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ALLOCATION OF TIME AND COST IN PROJECT MANAGEMENT PROBLEM THROUGH GOAL PROGRAMMING

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Abstract One of the myriad applications of the Goal Programming optimization technique is its application to project management problems. In this paper, we use the Goal Programming approach to allocate the time and cost constraints in a construction project optimization problem. Here, we consider a project that has eight objectives and analyse the results for an optimized time and cost allocated for the project. It illustrates a case study with real-life data with this novel approach.

1 Introduction

Project Management is the process of conducting and organizing the work of a team using novel management facilities to attain proposed goals of scope, cost, time, and quality. The purpose of project management is to develop an entire project that organizes the client's objectives and also to build or restore the client's advice to feasibly address the objectives. An extension of project management is construction management. It uses the same model to achieve the same goal but in a construction context. Construction management proceedings lead to maximal production at the least cost. It results in the completion of a construction project within the stipulated budget. It provides importance for optimum utilization of resources and results in the completion of a construction project with reasonable use of available resources.

The basic concept in the construction project management, whether it is agricultural, residential, commercial, institutional, industrial, heavy civil, or environmental, involves three phases-planning, scheduling, and controlling of the project. The planning phase comprises defined goals and objectives of the project, taking the notice of company policies, procedures, and rules. Planning helps to reduce the cost by optimum usage of available resources. It strengthens innovation and creativity among the construction managers. The scheduling phase comprises determining the time and sequence between project activities. It is the process of adapting the planned functions in an organized manner, assigning the starting and completion dates to each activity. The control phase deals with unexpected events in order to maintain the time and budget requirements. This phase is carried during the execution of the project. The difference between the scheduled work and actual work are reviewed once the project starts.

The controlling of the project has several objectives to be performed: excavation and foundation, superstructure, exterior closure, roof, interior construction, conveying, etc. Execution of the project involving multiple objectives can be solved using multiple-objective programming. This paper uses one of the techniques of multiple-objective programming called the Goal Programming in the allocation of budget and time for all the objectives and analyses the results to attain an optimized solution. The goal programming technique was originally developed by Charnes and Copper.

Goal Programming being a generalization of linear programming, to handle multiple and conflicting objectives for which effective algorithms are available. Multiple goals are taken into consideration while seeking the best solution from among a set of feasible solutions and deviation toward the goals are minimized. Deviation in the goals of an organization can be found by using the Goal Programming technique.

Several studies have been done on applications of the Goal Programming in project management. Abdelkrim Yahia-Berrouiguet and Khadija Tissourassi have done an application of the Goal Programming model for allocating time and cost in project management with a case study from the company of construction Seror considering three projects with three main phases. D. S. Hada., applied the Weighted Goal Programming to project management decisions with multiple goals. V. Prakash, A. M. Vijaya M.E, and A. S. S. Sekar developed time, cost trade-off techniques to attain the delivery of the project at the required time &with the minimal cost associated with the project. Mukherjee and Bera investigated the project selection decision using the Goal Programming technique. The model was applied to the Indian coal mining industry. Gyu and John experimented with the Goal Programming model for project selection and resource planning. Masood et al. developed a project selection model for health service institutions that assimilated research and development, investment plans, capital budgeting, etc. The decision model used was the 0-1 Goal Programming model, which is validated by applying it to real project selection data. Fabiane et al examined goal programming to a Brazilian forest problem. Liang focuses on developing a two-phase fuzzy mathematical programming approach for solving the multi-objective project management decision problems in a fuzzy environment. The model designed minimizes simultaneously total project costs, total completion time, and crashing costs concerning direct costs, indirect costs, contractual penalty costs, duration of activities, and the constraint of available budget.

This study aims to apply the Goal Programming model for allocating time and cost in the project management of a company. The paper is structured as follows: Section 2 presents the statement of the problem, and the solution procedure. Section 3 presents the model of the formulation of the problem with their respective notations. Section 4 presents a numerical example to test validity. Section 5 interpretation of the results. Section 6 concludes the study.

