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Goal Programming: A Modern Management Technique in Decision Making

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Abstract

Managerial objectives vary according to the characteristics, types, philosophy, and particular environmental conditions of the organization. There is no single universal goal for all organizations. However, in modern times most of the business and industrial organizations do not consider profit maximization as their sole objective and goal. They are equally concerned about market share goals, financial liquidity goals, employment goals, production goals etc. Besides, a wide range of social, political, economic and ethical aspects are increasingly being treated as goals by organizations. Thus, modern management has multiple conflicting objectives. This multiple conflicting objectives problem cannot be solved easily by traditional mathematical techniques. Goal programming is the most appropriate quantitative technique for solving such complex decision making problems. This paper shades light on the concept, philosophy and applicability of goal programming model in managerial decision.

Keywords

Goal Programming, Management Technique, Decision Making

1. Introduction

Managerial objectives vary according to the characteristics, types, philosophy, and particular environmental conditions of the organization. There is no single universal goal for all organizations. Profit maximization, which is regarded as the sole objective of the business firm in classical economic theory, is one of the most widely accepted goals of management. However, in modern times most of the business and industrial organizations do not consider profit maximization as their sole objective and goal. They are equally concerned about market share goals, financial liquidity goals, employment goals, production goals etc. Sometimes the liquidity goal or market share goal, for instance, may conflict with the profitability goal in that higher liquidity or market share may mean lower profitability. There is a trade-off depending on the importance attached to various goals (Kothari, 1996). Besides, a wide range of social, political, economic and ethical aspects are increasingly being treated as goals by organizations. Government organizations are very much concerned about such objectives as employment generation, public health, equitable distribution,

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consumer protection, environmental control and so on. It is seen that some firms place greater emphasis on social responsibilities, social contribution, public relations, industrial and labour relations, etc. than on profit maximization. Such goals are sought because of outside pressure or voluntary management decisions and therefore, non-economic goals exist and are gaining greater significance. Thus, management has multiple conflicting objectives to achieve in the present day business scenario. This implies that the decision criteria should be multidimensional and the decision involves multiple conflicting goals. The problems involving multiple objectives or goals cannot be easily solved by traditional mathematical techniques. The objective no longer will be restricted to a cardinal criterion like just profits or costs. Goal programming, based on the ordinal solution approach, appears to be the most appropriate, flexible, capable and powerful quantitative technique for complex decision problems involving multiple conflicting objectives (Lee and Moore, 1975).

The main objectives of the study are to highlight the concept of Goal Programming technique, to encourage the executives to use the modern management techniques particularly Goal Programming technique, when multiple conflicting objectives are involved in their decision making. The secondary sources of data are used for the study. The main sources of data are different books, journals etc. related to Goal programming.

2. What is Goal Programming?

Goal Programming is capable of handling decision problems involving multiple goals. The concept of Goal Programming was introduced by Charnes and Cooper (1961) and has been refined and extended by Lee (1972) and Ignizio (1976). They suggested a method for solving infeasible Linear Programming problems arising from various conflicting resource constraints. A few examples of multiple conflicting goals are maximize profits and increase wages paid to employees, upgrade product quality and reduce product cost, reduce credit losses and increase sales etc.

In typical decision-making situations, the goals set by management can be achieved only at the expense of other goals. It is necessary to establish a hierarchy of importance among these goals so that lower priority goals are tackled only after higher priority goals are satisfied. Since it is not always possible to achieve every goal to the extent the decision maker desires, Goal Programming attempts to reach a satisfactory level of multiple objectives. This, of course, differs from Linear Programming, which tries to find the best possible outcome for a single objective. Nobel laureate Professor Herbert A. Simon (1960) states that modern managers may not be able to optimize, but may instead have to 'satisfies' or 'come as close as possible' to reaching goals. This is the case with models such as Goal Programming. Thus, we can say that Goal Programming is an appropriate technique for modern management.

In Goal Programming, the objective function contains primarily the deviational variables that represent each goal or sub-goal. The deviational variable is

represented in two dimensions in the objective function, a positive and a negative deviation from each sub-goal and / or constraint. Then, the objective function becomes the minimization of these deviations, based on the relative importance or priority assigned to them.

