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Time and Cost Optimization by using Network Compression Technique: A Case Study.

[1]Sunil Kshirsagar, [2]Sweety Bagade, [3]Shivani Patil, [4]Akash Kate, [5]Prof.Onkar Chothe.

Department of Civil Engineering,
Dr. D. Y. Patil Institute of Engineering, Management and Research, Akurdi,
Pune, India.

Abstract: This paper gives and brief idea about the time and cost optimization by using network crashing technique. In this paper, the construction of a girl's hostel building is taken as a case study. The brief procedure of network crashing is explained with proper example. The application of network compression technique is shown with all the necessary calculations in proper table format. We can get adequate result and conclusion by adopting this procedure and also obtain the optimum duration of the project with respect to its optimum cost.

Index Terms – **Time Optimization, Cost Optimization, Network Compression Techniques.**

I. Introduction

Every Construction Project requires time and cost optimization for the successful completion of the project within stipulated time and budget. This can be done by reducing the duration of the critical activities in the network corresponding to the minimum total cost of the project. This will minimize the overall duration of the project that will avoid excessive expenditure and prove to be economical.

Hesham A. Abdelkhalek [1] has mentioned that the, Construction of buildings especially high rise building has become one of the most successful business where business people invest large amount of their money in this field. The prosperity of nations and their economy increases by the increase of the size of their construction industry. That's why it's thought of one in every of the foremost vital topic that researchers ought to specialise in the way to safely proceed the work. the development method is split into a gaggle of little activities that ought to be place in their right sequence to take care of swish construction method with the foremost economic arrange of optimized time and price.

Anuja Rajguru [2] have mentioned that it is necessary to arrange sequentially all the activities and collect proper data related to it. The method and materials used in construction also play an important role for determining the time required for completion. One way of overcoming such problems is by using network models. Network models are conventional methods of finding the most appropriate way to link a number of activities directly or indirectly in so that it can satisfy supply and demand requirements at different activity locations and project scheduling. The need for networking arises in building construction to program and monitor the progress of the stages involved so that the building project is completed in the minimum time. In this project we have listed down the activities related to construction of a building, found out its expected time and cost and used network compression method to compress it and determined a critical path which would give us a minimum time for the project along with its optimum cost.

Asrul Ismail [3] has mentioned that, to crash a project successfully, we examine the network, note its activities and compare normal costs with crash costs for each activity. Our goal is to find those activities on the Critical Path there time can be cut substantially with minimum extra dollar spent. Our goal is that the greatest reduction in project time for the smallest amount increase in project value. However what if the vital path contains one or a lot of vital activity that have quite one methodology to finish the activity.

Nafish Sarwar Islam [4] has mentioned that for unit crashing reduces the cost of project. When activities are crashed by 1 day then only the crashing cost corresponding to 1 day is increased, reducing the project duration as well as cost. The purpose of this case study is to explore the suitability of a new method to crash PERT networks. This approach is well suitable for locations where cost is considered as of major consideration. Plans for future research includes running the simulation on additional networks, preferably real-world project. Algorithm prescribed in this section is so designed to give the mathematically correct time-cost trade-off curve for small project networks which are to be solved by hand. The algorithm which proceeds from a network description of the project and the normal and crash times and duration for the project activities to a set of tables which shows the time-cost trade-off graph that has been plotted.

Chothe O. K.[1] [5] has mentioned that, it is necessary to determine the total cost and time required to complete the project within specification to get the optimum results. Thus optimization is the best option to be carried out which gives more margin benefit and saves time as well required. Cost Optimization can be defined as the achievement of real and lasting reduction in the unit cost of services provided without damaging their suitability in plan used. There are multiple ways to obtain cost optimization but still many of the projects still are not using it in actual implementation. Optimizing avails us with number of methods associated to perform a specific activity to complete the project within less time.[20]. Hence it is necessary to arrange sequentially all the activities and collect proper data related to it. The method and materials used in construction also play an important role for determining the time required for completion. One way of overcoming such problems is through the use of network models. Network models are conventional methods of finding the most appropriate way to link a number of activities directly or indirectly in so that it can satisfy supply and demand requirements at different activity locations and project scheduling.

