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Comparison between Deterministic and Stochastic Time Estimating Techniques

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ABSTRACT: This paper started with a brief history of the two main techniques (CPM and PERT) used in estimating project durations. It then discussed the differences between the two techniques. Next, a table with quantitative data and graphical diagrams were used to illustrate estimation of project durations using the two techniques cited. In the process, the critical path and the tasks that determine the estimated duration of the project were identified. Besides, the level of risk in completing the project before its required duration was calculated. Finally, recommendations as to when it is appropriate to use one or the other technique were provided. In project management, time is one of the variables which provide inputs for use in project scheduling. There are two time dimensions that influence time management: actual time and calendar time. There are a number of available estimating techniques. Among the various techniques, two techniques are most commonly used in the time estimation process: deterministic (single-point) estimating technique and stochastic (three-points) estimating technique. Traditionally, however, most project management practitioners use one or the other as their principal time estimating technique. This paper analyzed the two techniques and determined as have others that no one technique is appropriate in every estimating situation. It recommended as confirmed by others that CPM should be used in situations in which the activity times are predictable (deterministic) while PERT techniques should be used in situations in which activity times are unpredictable (probabilistic). In projects that allow for a longer period of time for completion and which are difficult to estimate, PERT provides a more accurate estimate. On the other hand, for conventional projects with predictable activities and tasks, CPM is a suitable choice. Therefore, on the whole, it is concluded that PERT provides a better estimating model than CPM.

KEYWORDS: PERT, CPM, single-point estimate, three-point estimate, project scheduling, critical path.

I. INTRODUCTION

In project management, time estimation is a natural outgrowth of the Work breakdown structure (WBS) process. However, before the project team estimates how long it will take in actual time and in calendar time to complete the project, two things need to be ascertained: the work necessary to complete the project should be defined and the resources (persons, including their types and quantities) who will do the work should be determined. These two estimates combined with estimates about material and equipment needs; overhead costs; wages and benefits cost estimates; and reserve amounts serve as inputs to the cost estimation and the project budget determination.

Nevertheless, this study focuses on project time estimates which provide the inputs for use in project scheduling. Hartley (2009) suggested a number of available estimating techniques. Among others are the followings:

- analogous estimating (historical)
- using resource unit rates
- bottom-up estimating
- parametric estimating (metric or value)
- educated (or otherwise) guess
- wide band Delphi (a weighted average of an optimistic, pessimistic, and most probable estimates)

This study is concerned with the first and last bullet point items in the above list. These are the two most prominent techniques used in practice and cited in the literature. In this respect, traditionally, the two time estimating techniques commonly used are the single-point estimates and three-point estimates also referred to as the deterministic and stochastic estimating techniques respectively (Gido& Clements, 2015). Schuyler (1994) postulates that CPM and PERT are the classic modeling techniques for controlling project schedule. And that both identify the deterministic critical path. Each of these techniques is used under different conditions. In any case, most project teams use only a single-point estimate in the duration estimating process. That said, the objectives of this study are therefore to analyze these two project time estimating techniques in order to:

- provide historical background of the two techniques.
- discuss differences between the two techniques.
- calculate a project's estimated duration and determine its critical path(s) and critical tasks using both single-point and three-point estimating techniques on the same project.
- Determine the probability of completing the project before its required completion time.
- Identify the better technique between a single-point and three-point estimation methods.
- Formulate recommendations on project scheduling for practice

This study is expected to benefit project management practice in that currently, many organizations by default, use only one type of time estimating technique. This creates a problem because no one estimating technique is appropriate in every situation. Developing a realistic schedule is one of the most important jobs in project management. Sullivan (1978) supports this view saying that a major event in history of management science occurred twenty years ago when network analysis was introduced as a tool for planning, scheduling, and controlling large scale projects. Yet, inadequate attention is given to this area in project management practice. Using the wrong estimating technique is partly to blame for project delays and cost overruns. Meyer (2016) emphasizes this point, stressing that estimation is at the heart of most project disciplines, and project cost and time overruns can often be traced back to inaccurate estimates. Swanson (2011) extends this concern when she expressed that an underlying truth is that misestimates for major projects are all too frequent. She cited a study of 258 projects in 20 countries which showed that nine out of 10 projects have cost overruns. Although Swanson's comments are about cost, they are equally applicable to time estimates. She advises that project managers can take specific steps to minimize estimating errors and avoid derailed projects. Further, Markel and Downs (2014) caution that unreliable estimates of project effort can lead to a failure to deliver and a lasting negative perception and lack of confidence among leadership, customers, and stakeholders.

