Cost Estimation of Accelerating a Project

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Abstract – *In implementing a project it may become necessary to crash or accelerate the process due to various demands. This may be due to delays in* ***implementation.*** *It also becomes necessary to accelerate the project as a requirement at the top executive level. Very often the need is to complete the remaining activates in a shorter time period.*

For this purpose additional resources may be required of which the cost has to be estimated to be provided to the chief executives. This may be done arbitrarily thus creating more issues on the management of the project.

This paper proposes a novel way the above cost could be estimated based on heuristic principles of the Critical Path Analysis (C.P.A) and Project Evaluation Review Technique (P.E.R.T)

It is a common feature in PERT to estimate the duration (d) of an activity, to use the heuristic method of determining optimistic (a), moderate (b) and pessimistic (c) time durations and based on Simpson's rule take d = (a +4b + c)/6.

In the present paper a modified PERT technique is proposed to estimate the cost that will be required to accelerate the remaining part of the project at some stage of implementation. To accelerate, for each critical activity of the remaining portion of a project, a quantity called cost slope

$$cs = \frac{(crash\ cost - normal\ cost)}{(normal\ duration - crash\ duration)}$$

has to be calculated and accelerating is carried out starting with the activity having the minimum cost slope. At present there appears to be no method for evaluating the above two costs and the minimum crash duration of any activity, apart from the estimates made by planner based on his/her experience.

In this paper it is proposed to make use of the PERT technique in estimating cost values too,

This method will also allow the managers to monitor the time and cost factors at stages of implementation of any project, a matter vital in project management.

Keywords: Critical Path Analysis, Project Evaluation *Review Technique,* Crashing Projects

I. INTRODUCTION

Critical Path Analysis (CPA) and its counterpart Program Evaluation and Review Technique (PERT) had been well known and documented from late fifties (Fazan 1959) with others such as (Kelly 1960), (Baker 1997) and (Taha 2012) and others adding a variety of tools and innovations to the subject. AS such it is not the intention of this paper to go into all the details of the knowledge area. The literature survey conducted for this research indicates many aspects of using PERT, ref (Kelley & Morgan, 1954, Theyer 1996, Hendrikson 2008). However, the authors did not come across any findings on how cost estimations could be made to crash projects.

Basically a projected is divided into components or activities and is modeled as a network of nodes and arcs. Nodes represent stages between activities which are represented by arcs. Activities are unidirectional starting from a "Start" going up to an "End" node. The main objective of both CPA and PERT is to determine the total duration (D) for the project and this to identify the critical path (S) which is the chain of activities delay of any of which will cause the total delay of the project.

The focus of the paper is to determine strategies to overcome any or both the following issues that may arise from implementing the project. They are

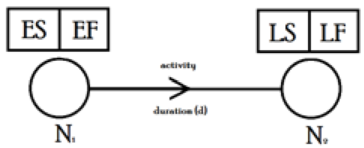
The project may be carried out with any delays of critical activities; but for some reason the senior management may need to expedite the project in time < D.

The project may have already got late and now required to take steps to complete it in time D.

Both these operations call for crashing or accelerating the project and resources have to be added to the crash the balance project and it the objective of the paper to identify strategies to estimate the additional financial resources required for this purpose.

Features that are required to describe estimation of additional resources required for crashing will be outlined in Section 2 with a case study given in section 3.

II. CPM & PERT



Activities which can be serial or parallel have the features are marked by two nodes N1 and N2; with d being the duration or time taken for the activity.

In PERT; duration d is estimated by taking optimistic (a), moderate (b) and pessimistic (c) estimates and d is calculated using the following formula.

$$d = \frac{1}{6}(a + 4b + c)$$

There are four cages marked Earliest Start (ES), Earliest Finish (EF) at Node N1 and Earliest Finish (EF) and the Latest Finish (LF) at N2. ES is the earliest time at which the activity can start and is O for the start node.

Forward planning is first conducted as ER = ES + d.

Proceeding forward the final EF is the total duration D the project which is the LF of the last node. Working backwards LF is the latest time at which the activity should end and LF = LF – d.