Mr. Umesh Kamble[1][7] has mentioned that, in today's era there are many heaps of sectors which are increasing globalization & civilization such as IT's, Infrastructures, Energy conservative projects. In these, one of the major sector is Infrastructure which is profoundly increasing the economy of the country. Leading to this mainly time & cost is exceedingly more into consideration in this world. Everyone wants to be more conservative when it comes into time constraint & within shorter duration work should be done giving more profitable results. In the different approach of profitable results value constraint is predominating the potency of labor to be worn out housing industry. More often cost is directly proportional to the work to be carried out by the resources.

Komesh Sahu[1] [8] has mentioned that, it is found that there is there project schedule to determine the optimum cost and time by CPM/PERT network analysis. Project duration can often reduce by assigning more labor to project activities. However further labor, overtime and resources increase the project value. The decision to reduce project duration must be based on analysis of tradeoff between time and cost.

Florentin Smarandache[2] [9] has mentioned that, The Complex projects require a series of activities, some of which must be performed sequentially and others that can be performed in parallel with other activities. This assortment of series and parallel tasks will be sculptural as a network.

Shifat Ahmed[1] [10] has mentioned that the, Project management consists of planning, designing, and implementing a set of activities to accomplish a particular goal or task. For many years, 2 of the foremost well-liked approaches to project management are the vital Path technique (CPM) and therefore the Project analysis and Review Technique (PERT).

Mr.Bhushan V[1][11] has mentioned that, the project total cost is classified into direct cost and indirect cost which are the major types of cost related to construction in considering the optimization cost. Time and cost are the two important factors in construction projects. Over the last several years, critical path method has been used in the construction industry for the project scheduling and control. One major drawback of the deterministic

M. Hanefi CALP[1] [12] has mentioned that, it is necessary to manage the sources properly in today where time is important and sources are limited. In the opposite case, undesired consequences may be encountered. Evaluation and use of these resources optimally can be possible by planning process from the beginning to the end of the project. This situation reveals the concept of project management. Project management is delineated in literature as follows: "planning and dominant of method so as to form project arrive desired targets in an exceedingly best ways that and in an efficient manner", "planning, programming (scheduling) and dominant of project activities to realize project targets", "planning, organizing, death penalty and dominant of common activities of monetary and human resources utilized in order to realize a definite desired result". The most aim of project management is to finish a project within the planned amount with the minimum price and at the wished quality level. As it is seen from the above-mentioned definitions of the project management, planning and controlling of projects to be carried out are significant effecting elements for success of the project. Network analysis is one of the most widespread methods in the planning and controlling of the project. Sources of complicated comes may be managed additional effectively by analyzing with networks that square measure modal illustrations of a series of events and activities. Network means that schedule that happens from required activities and events to attain the aim of the program, and shows connections and relations between activities and events for coming up with demand. During this study, GA was applied for the project analyzing on the networks rather than spirited or CPM ways. Spirited and CPM are developed to assist coming up with, form and dominant of enormous scaled complicated comes. The networks square measure sometimes giant and elaborated thus this example forces to use a malicious program to search out project completion amount by applying these techniques.

Ibrahim Abed Mohammad[2] [13] has mentioned that, one important process in project management issue is the analysis of possible time crashing for an assumed additional resources. Project bally and value law improvement usually was studied in many times to feature new info to existing body of information. The simulation approach for improvement project value and schedule is one in all tools that may be accustomed bring back the project in restraint. The simulation approach consists a collaboration between project manager and IT department in company to make optimum scheduling time and cost overruns. The optimization of your time and value method may be thought of as commonplace method for every project separately; the time spent on the particular blooming was lowest and also the project Linear Programming (also called linear optimization) is a special technique from mathematical optimization that aims to achieve best outcomes in minimal or maximal sense from a linear relationship of many variables that are simultaneously subjected to linear equalities and/ or inequalities constraints. This paper is devoted to give and illustrate a methodology of optimal time crashing of a mega project by utilizing the analysis of milestones characteristics and linear programming technique.

The Objectives:

Why is this project needed?

The objectives must meet the three fundamental criteria:

1. Find out various alternatives for the activities.
2. To obtain the critical path.
3. To obtain the direct and indirect cost which effect on the project cost.
4. Obtain the Optimum Duration and Optimum Cost of the project.

II. METHODOLOGY

Flow Chart:

Collection of literature review related to NETWORK COMPRESSION.

↓

Collection of data regarding activities, cost and time from existing site in Aurangabad.

