COMPARATIVE STUDY OF TIME-COST OPTIMIZATION

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ABSTRACT
Construction Planning is the most important phase of the project. Planning regarding crew size, materials, equipments etc., should be done in the planning phase. Construction planners use Critical path Method & PERT analysis to reduce the duration of the project. As the duration of the project reduces, the cost of the project increases i.e. there is a Trade-off between Time & Cost. Using CPM the overall cost of the project can be reduced by using less expensive resources on Non-critical activities. It could be used by construction managers in a planning stage to explore numerous possible opportunities to the contractor and predict the effect of a decision on the construction to facilitate a preferred operating policy given different management objectives.
The Study shows comparative results of the three techniques used to achieve Time-Cost Optimization. The two techniques used were Critical Path Method-Project Crashing Method, Linear Programming Method (LP). To compare the results a case study was considered i.e. construction of a Water Treatment Plant. Hence this paper presents:
1) Application of Project Crashing Method
2) Application of Linear Programming (LP)

KEYWORDS: Cost-optimization, Trade-off, Project crashing method, Linear Programming.

I-INTRODUCTION

Construction Project Management (CPM) is one of the important things to carry out the construction project. The construction planners go through different phases of Construction Project Management (CPM) successfully deliver the Project. CPM has been proved important to construction industry in the recent past years. Hence small, large and complex construction project using CPM tools have proved to be successful and have met the entire client's requirement. CPM aims to deliver a functional and financially viable project. Construction industry comprises of 3 sectors: Residential, Commercial and industrial. Hence CPM has proved to be useful in all the sectors of construction. CPM mainly comprises of 3 phases such as Planning Phase, Project scheduling Phase and Project Control Phase.

1.1. Phases of Construction Project Management:

1.1.1. Construction Planning Phase:

In this phase construction planners use various methods of planning to plan the schedule of the projects. The construction methods and technologies, equipments to be used and resources required will be decided in this stage. Work-breakdown structure and activities to execute the project are decided. The network diagram of the activities is drawn and precedence of each activity is decided. The durations for each activity is decided in this phase. Hence the total time required to complete the project is calculated. Cost estimations for the decided activities is calculated. Hence financial planning of the project is done.

1.1.2. Project scheduling Phase:

In this phase the actual action happens. The execution of the activities takes place as per planned schedule. Hence the resources are deployed and mobilization of equipments takes place in this phase. The resources assigned with activities and the resources carry out the assigned task for completion of the project. The main objective of this is to carry out the tasks smoothly so that the project gets completed as per planned schedule. If in this the execution takes place as per planned schedule the Project is considered to be successful and contractor meets the desired profits.

1.1.3. Project Control Phase:

In this phase if the project incurs with any delay or any complications, then to get the project back on track project control techniques are used. Rescheduling of the master schedule is done in this phase so that the project gets completed as per planned duration and cost. The critical activities are planned and executed with at most attention. Hence this phase is considered to be an important phase in CPM.

Existing Techniques for Time-Cost Optimization

The existing techniques for the construction time-cost optimization can be categorized into two areas: heuristic methods and mathematical programming models.

Time Cost Optimization is useful in following situations:

- Finish the project in a deadline date.
- Recover early delays.
- Avoid damages
- Free key resources early for other projects.
- Avoid weather conditions that might affect productivity.
- Receive early completion-bonus.
- Improve project cash flow.

Techniques used in this thesis: In this dissertation work a comparative study is done to find out the efficient method useful for Time-Cost Optimization (TCO). Hence a live project was taken into consideration. The project was construction of School building. Two methods of TCO analysis were used and compared. The two methods are as follows:

1) Project Crashing Method

2) Linear Programming Method

II-LITERATURE REVIEW

2.1 Review of Time-Cost optimization from previous studies:

Time and cost are two main desirables in construction projects. In the construction industry, contractors usually estimate the project duration and cost of a new project based on previous experiences. Typically, a project is divided into activities, for these activities the resources can be assigned and durations and costs estimated. The activities are linked according to work sequences to form a network. CPM techniques used to analyze the network to identify critical path(s) and project duration. In general, the more resources assigned to an activity, the less time it will take to complete the activity, but cost is usually higher. This optimization between time and cost gives construction planners both challenges and opportunities to prepare the best construction plan that optimizes time and cost to complete a project. In many cases, projects are required to be completed within certain duration. Mathematical methods convert CPM network and time-cost relationships into constraints and objective functions. Mathematical programming algorithms are used to obtain the optimal solutions. The advantages of mathematical approaches include efficiency and accuracy. However, formulating constraints and objective function is time-consuming and prone to errors. Mathematical programming knowledge is necessary to formulate these mathematical models correctly. Few construction planners trained to perform this type of formulation.