2 PROBLEM STATEMENT

The scope of this study is limited to applications of the Goal Programming model to real-time situations in the multi-objective decision-making problem. As a case study, we develop the Goal Programming model, taking an apartment complex construction problem (to maintain the secrecy of the data, we hide the company name), that has 4 floors and 12 flats, wherein, each floor has three flats (1-B.H.K, 2-B.H.K, and 3-B.H.K). The construction project has eight budget-related and time-related objectives, (i) Excavation and Foundation, (ii) Super Structure, (iii) Exterior Closure, (iv) Construction of Roof, (v) Interior Construction, (vi) Conveyance, (vii) Mechanical, and (viii) Electrical; and analyses the results for an optimized time and cost allocated for this project.

3 MODEL FORMULATION

Following is the proposed Goal Programming model formulation for allocating time and cost in project management.

Minimize $Z = \sum_{l=1}^{8} P_l(d_l^- + d_l^+)$

Subject to,

$$\sum_{l=1}^{8}\sum_{m=1}^{3} A_{lm}Y_m + d_l^- - d_l^+ = T_l$$

$$Y_{lm}, d_l^-, d_l^+ \geq 0; \forall l = 1, 2, \ldots, 8;\ m = 1, 2, 3.$$

3.1 Notations

$(l = 1, 2, 3, \ldots, 8)$: Set of Objectives.

$(m = 1, 2, 3)$: Three types of flats.

Z : Value of the objective function.

P_l : Pre-emptive priority of l^{th} objective.

d_l^- : Under achievement of l^{th} objective.

d_l^+ : Over achievement of l^{th} objective.

A_{lm} : Time and budget allocated for l^{th} goal and m^{th} flat.

Y_m : Decision variables.

T_l : Target value(Aspirational Value) of l^{th}goal.

Type-1 : 1-B.H.K flat.

Type-2 : 2-B.H.K flat.

Type-3 : 3-B.H.K flat.

4 NUMERICAL EXPERIMENT

The main objective of this paper is to develop a model of executing the allocation of time and cost to project management problems and to obtain an optimal feasible solution that satisfies all the goals of the project. The estimated costs in executing the projects are presented in (1) . The time allocation for project duration is presented in (2). Here, the priorities of all the goal constraints are fixed and the assumptions for executing the project are as follows:

(a) There are no restrictions on conveying the cost and time of the resources.

(b) Emergency requirement of the labour is not addressed.

(c) The working hours and pattern for executing the project remain the same as per the company rules.

(d) Natural calamities are not accounted during the execution of the project.

Table 1. Estimated Costs of the Project

S.No	Goals	Type-1 (Lakhs)	Type-2 (Lakhs)	Type-3 (Lakhs)	Target Values (Lakhs)	Priorities
1	Excavation & Foundation	56.1	117.30	132.60	375.123	P_1
2	Super Structure	12.466	26.067	29.467	83.26	P_2
3	Exterior Closure	17.453	36.493	41.253	116.704	P_3
4	Roof	5.211	10.896	12.317	34.844	P_4
5	Interior Construction	8.976	18.768	21.216	60.02	P_5
6	Conveyance	0.524	1.095	1.238	3.5	P_6
7	Mechanical	19.947	41.707	47.147	133.379	P_7
8	Electrical	3.989	8.342	9.429	26.675	P_8

Table 2. Estimated Time of the Project

S.No	Goals	Type-1 (Days)	Type-2 (Days)	Type-3 (Days)	Target Values (Days)	Priorities
1	Excavation & Foundation	1	1	1	5.45	P_1
2	Super Structure	27.5	57.5	65	150	P_2
3	Exterior Closure	3.113	6.51	7.36	17	P_3
4	Roof	9.17	19.17	21.67	50	P_4
5	Interior Construction	18.33	38.33	43.33	100	P_5
6	Conveyance	2.75	5.75	6.5	15	P_6
7	Mechanical	3.67	7.67	8.67	20.02	P_7
8	Electrical	3.67	7.67	8.67	20.02	P_8

4.1 Problem Formulation

The Goal Programming problem for allocating time and cost to of the project is formulated as below. The solution of the work is obtained by using LiPS(Linear Program Solver) for windows and results are discussed.