Slack of an activity is defined as

slack= LF – EF = EF –ES

Critical path lies along activities with zero slack.

II. CRASHING PROJECTS

As stated earlier, the crashing of a project has to take place during the implementation stages. As such the only activities that have not been implemented have to be taken into account. For this paper we will not consider only activities that have been partially implemented. For such activities by considering proportions a suitable adjustment can be taken to regard it as an incomplete activity.

For the balance activity critical path (CP) has to be formed. As such it would be necessary to construct dummy activities and construct a new network starting from a Start and end nodes.

Also the total time (D) taken to complete the new project has to determine and an expected total crash time (D') should also be decided at a realistic level.

As found in literature, Karunarathne (1995) for the new network for activities in the CP the following four quantities assumed to be estimated.

They are as follows.

- Normal cost
- Crash cost
- Normal duration
- Crash duration

Next for each such activity; a value called cost slope which is defined below has to be calculated.

$$Cost\ slope = \frac{(Crash\ cost - Normal\ cost)}{(Normal\ duration - Crash\ duration)}$$

An activity on the CP with the least cost slope is selected and duration changed to assumed crash duration.

Next CP of the new network has to be found and if the total project time is close to D' then crashing is complete and additional cost is needed has to be calculated. Otherwise procedure has to be repeated until the total project time for the new network is closer to D'.

III. PROPOSED SCHEME TO ESTIMATE CRASH COST

During the initial planning stages of a project it is necessary to find identify the following.

- Time for each activity
- Cost requirement for each activity

The above could be done by a consultant or a group. However to crash a project in the middle of a project will cause great difficulty.

It is envisaged in this paper that it would be better to use the heuristic method applied on PERT for both time and cost estimations. The matter of taking the duration time of an activity as a, b and c had been discussed. For costs too it is proposed that these estimates as optimistic, moderate and pessimistic are made as α, β and γ.

For the original project it is assumed for the duration times this approach had been taken. It is proposed that for cost estimates too the same approach is taken. Let the cost estimated for the total planned project under this scheme is C.

Crashing has to be now performed after

implementing some activities of the on-going project. Let the network completed be called Nc and the new network to be crashed called Nn. The cost that was incurred for Nc is taken as Cc.

As in time estimation for normal situation; each activity duration and cost can be calculated in the following fashion.

$$duration = \frac{1}{6}(a + 4b + c) \ \& \ cost = \frac{1}{6}(\alpha + 4\beta + \gamma)$$

For crash duration, the optimistic estimate a can be taken for time and the pessimistic estimate γ for the cost. These four values give the cost slope for activities on the CP at each step.

Thus finally when crashing is completed to the total new duration required, the total cost required for crashing is given by the following formula.
Crash Cost = Cc + Cn - C

IV. A CASE STUDY

Let us consider a simple example of CPM/PERT shown in Figure 1 with activity durations calculated for data of Table 1.

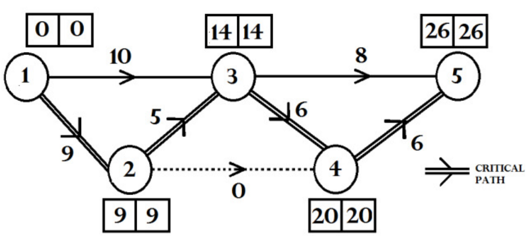


Figure 1 – Network

Activities	Optimistic Estimate (a)	Moderate Estimate(b)	Pessimistic Estimate (c)	Duration $d = \frac{1}{6}(a + 4b + c)$
1 – 2	5	8	17	9
1 – 3	7	10	13	10
2 – 3	3	5	7	5
2 – 4	0	0	0	0
3 – 4	4	6	8	6
3 – 5	6	8	10	8
4 – 5	4	6	8	6