↓

Sequential arrangement of activities and their respective durations.

↓

Creating a network and determining the critical path.

↓

Applying Network compression technique on it.
(Adding and assigning alternative resources.)

↓

Selecting optimum cost value and time duration from the compressed network obtained.

Procedure of Network Crashing:

STEP 1:- Identify the critical path of the network and determine the project cost.
STEP 2:- Find the cost-slope of critical activities by using following formulae:

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

STEP 3:- Rank the critical activities in the ascending order of the cost slope.

STEP 4:- Crash the activities in the critical path as per the ranking.
(Activities can only be crashed up to its crash duration).
STEP 5:- Calculate the cost of project after crashing.
STEP 6:- Also workout the related Direct and Indirect costs of the project.
STEP 7:- Repeat the same procedure till the optimum cost and duration are obtained.
Note:- There is a possibility that the Critical Path changes every time the critical path has been crashed.

Terms Related to Network Crashing:

1) Activity: An activity is the actual performance of the task. It is the work required to complete a specific event. An activity is a recognizable part of a work project that requires time and resource for its completion. Depending upon interdependency we can categorize activities as activity.
Parallel activity: Activity which can be performed simultaneously and independently to each other are known as parallel activities.

Serial activity: Activities are those which are to be performed one after other in succession. These activities cannot be performed independently to each other.

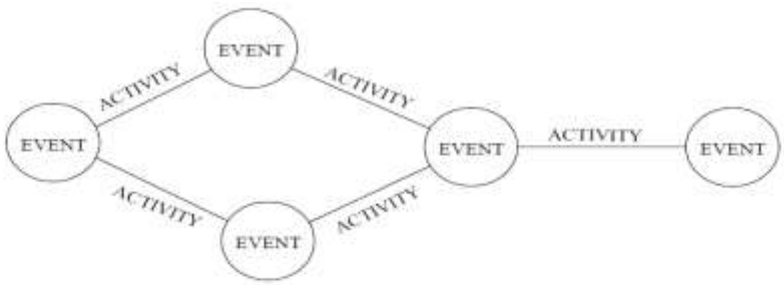


Fig No: 01 Network Diagram.

2) Event:
The commencement or completion of an activity is called as event. An event is that particular instant of time at which some specific parts of a plan has been or is to be achieved.
Type of events:
A particular event out of various events on the network diagram may be specified as:
1) Tail event
2) Head event
3) Dual role event

3) Dummy Activity: A dummy is a type of operation in a network which neither requires any time nor any resources.
But is merely a device to identify a dependency among operations. A dummy is the connecting link for control purposes or for maintaining uniqueness of activity. A dummy is also represented by arrow. But it is not an activity. It is represented by dashed arrow. A dummy is identified by the numbers of terminal node.

Fig No: 02 Dummy Activity.

4) Crashing: Crashing refers to a particular variety of project schedule compression which is performed for decreasing total project schedule duration. The decreasing of the project time take place after a careful and thorough analysis of all possible project duration minimization alternatives in which motive is to attain the maximum schedule duration for the least additional cost. The purpose of crashing a network is to determine the optimum project schedule. Crashing may also be required to accelerate the execution of a project, irrespective of the increase in cost. Each phase of the project consumes some. Resources and hence has cost associated with it. In most of the cases cost vary to some extent with the amount of time consumed by the design of each phase. The aim is always to strike balance between the cost and time and to obtain an optimum project schedule. An optimum minimum cost project schedule implies lowest possible cost and the associated time for the project management.

5) Project time-cost relationship: Total project costs include both direct and indirect costs for performing the activities of the project. If each and every activity of the project is being scheduled for the duration that results in the minimum direct cost (normal duration) then the time to complete the entire project may be too long and large penalties associated with the late project completion might be incurred. At the other extreme, Manager might complete the activity in the minimum possible time, called crash duration, but at a maximum cost. Thus, planners perform network compression to determine an optimum solution for completion of the project. This can be done by taking out some activities on the critical path to shorten their duration. As the direct cost for the project equals the sum of the direct costs of its activities, then the project direct cost will increase or decrease up to optimum level by decreasing its duration.
The project total time-cost relationship can be valued by adding up the direct cost and indirect cost values together. The optimum project time or duration can be determined as the project duration that results in the least project total cost.