Given the above background, it is expected that using quantitative data, tables, and graphical charts, the stated objectives of the study will be achieved and the following research questions will be answered:

- Why use a range of likely values in PERT?
- Does a single-point estimate produce a reasonable estimate of duration?
- Can a project manager determine how likely it is that the required duration can be met?

Despite the popularity and importance of the two techniques under consideration, their analysis on the same project with a view to ascertaining which technique provides better estimates is lacking in the literature. This study addresses this gap. The study will use both the deterministic and stochastic estimating techniques on the same project in order to highlight the strengths and weaknesses of each technique and then will identify the better method.
In order to appreciate the practical implications of scheduling technique in project management, it is felt necessary to gain an insight into the history of activity and project scheduling techniques. It would be challenging to understand activity and project scheduling without knowing the historical context of the two techniques and how they found their way into the mainstream discourse and practice in project management. This view is shared by Maylor (2010), proposing that in order to understand the shortcomings of the techniques and search for potential solutions, you must first understand the [history of the] techniques themselves. It should be noted though, that Maylor expressed some reservations about the effectiveness of the techniques. He provided justification for his contention that the techniques of CPM and PERT do not work. The author of this work, however, is a believer in the techniques. Be that as it may, this paper will start with a brief history of the two main techniques used in estimating project durations. It will then discuss the differences between the two techniques. Next, a table containing quantitative data and graphical diagrams will be used to illustrate estimation of project durations using the two techniques cited above. In the process, the critical path and the tasks that determine the estimated duration of the project will be identified. Besides, the level of risk in completing the project before its required completion time will be determined. Finally, recommendations as to when it is appropriate to use one or the other technique will be provided.

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A. A brief history of PERT and CPM

Much has been written about the beginnings of modern project management. No history of modern project management would be complete without a history of the Program evaluation and review technique (PERT) and the Critical Path Method (CPM). Kerzner (2013) observes that PERT was originally developed in 1958 and 1959 to meet the needs of the "age of massive engineering" where the techniques of Taylor and Gantt were inapplicable. In this respect, Archibald (1987) comments that the U.S. Navy Special Projects Office working with the consulting firm of Booze, Allen, and Hamilton developed the basic concepts of PERT. He asserts that the objective of the program was to create a management method for handling the hundreds of contractors who would be designing, constructing, and testing the POLARIS submarine and missiles systems. This effort occurred at about the same time as the DuPont Company initiated a similar technique known as the critical path method (CPM) which produced the Time/Cost Trade-off Model. Parallel to this was the work that produced the precedence diagramming method (PDM) to network planning. In the early 1959, the U.S. Navy laid the PERT requirements on the POLARIS to the contractors involved. At that time, Lockheed was the missile system integration contractor. Archibald (a pioneer in the development of PERT) believes that PERT/CPM/PDM (i.e., network planning and critical path scheduling) were one generic technique. Along similar line of thinking, Schuyler (1994) states that PERT is CPM with the substitution of probability distribution for activity completion times.

Archibald's sentiment was echoed by Meredith, Mantel, and Shafer (2016) when they observed that the use of PERT has decreased sharply in recent years because a large majority of project management software generates CPM networks. And that the two methods are quite similar and are often combined for educational presentation. Besides, they decry some writers who insist on a strict differentiation between PERT and CPM. This, they dismiss as unnecessary. They emphasize that onecan estimate probabilistic CPM times, and can "crash" PERT networks. The author of this article shares these orientations. Billows (2016) on the other hand, asserts that the three-point estimating technique comes from the NASA space program. Even though today, the term PDM is often used as a generic term to refer to both PERT and CPM (Gido& Clements, 2015), it has not always been that way. The history and importance of PERT and CPM in modern day project management practice lends them the legitimacy for these techniques to be referred to as individual scheduling techniques.
Kloppenborg (2015), writing about the historical development of project schedules articulated that two project scheduling methods were developed in the 1950s: PERT and CPM. According to Kloppenborg (*ibid*.), the CPM is a method used to estimate the minimum project duration and determine the amount of scheduling flexibility on the logical network paths within the schedule model. PERT on the other hand, was developed because of the uncertainty involving the duration and concern about unproven technology with regard to the development of the Polaris Weapons Systems by the U.S. Navy. PERT enabled project managers to estimate the most likely amount of time needed to complete a project, and the level of confidence in completing it in a particular time. He maintains that both CPM and PERT were founded on the concepts still in place today of identifying activities, determining their logical order, and estimating the duration for each. As a result, networks representing the activities were developed and the schedule calculated. However, each of the techniques also boasted a capability that the other did not possess. CPM was developed by DuPont as already observed by others earlier. Planners usingCPM, Kloppenborg(2015) maintains, estimated the time for eachindividual workactivity using a single time estimate. This is a different method from that of PERT which uses three time estimates.

