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MULTIPLE CRITERIA DECISION MAKING AND GOAL PROGRAMMING

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Modern decision making process involves not just single objective of profit maximization but multiple conflicting objectives which encompass production, marketing, and others. The incompletion of single objective criterion and the importance of multiple objectives criterion in today's dynamic environment are emphasized both through normative and empirical studies. In this connection goal programming is introduced as one of the most effective techniques for multiple criteria decision making problems. A simple case is illustrated for the formulation of a goal programming model. Finally, historical background and application studies of goal programming are presented.

I. MULTIPLE CRITERIA DECISION MAKING

The purpose of this paper is to discuss the importance of multiple criteria decision making both normatively and empirically and introduce the concept of goal programming which is widely accepted as one of the most effective techniques for multiple criteria decision making problems. Also discussed is areas where goal programming is applied.

The process of decision making always involves a set of objectives. The classical economic theory advocates profit maximization as the sole objective of a firm. The theory rests upon the idea that the only dependable human motive is self-interest and individuals or corporations

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engage in business with the avowed purpose of making profits. Appealing as it might be, the theory of profit maximization as the firm's sole objective raises many serious questions. First, profit maximization must be viewed in a long term perspective if it is to have any realistic meaning. However, a precise determination of long term profit is extremely difficult, if at all possible, in business operations where uncertainties and risks are pervasive. Thus, a number of variables which are important for long term profit can be treated as remote surrogates to long term profit and accepted as goals. These variables include market share, image of the firm, employees' attitude, and the like.

It is also argued that the profit maximization is not the only goal of a firm but merely one among several goals. Especially when the separation of management and ownership is prevalent, this is likely to be the case. Management is not only interested in profit per se but also interested in power, and social responsibility, and survival on the job, to name a few, which are called "psychic income" by Simon (30).

Drucker (10) mentioned along this line that "to manage a business is to balance a variety of needs and goals" and pointed out eight areas where goals have to be set. The eight areas are market standing, innovation, physical and financial resources, profitability, manager performance and attitude, and public responsiblity. White (31) also made an observation that profit maximization is in reality a heterogeneous collection of multiple goals and identified two types of goals: market goals, image goals and power goals as external goals; and production goals and fincial goals internal goals. Cyert and March (9) defining goals as a series of less of more or less independent constraints imposed on the organization, identified five major goals in the areas of production, inventory, sales, market share, and profit.

Another line of criticism against profit maximization has been made by Simon (30). He argues that profit maximization is indeterminate, and that the entrepreneur may not care to maximize but may simply want to earn a return that is regarded as satisfactory. Thus, he concludes that the firm's goal is not to maximize profit, but to attain a certain share of market or certain level of sales. In other words,

the firm would try to "satisfice" rather than to "maximize". This concept of "satisficing" is based on the behavioral theory which substitutes "aspiration level" for traditional economic motivation. Aspiration level acts as a psychological force which drives people to act, and is adjusted upward or downward on the basis of experience. When performance falls short of the level of aspiration, search for new alternative is induced.

In addition to the above normative theories, there are also a number of empirical studies that support the existence of multiple objectives in the firm. Johnsen (14) made empirical observations in Danish firms and confirmed that the overwhelming majority of firms were managed in accordance with multiple objectives. Kaplan, Dirlam, and Lanzillotti (15) studied pricing policy in American big business and noted that most of the companies surveyed follow different goals for different products.

The study made by Shubik (29) showed some of the difficulties in defining the goals of the firm and the existence of multiple objectives in the firm. The primary goal of the firm includes a wide range of political, social, economic, and ethical aspects and the profit as a primary goal is preceded by social responsibility and public relations with employees, customers, and stock holders. Ackoff (1) also made an observation that the multiple objectives problem is simply accepted and thus the general principle of the solutions is to convert several objectives into utility function of some sort and then maximize the utility function. Cyert and March (9) presented four case studies that involved multiple goals and where the decisions took the form of satisfactory soluions which met some minimum requirements laid down by the organization.

There are not many effective techniques that can handle problems with multiple objecives. The problems become more complicated when these multiple objectives are in conflict. The following techniques are identified as tools to analyze multiple-objective decision problems:

1) systems models
2) utility models
3) simulation models

4) goal programming models.

