



APPLICATIONS OF OPTIMIZATION TECHNIQUES IN CONSTRUCTION MANAGEMENT

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ABSTRACT

The time management for a construction project can better justify by using optimization methods. Nowadays many computerized software are used to explore, to design, to analyze, and to solve different engineering problems. Construction management is not only a concept to manage a project work under the guidelines of 5M aspects, while it is actually a whole of initialization and termination of the particular construction project work. This concept can better understand by incorporating optimization techniques to find feasible solutions of different situations arise during the execution of an activity. An activity may be a matter of complication if it is started without planning. The worse results of activity reflected at end of the work in the form of uneconomical achievement. Thus, to overcome these unforeseen situations, it may be suitable to solve them using optimization methods and get an optimal result.

KEYWORDS – *Optimization Techniques, Construction Project Management, Linear Programming Problem, Minimum Construction Cost.*

1. INTRODUCTION

Optimization; in fact is a method of finding the feasibility of anything that happen. The optimization techniques are useful in finding the optimum solution or unconstrained maxima or minima of continuous and differentiable functions. These are analytical methods based on mathematical approach and used in locating the optimum solution of various engineering problems. When general optimization is used for engineering application then is termed as Engineering optimization in which various optimization techniques use to achieve design goals in engineering. It is sometimes referred to as design optimization.

1.1 Types of Optimization

Based on advanced mathematical approach the various types of methods of optimization are used for modeling of the different goals and to find the possible results. The various types of optimization are, that generally used in almost all disciplines of analytical studies -

- Continuous Optimization.
- Bound Constrained Optimization.
- Constrained Optimization.
- Derivative-Free Optimization.
- Discrete Optimization.
- Global Optimization.



- Linear Programming.
- Non-differentiable Optimization.

2. USE OF OPTIMIZATION TECHNIQUE IN SOLUTIONS OF (CPM) WORK RELATED PROBLEMS

The optimization is the best method to find the feasible solution of a formulated linear programming problem (LPP). It can be used to find out a feasible solution (mathematically) of a construction project activity regarding its progress and to find minimum construction cost calculation in performing the various activities (like to find out the best suitable path for performing various activities at priority and also result in getting minimum construction cost). This concept can be used as optimizing the solution to problems regarding progress of work. These two major problems related to project management, can be formulated as optimizing problems and their feasible solution can be found. The following examples are better describe the feasible use of this technique -

2.1 Example : *Problem 1* – is regarding for the progress of work, and

2.2 Example : *Problem 2* - is regarding for finding the minimum cost of construction choosing best suitable path.

Problem 1 –

For a sewer line project work, it is seen that the critical activity is of **7 months** for the **block no.-21** and **5 months** for the **block no.-27** i.e. **5040 hrs.** and **3600 hrs.** respectively (in the **block no. 21, 27** the running sites have to do job almost **720 hrs./month**). Both blocks move to sites **A1, A2, A3** and **A4** per day.

Block no.-21 requires **7 hrs.** to site **A1**, **6 hrs.** of site **A2**, **6 hrs.** of site **A3** and **5 hrs.** of site **A4**, but the sites of this block namely **A1, A2, A3** and **A4** have moved to work for **180 hrs., 120 hrs., 150 hrs.** and **90 hrs.** per month. Similarly **block no.-27** requires **8 hrs.** of site **A1**, **5 hrs.** of site **A2**, **5 hrs** of site **A3** and **6 hrs.** of site **A4**. But the sites of this block namely **A1, A2, A3** and **A4** have moved to work for **210 hrs., 90 hrs., 120 hrs.,** and **180 hrs.** per month. The loss in cost of construction of sewer line at site **A1** is **Rs.18000.00**, at site **A2** is **Rs. 15450.00**, at site **A3** is **Rs. 16250.00** and at site **A4** is **Rs. 14000.00** of both blocks. If the work is not completed at each site by the time than to how many sites need more stress to check it out.

Solution :

Artificial variable technique – Two phase method has been adopted in solving the given problem.

Let x_1, x_2, x_3 and x_4 are numbers of hours of sites **A1, A2, A3** and **A4**.

Total loss in Rs. will be given by-

Minimize to $Z = 18000 x_1 + 15450 x_2 + 16250 x_3 + 14000 x_4$

First we convert the problem from minimization to that of maximization.