6) Slope of Direct Cost Curve:
The direct cost curve can be approximated by straight line or more than a straight line depending upon flatness of curve. The straight line or segmented approximation of direct cost curve is helpful in carrying out the project cost analysis and for such analysis "COST SLOPE" is used.
Cost Slope: The cost slope is slope of the direct cost curve, approximated as straight line. It is defined as

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

The total duration or time which induces minimum direct cost is called the normal duration and the minimum possible time to complete an activity is called crash duration, but at a maximum cost. The slope of the line connecting the normal point (lower point) and the crash point (upper point) is called the cost slope of the activity. Slope of this line can be calculated mathematically by knowing the coordinates of normal and crash points.

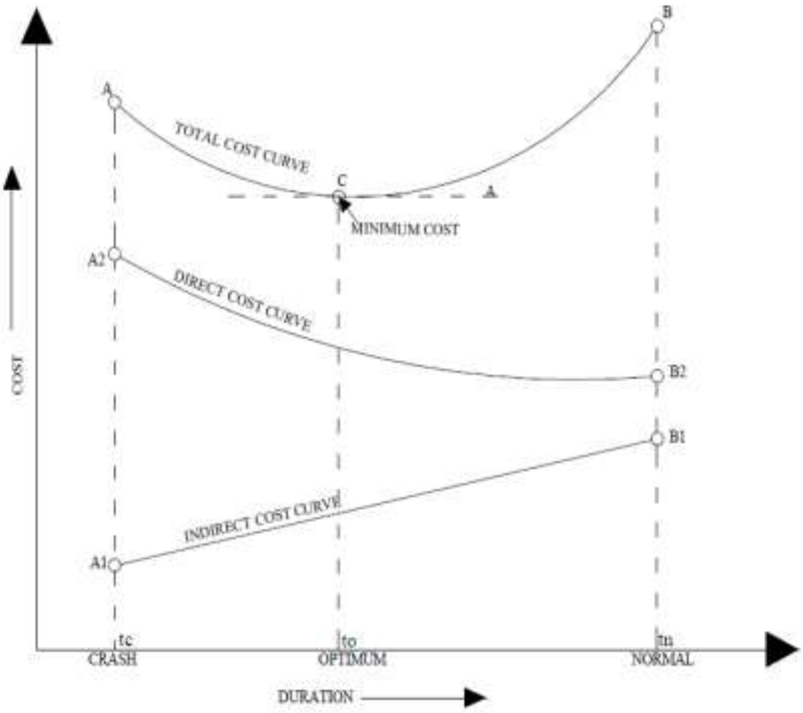


Fig No: 03 Total Cost Curve.

7) Critical Path: Critical path is the one which connects the events having zero or minimum slack times. All the events along the critical path are considered to be critical in sense that any delay in their occurrence will cause in the delay in scheduled completion of the project.

- Critical path is the longest path connecting to initial and end event.
- A critical path is distinctly marked in the network usually by zig zag line.

Network Rules:

i. Initial nodes must have outward going arrows and there is only single initial node in a network.
ii. An event cannot occur until all the activities related to it are completed.
iii. An event cannot take place twice in a network i.e. there cannot be any network path looping back to previous occurred event.
iv. No activity can start until its tail end event has occurred.
v. Any arrow should represent unique conditions.
vi. Every activity must be completed to reach the end objective.
vii. All interdependencies should be showed properly by use of appropriate dummies.
viii. Logic of network should always be maintained i.e. arrow heads point correct way to indicate true control situation.
ix. The time flow must be shown from left to right.

Cost Scheduling Computations:
Here,
NT = Normal Time (completion time of an activity with allocation of resources.)
NC = Normal Cost (cost associated with normal time.)
CT = Crash Time (shortest completion time of an activity with extra resources.)
CC = Crash Cost (cost associated with crash cost.)

$$\text{Cost Slope} = \frac{\text{Change in cost}}{\text{Change in time.}} = \frac{\text{Crash cost-Normal cost}}{\text{Normal duration- Crash duration.}}$$

Forward Pass (Earliest Occurrence Times):
The earliest start time of an activity is equal to the largest of the earliest finish times and of its immediate predecessors.
ES = Earliest Start time of a particular activity.
EF = Earlier Finish time of a particular activity.
Where,
EF = ES + (estimated) duration of project.
(For every activity that starts the project its earliest start time is ES = 0).