Table 1 – PERT Values

Activities	Optimistic Estimate (α)	Moderate Estimate (β)	Pessimistic Estimate (γ)	Normal Cost $\frac{1}{6}(\alpha + 4\beta + \gamma)$	Cumulative Cost
1 – 2	30	50	70	50	
1 – 3	21	28	35	28	
2 – 3	20	20	20	20	
2 – 4	0	0	0	0	98
3 – 4	40	64	136	72	
3 – 5	15	18	21	18	
4 – 5	10	30	50	30	218

Table 2 – The Slack Table

Activities	Duration (d)	Earliest Start (ES)	Latest Start (LS)	Earliest Finish (EF)	Latest Finish (LF)	Slack (SL)
1 – 2	9	0	9	0	9	0
1 – 3	10	0	10	4	14	4
2 – 3	5	9	14	9	14	0
2 – 4	0	9	9	20	20	11
3 – 4	6	14	20	14	20	0
3 – 5	8	14	22	16	26	12
4 – 5	6	20	26	20	26	0

Table 3 – PERT Cost Values

Activities	Normal Duration (d)	Crash Dura-tion(a)	Normal Cost (NC)	Crash Cost (CC)	Cost Slope CS
3 – 4	6	4	72	136	32
4 – 5	6	4	18	21	1.5

Table 4 – The Cost Table for Crashing

The Network in Figure 1 with durations and Earliest Start (ES) and Latest Finish (LF) shown in cages do not indicate the CPM. Slack table is formed for this purpose as shown in Table 2.

Therefore the Critical Path is along the activities 1 – 2, 2 – 3, 3 – 4 and 4 – 5 as shown in figure 1.
Thus the total duration of the project = d = 26.
Let us imagine when the project has reached node 3, after the completing the first phase in 14 units of time, it had been decided to crash the balance part of the project for 12 units to 8 units of time.

Let the PERT type cost estimates for the activities be as shown in Table 3.

The new Project to be crashing is to be done is shown in Figure 2.

Since cost slope is least for activity 4 – 5, this activity has to be crashed and the allowable new duration is 4 units of time which is the optimistic estimate a of that duration. Thus crashing for 2, with this new duration a new critical path has to be constructed for the new balance project which is shown in Figure 3.

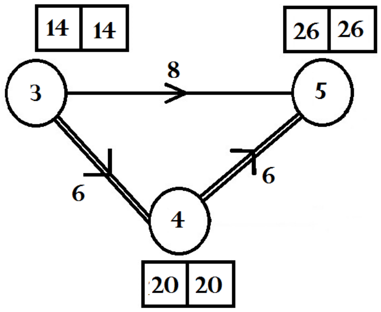


Figure 2 = Activities to be Crashed

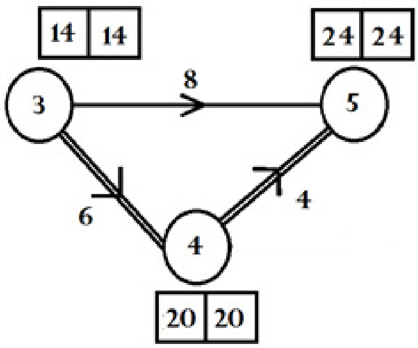


Figure 3 - Crashed Activities

It is obvious that the critical path for this project will not change. Hence 2 more time units have to be removed. The activity 3 – 5 which is possible giving a new crash duration 4 for the activity. Thus total duration for the entire project will be 14 + 8 = 22 time units.

Additional cost of crashing = 98 + 136 + 21 – 218 = 97

Thus crashing by 4 units of time at node 3 will need an additional cost of 97 monetary units.

Conclusion

Project Managers are often requested to crash or accelerate the balance activities during some stage of implementation. Such a procedure has to be adopted.

V. CONCLUSION

A novel concept to estimate extra costs needed to crash a project is proposed in the paper, with the novel feature to use heuristic method of PERT to estimate the cost of activities using optimistic, moderate and pessimistic estimates. Yet another feature is that the optimistic estimate for the duration of an activity is taken as lowest duration to crash the activity.

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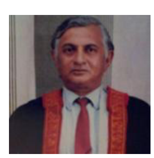

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