Minimize Time and Cost for Successful Completion of a Large Scale Project applying Project Crashing Method

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ABSTRACT: The design and operation of large scale project has become of concern to an ever increasing segment of the scientific and professional world. It is very difficult task to complete the selected project within the range of Budget resources and time. Thus scheduling and Estimation of cost are tremendous tasks for the project. Large project involves a lot of activities and barrier to schedule and estimate. In this work a new idea which is very effective to schedule time as well as cost estimation of the large project applying PERT/CPM and Project Crashing Method are developed. At first divide the whole project into number of activities and select the preceding and succeeding activities to build up a network diagram which ensures the critical path of the project. Then we use crashing to find the minimum required time for successful competition of the project. In addition to this work we have included a new scheduling technique by using the Earliest event time that can easily compute the time and cost of the project. Finally, algorithms are developed to perform the mentioned task in a sequential manner.

Index Terms— Critical Path, Crash cost, CPM, Project management, PERT, Budget

1 INTRODUCTION

Project management is the discipline of planning, organizing, securing and managing resources to bring about the successful completion of specific engineering project goals and objectives. It is sometimes conflated with program management, however technically that is actually a higher level construction: a group of related and somehow interdependent engineering projects.

A project is a temporary endeavor, having a defined beginning and end (usually constrained by date, but can be by funding or deliverables), undertaken to meet unique goals and objectives, usually to bring about beneficial change or added value. The temporary nature of projects stands in contrast to business as usual (or operations), which are repetitive, permanent or semi-permanent functional work to produce products or services. In practice, the management of these two systems is often found to be quite different, and as such requires the development of distinct technical skills and the adoption of separate management.

The primary challenge of project management is to achieve all of the engineering project goals and objectives while honoring the preconceived project constraints. Typical constraints are scope, time, and budget. The secondary—and more ambitious—challenge is to optimize the allocation and integration of inputs necessary to meet pre-defined objectives.

Project management consists of planning, designing, and implementing a set of activities to accomplish a particular goal or task. For many years, two of the most popular approaches to project management have been the Critical Path Method (CPM) and the Project Evaluation and Review Technique (PERT). J.E. Kelly of Remington-Rand and M.B. Walker of DuPont developed CPM in the 1950's to assist in scheduling maintenance shutdowns of chemical processing plants. Pert was developed shortly after by the U.S. Navy to manage the development of the Polaris missile. The original PERT Navy report (1958) does not identify the names of the developers. Both PERT and CPM are network based techniques.

In this work we are now going to estimate cost of the project in Control Estimates manner. In this process we collect data from the construction of 3-stored modern guest house with 6-stored foundation covering 5,000sft. Floor area each floor add Bangladesh Bank premises Bogra.

In this project the projected total Budget is Tk. 10518000.00 And the estimated time were whose Head of the work as follows in the table below:

HEAD OF THE WORKS	AMOUNT IN TAKA

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A. CIVIL WORKS	
A1. Foundation upto PL	45,25,000
A2. Superstructure works	5283000
Total for (A.1+A.2)=A	**9808000**
B. SANITARY & WATER SUPPLY WORKS	**350000**
C. INTERNAL ELECTRICAL WORKS	**360000**
GRAND TOTAL FOR (A+B+C)	**10518000**

2 PLANNING AND SCHEDULING PROJECT COSTS

2.1 The Budgeting Process

In the budgeting process it is required to determine how much is to be spent per unit time (day or week or month). To attain the unit time cost the following four steps are followed:

i) Identify all types of cost associated with each of the activities and sum up them together to obtain the total estimated cost or budget for each activity.

ii) In case of a large project, combine groups of several activities into a work package (a logical collection of activities).

iii) Transform budgeted cost per activity into a cost per unit time. The assumption is that the cost of completing any activity is spent at a uniform rate over time. Thus if the budgeted cost for an activity is Tk.60,000 and its completion time is 10 days, then the budgeted cost per day is 60,000/10 = Tk. 6000.

iv) With the help of earliest and latest start times, estimate how much money should be spent per unit time in order to complete the project within the given deadline.