Since all goals usually are not equally important; some goals are more important than other goals, deviations (negative and/or positive) from these goals are not additive. Hence to achieve these goals according to their importance a 'pre-emptive' priority factor P_1, P_2, ..., and so forth is assigned to goal deviations in the formulation of the objective function to be minimized. The P's do not assume numerical value, they are simply a convenient way of indicating that one goal is more important than another. Thus the priority factors have the relationship of $P_1 >> P_2 >> \ldots\ldots >> P_k >> P_{k+1} \ldots\ldots$ where >> means "more important than". This means $P_j >> nP_{j+1}$ (j=1,2,3,.....k) where n is a very large number, implies that multiplication by n cannot make a lower order goal as important as the higher order goal. Hence, a lower-priority goal will never be achieved at the expense of a higher priority goal. It is possible that two or more goals may be assigned equal priority factor i.e. they are equal in importance. Further, within a given priority there may be sub-goals of unequal importance which must be given due importance (weightage). In other words, the differential weights are assigned to the individual deviational variable with the identical priority factor in the Goal Programming objective function. It is worthy to note that the deviational variables at the same priority level must have the same unit of measurement (commensurable), although deviations that are at different priority levels need not be commensurable.

Thus, Goal Programming has been defined as an "--- extension of Linear Programming in which management objectives are treated as goals to be attained as closely as possible within the practical constraints of the problem. Each goal, instead of being part of the objective function is expressed as a constraint. The objective function contains variables that measure the amount by which goal achievements deviate from target values set by management. The objective of the goal program is to minimize these deviations". The Goal Programming model attempts to obtain a satisfactory level of goal attainment that would be the best feasible solution in view of the priorities of the goals. Thus, higher priority goals can be attained at the expense of the lower priority goals.

Preemptive Goal Programming

A preemptive goal program is an alternative procedure for accommodating several goals without using artificial penalty weights. Goals are prioritized. The goal deviation variables and constraints are the same as in a regular program. In place of the omnibus objective is a single-variable objective: minimizing the goal deviation variable representing the amount of violation from goal 1. If goal 1 is met by the LP solution then a new constraint is added to the others, forcing the goal 1 deviation to be zero. The new objective seeks to minimize the goal deviation variable for goal 2. The LP is expanded as before and so on until one of the goal targets is violated. The process then stops and the last solution apply.

3. Linear Programming Versus Goal Programming

Although Linear Programming applications can be found throughout organizations worldwide, when several competing objectives must be considered simultaneously, a more sophisticated tool like Goal Programming technique is needed. The main differences of Linear Programming and Goal Programming are shown in the following table.

Dimension	Linear Programming (LP)	Goal Programming (GP)
Goal and objectives	One primary – to be maximized or minimized.	All objectives are ranked each with a target.
Targets or constraints	Inflexible, no deviations are allowed.	Flexible, deviations are acceptable, constraints can be relaxed.
Objective function	Maximize (minimize) the value of the primary goal	Minimize the sum of the undesirable deviations (weighted by their relative importance)
Purpose	Optimization	Satisfaction
Theory	Mature	Relative young, developing.
Computer programs	Very efficient, many packages	Inefficient, few computer packages
Applications	Many and varied	Few, but increasing.

Source: Turban and Merideth (1998)

4. Goal Programming Model- An Example

Here, we set an example of Goal Programming problem for better understanding of the concept, formulation and solution procedure of the model. Such problems are available in different texts of Goal Programming (Render et. al., 2003; Turban and Merideth, 1998). Let us assume that *The General Electric Company* produces two products Table fan and Ceiling fan. Both the Table fans and Ceiling fans require a two-step production process involving wiring and assembly. It takes about 2 hours to wire each Table fan and 3 hours to wire a Ceiling fan. Final assembly of the Table fan and Ceiling fan requires 6 and 5 hours respectively. The production capacity is such that only 12 hours of wiring time and 30 hours of assembly time are available. Each Table fan contributes $7 and each Ceiling fan contributes $6. The management has set the following goals, in descending order:

Goal 1: Make a profit at least $30.

Goal 2: Fully utilize the available hours in the wiring department.

Goal 3: Avoid overtime in the assembly department.

Goal 4: Meet a contract requirement to produce at least 7 ceiling fans.