Heuristic methods are non computer methods that require less computational effort than mathematical methods. Examples of heuristic methods include Fondahl's method (FondahI1961), Prager's structural model (Prager 1963), Siemens's effective-cost slope model (Siemens 1971), and Moselhi's structural stiffness method (Moselhi 1993). These heuristic methods provide a way to obtain good solutions but do not guarantee optimal solutions. In addition, the solutions offered by heuristic methods do not provide the range of possible solutions. The simulation approach for optimization project cost and schedule was one of a variety of tools that could use to bring projects back under control and reinforce the use of project management in organizations. The use of simulation to crash project management networks in order to reduce time and cost overruns was a worth endeavor.The optimization of time and cost process technique could be incorporated as a standard procedure for every project was concluded, the time spent on the actual crashing was minimal and the project management schedule could be reduced to a minimum.

optimum level to save time and money. Judging from the state of research, there is a need to develop a more efficient and accurate method to solve the time-cost optimization problems for construction planning. The following sections describe a new approach to solving construction time-cost optimization problems that provides an efficient means of finding optimal strategies for construction time-cost decisions

2.2. Statement of the problem

Time and cost are two important parameters of the project. The main objective of the construction planners is to finish the project in the minimum cost and optimum duration. Hence optimization of time and cost are required as cost increases with increase in duration and also cost increases with decrease in duration. Hence this comparative study helps the planners to adopt a simple and easier optimization technique which can be used to get a brief idea about the optimum duration and minimum cost. Also helps the planners to crash the duration of the project in case of delay. This study can also help the planners to take optimal decisions and increase the profit margin of the project.

Objectives of the study

- Objective 1: Identifying various activities carried out during the construction of a project (Case study).
- Objective 2: Calculation of Normal Durations, Crash Durations, Normal cost & Crash cost.
- Objective 3: Applying Time Cost optimization by linear programming method (LPM).
- Objective 4: Applying Time Cost optimization by Critical Path method-Crashing of activities.

2.4. Scope of the study

Time cost optimization (TCO) helps to balance the optimization between time and cost of the project. The budget of the project can be controlled by this study. The deadline given by the client can be met by applying this study. Compare the results obtained from the analysis the planners can select the most optimum results and also the easiest method to find the time – cost optimization.

III-METHODOLOGY

The methodology used conduct this comparative study is as follows: Data collection, Work Break-down structure, List of activities for completion of the project, drawing of the network diagram, calculation of normal duration of the each activities, calculation of crash duration of the each activities, calculation of normal cost of the each activities, calculation of crash cost, calculation of the cost slope, finding out the critical path on the network diagram. The initial computations done to analyze Time-Cost Optimization of the project. After computations of the above data three analysis were carried out which are Project Crashing Method, Linear Programming Method (LPM). The results of the analysis were compared and the better method used for optimization was identified.

3.9. Time-Cost optimization analysis

After computation of the initial data, three Time-Cost optimization analyses were done to compare the results. Three techniques of analysis were used which are as follows:

3.9.1. Project Crashing Method

The Project Crashing method was used to find the optimum duration and minimum cost of the project. The procedure for shortening project duration can be summarized in the following steps:

1. Draw the project network diagram.
2. CPM calculations and identify the critical path, use normal durations and costs for all activities.
3. Compute the cost slope for each activity from the following equation: cost slope = crash cost – normal cost / normal duration – crash duration
4. Start by shortening the activity duration on the critical path which has the least cost slope and not been shortened to its crash duration.
5. Reduce the duration of the critical activities with least cost slope until its crash duration is reached or until the critical path changes.

6. When multiple critical paths are involved, the activity(ies) to shorten is determined by comparing the cost slope of the activity which lies on all critical paths (if any), with the sum of cost slope for a group of activities, each one of them lies on one of the critical paths.
7. The cost increase due to activity shortening is calculated as the cost slope multiplied by the time of time units shortened.
8. Continue until no further shortening is possible, and then the crash point is reached.
9. This is the project direct-cost / time relationship. By adding the project indirect cost to this curve to obtain the project time / cost curve. This curve gives the optimum duration and minimum cost.