Let us suppose that we are carefully to compute the costs associated with each of its 11 activities and found out the cost per unit time. Activity cost per unit time and the total cost for the project are shown in the table below:

Activity	Expected time (t)	Total Budget	Budget cost/day
ac_1	11.17	80000	7162.04
ac_2	11.17	60000	5371.53
ac_3	11.17	60000	5371.53
ac_4	6.00	240000	40000
ac_5	6.00	200000	33333.33
ac_6	16.33	225000	13777.32
ac_7	9.00	1200000	133333.33
ac_8	57.34	1235000	21659.07
ac_9	157.02	6508000	41446.95
ac_{10}	17.17	350000	31333.93
ac_{11}	9.00	360000	40000
		Total= 10518000	

Table: Schedule and activity Cost for Reliable Construction Project

Starting every activity at the earliest start time, the day budget, the total up to date day budget of the project, the total spending for an activity and the activities to be performed in a day are shown in the following table: The day budget and the total spending up to a day are calculated in the rows respectively. Here in the table the unit column of each number contains 6 days. Therefore the amount of the cost of each activity is multiplied by 6. On the basis of this measure we formulate the budget for the project herein the following table.

2.2 Critical Path Method (CPM) for crashing project activity

Project crashing is a method for shortening the project duration by reducing the time of one or more of the critical project activities to less than its normal activity time. The objective of crashing is to reduce project duration while minimizing the cost of crashing.

CRASHING is reducing project time by expending additional resources.

CRASH TIME is an amount of time an activity is reduced.

CRASH COST is the cost of reducing activity.

It has already been mentioned that CPM is a deterministic network model. Like PERT, CPM does not calculate the activity time using probabilistic method. Instead, CPM uses two sets of time and cost estimates for each activity: a **normal time** and **associated cost,** and a **crash time** and **associated cost**. The normal time of an activity is like the expected time of PERT to finish the activity and **the normal cost** is an estimate of the associated cost. The crash time of an activity is the shortest possible activity completion time and **the crash cost** is the associated required cost. The critical path calculation for CPM is the same as in PERT. The process of shortening a project is called crashing and is usually achieved by adding extra resources (overtime, hiring additional temporary help, using special time saving materials, engaging a special equipment, etc.) to an activity. Naturally, crashing costs more money and managers want to speed up a project with least additional cost. Project crashing with CPM involves the following four steps algorithm:

Step 1 Find the normal critical path and identify the critical activities.

Step 2 Compute the crash cost per unit time for all activities in the network using the formula below:

$$\text{Crash cost/unit time} = \frac{\text{Crash cost - Normal cost}}{\text{Normal time - crash time}}$$

Step 3 Select the activity on the critical path with the smallest crash cost per unit time. Crash this activity to the maximum extent possible or to the point at which desired project completion time has been reached. If the desired completion time is attained, go to step (5) else follow the next step 4.

Step 4 Check whether the critical path is still critical (often a reduction in the activity time in the critical path causes a non-critical path or paths to become critical). If the critical path is still critical, return to step (3). If not, find the new critical path and then return to step (3).

Step 5 Stop

For most applications it is assumed that the crashing costs are linear as shown in the following figure

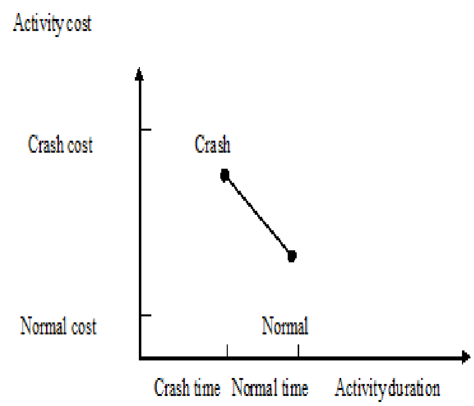

Figure: A typical time–cost graph for an activity

The following table gives the data for normal and crash times and their costs, maximum reduction in activities times and crash cost per day.