B. Differences between deterministic and stochastic estimating techniques

While PERT and CPM have a great deal in common, the two techniques differ in many respects (Emelda, 2011). As network diagrams, both are graphical representations of activities with their relationships. They are both used to develop a schedule and to do schedule calculations to determine critical and near-critical paths (Wajid Rai, 2016). Emelda (*op. cit*.) expresses that CPM is a technique that is used in projects that have predictable activities and tasks such as in construction projects, adding that it is a deterministic tool …. PERT, on the other hand, Emelda (*op. cit.*) continues, is used in projects that have unpredictable tasks and activities such as in research and development projects, that it utilizes three estimates of the time to complete the project …; adding that it is a probabilistic tool using several

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estimates to determine the time completion of the project and to control the activities involved in the project so that it will be completed faster and at a lower cost. Meredith, Mantel, and Shafer (*2016*) also confirm that PERT was

originally developed for research and development projects while CPM was developed for construction projects. Today, however, the application of the two scheduling techniques has wide spread use in a variety of industry and application areas. Eli Lilly company, for example, uses CPM for its research projects even though CPM was originally developed for construction projects.
Emelda (*op. cit.*) suggests that in projects that allow for a longer period of time for completion and which are difficult to estimate like in research, PERT is suitable. And that for conventional projects with predictable activities and tasks, CPM is suitable. Similar sentiments are echoed by others in different ways. The Project Management Institute (PMI, PMBOK® Guide, 2013) for example, defines PERT as a technique for estimating that applies a weighted average of optimistic, pessimistic, and most likely estimates when there is uncertainty with the individual activity estimates. PMI believes that the accuracy of activity duration estimates can be improved by considering estimation uncertainty and risk. PMI further states that PDM is a method used in Critical Path Methodology (CPM) for constructing a project schedule network diagram that uses boxes or rectangles, referred to as nodes, to represent activities and connects them with arrows that show the logical relationships that exists between them. This supports others' view that the PDM or CPM technique is also called Activity-On-Node (AON), and is the method use by most project management software packages. Others assert that CPM is activity-oriented technique while PERT is event-oriented technique. Some also equate PERT with the ADM (Arrow Diagramming Method or Activity on Arrow (AOA) while they equate CPM or PDM with Activity on Node (AON). The following table (1) provides a three-column information highlighting some of the differences between PERT and CPM.

TABLE 1: Differences Between PERT and CPM

BASIC	PERT	CPM
Relationship Type	Uses only FS	Uses all four types
Orientation	Event-oriented	Activity-oriented
Activity	Shown on arrows	Shown in nodes (rectangles)
Technique	Stochastic (Probabilistic)	Deterministic
Focuses on	Time	Time-cost trade-off
Management of	Unpredictable activities	Predictable activities
*Crashing concept	Not applicable	Applicable
Estimates	Three-time estimates	Single-time estimates
Dummy activities	Uses dummies	Does not use dummies
Triangular and Beta Distribution	Possible	Not possible

*A note about the item in table 1 with asterisk is worth expanding on. The idea that crashing is not applicable to PERT is debatable. Some scholars and practitioners reject that idea. Johnson and Schou (1990) for example, contend that PERT is a commonly used tool in project management in which a technique called crashing is frequently used to expedite a project. They assert that there are two types of PERT networks – deterministic (where the path through the network is predetermined) and stochastic (where the path is based on some probability distribution). They postulate that deterministic networks are characterized by single time estimates; or in order words, time estimates are treated as though there is no uncertainty in their value. Johnson and Schou's arguments are convincing enough that other scholars have adopted similar approaches. For example, Burke (2009); Brown and Hyer (2010); Lockyer and Gordon (2005); and Meredith, Mantel, and Shafer (2016) have used similar approaches in their presentations. The author of this article shares these sentiments and has adopted these techniques in this paper.

C. Further review of deterministic and stochastic estimating techniques

Karns and Swanson (1973) allude that while both CPM and PERT have much in common, they were independently derived and are based on different concepts. Both techniques, they continue, define the duration of a project and the relationships among the project's component activities. They argue that CPM uses a single deterministic time estimate to emphasize minimum project costs while downgrading consideration of time constraints. PERT, on the other hand,