3.9.2. Linear Programming Method

In this method the objective function is found by adding the cost slopes. This objective function is subjected to a number of constraints. The constraints are decided according to the normal duration and crashed durations. This equation is subjected to linear programming methods to find the optimum time and cost. A number of iterations are done. The LP method was subjected to equation by using LINDO software and results were found. The equation was created using the project cost formulation. In project cost formulation each activity is associated with the following three quantities.

- Crash duration a (i , j)
- Normal duration b (i, j)
- Cost slope c (i, j)

Assume that the cost of executing activity i-j increases linearly with decrease in time, while determining the cost slope.Activities are also known as decision variables such as x1, x2, x3,……(all are non-negative). Each Linear Programming model must have an exclusive objective function i.e. a single objective optimization is an essential requirement. There are always certain limitations or constraints on the use of limited resources. Standard form of LP can be represented as follows:
Let there be ‘n’ number of decision variables and ‘m’ constraints. Let the decision variables be x1, x2, x3…...xn. We have optimize (minimize) the values of x1, x2, ….xn. i.e. optimize Z = C1x1 + C2x2 + …… Cnxn where C1, C2, C3…… are constants. Subject to: a11 x1 + a12 x2 + ……..an xn
[≤, =, ≥] b1, an1 x1 + an2 x2 + ……..amn xn [≤, =, ≥] bm
And x1, x2,….xn > 0. We can solve the LP equation by simplex method.

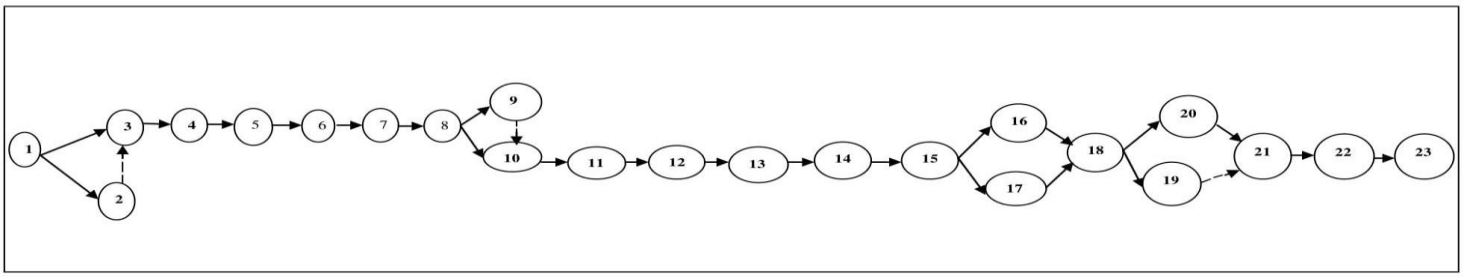
IV-Results and Discussion

Computation of Normal Cost, Crash cost and Cost slope

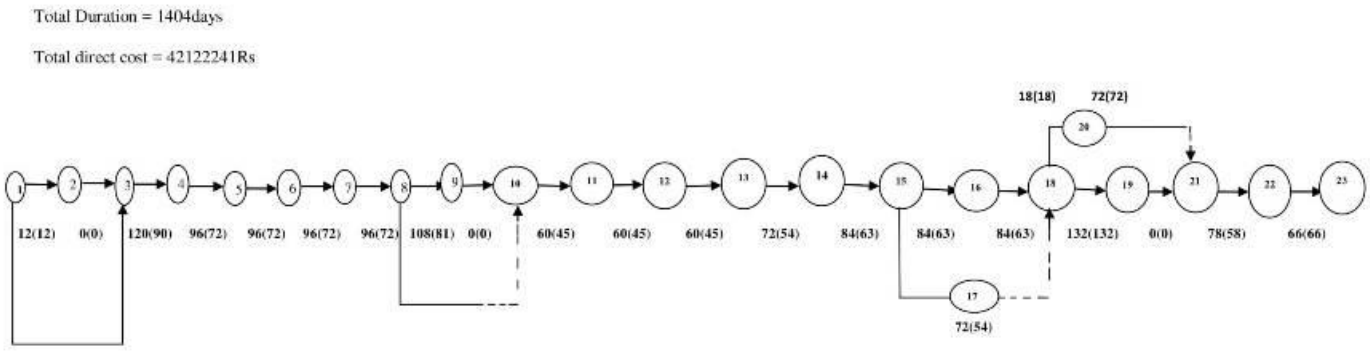
Activity ID	Normal Cost	Normal Duration	Crash Cost	Crash Duration	Cost Slope
1-3	12	12	36486.47	36486.47	0
1-2	12	12	35780	35780	0
3-4	120	90	2468954	3086193	20574.63
4-5	96	72	2392127.58	2671909.2	11657.56
5-6	96	72	3627652.74	4034714.1	16960.90
6-7	96	72	409228.36	476936.68	2821.20
7-8	96	72	547606.60	637493.14	3745.27
8-9	108	81	586334.32	777866.54	7093.80
8-10	102	76	1218116.14	1418079.24	7841.69
10-11	60	45	2017853.11	2303704.56	19056.76
11-12	60	45	1767644.11	2276765.96	33941.45
12-13	60	45	970368.299	1493190.75	34854.83
13-14	72	54	607704.39	778650.42	9497
14-15	84	63	2966674.66	3850116.28	42068.64
15-16	84	63	2445559	2919894.80	22587.42
16-18	84	63	988269.78	1287654.48	14256.41
17-18	72	54	1897767.96	2545867.96	36005.55
18-20	18	18	544293.66	544293.66	0
18-19	132	132	734031.48	734031.48	0
20-21	72	72	8273877.82	8273877.82	0
21-22	78	58	270018.86	356567.66	4438.4
22-23	66	66	2261209.61	2261209.61	0