Backward Pass (Latest Occurrence Times):
The Latest start time for an activity can be termed as the latest possible time that can start without delaying the completion of the project.
LS = Latest Start time of a particular activity.
LF = Latest Finish time of a particular activity.

Where,
LS = LF – (estimated) duration of project.
(Latest Finish Time of an activity is equal to the smallest of the latest start times of its immediate successor).

III. CASE STUDY:

Type of structure: Institutional Building.
Name - Dr. Babasaheb Ambedkar Marathwada University, Girls Hostel, Aurangabad.
Location: Aurangabad.
No. Of floors: G + 1.

Area Statement:

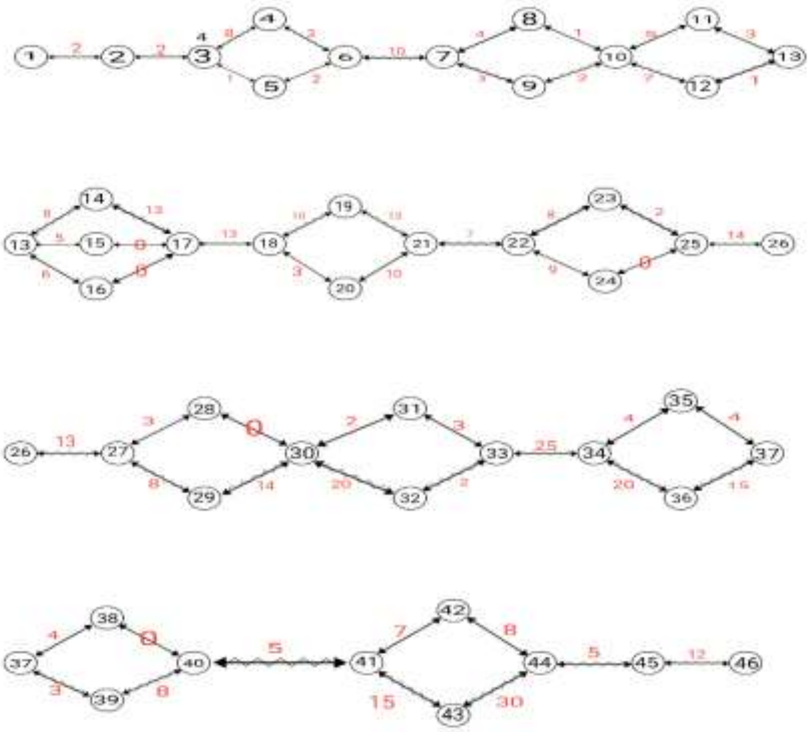
I. Plot Area: 722.96 m^2 (7781 sq.ft).
II. Total Built up Area: 1032.8 m^2 (11116.96 sq.ft).
III. Built up Area Each Floor: 516.5 m2 (5558.4 sq.ft).
IV. Carpet Area per Floor: 397.21 m^2 (4275.53 sq.ft).

Alternatives Used:

I. Excavation - JCB 40HP.
II. Concreting - RMC.
III. Brickwork - Si-Porex Blocks.
IV. Plastering, Painting, Flooring and Finishing works - Providing Additional Labors

Sr.no	Activity	Convectional	Alternative
1.	Excavation	Labor a) Hard Soil-2.10m^3 /day b) Soft Soil-3.12m^3 /day Labor Rate: 500-600/day	JCB Hard soil- 25-30 m^3 /hour. Soft Soil- 35-40 m^3 /hour. JCB Rate- 1200/hour.
2.	Concreting	Labor + Machinary Concrete Casting Rate: Rs. 3300/m^3 Labor Output: 3m^3 /day.	RMC Rs. 4500/m^3 (Excluding Transportation and Pumping Cost).
3	Brickwork	Red Burnt bricks with morter 1: 4 Rate per brick: Rs. 6-8 /piece. No of bricks required for 1m^3 volume- 500 pieces. Labour Output: 1.2 m^3/day.	Siporex Lightweight Block (Size-625*240*150 mm) Rate per block: Rs. 36/Piece No of bricks required for 1m^3 volume- 44 pieces. Labour Output: 2.12m^3 /day.