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they add, uses three time estimates to define a probability of activity times which emphasize minimum project duration while downgrading consideration of cost constraints. Karns and Swanson (1973) assertions provide the answers to question one of this study.
MacLeod and Peterson (1996) corroborate Karns's and Swanson's observations. In MacLeod and Peterson's view, CPM and PERT share common goals of setting a project completion time and determining which activities require particular attention to avoid delaying project completion. They maintain that beyond that, the two techniques differ in the information required and the ability to predict completion. For Haga and Marold (2004), the traditional method of crashing PERT networks ignores the stochastic nature of activity completion times, reducing the stochastic model to a deterministic CPM model and simply using activity time means in calculations. The author of this study adopts this method to illustrate the two scheduling techniques under consideration. This is in line with objective three of this study as both techniques are illustrated with the same project data (for the normal value). Next, the two scheduling techniques are used to illustrate time estimating techniques using both deterministic (CPM) and stochastic (PERT) methods with quantitative data, tables, and network diagrams.
Given the information in table 2, a network diagram is constructed; using the two-pass (forward and backward) process, the earliest start (ES), earliest finish (EF), latest start (LS), and latest finish (LF) are determined; estimated duration of the project is calculated; and the critical path and critical activities are determined. This is the single-point technique stated as part of bullet point 3 of this study's objectives.

Table 2: Precedence Table with CPM Time Estimates

Activity	*Immediate Predecessor(s)*	*Estimated Activity Duration (in days)*
A	-	*2*
B	*A*	*4*
C	*A*	*6*
D	*B*	*5*
E	*C,D*	*8*
F	*D*	*7*
G	*C*	*5*
H	*E,F,G*	*3*

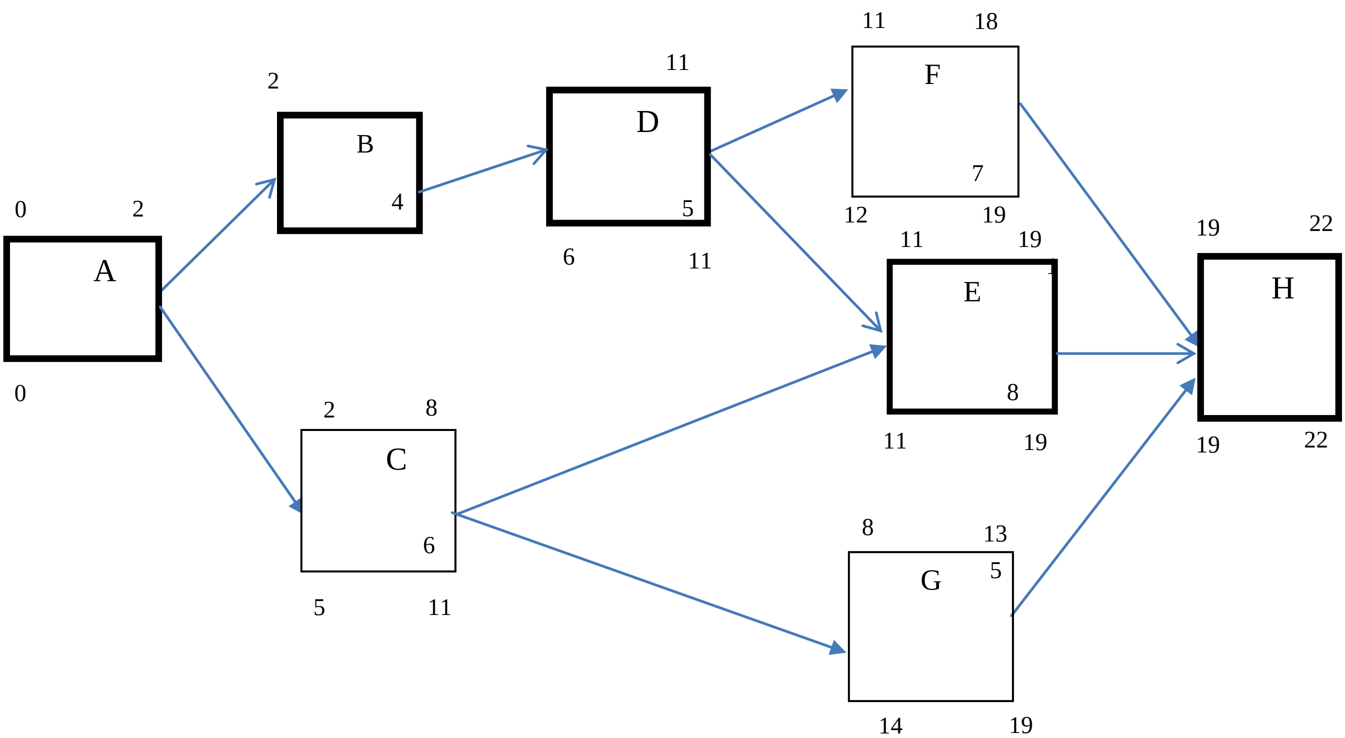

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Figure 1 CPM or AON Network Diagram

Legend

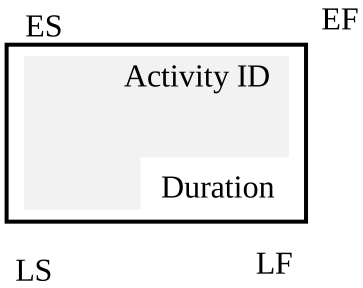

Figure 1 is a network diagram constructed from the schedule in table 2.