4.1.1 Allocation of Budget

$$\text{Minimize Z} = P_1(d_1^- + d_1^+) + P_2(d_2^- + d_2^+) + P_3(d_3^- + d_3^+) + P_4(d_4^- + d_4^+) + P_5(d_5^- + d_5^+) + P_6(d_6^- + d_6^+) + P_7(d_7^- + d_7^+) + P_8(d_8^- + d_8^+)$$

Subject to the constraints,

$$56.1Y_1 + 117.3Y_2 + 132.6Y_3 + d_1^- - d_1^+ = 375.123$$
$$12.466Y_1 + 26.067Y_2 + 29.467Y_3 + d_2^- - d_2^+ = 83.26$$
$$17.453Y_1 + 36.493Y_2 + 41.253Y_3 + d_3^- - d_3^+ = 116.704$$
$$5.211Y_1 + 10.896Y_2 + 12.317Y_3 + d_4^- - d_4^+ = 34.844$$
$$8.976Y_1 + 18.768Y_2 + 21.216Y_3 + d_5^- - d_5^+ = 60.02$$
$$0.524Y_1 + 1.095Y_2 + 1.238Y_3 + d_6^- - d_6^+ = 3.5$$
$$19.947Y_1 + 41.707Y_2 + 47.147Y_3 + d_7^- - d_7^+ = 133.379$$
$$3.989Y_1 + 8.342Y_2 + 9.429Y_3 + d_8^- - d_8^+ = 26.675$$

$Y_{lm}, d_l^-, d_l^+ \geq 0; \forall l = 1, 2, \ldots, 8;\ m = 1, 2, 3.$

4.1.2 Allocation of Time

$$\text{Minimize Z} = P_1(d_1^- + d_1^+) + P_2(d_2^- + d_2^+) + P_3(d_3^- + d_3^+) + P_4(d_4^- + d_4^+) + P_5(d_5^- + d_5^+) + P_6(d_6^- + d_6^+) + P_7(d_7^- + d_7^+) + P_8(d_8^- + d_8^+)$$

Subject to the constraints,

$$Y_1 + Y_2 + Y_3 + d_1^- - d_1^+ = 5.45$$
$$27.5Y_1 + 57.5Y_2 + 65Y_3 + d_2^- - d_2^+ = 150$$
$$3.113Y_1 + 6.51Y_2 + 7.36Y_3 + d_3^- - d_3^+ = 17$$
$$9.17Y_1 + 19.17Y_2 + 21.67Y_3 + d_4^- - d_4^+ = 50$$
$$18.33Y_1 + 38.33Y_2 + 43.33Y_3 + d_5^- - d_5^+ = 100$$
$$2.75Y_1 + 5.75Y_2 + 6.5Y_3 + d_6^- - d_6^+ = 15$$
$$3.67Y_1 + 7.67Y_2 + 8.67Y_3 + d_7^- - d_7^+ = 20.02$$
$$3.67Y_1 + 7.67Y_2 + 8.67Y_3 + d_8^- - d_8^+ = 20.02$$

$Y_{lm}, d_l^-, d_l^+ \geq 0; \forall l = 1, 2, \ldots, 8;\ m = 1, 2, 3.$

5 INTERPRETATION OF RESULTS

5.1 Result Interpretation of Budget and Time Allocation

Here is the interpretation of the result for the allocation of budget and time for the construction project with fixed priorities using LIPS.

- Priority1(goal1: Excavation Foundation) and Priority 2(goal2: Super Structure) is fully achieved without any deviations (i.e., $d_1^- = d_1^+ = d_2^- = d_2^+ = 0$). That means, the excavation and foundation, and superstructure of the building is completely done within the allotted budget and time as per the scheduled plan.
- Priority3(goal3: Exterior Closure), Priority5(goal5: Interior Construction), and Priority7(goal7: Mechanical) is achieved. i.e., the execution of the project for exterior closure, interior construction, and mechanical works went on according to the planned schedule and could save some budget and time too.
- Priority6(goal6: Conveyance) is achieved. i.e., the transportation cost of the required resources went a bit up than the actual cost but was on time.
- Priority4(goal4: Roof) is achieved. But both the budget and time are slightly on the higher side than the actual.
- Priority8(goal8: Electrical) is achieved and could be finished within the budget but took more time.
- Graphical representation of allocation of budget and time of constraints, is defined in graph (1) and (3), and the results for both in (2) and (4).