For Plastering, Painting, Electrification, Flooring, Sanitary Fitting, Plumbing, Steel work etc., the alternative used for crashing the network and reducing the total duration of the project was done by providing Additional labours.



1-2-3-4-6-7-9-10-12-13-14-17-18-19-21-22-23-25-26-27-29-30-32-33-34-36-37-39-40-41-43-44-45-46

Fig no: 05 Critical Path.

Crashing the Activity by using alternate resources:

Excavation:
Normal time = 8 days.
Normal cost = Rs. 48941.36./-
Labor output = Hard soil - 2m^3/labor/day.
Soft soil - 3m^3/labor/day.
Quantity = Hard soil - 170.26 m^3
Soft soil - 144.7 m^3
Alternative used = 40 HP JCB.
Output of JCB is dependent on its power in HP and the capacity of the bucket.
40 HP JCB can excavate:
25 – 30 cum/hour in HARD SOIL.
35 – 40 cum/hour in SOFT SOIL.
Total working hours = 8 hours/day.
Work done in hard soil/day = 30*8 = 240 cum/day.
Work done in soft soil/day = 40*8 = 230 cum/day.
Total hours required to excavate in hard soil with 30 cum/hour = 30*6 = 180cum i.e. 6 hours
Total hours required to excavate in hard soil with 30 cum/hour = 40*4 = 160cum i.e. 4 hours
Total work requires 10 hours i.e. 1 day to complete the work.
Rate of JCB = 1200/hour.
Total cost of work for 1 day = 10*1200 = Rs. 12000/-
Crash time = 1 day
Crash cost =Rs. 12000/-

Concreting:
Normal time = 10 days.
Normal cost = 648809/-
Labor output = 3 m^3/labor/day.
Quantity = 58.77 m^3.
Alternative used = RMC.
RMC truck capacity = 6.1 m^3.
(As about 6 to 8 tonne i.e. 16.99 m^3 to 22.65 m^3 fresh concrete can be produced every day that will be equal to 3 to 4 trucks per day).
Assume work to be done on site per day = 2 trucks.
Work done by RMC/day = 6.1*2 = 12.2 m^3.
Days required = $\frac{58.77}{12.2}$ = 4.81 = 5 days.
RMC Cost/m3 = Rs. 4500/-
(Excluding labor, transportation, and pumping, steel charges.)

RMC Cost/m^3 = Rs. 13540/-
(Including labor, transportation, and pumping, steel charges.)
RMC Cost/day = 13540*12.2 = Rs.165188/-
Total Cost of work for 5 days = 165188*5 = Rs.825940/-
Crash time = 5 days.
Crash cost = Rs. 825940/-

Brickwork:
Normal time = 8 days.
Normal cost = Rs. 802337.62./-
Labor output for convectional brickwork = 1.2m^3 /day.
Labor output for Si-Porex block work = 2.12m^3 /day.
Quantity = 133.57 m^3.
Alternative used = Si-Porex Block (size 625mm*240mm*150mm).
Total no. of Red burnt bricks required for 1 m^3 = 500 bricks.
Total no. of Si-Porex blocks required for 1 m^3 = 44 blocks.
Total no. of Red burnt bricks required to cover the work of 133.57 m^3 = 133.57*500 =66785 bricks.
Total no. of Si-Porex blocks required to cover the work of 133.57 m^3 = 133.57*44 =5760 blocks.
Cost of 1 Red burnt brick = Rs. 8/piece.
Total cost of Red burnt brick work = 66785*8 =534280/-
Cost of 1 Si-Porex block = Rs. 36/piece.
Total cost of Si-Porex block work = 5760*36 =207360/-
No. of labor required per day for Red burnt brick work = 14 labor/day. (For 8 days)
No. of labor required per day for Si-Porex block work = 12 labor/day. (For 5 days)
Labor cost for Red burnt brick work = 14*500 = 7000/day = 7000*8 =Rs. 56000/-
Labor cost for Si-Porex block work = 12*500 = 6000/day = 6000*5 =Rs. 30000/-
Crash time = 5 days.
Crash cost = Rs. 237360/-

ACTIVITY AND COST RELATIONSHIP

ACTIVIT Y	EVENT	NOR-MAL COST (NC)	NOR-MAL DURATION (ND)	CRASH COST (CC)	CRASH DURATION (CD)	COST SLOPE
-	-	-	-	-	-	-

- The cost slope required for further process of crashing the activities can be calculated by above mentioned tabular format.
- The Normal cost and Normal duration are calculated from the data obtained from the existing site at Aurangabad.
- The Normal cost and Normal duration along with the calculated crash cost and crash duration are to be put in the above table to calculate the cost slope of each activity by using the formulae given below:

- Cost Slope = $\frac{\text{Change in cost}}{\text{Change in time.}}$

$$= \frac{CC - NC}{ND - CD}$$

Where,
NT = Normal Time.
NC = Normal Cost.
CT = Crash Time.
CC = Crash Cost
After which the activities can be arranged in an ascending order and crashed respectively.