Figure 1 is a simple four paths, eight activities network diagram to offer a visual illustration of the critical path algorithm. Next, using the critical path algorithm, the ES, EF, LS, LF activities are identified. Thereafter, the estimated duration of the project, TF, and FF are calculated. Finally, the critical path and critical activities are identified.
Following is the detailed results from the network analysis.

II. DISCUSSION AND ANALYSIS OF CPM TECHNIQUE

The ES of a successor activity is the EF of its immediate predecessor activity. However, if the activity is a merge, then, its ES is the predecessor(s) EF with the larger value using a forward pass process. The earliest times begin with the start activity whose ES is usually 0. The EF of an activity is the sum of its ES and its estimated duration. The latest times are calculated using a backward pass process. The backward pass starts with the last activity on the network whose LF is the duration of the EF of the last activity or the required completion time of the project if this is given. In this respect, the LS of an activity is the LF of the activity minus its duration. The LF of a predecessor activity is the LS of its successor activity. However, if the predecessor activity is a burst, then, its LF is the lower value of its immediate successor(s) LS.
In figure 1, the four paths are:
Path 1: A-B-D-F-H = 2+4+5+7+3 = 21 days
Path 2: A-B-D-E-H = 2+4+5+8+3 = 22 days
Path 3: A-C-E-H = 2+6+8+3 = 19 days
Path 4: A-C-G-H = 2+6+5+3 = 16 days

Looking at the four paths, it is obvious that Path 2: A-B-D-E-H is the critical path. This is because, it has the longest duration (22 days). Therefore, this project is estimated to be complete in 22 days and the critical activities are activities ABDEH. In this network, the critical activities have zero slack and are indicated in figure 1 with borders thicker than the non-critical activities. Slack is also referred to as float and it is calculated as LF-EF or LS – ES. The two methods should always give the same result. This is for total float (TF) or total slack (TS). There is also free float (FF or free slack (FS) which is calculated as ES of a successor activity – the EF of its predecessor or the ES – its predecessor's ES – Duration. Using these formulas, all the critical path activities have zero slacks. However, the non-critical activities have slacks or floats. For example, activities C, TF = 3; F, TF = 1; and G, TF = 6. Incidentally, activities F and G, FF is the same as their TF. However, for activity C, its FF is 0 even though its TF is 3 days. Given these data, the AON (Activity-on-Node) network in figure 1 is based on the project detail in table 2.

III. DISCUSSION AND ANALYSIS OF PERT TECHNIQUE

Next, the project that was planned for the CPM application shown in table 2 is further examined. For PERT application, however, the times estimated for each of the activities are expanded to include an optimistic time and a pessimistic time element as shown in table 3 with the calculation of expected time estimate, standard deviation, and variance for each

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activity. The results are shown in table 3. This is in line with part of objective three of the study, illustrating the two scheduling techniques with the same project.

Table 3: PERT Time Estimates with Expected Times ($t_{(e)}$), *Standard Deviations (s),* and Variances (s^2)

	Time estimates (days)					
Activity	$t_{(o)}$	$t_{(m)}$	$t_{(p)}$	$t_{(e)}$	*s*	s^2
A	*1*	*2*	*14*	*3.8*	*2.17*	*4.70*
B	*2*	*4*	*10*	*4.7*	*1.33*	*1.77*
C	*3*	*6*	*14*	*6.8*	*1.83*	*3.35*
D	*2*	*5*	*13*	*5.8*	*1.83*	*3.35*
E	*5*	*8*	*15*	*8.7*	*1.67*	*2.79*
F	*4*	*7*	*18*	*8.3*	*2.33*	*5.43*
G	*3*	*5*	*11*	*5.7*	*1.33*	*1.77*
H	*2*	*3*	*9*	*3.8*	*1.17*	*1.37*

In table 3, PERT uses the following formulas to calculate activity times:
For the expected time estimates of each activity, $t_{(e)} = (t_{(o)} + 4\ t_{(m)} + t_{(p)\ )/6}$
For the standard deviation of each activity, $s\ = (t_{(p)} - t_{(o)\ )/6}$
For the variance of each activity, $s^2 = [(t_{(p)} - t_{(o)\ )/6]}^2$

Therefore, the standard deviation could also be calculated as: $\sigma = \sqrt{\sigma^2}$

It should be noted that these formulas are based on the beta statistical distribution. Besides, optimistic and pessimistic times are defined as the durations that represent 99 percent certainty. In other words the actual duration of an activity will be less than the optimistic or greater than the pessimistic only one percent of the time. These three formulas are used in calculating the $t_{(e),}$ *s*, and s^2 columns in table 3.Next, the s, s ^{2}, $T_{(E)}$ for each path will be calculated. Since the single time and three time estimates are based on the same project network, the same paths are used here.