Taking $Z = - Z$

Minimize to $Z' = 18000 x_1 + 15450 x_2 + 16250 x_3 + 14000 x_4$

Becomes

Maximize to $Z = -18000 x_1 - 15450 x_2 - 16250 x_3 - 14000 x_4$

Introducing surplus variables, we convert the constraints into equations-

i.e. $7 x_1 + 6 x_2 + 6 x_3 + 5 x_4 + x_5 \geq 540$

$8 x_1 + 5 x_2 + 5 x_3 + 6 x_4 + x_5 \geq 600$

x_1, x_2, x_3 and $x_4 \leq 0$

Artificial variable technique - Two phase method has been used to solve the problem –


Phase -1 : (Removal of artificial variable)

B	x_B	Y1	Y2	Y3	Y4	A1(S1)	A2(S2)
A1	540	7	6	6	5	1	0
A2	600	8	5	5	6	0	1
	x_j	0	0	0	0	540	600

↑
↓

Here **A1** and **A2** are artificial column vectors corresponding to variables x_5 and x_6 .

We first remove the artificial variable vectors from the basis matrix.

We select **Y4** to enter the basis matrix in place of **A2** (it can be seen that if **Y1** is chosen to enter the basis matrix, the revised solution is not non negative).

Dividing the second row by 6 and then subtracting its 4 times from the first row, we have-

B	x_B	Y1	Y2	Y3	Y4(S4)	A1(S1)	A2
A1	140	5/3	8/3	8/3	0	1	-4/6
	100	4/3	5/6	5/6	1	0	1/6
Y2	x_j	0	0	0	100	140	0

↑
↓

We delete the vector **A2** since x_6 has become 0. Now to remove **A1**

We introduce **Y1** in its place (for similar reasoning as above) in the basis matrix.

For this we multiply first row by 3/5 and then subtract 4/3 times of it from the second row.

B	x_B	Y1(S1)	Y2	Y3	Y4(S4)	A1
Y1	84	1	40	40	0	3/5
Y2	98.66	0	-2.71	-2.71	1	-0.63
	x_j	84	0	0	98.66	0

As artificial variable x_5 has also become 0. We delete the vector **A1** also.

Thus the solution after phase 1 is –

$$x_1 = 84, \quad x_4 = 98.66, \quad x_2 = 0 \quad \text{and} \quad x_3 = 0$$

This is the starting basic feasible solution to start the simplex routine.



Phase - II :Starting simplex table

B	C _B	x _B	Y1(S1)	Y2	Y3	Y4(S4)
Y1	1	84	1	40	40	0
Y4	1	98.66	0	-2.71	-2.71	1
Z' = C_Bx_B = 84-98.66 = -14.66		x _j	84	0	0	98.66
		C _j	1	0	0	1
		D _j	0	37.29	37.29	0

In the above table

$$D_2 = C_2 - C_B Y_2 = 0 - (1,1) (40,40)^T = 37.29$$

$$D_3 = C_3 - C_B Y_3 = 0 - (1,1) (-2.71, -2.71)^T = 37.29$$

Since D₂ and D₃ are both positive the optimal solution is –

$$x_1 = 84 \text{ hrs.}, \quad x_4 = 98.66 \text{ hrs.} \quad \text{and} \quad Z = 82.66$$

Ans.