IV. Results

The Direct and Indirect costs calculated after crashing the activities on the critical path are as follows:

CALCULATIONS
Direct cost of project = 16260913.7
Indirect cost of project = 5341710.15
Total cost of project = 21602623.9
Total project duration = 327 days
Per day indirect cost = 16335.50

Sample Calculation:-
1) Crashing activity 1-2 by 3 days
Cost Slope = -176659 Rs

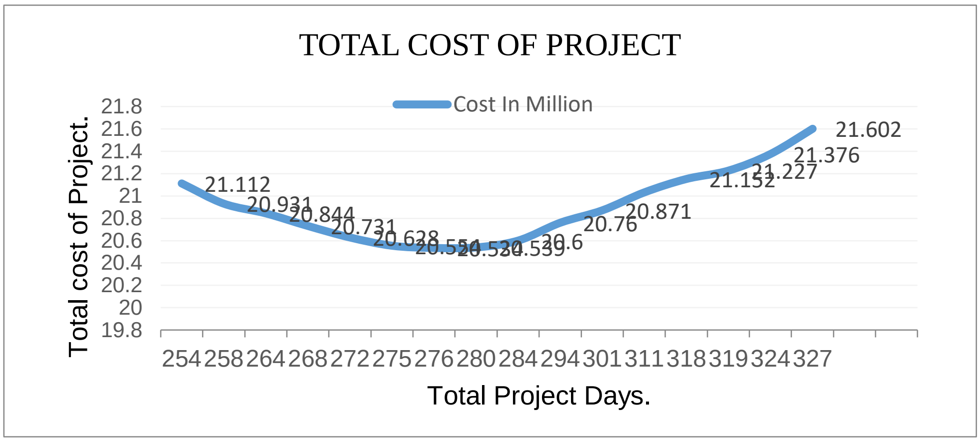
Total Cost = Total cost of project + (Cost Slope*Crash time) – (Crash time*Inirect Cost)
Total cost = 21602623.9 + (-176659.17) – (3*16335.50)
= 21376958.05
Total day = 324.

2) Crashing activity no.2 by 5 days
Cost slope = -67552.63
Total Cost = Total cost of project + Cost Slope – (Crash time*Direct Cost)
Total cost = 21376958.05 + (-67552.63) – (5*16355.50)
= 21227627.921
Total days = 319 days.
And so on..

TOTAL PROJECT COST:

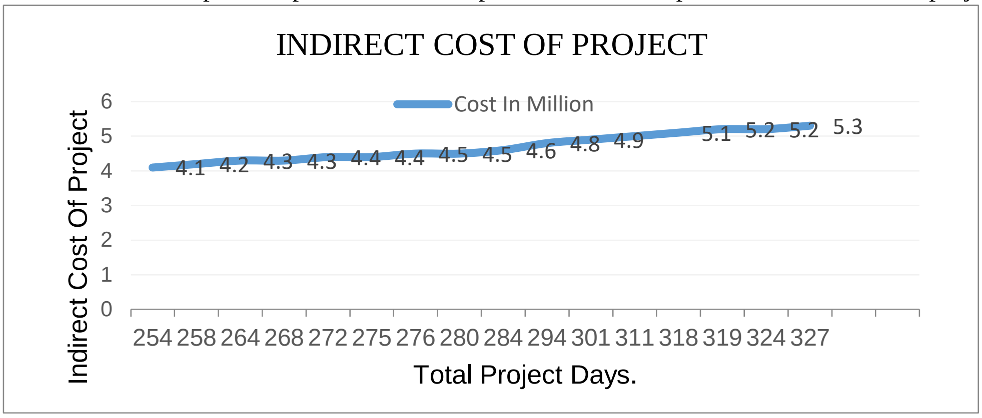
SR. NO.	ACTUAL DURATI-ON	DIRECT COST	INDIRECT COST	TOTAL COST
1	327	16260913.7	5341710.15	21602623.9
2	324	16084256.05	5292702.0	21376958.05
3	319	16016603.43	5211024.5	21227627.92
4	318	15957900.90	5194689.0	21152589.92
5	311	15952623.59	5080340.5	21032964.09
6	301	15954783.59	4916985.5	20871859.09
7	294	15957445.01	4802637.0	20760082.01
8	284	15961045.01	4639282.0	20600327.01
9	280	15965215.76	4573940.0	20539155.76
10	**276**	**16026035.58**	**4508598.0**	**20534633.58**
11	275	16062244.40	4492262.5	20554506.9
12	272	16185052.34	4443256.0	20628308.3
13	268	16353715.24	4377914.0	20731629.24
14	264	16532047.57	4312572.0	20844619.5
15	258	16716574.97	4214559.0	20931133.97
16	254	16963504.63	4149217.0	21112721.65