- Path 1: A-B-D-F-H = 3.8+4.7+5.8+8.3+3.8 = 26.4 = 26 days (rounded)
- Path 2: A-B-D-E-H = 3.8+4.7+5.8+8.7+3.8 = 26.8 = 27 days (rounded)
- Path 3: A-C-E-H = 3.8+6.8+8.7+3.8 = 23.1 = 23 days (rounded)
- Path 4: A-C-G-H = 3.8+6.8+5.7+3.8 = 20.1 = 20 days (rounded)

Again, the critical path still remains the same as path 2: A-B-D-E-H as highlighted in figures 1 and 2. However, all the paths have increased the expected time estimates in the PERT table (3) and figure (2). Forthe critical path, it has increased from 22 days with the single time estimating model to 27 days with the PERT estimating model. This means that the project's estimated completion duration is 27 day with the PERT schedule. A closer examination of figure 2 reveals that activities C, F, and G TFs are 3.7 days, 0.4 days, and 6.7 days respectively. Here, incidentally, the FFs are the same as the TFs for all the non-critical activities.

Figure 2 is a network diagram constructed from the schedule in table 3 (i.e., the PERT table). It should be noted that in figure 2, only the computed expected time estimates for each activity is shown. Since these values are derived from their respective three times estimates, the three times estimates are not shown on the PERT network diagram. However, PERT's $t_{(e)}$ for each activity is shown in the network and $t_{(o),}t_{(m)}$, and $t_{(p}$ shown in the table. Since both the single point estimating and three point estimating models highlight the same path as the critical one, albeit, different durations, what else does PERT offer that the single point estimate does not offer? To begin with, the single time estimating technique ignores the presence of uncertainty which is inevitable in activity time estimates. PERT incorporates uncertainty in its estimating models. Uncertainty is discussed following the PERT network diagram.

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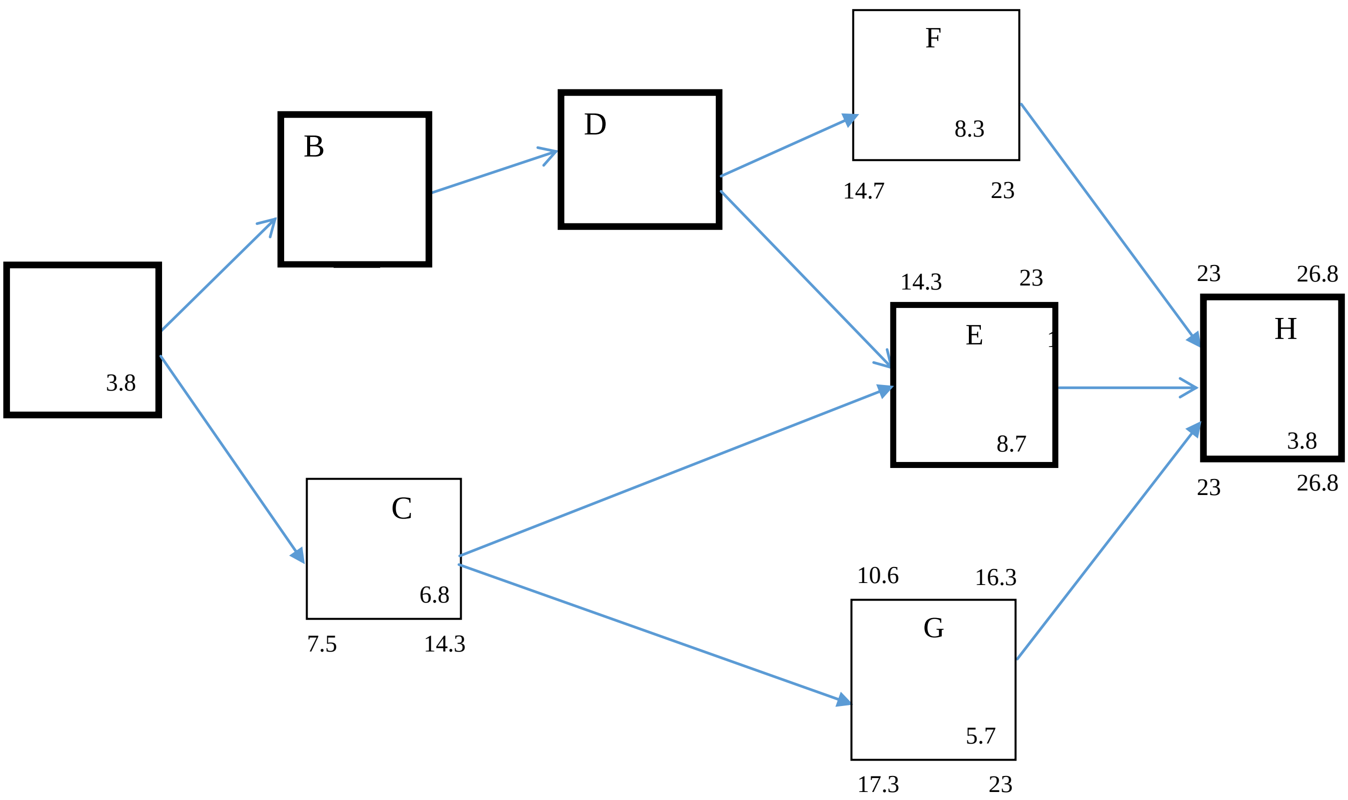
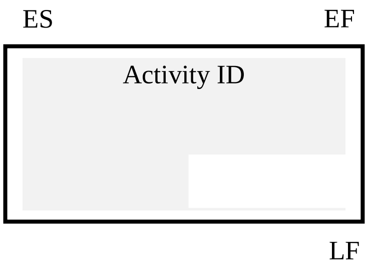