Table- 4.1.1

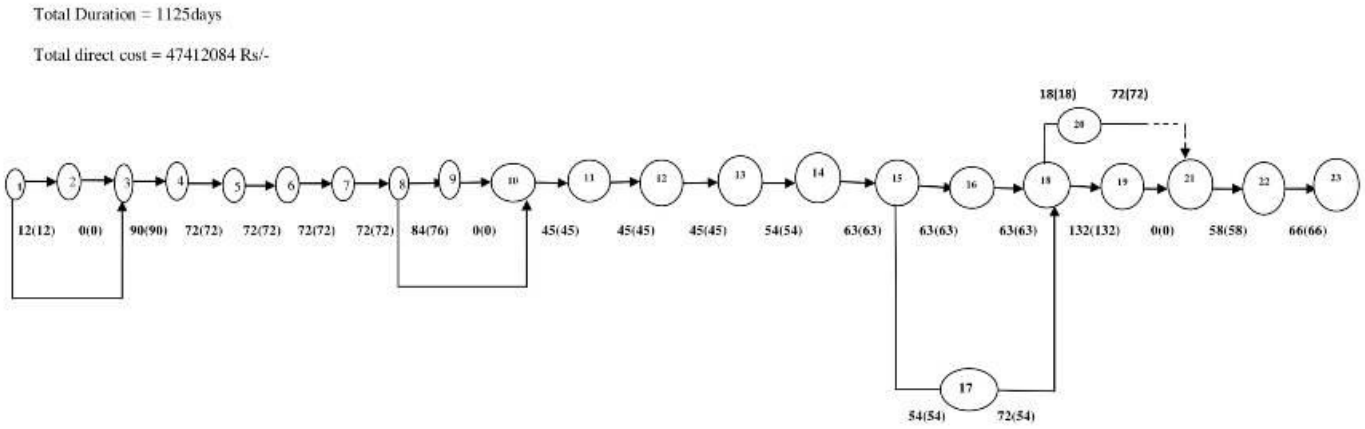
Network Diagram and Critical Path



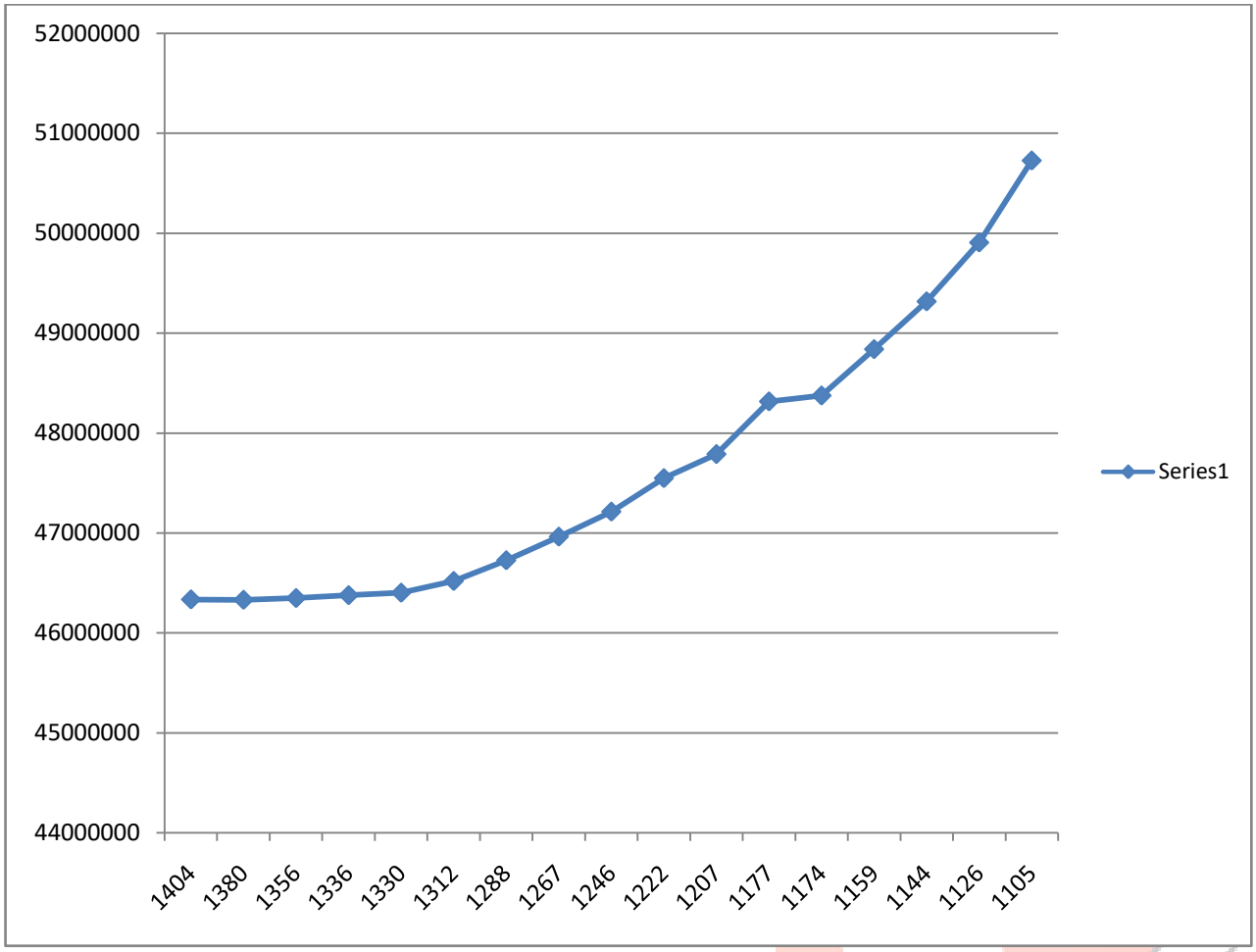
Critical Path = 1-2-3-4-5-6-7-8-9-10-11-12-13-14-15-16-18-19-21-22-23



Network diagram of initial stage of crashing



Network diagram of 16th stage of crashing



Graph Time v/s cost

V-CONCLUSION

5.1 Conclusion

A Comparative study of time -cost optimization analysis was done in this study. The optimization was achieved by two analysis techniques- 1) Project Crashing Method 2) Linear Programming Method (LPM). Initially, Work-break down structure, Activities, Network diagram, Normal & Crash Duration, Normal & Crash cost were calculated. The results obtained from all the two analyses are given below in the table 5.1.1.

Method	ProjectCrashing Method	Linear Programming Method(Lindo)	Linear Programming Solver
Optimum Duration(days)	1380	1404	1404
Minimum Cost(Rs.)	46329945 /-	46334241/-	46334241/-

Table 5.1.1

From the results we can make two comparative conclusions: 1) Comparing the results of Project Crashing Method and Linear Programming Method and 2) Comparing the results of Linear Programming obtained from LINDO and Linear programming solver.

Hence from this study we can conclude that Linear Programming method from LINDO is better than the other method employed. After going through the results Project Crashing Method gives better results than linear programming method. Also it does not have much computational efforts. Also LINDO is the best software as it does not involve any coding, it is easy to understand and can be operated by anyone. The software gives almost same optimized results. Hence Linear Programming Method using LINDO and LINEAR PROGRAMMING SOLVER is a better method for time-cost optimization since our objective was to obtain Minimum cost and optimum duration.

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