Activity	Time in days		Cost (Tk.)		Maximum in reduction	Crash cost/ day Saved
	Normal	Crash	Normal	Crash		
ac_1	11.17	3	80000	94342.08	2	14324.08
ac_2	11.17	3	60000	65371.53	1	5371.53
ac_3	11.17	3	60000	65371.53	1	5371.53
ac_4	6.00	0	240000	280000	0	0
ac_5	6.00	0	200000	233333.33	0	0
ac_6	16.33	3	225000	266331.96	1	13777.32
ac_7	9.00	3	1200000	1239999.99	1	133333.33
ac_8	57.34	5	1235000	1451590	2	43318.14
ac_9	157.02	15	6508000	8683946.95	3	145064.33
ac_{10}	17.17	3	350000	443999.99	1	31333.93
ac_{11}	9.00	2	360000	440000	1	400000

Table: Data for normal and crash times and their associated costs

By observing the above table it can be shown that the highest amount of saving amount has found from the activity ac_1 and it can reduces the amount money is 14324.08 Taka.

Corresponding to13 days duration of the project. It is mentionable that the total amount of cost save is Tk. 746287.36 with this crash time the critical path will be same but the length of the duration will be shorter than the previous value of the duration. The projected Crash Critical path presented in the following Network diagram where dotted line reveals the dummy activity and bold line shows the Critical path of the project.

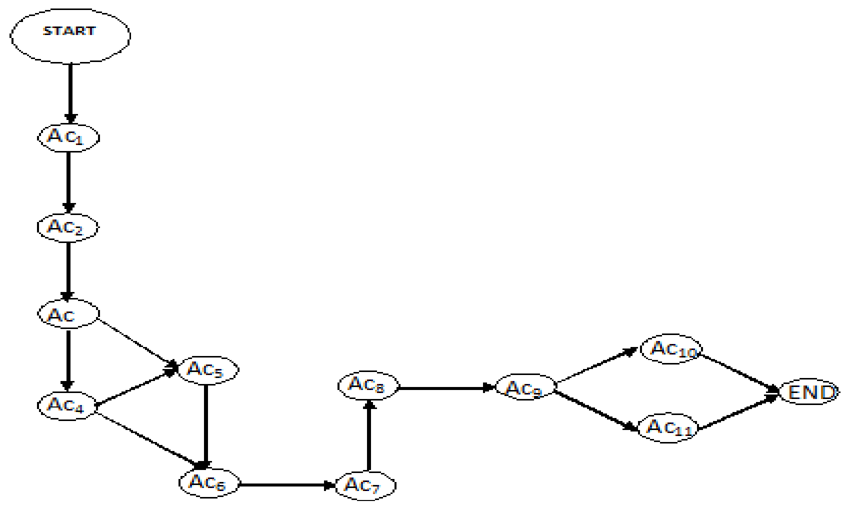

Figure: Crash Critical Path of the project

Project Crashing with Linear Programming
In this procedure at first we need to build up a mathematical model of the project crashing problem using linear programming to minimize the total cost of crashing activities. The modeling approach will be explained here with the modeling of our example problem of Reliable Construction Company project.