Figure 2 PERT AON Network Diagram

Legend on Figure 2



The chance of completing a project within a given time period can be calculated. The variance of a set of activities is equal to the sum of the variances of the individual activities comprising the set. These are the variances of activities on the critical path (path 2) in this case. Then the probability of meeting a particular project duration can be calculated as:

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$Z = D - T_{(E)} / \sqrt{s^2}$

where

Z = number of standard deviations of a normal distribution
D = desired (targeted) project completion time
$T_{(E)}$ *= estimated path completion time (sum of the* $t_{(e)s}$ on the critical path)
$\sqrt{s^2}$ *= standard deviation for the path completion time.*

Since $s = \sqrt{s^2}$, *it then follows that:*

s Path 2: A-B-D-E-H = $\sqrt{4.70+1.77+3.35+2.79+1.37} = \sqrt{13.98}$ *days = 3.74.*

This completes objective three of the study.

IV. DETERMINING THE PROBABILITY OF COMPLETING THE PROJECT BEFORE ITS REQUIRED COMPLETION TIME

The probability of completing the project within 28 days would be:

$Z = D - T_{(E)} / \sqrt{s^2} = 28-27/3.74 = 0.267$

Using a Z-table reveals that a z value of 0.267 corresponds to a probability of 0.9962. Therefore, the probability that path A-B-D-E-H will be completed within 28 days is 99.6%. Now, let us also find the probability of completing this project with 23 days.

$Z = 23-27/3.74 = -1.07$

Since the Z-value is negative, when determining the probability of occurrence, we need to first use the Z-table to find the probability of the absolute value of Z. Then, we calculate the probability of the negative Z-value. Using a Z-table, a Z-value of 1.07 corresponds to a probability of 0.3577 or 35.8%. Because the actual Z-value is negative, the probability that path A-B-D-E-H will be completed within 23 days is 1 – 0.3577 = 0.6423 or about 64.2%. Since 23 days is closer to 22 days as highlighted in figure 1 than 28 days, there will be less chance of completing the project within 22 days than within 27 days as highlighted in figure 2 (i.e., 64.2% versus 99.6%). This means that PERT estimates provide a better prediction than CPM estimates. This completes objective four of this study and provides the answer for question three of the study.

In light of the above results, it is obvious that PERT estimating technique provides better activity estimates and hence project estimates than the single time estimating technique. Besides, with single time estimates, it is not possible to determine the probability of completing the project within a given time period. The single time estimate does not allow the calculation of standard deviations without which probabilities cannot be determined. This confirms the superiority of PERT over CPM as project activity scheduling techniques and completes answers to question two. This also concludes objective five of this study.