The Optimum Duration of the project with respect to Optimum Cost is obtained by crashing the network up to 276 days that is represented by the graphs given below:



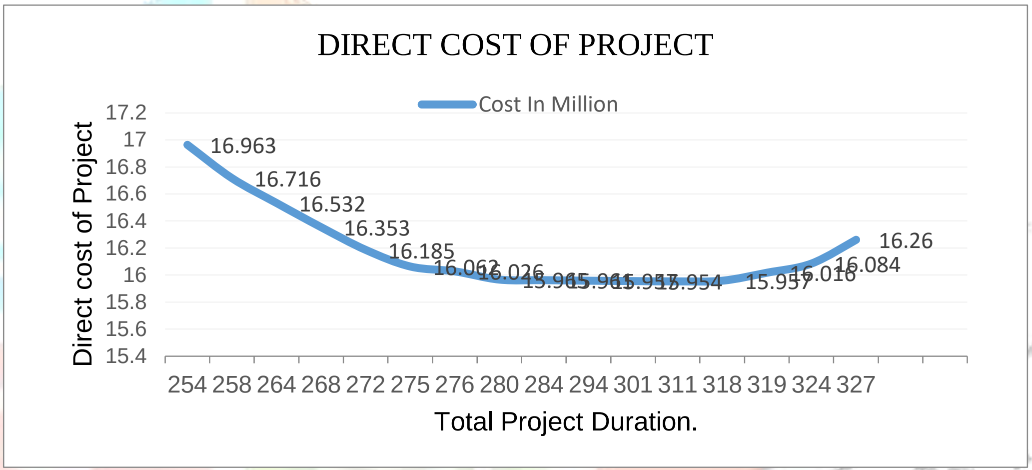
Graph No: 01

- As the process of crashing was started, the total duration of project went decreasing along with the total cost of the project, and obtained a certain point, after which the total cost went slightly increasing.
- The point obtained here was the optimum point which the optimum cost and optimum duration of the project i.e. up to 276 days.



Graph No: 02

- As the process of crashing was started, the indirect cost went decreasing in terms of indirect cost per day.
- The indirect cost was decreased as the duration of the project went decreasing.
- Decreasing duration of the project is directly proportional to the decreasing indirect cost.



Graph No: 03

- The direct cost of project goes on decreasing slightly up to a certain point, after which it goes on increasing further.

Results Obtained from the above mentioned calculations:

The normal duration of the project is 327 days.
The optimum duration obtained is 276 days.
The total days reduced are 51 days.
Total Cost of Project is Rs. 21602623.9/-
The total cost saved is Rs.1067990.32/-
The total indirect cost saved is Rs.833110.5/-
The total direct cost saved is Rs.234879.82/-

VI. CONCLUSION

As per the network crashing technique we obtained the Optimum duration with respect to optimum cost at a certain point and further we noticed increased in the cost, at that point we obtained the optimum cost and the optimum duration of the project.

The crashing of the project duration can also be done beyond its optimum point, if the resources and alternative are easily available and accessible, and also in case when the recovery of invested amount i.e. the refund amount can be obtained in a short period after the completion of the work.

Usually possible in case of commercial and institutional buildings or depending upon the respective purpose of the construction.

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