Maximization of Construction Work Activities within Prefixed Budget Using Simplex Method

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Abstract- Operation research especially linear programming models are considered one of the most important tools used in optimization applications at many fields of production engineering and mass production, also linear programming applications was developed to construction engineering field. Linear programming implementation shows the practice of wide variety for construction problems especially cost with time issues and it is more applicable to generate a shortest computational effort and time with low cost. This paper focuses of optimizing number of works in order to reduce the maximum cost per apartment. This helps construction manager to decide the optimum bifurcation of each work for respective cost and completing project within certain fixed budget. Target cost control of construction projects is an important part of project management, and it plays a crucial role on the benefit of construction projects so here we try to minimize the cost involved using the simplex method. This project gives initial strategy to do so for small scale construction project first, and after successful implementation, it can be applied to the large-scale construction project.

Indexed Terms- Construction, Cost Control, Simplex method, Solver, Work Maximization

I. INTRODUCTION

A key problem manager's face is how to allocate scarce resources among various activities or projects. Linear programming, or LP, is a method of allocating resources in an optimal way. In this context, it refers to a planning process that allocates resources— labor, materials, machines, capital—in the best possible (optimal) way so that costs are minimized or profits are maximized. In LP, these resources are known as decision variables. The criterion for selecting the best values of the decision variables (e.g., to maximize profits or minimize costs) is known as the objective function. Limitations on resource availability form what is known as a constraint set. Sometimes one seeks to optimize (maximize or minimize) a known function (could be profit/loss or any output), subject to a set of linear constraints on the function. Linear Programming Problems (LPP) provide the method of finding such an optimized function along with/or the values which would optimize the required function accordingly. Every project is associated certain fixed cost, and project manager needs to complete the project less than or equal to that amount. This study helps manager to maximize the work with constrained on certain type of costs and then to find optimum number of work so as to get cost bifurcation for each type of work. So, same work can be done with the cost which is less than the fixed budget by satisfying all kind of budget.

II. LITERATURE REVIEW

The paper referred for analysis is *"An Approach to Maximize Profit of a Constructing Project within Limited Budget by Using Simplex Method"* by Shifat Ahmed, published in International Journal of Scientific & Engineering Research, Volume 6, Issue 11, November-2015. The paper is about how one can make use of simple statistical optimization technique like Simplex method in order to solve management issues in construction sector. In this paper they have taken data from the book Schedule of rates for civil works published by Public work department (Government of the people's, republic of Bangladesh) and the Mat

Home Limited, a real estate company. The objective was to arrange such type of model problem to complete maximum work in our limited budget. Hence the constraints were related to cost like material cost, transportation cost, labor cost, etc and the objective function involved the work arrangements like civil work (per floor) and internal electric, water supply and sanitary work (per floor) which had to be maximized. The analysis was done using simplex method and results were checked graphically.

Another paper which was under analysis was *"Application of Linear Programming in Multi-Design Selection"* by Mee-Edoiye M. Andawei, published in The International Journal Of Engineering And Science (IJES), Volume 3, Issue 1, 2014. This paper discusses the need of contractor as minimizing the cost using optimal linear programming methods. The paper assumes hypothetical situations with multi design setup and helps decision making in dynamic situation. It tries to minimize the cost directly using simplex method with simpler constraints without having deeper idea about other phenomenon involved in cost and construction sector. The paper considered only several design units and the objective was to maximize the profit by selecting optimum number of units produced for each design type. This paper moreover focuses on application of simplex method, however our objective was to use LPP in construction sector. The referred paper has more detailed idea and deeper understanding of cost with having interpretation of dual and primal.