Formulation of the Given Goal Programming Problem

$$\text{Minimize } Z = P_1 d_1^- + P_2 d_2^- + P_3 d_3^+ + P_4 d_4^-$$

Subject to,

$$7x_1 + 6x_2 + d_1^- - d_1^+ = 30$$
$$2x_1 + 3x_2 + d_2^- - d_2^+ = 12$$
$$6x_1 + 5x_2 + d_3^- - d_3^+ = 30$$
$$x_2 + d_4^- - d_4^+ = 7$$
$$x_1, x_2, d_1^-, d_1^+, d_2^-, d_2^+, d_3^-, d_3^+, d_4^-, d_4^+ \geq 0$$

where x_1 = Number of Table fan produced.

x_2 = Number of ceiling fans produced.

d_1^- = underachievement of the profit target.

d_1^+ = overachievement of the profit target.

d_2^- = idle time in the wiring department.

d_2^+ = overtime in the wiring department.

d_3^- = idle time in the assembly department.

d_3^+ = overtime in the assembly department.

d_4^- = underachievement of the ceiling fan goal

d_4^+ = overachievement of the ceiling fan goal.

P_1 = First Priority.
P_2 = Second Priority.
P_3 = Third Priority.
P_4 = Fourth Priority.

5. Solution of the Given Goal Programming Problem

Goal programming problems can be solved by using graphical method as well as by Goal programming algorithm. The graphical approach to Goal Programming has the same drawbacks as Linear Programming – namely, it can only handle problems with two real variables. There are many computer softwares of Goal Programming that are available to solve Goal Programming problem. We solve the given Goal Programming problem by using Goal Programming algorithm (Appendix -1).

The solution of the given Goal Programming problem is:

x_1 = 0 Table fan produced, x_2 = 6 ceiling fans produced, d_1^- = \$0, d_1^+ = \$6 over the profit target, d_2^- = 0 hours, d_2^+ = 6 wiring hours over the minimum set, d_3^- = \$0 hours, d_3^+ = 0 hours, d_4^- = 1 ceiling fan less than desired, d_4^+ = 0 ceiling fan.

Thus, the profit goal is met and exceeded by $6 (a $36 profit was attained), the wiring department is fully utilized as 6 hours overtime, the assembly department has no idle time (or overtime) and the ceiling fan goal is underachieved by only one fan. This is the most satisfactory solution to the problem.

6. Application Area of Goal Programming

The salient feature of Goal Programming is its capability to handle managerial problems that involve multiple incompatible goals according to their importance. If management is capable of establishing ordinal importance of goals in a linear decision system, the Goal Programming model provides management with the opportunity to analyze the soundness of their goal structure. Scope of application of Goal Programming is enormous. Goal Programming has been applied to a wide range planning, resource allocation, policy analysis and functional management problems and many other areas where management faces conflict in multiple objectives with differential weights. However, we mention below a few areas where Goal Programming can be used effectively and efficiently.

i. Goal Programming is useful to the Production Management. It can be applied to aggregate production planning and scheduling. Goodman (1974) applied this model in aggregate planning of production work force.

ii. Goal Programming is useful to the Marketing Management. It can be applied to media planning product mix decisions. Charnes et al (1968) first used the model for advertising media planning. Lee and Bird (1970) and Lee and Nicely (1974) have used this technique in other strategic marketing decision analysis.

iii. Goal Programming is useful to the Financial Management. It can be applied to portfolio selection, capital budgeting and financial planning.

iv. Goal Programming is useful to the Personnel Management. It can be applied for manpower planning. Charnes et al (1968a) used this technique in manpower planning.

v. Goal Programming is useful to the Academic Field. It can be used in assigning faculty-teaching schedules and for university admissions planning. Lee and Clayton (1972) used the model for academic resource allocation.

vi. Goal Programming is useful to the Allocation of Scarce Resources. It can be applied to economic planning, transportation systems and medical care planning etc. Charnes et al (1976) used the model for resource allocation in a marine environmental protection program.

7. Modern Management Techniques Application in Bangladesh

Bangladesh is a developing country. Development strategists and economists identified the lack of organization ability, skill and efficiency of human resources as one of the major factors of inability to utilize the resources properly for development. Gunnar Myrdal (1968), Sen (1990), Chenary and Strout (1966) emphatically indicated that the acquiring of necessary competency in management of resources and organization is a precondition for purposeful implementation of development strategies in order to achieve economic progress. Not only that, sustenance of the fruits of development and the continuance of the economic growth, the efficiency and competency of management is imperative.