The Critical path in the Network diagram of the project is as follows

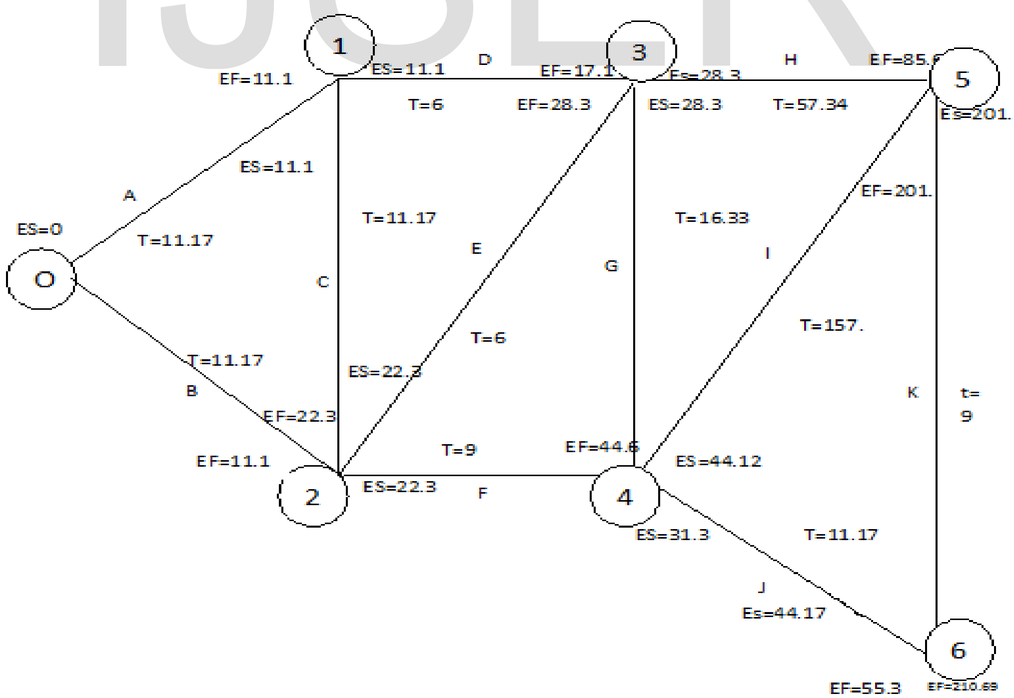

Figure: Determining earliest start time and earliest finish time

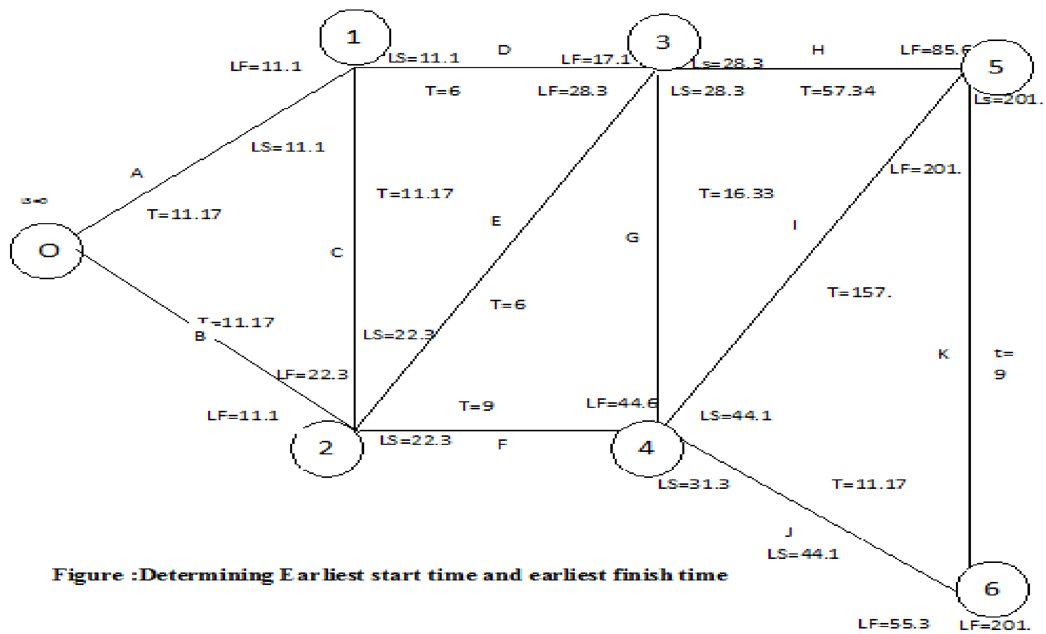

Figure :Determining Earliest start time and earliest finish time

Critical path: A-C-E-G-I-K

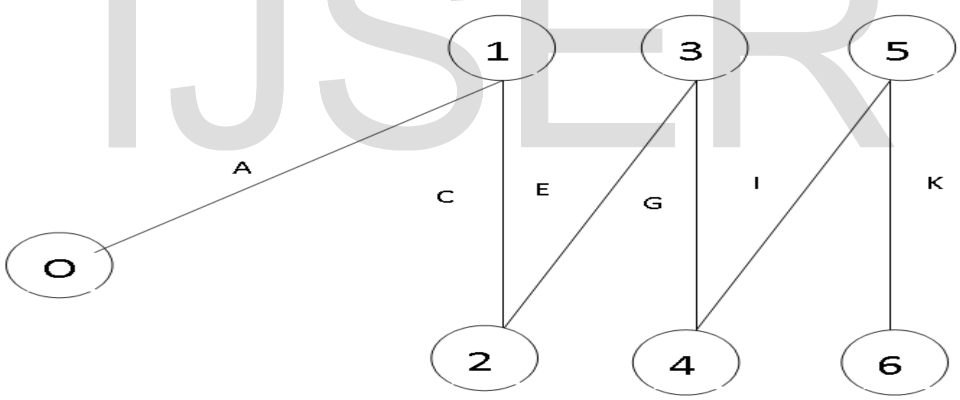

Figure: Critical path

On basis of the duration of the each activity of the project and their relative preceding activities if we present in the project Management software and try to find out the required completion time we find it is 210.69 days and the GANNT CHART looks like the following figure which also represent the critical activity of the project.

We begin by defining the decision variables. If X is the time an event will occur, measured since the beginning of the project, then:

X_0= time event 0 will occur
X_1= time event 1 will occur
X_2= time event 2 will occur
X_3= time event 3 will occur
X_4= time event 4 will occur
X_5= time event 5 will occur
X_6= time event 6 will occur

Is defined as the number of days that each activity is crashed. Y_A is the number of days we decide to crash activity A, Y_B the amount of crash time used for activity B, and so on , up to Y_K

Objective Function: Since the objective is to minimize the cost of crashing the total project, our LP objective function is:

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Minimize crash cost= $14234.08Y_A+5371.53Y_B+5371.53Y_C+0.Y_D+0.Y_E+13777.32Y_F+13333.33Y_G+43318.14Y_H+145064.33Y_I+31333.33Y_J+40000Y_K$

Subject to the constraints:

$Y_A \le 2$
$Y_B \le 1$
$Y_C \le 1$
$Y_D \le 0$
$Y_E \le 0$
$Y_F \le 1$
$Y_G \le 1$
$Y_H \le 2$
$Y_I \le 3$
$Y_J \le 1$
$Y_K \le 1$