Similarly, several such papers in construction domain having brief about were observed and compared. Considering the objective and resources available for analysis the referred paper were chosen. The list of some of the papers that were compared as follows:

1. *Profit Maximization In A Product Mix Company Using Linear Programming* by Waheed Babatunde Yahya, published in European Journal of Business and Management, ISSN 2222-1905 (Paper) ISSN 2222-2839 (Online), Vol 4, No.17, 2012
2. *Maximizing the value of residential projects using fuzzy rule based linear programming* by Alp USTUNDAG, Emre CEVIKCAN published in JOURNAL OF CIVIL ENGINEERING AND MANAGEMENT, ISSN 1392-3730 / eISSN 1822-3605, 2016 Volume 22(7): 853–861

III. TERMINOLOGIES USED

A good construction plan is the basis for developing the budget and allocation of work. Construction planning is a fundamental and challenging activity in the management and execution of construction projects. The choice of technology, the definition of work tasks, the estimation of the required resources and durations for particular work tasks, and the identification of any interactions among the different work tasks are very important.

A. Different types of work involved in construction activity

Construction work basically falls into 4 basic work, these are typically civil work, water supply, electrical work and transportation work.

1. Civil work

Civil work is all about designing, constructing and maintaining the physical and naturally built environment. It is the art of building bridges, dams, roads, airports, canals, and buildings.

2. Water supply work

Water supply work includes construction of facilities for water intake, water purification, or water distribution for public water supplies or factories or installation of public sewage or basin sewage handling facilities.

3. Electrical work

Electrical work includes installation of power generation, transformer, power distribution, and interior electrical facilities.

4. Sanitary work

Sanitary work deals with sanitary discharge pipes and sanitary appliances, such as installing, changing or relocating toilet bowls and sanitary piping system, for carrying used water from the premise/building to the used water system.

B. Different types of cost involved in construction activity

There are 3 main cost involved in construction work, these costs are material, labor and transportation cost.

1. Material cost

Material cost is the cost of materials used to manufacture a product or provide a service.

2. Labor cost

Labor cost is the sum of all wages paid to employees, as well as the cost of employee benefits and payroll taxes paid by an employer.

3. Transportation cost

Transportation cost involves cost in moving products or assets to a different place, which are often passed on to consumers.

IV. ALLOCATION OF TOTAL BUDGET INTO DIFFERENT TYPES OF COST

Construction is a challenging and a large-scale project. It is very difficult task to arrange total amount in starting of large project. In this case we execute our work with limited budget. Here we plan to complete maximum work in our limited budget. For simplicity we have combined civil work, sanitary work & water supply work. We use two variables X_1 and X_2. X_1 represents civil work, water supply work, sanitary work whereas X_2 represents electric work. Here we are focusing on primarily three types of costs, i.e. Material cost, labor cost and transport cost. Below table gives the percentages of material cost, labor cost and transportation cost allotted to each of the construction work i.e. (civil work + water supply + sanitary work) and electric work.

Cost	Construction work	
	Civil work + Water supply + Sanitary work	Electrical work
Material cost	70%	70%
Labor cost	20%	25%
Transportation cost	10%	5%

Table 1. Cost Distribution for various construction work (in %)

In Table 1, 70% indicates that out of the total cost allotted for completing (civil work + water supply + sanitary work) 70% of the total amount will be spend on material similarly 20% will be spend on labor wages and 10% spend for the transportation purpose related to (civil work + water supply + sanitary work).

Here we are fixing our maximum budget as 10 lakhs and hence further constraints on costs are divided as follows:

We divide our amount as total material cost never exceed 6 lakhs, total labor cost never exceed 3 lakhs and total transport cost never exceed 1 lakh. Also, the total budget for (civil work + water supply + sanitary work) is 4,86,000 and for electric work it is 30,000

Below table gives the total amount for completing the work

Type of work	Total bugdet
Civil work + Water supply + Sanitary work	4,86,000
Electric work	30,000

Table 2. Total budget for several construction works

As discussed earlier, of the total cost allotted for completing (civil work + water supply + sanitary work) 70% of the total budget will be spend for material

So, 70% of 486000 i.e. 0.7 x 486000 = 340200

Similarly, from remaining percentages the total amount spend can be calculated. Below table gives the bifurcation of total budget allocated for completing construction work into different types of costs.