V. CONCLUSION AND RECOMMENDATIONS

There is no one estimating technique that is appropriate in all situations and conditions. With CPM using a one-time estimate, one cannot determine the standard deviation and the probability of completing the project earlier or later than its completion deadline. In any case, if the uncertainty of schedule duration is minimal or the activities and tasks are predictable and the project is of short duration, one should choose to use CPM in the scheduling process. However, with projects for which there is a high degree of uncertainty about the estimated durations for activities, three-time estimates should be considered. These times are the optimistic time estimate, most likely time estimate, and pessimistic time estimate. Furthermore, PERT enables project managers to estimate the most likely amount of time needed to

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complete a project, and the level of confidence in completing it in a particular time. PERT also has the advantage of its extensive planning. Besides, interdependencies and problems that are not obvious with other scheduling techniques are easily revealed with PERT. By this, PERT can point to where the greatest effort should be directed at in order to keep the project on schedule. CPM schedules activities as if there is no uncertainty in the value.

Given the analyses and results of the two techniques, it is obvious that PERT provides a better time estimating model than CPM model. Therefore, practitioners should weigh their options in choosing a scheduling technique. This should be informed by the various conditions in which the estimates are made as highlighted above.

REFERENCES

[1] *A Guide to the Project Management Body of Knowledge (PMBOK® Guide)*, 5th ed. Newtown Square, PA: Project Management Institute, 2013.
[2] Archibald, R. D. (1987). The history of modern project management. Key milestones in the early PERT/CPM/PDM days: how did we get here where do we go? *Project Management Journal*, 18(4), 29-31.
[3] Billows, D. (2016). *Estimating Techniques, Leading project teams*. Retrieved May 31st 2017, from http://4pm.com/3-point-estimating/.
[4] Brown, A. K. and Hyer, N. L. (2010). *Managing Projects: A Team-Based Approach*. New York: McGraw-Hill.
[5] Burke, R. (2009). *Project Management Techniques*. Hong Kong, China: Burke Publishing.
[6] Emelda, M. (2011). *Differences Between CPM and PERT*. Retrieved April 15th 2017, from http://www.differencesbetween.net/business/management-business/differences-between-cpm-and-pert/
[7] Gido, J. and Clements, J. P. (2015). *Successful Project Management*, 6e. Stamford, CT, USA: Cengage Learning.
[8] Haga, W. A. and Marold, K. A. (2004). A simulation approach to the PERT/CPM time-cost trade-off problem. *Project Management Journal*, 35(2), 31-37.
[9] Hartley, S. (2009). *Project Management: Principles, Processes, and Practice*, 2e. Frenchs Forest NSW 2086, Australia: Pearson Education.
[10] Johnson, G. A. and Schou, C. D. (1990). Expediting projects in PERT with stochastic time estimates. *Project Management Journal*, 21(2), 29-34.
[11] Lockyer, K. and Gordon, J. (2005). *Project Management and Project Network Techniques*, 7e. Essex CM20, England: Pearson Education Limited.
[12] Kerzner, H. (2013). *Project Management: A Systems Approach to Planning, Scheduling, and Controlling*, 11e. Hoboken, New Jersey: John Wiley & Sons.
[13] Kloppenborg, T. J. (2015). *Contemporary Project Management: Organize/Plan/Perform*, 3e. Stamford, CT, USA: Cengage Learning.
[14] MacLeod, K. R. and Peterson, P. F. (1996). Estimating the trade-off between resource allocation and probability of on-time completion in project management. *Project Management Journal*, 27(1), 26-33.
[15] Markel, J. and Down, K. (2014). *Estimating as a capability: The business case for estimation competency*. Paper presented at PMI® Global Congress2014 – North America, Phoenix, AZ. Newtown Square, PA: Project Management Institute.
[16] Maylor, H. (2010). *Project Management*, 4e. Essex CM20 2JE, England: Pearson Education.
[17] Meredith, J. R., Mantel, S. J., and Shafer, S. M. (2016). *Project Management: A Managrial Approach*, 9e. Hoboken, NJ: John Wiley & Sons.
[18] Meyer, W.G. (2016). *Estimating: the science of uncertainty*. Paper presented at PMI® Global Congress 2016 – EMEA, Barcelona, Spain. Newtown Square, PA: Project Management Institute.
[19] Schuyler, J. R. (1994). Decision analysis in projects: Other probabilistic techniques. *PM Network*, 8(4), 20-24.
[20] Sullivan,R. S. (1978). Alternatives to PERT for stochastic network analysis. *Project Management Quarterly*, 9(4), 13-18.
[21] Swanson, S. A (2011). Estimating errors. PM Network, 25(10) 62-67.
[22] Wajid Rai, M.A. (2016). *Types of Network Diagrams*. CEM Solutions. Retrieved April 10th 2017 from, http:censolutions.org/types-of-network-diagrams/