Project competition constraints:

$X_6 \le 210.69$

Constraints describing the network:

For event 0, $X_0=0$
For event 1, $X_1 \ge 11.17-Y_A$
For event 2,
$X_2 \ge 11.17-Y_B$
$X_2 \ge 11.17-Y_C+Y_A$
For event 3,
$X_3 \ge 6.00-Y_D+X_1\backslash$
$X_3 \ge 6.00-Y_E+X_2$
For event 4,
$X_4 \ge 9.00-Y_F+X_2$
$X_4 \ge 16.33-Y_G+X_3$
For event 5,
$X_5 \ge 57.34-Y_H+X_3$
$X_5 \ge 157.02-Y_I+X_4$
For event 6,
$X_6 \ge 9.00-Y_K+X_5$
$X_6 \ge 44.17-Y_J+X_4$

This linear programming problem can be solved for the minimum value of the objective function at the optimal values of x_j and $y_{j.}$ This model can be solved using AB:QM, LINDO, STORM, MATLAB or with one of the many other LP computer programs available.

The presented budgeting processes will carry out the meaningful results in any Construction budget. Though there some assumption in selection of the activity to select the Preceding and succeeding activity but the results justified the total budget and time scheduling that uses in the another budgeting and scheduling procedure.

2.3 Results Analysis

Project Variance= sum of the variance of the activities in the critical path. We know the standard deviation is given by the square root of the variance. So, project standard deviation $\sigma_T = \sqrt{2.22} = 1.49$.

The probability of finishing a project on time is calculated based on two assumptions. These are as follows:

i) Project completion time follow a normal probability distribution
ii) Activity times are statistically independent

With these assumptions the bell shaped curve shown in the following figure used to represent the project's completion dates.

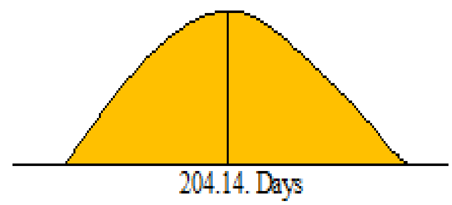

Figure : Probability distribution for project completion time.