Cost	Construction work	
	Civil work + Water supply work + Sanitary work	Electrical work
Material cost	3,40,200	21,000
Labor cost	97,200	7,500
Transportation cost	48,600	1,500

Table 3. Cost distribution for variables

V. FORMULATION OF OBJECTIVE FUNCTION

The aim is to maximize the total work, i.e. to maximize civil work, water supply work, electrical work and sanitary work in a limited budget (satisfying all the constraints of costs).

Objective function is

$$Max\ Z = a\ x_1 + b\ x_2$$

Where,
a = Total budget for completing (civil work + water supply + sanitary work)
b = Total budget for completing electrical work
Substituting the values of a and b we get,

$$Max\ Z = 486000x_1 + 30000x_2$$

$x_1, x_2 >= 0$

VI. FORMULATION OF MODEL CONSTRAINTS

The objective function is subject to following constraints:

- Total material cost should never exceed 6, 00,000. That is,
  $340200x_1+21000x_2 \leq 600000$ (1)
- Total labor cost should never exceed 3, 00,000. That is,
  $97200k_1+7500x_2 \leq 300000$ (2)
- Total transportation cost should never exceed 1, 00,000.
  That is,
  $48600x_1+1500x_2 \leq 100000$ (3)

VII. MODEL SOLUTION

Simplex Method has been used to solve the standard minimization problem.
The standard form of LPP can be given as
$Max\ Z = 486000x_1 + 30000x_2 + 0S_1 + 0S_2 + 0S_3$
$Subject\ to\ 340200x_1 + 21000x_2 + S_1 + 0S_2 + 0S_3 = 600000$
$97200x_1 + 7500x_2 + 0S_1 + S_2 + 0S_3 = 300000$
$48600x_1 + 1500x_2 + 0S_1 + 0S_2 + S_3 = 100000$
$x_1, x_2, S_1, S_2, S_3 >= 0$
The solution to the LPP has been obtained using the Excel Solver. The solution is:
$X_1 = 1.76$ & $X_2 = 0$

Below is the table displaying the results solved on MS-Excel Solver

Objective Function	486000	30000	
Optimum Value	1.7637	0	
Costs involved	Civil work, Water work & Sanitary work	Electric work	Max Budget
Material	340200	21000	600000
Labor	97200	7500	300000
Transport	48600	1500	100000

Table 4. Solver solution for basic variables.

We consider different combinations of basic variables in order to obtain the optimum combination.
The combinations were,

1. Civil work-Electric work &Water work–Sanitary work
2. Civil work-Water work & Electric work–Sanitary work

Following are the standard LPP and results of respective combinations.

1. Civil work-Electric work & Water work–Sanitary work

The standard form of LPP can be given as
$Max\ Z = 430000x_1 + 86000x_2 + 0S_1 + 0S_2 + 0S_3$
$Subject\ to\ 333250x_1 + 53750x_2 + S_1 + 0S_2 + 0S_3 = 600000$
$75250x_1 + 21500x_2 + 0S_1 + S_2 + 0S_3 = 300000$
$21500x_1 + 10750x_2 + 0S_1 + 0S_2 + S_3 = 100000$
The solution to the LPP has been obtained using the Excel Solver
The solution is:
$x_1 = 0.4430$ & $x_2 = 8.4164$

Below is the table displaying the results solved on MS-Excel Solver

Objective Function	430000	86000	
Optimum Value	0.4430	8.4164	
Costs involved	Civil work & Electric work	Water work & Sanitary work	Max Budget
Material	333250	53750	600000
Labor	75250	21500	300000
Transport	21500	10750	100000

Table 5. Solver solution for variable combination Civil work + Electric work and Water work + Sanitary work