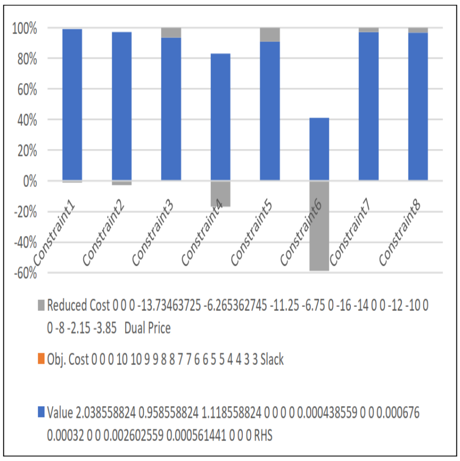

Figure 1. Budget Allocation Graph

Table3: Result of Budget Allocation

Optimal solution FOUND
Minimum Z = 0.025419

Variable	Value	Obj. Cost	Reduced Cost
Y1	2.03856	0	0
Y2	0.958559	0	0
Y3	1.11856	0	0
d1-	0	10	-13.7346
d1+	0	10	-6.26536
d2-	0	9	-11.25
d2+	0	9	-6.75
d3-	0.000438559	8	0
d3+	0	8	-16
d4-	0	7	-14
d4+	0.000676	7	0
d5-	0.00032	6	0
d5+	0	6	-12
d6-	0	5	-10
d6+	0.00260256	5	0
d7-	0.000561441	4	0
d7+	0	4	-8
d8-	0	3	-2.15
d8+	0	3	-3.85

Constraint	RHS	Slack	Dual Price
Constraint1	375.123	-	-3.73464
Constraint2	83.36	-	-2.25
Constraint3	116.704	-	8
Constraint4	8711/250	-	-7
Constraint5	60.02	-	6
Constraint6	3.5	-	-5
Constraint7	133.379	-	4
Constraint8	1067/40	-	0.85

Figure 2. Result of Budget Allocation

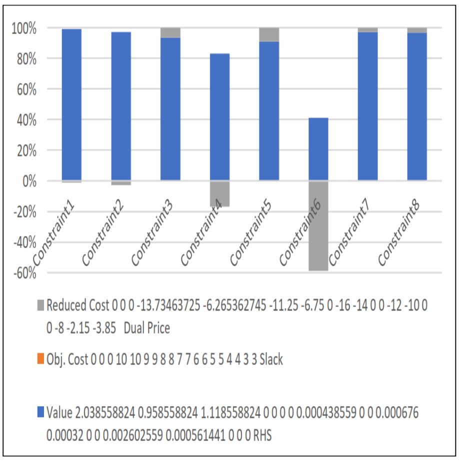

Figure 3. Time Allocation Graph

Table4: Result of Time Allocation

Optimal solution FOUND
Minimum = 0.408947

Variable	Value	Obj. Cost	Reduced Cost
Y1	817/150	0	0
Y2	0	0	-3/625
Y3	1/300	0	0
d1-	0	10	-9.96827
d1+	0	10	-10.0317
d2-	0	9	-13.006
d2+	0	9	-4.99397
d3-	0.0199933	8	0
d3+	0	8	-16
d4-	0	7	-14
d4+	109/6000	7	0
d5-	109/6000	6	0
d5+	0	6	-12
d6-	0	5	0
d6+	0	5	-10
d7-	11/6000	4	0
d7+	0	4	-8
d8-	11/6000	3	0
d8+	0	3	-6

Constraint	RHS	Slack	Dual Price
Constraint1	5.45	-	119/3750
Constraint2	150	-	-4.00603
Constraint3	17	-	8
Constraint4	50	-	-7
Constraint5	100	-	6
Constraint6	15	-	5
Constraint7	20.02	-	4
Constraint8	20.02	-	3

Figure 4. Result of Time Allocation

6 CONCLUSION

The goal of this paper was to test the Goal Programming model for allocating time and cost in project management; a case study was accomplished for a company of construction management problem. Results acknowledge that the model provides satisfactory levels of achievement for managing the project with eight pre-emptive goals.

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