Problem 2 -

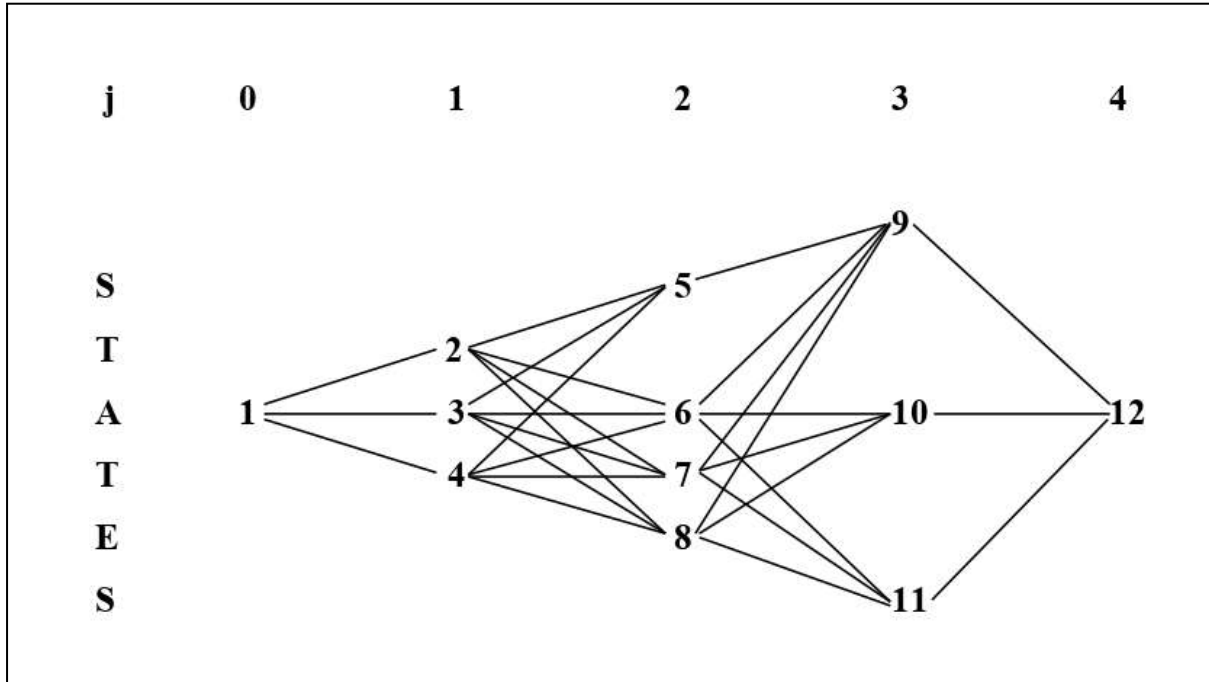
The ongoing sewer line project has to move from 1 to 12 various activities (no. of activities is not limited to 12). The average cost is Rs. in the multiple of 5000 of completion of an activity, then to move next. Determine the best suitable path should adopt to minimize the average cost of completion of all the activities.

From activity / to activity	2	3	4	5	6	7	8	9	10	11	12
1	5	3	6								
2				4	3	7	7				
3				5	5	3	4				
4				7	4	6	3				
5								7	6	9	
6								6	7	6	
7								8	9	6	
8								8	10	8	
9											9
10											12
11											8

Solution :

The problem is divided into 5 stages (j = 0,1,2,3,4) and each stage has no. of states associated with it. The various stages and states can also be exhibited as follows :

Stages -



Here $x_0 = 1$ and $x_4 = 12$. There are respectively 3, 4 and 3 states in stages 1, 2 and 3, the total no. of stages being 5.

To find the minimum cost of construction when a number of options are available at each stage, we use the relation –

$$f_n^*(S_n) = \min_{x_n} [C_{sxn} + f_{n+1}^*(x_n)]$$

Recursively as shown in tabular form :

j=3	State (s)	$f_4^*(s)$	x_4^*
	9	9	12
	10	12	12
	11	8	12

(Since there is only one path to get the minimum cost in each case i.e. move through activities 9, 10, 11 at priority)



j=2		< - Total cost for remaining stages->				
$\begin{matrix} x_3 \\ s \end{matrix}$		$f_3(s, x_3) = C_s x_3 + f_4^*(s)$				
		9	10	11	f_3^*	x_3^*
5		16	18	17	16	9
6		15	19	14	14	11
7		17	21	14	14	11
8		17	22	16	16	11

j=1		< - Total cost for remaining stages->					
$\begin{matrix} x_2 \\ s \end{matrix}$		$f_2(s, x_2) = c_{sx2} + f_3^*(s)$					
		5	6	7	8	f_2^*	x_2^*
2		20	17	21	23	17	6
3		21	19	17	20	17	7
4		23	18	20	19	18	6

j=1		< - Total cost for remaining stages->				
$\begin{matrix} x_1 \\ s \end{matrix}$		$f_1(s, x_1) = c_{sx1} + f_2^*(s)$				
		2	3	4	f_1^*	x_1^*
1		22	20	24	20	3

The total minimum cost = $f_1^*(s) = 20 \times 5000 = \text{Rs. } 1,00,000$

The root to be taken by the constructor for minimum cost is as follows:

Activity : 1 -> 3 -> 7 -> 11 -> 12

Ans.

3. CONCLUSION

The duration of activities for a particular project and cost can be minimized by the use traditional concept of CPM & PERT. These are the conceptual techniques under the project management planning and execution of work. Beside this technique the problems related to control and regulate critical activities and cost minimization can be easily obtained by using optimization. The result of problem-1 shows that the cost of activity can be minimized by reducing the duration of activities by optimization, which may result in cost control. The result of problem-2 shows that the suitable path for completion of critical activities of project work can be find by optimization. This is concluded that use of optimization techniques in solving critical situations arise during construction project management (CPM) is feasible.

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