It also means that there is a 50% chance the project will be completed in less than the expected 204.14 days and 50% chance that the project will be completed in more than the expected time. Using normal distribution we have

$$Z = \frac{Due\ date - Expected\ date\ of\ completion}{\sigma_T}$$

$$= \frac{210.69 - 204.14}{1.49}$$

$$= 4.40$$

where, Z= number of standard deviations the due date or the expected date .

From normal table we find a probability of 0.4999 corresponding to the Z value. Thus, there are 49.99% chances that the project will be able to finish the project in 210.69 days or less. This is shown in the following figure:

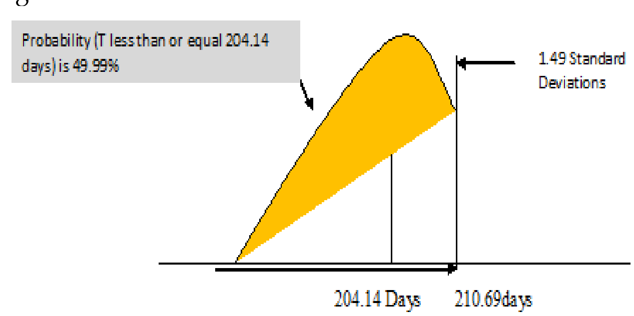

Figure : Probability of meeting 210.69 days deadline.

Thus the discussion provides us the following information for the successful completion of the project:

i) The expected completion time of the project

ii) Probability of finishing the project within the deadline

iii) Identify the critical activities delay of any of which will delay the project completion time.

iv) Slack or float times of activities which can be delayed to a certain extent

v) A detailed schedule of starting and finishing of each of the activities.

3 TIME ANALYSIS OF THE PROJECT

Every project consists of some complex task to be done. This is very important to maintain this work within the projected budget and within the schedule time. In this thesis we try to work out a way to calculate the shortest possible time of the project completion and on the basis of this task to formulate the budgeting process and calculation of the total required minimum amount to be complete. Here we use the CPM and PERT computational technique to find out the duration of the project, the total duration of the project. The following the table shows the duration of the project completion by using Crashing by CPM method and Normal required time for scheduling.

Activity	Normal Required time	Time obtained Crashing
ac_1	Normal	Crash
ac_2	80000	94342.08
ac_3	60000	65371.53
ac_4	60000	65371.53
ac_5	240000	280000
ac_6	200000	233333.33
ac_7	225000	266331.96
ac_8	1200000	1239999.99
ac_9	1235000	1451590
ac_{10}	6508000	8683946.95
ac_{11}	350000	443999.99

Table: Required time analysis

The above table expresses the amount of required time for completion of each activity in Normal and this activity is in the Crash time. These have been varied in terms of activity and also fluctuate over the project activity to activity. The amount of variation has shown in the graph in the below in time to time for every activity of the total project. Here the red line shows the time from the Normal time and Blue line shows the time obtained by Crashing of the project.

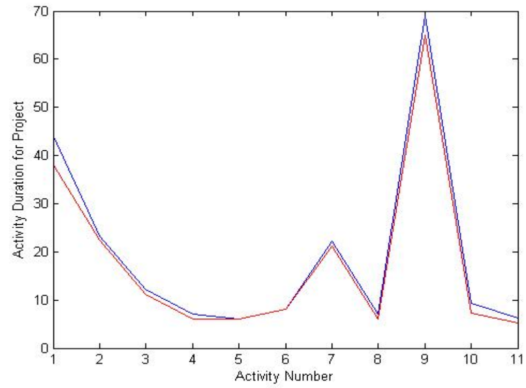

Table: The time distribution for each activity for project.

The expected time for the Project according to the budgeting and by inspection of the project manager was 210 days (approx) and our Critical Paths shows that the required time is 204.14 days which very significant time for successful completion of the project. However, the required time by using the Crashing we obtained the time is only 196 days. This required is the marginal time to complete the project, if we try to reduce the time, then we have to pay more for successful completion and also hamper our standard measurement of the construction.