1. Civil work-Water work & Electric work–Sanitary work

The standard form of LPP can be given as

Max Z = $428000x_1 + 88000x_2 + 0S_1 + 0S_2 + 0S_3$

Subject to $353100x_1 + 50600x_2 + S_1 + 0S_2 + 0S_3 = 600000$

$53500x_1 + 26400x_2 + 0S_1 + S_2 + 0S_3 = 300000$

$21400x_1 + 11000x_2 + 0S_1 + 0S_2 + S_3 = 100000$

The solution to the LPP has been obtained using the Excel Solver

The solution is:

$x_1 = 0.5498$ & $x_2 = 8.0214$

Below is the table displaying the results solved on MS-Excel Solver.

Objective Function	428000	88000	
Optimum Value	0.5498	8.0214	
Costs involved	Civil work & Water work	Electric work & Sanitary work	Max Budget
Material	353100	50600	600000
Labor	53500	26400	300000
Transport	21400	11000	100000

Table 6. Solver solution for variable combination Civil work + Water work and Electric work + Sanitary work

VIII. CONCLUSION AND INTERPRETATION

Using the optimum combination, we tried to maximize the work, considering all the constraints about each type of cost.

The optimal value obtained as,

$X_1 = 1.76$ = civil, water supply and sanitary work

$X_2 = 0$ = electric work.

Therefore, for per unit of civil work, water work and sanitary work we should spend Rs.1.76 whereas for unit of electric work we should spend very less amount as compared to civil, water and sanitary work to complete optimal work.

The prefixed budget for the project was 10 lac rupees, but using the optimal solution the total cost for the project is reduced to 8.47 Lac. With the help of this optimal solution we saved rupees 1.53 Lac behind the entire project, by maximizing our work and obeying all the constraints regarding each type of costs.

IX. SENSITIVITY ANALYSIS

Sensitivity analysis helps in how the optimal solution changes by changing the coefficients in the model.

It shows the allowable increase or decrease in the optimum value of objective function, here the maximized work which suggest that we can increase or decrease the availability of resources by the mentioned value in the table below.

Name	Final Value	Reduced Cost	Objective Coefficient	Allowable Increase	Allowable Decrease
Civil+water+sanitary work	1.76366843	0	486000	1.00E+05	0
Electric Work	0	0	30000	5000	10000

Table 7. Sensitivity analysis for Variables

From the sensitivity table given above, the current values of work variable x_1 i.e. Civil, water supply and sanitary work is 1.7636, while value of X2 i.e. electric work is negligible.

Solution for X1 is 1.7636 and coefficient of the objective function is 486000. The allowable increase and decrease column tell us that provided the coefficient of X1 in objective function lies between 486000 + 100000 = 586000 and 486000, optimum civil, water supply and sanitary work obtained using LPP will remain same.

Similarly for X2, since the value of X2 in objective function is zero, the allowable increase in coefficient of X2 in objective function is 30000 – 5000 = 25000 and 30000 + 10000 = 40000.

Name	Final Value	Shadow Price	Constraint R.H. Side	Allowable Increase	Allowable Decrease
material	600000	1.428571429	600000	100000	60000
labour	171428.5714	0	300000	1.00E+30	128571.4286
transport	85714.28571	0	100000	1E+30	14285.71429

Table 8. Sensitivity analysis for constraints.

From Table 8, it can be understood how much change in objective function can be caused if the constraints will be increased/decreased. This can be viewed by the column shadow price. The increase and decrease in the constraints should also be in a limit which is also mentioned in the table.

For, example, the actual constraint for total material cost is less than 600000. The shadow price for material cost says that one unit change in the constraint value for material cost will change the optimum value of budget by 1.4285 if the constraint is in between allowable increase/ decrease which is 700000 (600000+10000) and 540000 (600000-60000) without changing optimum work obtained. Similarly, change in labor and transport cost won't be having any effect on optimum budget.

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