Bangladesh started her development process with all evils of backwardness, but already showed positive signs of economic progress following the path of planned economy during last three decades. Industrialization of the economy has also been made a significant headway during this period. Liberalization of the economy has already been started since early part of eighties. This eventually should push the entrepreneurs and managers into new type of competition in a global scale. Players of the other world in this competition are equipped not only with advanced technology in production but also with competent and efficient managerial staffs that are educated enough to apply all modern managerial techniques like Goal Programming. Application of modern management techniques in Bangladesh in managerial decision-making process is unfortunately lagging behind its expected standard. Khan and Rahman (2004) undertook a survey on the level of application of Operations Research techniques i.e. modern management techniques in Bangladesh. They reported that about 90% top management of Bangladesh is unaware of modern management techniques. Not only that, most popular modern management techniques like Linear Programming, Goal Programming, Input-Output Model, Markovian Model, Transportation Model, Assignment Model, Information Theory, Computer Simulation etc. are not used in the surveyed organizations. International experience shows that by applying simple optimizing techniques, wastages of resources worth million of dollars can be avoided, additional revenue of million dollars can be generated (Appendix -2). We presume that there are so many areas in economic front of Bangladesh where, by using these modern management techniques, we can improve much more with regard to managerial efficiency without any foreign help.

8. Conclusion

Goal programming is a relatively newest and youngest technique in modern Management Science. It has great deal of flexibility and attainment of multiple goals with differential weights that makes it more suitable and effective in modern management. It can be applied to many real-life situations (i.e. manufacturing, marketing, advertising, banking sector etc) where multiple conflicting goals are involved. In this article, it is clearly shown that how an executive can use the Goal programming model for satisfying his/her multiple conflicting management objectives. Thus, its use in practical life problems of planning and policy analysis is especially helpful.

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Appendix – 1

Table – 1

Cj		0	0	p_1	p_2	0	p_4	0	0	p_3	0	Quantity
C_B	Solution mix	x_1	x_2	d_1^-	d_2^-	d_3^-	d_4^-	d_1^+	d_2^+	d_3^+	d_4^+	
p_1	d_1^-	7	6	1	0	0	0	-1	0	0	0	30
p_2	d_2^-	2	3	0	1	0	0	0	–1	0	0	12
0	d_3^-	6	5	0	0	1	0	0	0	–1	0	30
p_4	d_4^-	0	1	0	0	0	1	0	0	0	–1	7
p_4	Z_j	0	1	0	0	0	1	0	0	0	–1	7
	$C_j - Z_j$	0	–1	0	0	0	0	0	0	0	1	
p_3	Z_j	0	0	0	0	0	0	0	0	0	0	0
	$C_j - Z_j$	0	0	0	0	0	0	0	0	1	0	
p_2	Z_j	2	3	0	1	0	0	0	–1	0	0	12
	$C_j - Z_j$	–2	–3	0	0	0	0	0	1	0	0	
p_1	Z_j	7	6	1	0	0	0	–1	0	0	0	30
	$C_j - Z_j$	–7	–6	0	0	0	0	1	0	0	0	

Table – 2

Cj		0	0	p_1	p_2	0	p_4	0	0	p_3	0	Quantity
C_B	Solution mix	x_1	x_2	d_1^-	d_2^-	d_3^-	d_4^-	d_1^+	d_2^+	d_3^+	d_4^+	
0	x_1	1	$\frac{6}{7}$	$\frac{1}{7}$	0	0	0	$-\frac{1}{7}$	0	0	0	$\frac{30}{7}$
p_2	d_2^-	0	$\frac{9}{7}$	$-\frac{2}{7}$	1	0	0	$\frac{2}{7}$	–1	0	0	$\frac{24}{7}$
0	d_3^-	0	$-\frac{1}{7}$	$-\frac{6}{7}$	0	1	0	$\frac{6}{7}$	0	–1	0	$\frac{30}{7}$
p_4	d_4^-	0	1	0	0	0	1	0	0	0	–1	7
p_4	Z_j	0	1	0	0	0	1	0	0	0	–1	7
	$C_j - Z_j$	0	–1	0	0	0	0	0	0	0	1	
p_3	Z_j	0	0	0	0	0	0	0	0	0	0	0
	$C_j - Z_j$	0	0	0	0	0	0	0	0	1	0	
p_2	Z_j	0	$\frac{9}{7}$	$-\frac{2}{7}$	1	0	0	$\frac{2}{7}$	–1	0	0	$\frac{24}{7}$
	$C_j - Z_j$	0	$-\frac{9}{7}$	$\frac{2}{7}$	0	0	0	$-\frac{2}{7}$	1	0	0	
p_1	Z_j	0	0	0	0	0	0	0	0	0	0	0
	$C_j - Z_j$	0	0	0	0	0	0	0	0	0	0	