On the other hand this estimation will bounds the total project budget and will carry the change to not complete within the required time for the proper resources requirement. The total Net reduction of the estimate time is

$$(210-196)\ (approx.)\ days = 14\ days\ (approx.)$$

The percentage of reduce time= $\left(\frac{14}{210}\times 100\right)\% = 6.67\%$

3.2 Comments on Result

The total required time for successful completion of the project according the scheduled budget was 210 days (approx.) and, by our process is only 196 days. Thus the total reduced time is 14 days which is 6.67% of the total required time. This required time is very much significant in respect to a large project. Thus, our estimated schedule process will bring a brilliant success to calculate the shortest possible time to successful completion of any project.

4 PROJECT COST ANALYSIS

Project budgeting is always important than any other related activity of the project. The success of every project is mostly depends on the proper budgeting because all of the task of the project wholly depends on resources of the project and these are maintain by appropriate allocation of money in different activity of the project. That why it has good demand on the large project for monitoring and maintenance. On the contrary, it is also an important task to fix the minimum cost for any project. The minimum allocated budget for the large project can save a lot of money for the project Manager as well as for the construction management. In this thesis we derive a way to calculate the minimum budget for any Project by using the CPM/PERT technique and after that by using the Crashing technique for the project. The calculated budget by normal procedure and by Crashing is presented here in the following table reveals excellent benefits in terms of only the budget of Tk 10518000. The presented result will be more effective for large amount budget for any project.

Activity	Total Cost each activity	Cost obtained by Crashing
ac_1	2082338.00	2129481.71
ac_2	1124558.37	1269165.09
ac_3	227424.46	264829.78
ac_4	1008567.46	1152648.52
ac_5	500957.65	500957.65
ac_6	140688.42	140688.42
ac_7	32871.76	41089.58
ac_8	26838.38	33471.74
ac_9	3092797.53	3361736.43
ac_{10}	333104.00	440211.38
ac_{11}	335383.00	335383.00

Table: The Total budget for each activity in Normal and Crashing of the project

The above table expresses the amount of money required for completion of each activity in Normal budget and this activity is in the Crash budget. These have been varied in terms of activity and also fluctuate over the project activity to activity. The amount of variation has shown in the graph in the below in time to time for every activity of the total project. In the presented figure the red line represents the cost by Crashing time and the blue line express the amount that required for every activity in Normal Budgeting of the project.

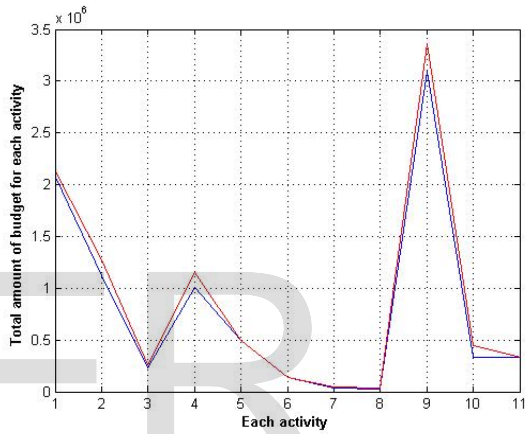

Figure: The cost distribution for each activity for project.

The budget obtained from the Construction firm was Tk. **10,518,000,** the total time reduce by our method is 14 days and for this reduced amount our method can decrease the total budget of about Tk.746287.36 and therefore the total required amount for successful completion is Tk. 9771712.64

$$\text{The percentage of Save Cost } = \left(\frac{746287.36}{10518000}\times 100\right)\% = 7.10\%$$

The total reduced cost is Tk. 746287.36 which is 7.10% of the total required cost of the project. This required cost is very much significant with respect to a large project. Thus, our estimated budgeting technique will bring a brilliant success to calculate the least possible amount for successful completion of any project

5 CONCLUSIONS

In this work introduces an effective scheduling and cost estimation technique based on method illustrates by using PERT/CPM. PERT/CPM method derive the critical path of the project.

The method can optimize the required time by 6.67% and those of cost are more than 7.10% of the previous estimated cost. Thus the total project can be successfully completed by using Project crashing method.

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