire project's life, hence, the critical path is made up of activities with zero floats.

After the definition of the activities and durations in a PERT format, the algorithm presented in figure 1 was used to describe the best iteration that describes the distribution of the PERT procedure.

Using the PERT stochastic method which follows beta distribution, the three time estimates were subsequently deployed in estimating the expected time (mean) T_e and variance of the distribution V. The expected time is the average weight of the three time estimates namely (optimistic T_a, pessimistic T_b and the most likely time T_m). With this in place it now becomes clear on how to know to estimate the probability of completing the envisaged scheduled date. Table 1 depicts the results and the variations in the estimates of each activity. Using the formulae: expected time (mean)

$$T_e \quad \frac{a+4m+b}{6} \quad \ldots\ldots\ldots\ldots\ldots(7)$$

and

Variance, V

$$\left(\frac{b-a}{6}\right)^2 \quad \ldots\ldots\ldots\ldots\ldots(8)$$

The results of PERT and simulation using the computer approach are represented in figures 3. This information as depicted in the solution panel includes the means (12.67 weeks), standard deviations (1.02 weeks), variance (1.05 weeks) and the various paths emanating from the iteration. The paths includes; D 3.5 weeks, C-I-J 11.5 weeks, B-H 8.5 weeks, B-G-K 10.17 weeks, B-F-J 12.67 weeks and A-E-K 12.01 weeks.

In computing the probability that the project will be completed assuming a due date of (15 weeks) as shown in figures 4 from the solution panel (i.e. the estimated completion + standard deviation). Therefore, the probability of meeting the deadline given the approximations using the normal distribution is; 0.9887. Thus, there is 98.87% chance that the critical path will be completed in less than 15 weeks. The solution panel in figures 4 shows the entire result once the calculate tab is clicked.

The computerization of the iteration process was carried out using the PERT scheduling method. Figure 2 shows the network diagram of the various activities in the project. The activity panel in figure 3 shows the graphic user interface showing the various activities for the project as well as the computation of expected time, T_e, and variance, V of activities A to K.

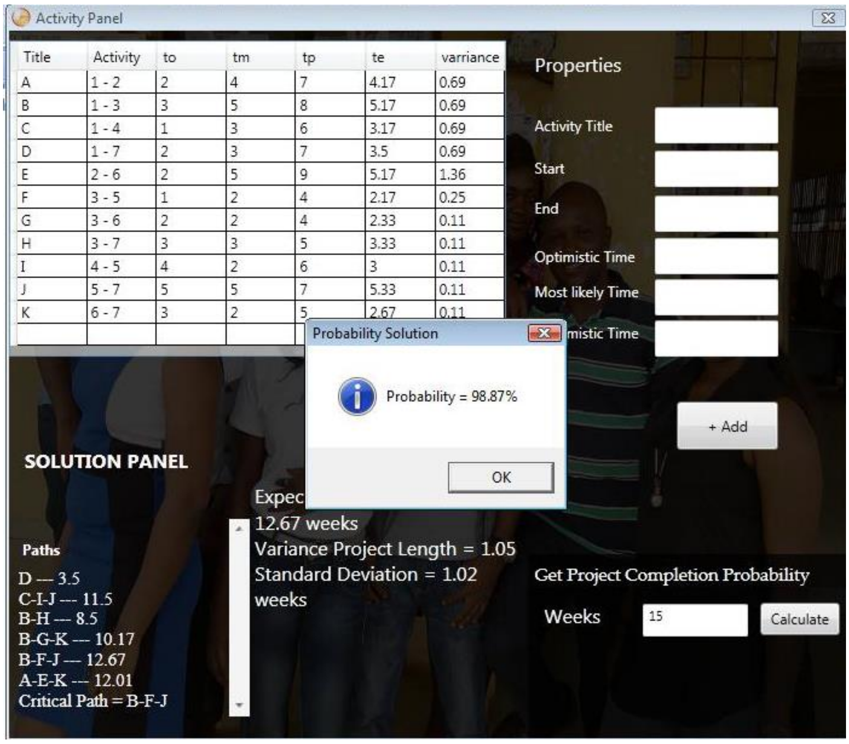

Figure 4: Graphic user interface of the activity panel showing the probability value

5. Conclusions

The idea behind the development this program is not only to determine the probability of completing a project at a certain due date alone, but it is also designed to enable project practitioners the ability to assign resources and manage any risky tendency by determining the completion of a project in the time specified by the click of a button. The computer based approach for determining the probability of completing a project at a certain due date can aid in supporting construction scheduling by providing a more accurate prediction of the due/completion time. The template has the ability to verify estimated project completion time viz its probability to achieve planned value of the project. The system provides various schedules for a project so that the user can compare the differences of the schedules and estimate the potential schedule involved in the project.

In a nut shell, the system can forecast the probability of completing a project at a given due date; determine an appropriate number of iterations for a given project; determine the probability of completing a project at a given level of confidence.

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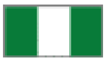

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