Table – 3

Cj		0	0	p_1	p_2	0	p_4	0	0	p_3	0	Quantity
C_B	Solution mix	x_1	x_2	d_1^-	d_2^-	d_3^-	d_4^-	d_1^+	d_2^+	d_3^+	d_4^+	
0	d_2^+	$\frac{8}{5}$	0	0	–1	$\frac{3}{5}$	0	0	1	$-\frac{3}{5}$	0	6
0	x_2	$\frac{6}{5}$	1	0	0	$\frac{1}{5}$	0	0	0	$-\frac{6}{5}$	0	6
0	d_1^+	$\frac{1}{5}$	0	–1	0	$\frac{6}{5}$	0	1	0	$-\frac{6}{5}$	0	6
p_4	d_4^-	$-\frac{6}{5}$	0	0	0	$-\frac{1}{5}$	1	0	0	$\frac{1}{5}$	–1	1
p_4	Z_j	$-\frac{6}{5}$	0	0	0	$-\frac{1}{5}$	1	0	0	$\frac{1}{5}$	–1	1
	$C_j - Z_j$	$\frac{6}{5}$	0	0	0	$\frac{1}{5}$	0	0	0	$-\frac{1}{5}$	1	
p_3	Z_j	0	0	0	0	0	0	0	0	0	0	0
	$C_j - Z_j$	0	0	0	0	0	0	0	0	1	0	
p_2	Z_j	0	0	0	0	0	0	0	0	0	0	0
	$C_j - Z_j$	0	0	0	1	0	0	0	0	0	0	
p_1	Z_j	0	0	0	0	0	0	0	0	0	0	0
	$C_j - Z_j$	0	0	1	0	0	0	0	0	0	0	

Appendix-2

Some Applications of Management Science Techniques in Different Organizations in the World:

Organization	Nature of Application	Year of Publication	Annual Savings
The Netherlands Rijkswaterstatt	Develop national water management policy, including mix of new facilities, operating procedures, and pricing	1985	$ 15 million
Monsanto Corp.	Optimize production operations in chemical plants to meet production targets with minimum cost.	1985	$ 2 million
Weyerhauser Co.	Optimize how trees are cut into wood products to maximize their yield.	1986	$15 million
Electrobras / CEPAL, Brazil	Optimally allocate hydro and thermal resources in the national electrical generating system.	1986	$ 43 million
United Airlines	Schedule shift work at reservation offices and airports to meet customer needs with minimum cost.	1986	$ 6 million
Citago Petroleum Corp.	Optimize refinery operations and the supply, distribution, and marketing of products.	1987	$ 70 million
SANTOS, Ltd. Australia.	Optimize capital investments for producing natural gas over a 25-year period.	1987	$ 3 million
San Francisco Police Dept.	Optimally schedule and deploy police patrol officers with a computerized system.	1989	$ 11 million
Electric Power Research Institute.	Manage oil and coal inventories for electric utilities to balance inventory costs and risk of shortages.	1989	$ 59 million
Texaco, Inc.	Optimally blend available ingredients into gasoline products to meet quality and sales requirements.	1989	$ 30 million
IBM	Integrate a national network of spare-parts inventories to improve service support.	1990	$20 million +$250million less inventory
Yellow Freight System, Inc.	Optimize the design of a national trucking network and the routing of shipments.	1992	$ 17.3 million
U.S. Military Aircraft Command	Quickly coordinate aircraft, crews, cargo, and passengers to run the Operation Desert Storm aircraft.	1992	Victory
Americans Airlines.	Design a system of fare structures, overbooking, and coordinating flights to increase revenues.	1992	$ 500 million more revenue
New Haven Health Dept.	Design an effective needle exchange program to combat the spread of HIV/AIDS.	1993	33% less HIV / AIDS.

Source: Hillier and Lieberman (1995), p.4