The systemes model is included because a set of goals may be represented as a system. The main decision criteria in systems analysis is benefit-cost analysis. Systems models are basically conceptual models. The utility models transform various goals into cardinal utility scales. However this process of transformation of goals into utility is not easy and thus the utility models have not been practical techniques. Simulation produces information that can be interpretated as a set of goals. Simulation produces a more satisfactory soluion than analytic approaches when there are numerous goals and many combinations of solutions must be compared, extension on models are descriptive models. Goal programming is special simulation of linear programming and considered the most powerful tool in handling multicriteria decision making problems (2), (12), (17). Following sections will be devoted to the discussion of goal programming.

II. GOAL PROGRAMMING

The general goal programming model can be expressed as:

$$\text{Minimize} \quad Z=\sum_{k=1}^{k}\sum_{i=1}^{m} P_k(w_i^{k-}\, d_i^- + w_i^{k+}\, d_i^+)$$

$$\text{subject to} \quad \sum_{j=1}^{n} A_{ij}X_j + d_i - d_i^+ = b_i \quad i=1,\ldots,m$$

$$X_j, d_i^-, \quad d_i^+ \leq 0$$

where d_i^- and d_i^+ are negative and postive deviational variables about goals respectively; w_i and p_k are, respectively, numerical and preemptive priority weights attached to these deviational variables; A_{ij} is the substitution rates; and b_i is the level of the i^{th} goal.

As shown above, the goal programming model includes deviational variables. Each deviational variable represents the amount of deviation from the desired goal level. The objective function of goal programming is to minimize these deviations according to the preemptive priority and numerical weights attached to them. Often, goals are achievable only at the expense of other goals. Furthermore, these goals may be

incommensurable. Thus, goal programming utilizes an ordinal solution approach based on the preemptive priority factors so that low order goals are considered only after higher order goals are achieved as close as possible to the desired level. When goals are commensurable, they may be on the same priority level but numerical weights may be utilized to differentiate their importance to the organization.

In order to illustrate how to formulate a goal programming model, the following problem is presented:

The Seoul Electronics Company produces two types of television sets: color and black and white. The production of a color set requires 10 man hr. of skilled labor and 100 man hr. of unskilled labor. The production of a black and white set, on the other hands, requires 5man hr. of skilled labor and 150 man hr. of unskilled labor.

The company has 100 man-hr. of skilled labor and 1500 man-hr. of unskilled labor normally available per month for the production of television sets. It is confirmed from the market study that the estimated number of color and black-and-white sets that can be sold are 70 units and 45 units per month respectively. The profit margin from the sale of a color set is W10,000, whereas it is W75,000 from a black-and-white set.

The company has set the following goals in the order of their importance:

I. Avoid the overutilization of skilled labor since skilled labor is hard to obtain in the labor market.

II. Minimize the underutilization of unskilled labor.

III. Maximize the sales of color and black-and-white sets (assign weights according to the unit profit of each product)

IV. Limit overutilization of unskilled labor to 100 man-hr.

The above problem is formulated as follows[1]:

$$\text{Min } Z = P_1d_1^+ + P_2d_2^- + 4P_3d_3^- + 3P_3d_4^- + P_4d_5^+$$

$$10X_1 + 5X_2 + d_1^- - d_1^+ = 100$$

$$100X_1 + 150X_2 + d_2^- - d_2^+ = 1500$$

1. For detailed explanation ofthe model, refer to Lee (17)

$$X_1 \quad + d_3^- - d_3^+ = 70$$

$$X_2 + d_4^- - d_4^+ = 45$$

$$d_2^+ + d_5^- - d_5^+ = 100$$

where X_i, d_j^-, d_j^+ 0

X_1=number of color sets produced per week,

X_2=number of black-and-white sets produced per week.

Ⅲ. HISTORICAL BACKGROUND AND APPLICATION STUDIES OF GOAL PROGRAMMING

Charnes and Cooper (2) introduced the concept of goal programming in connection with unsolvable linear programming problems. Raising the issue of "goal attainment," they state that ". . . any constraint incorporated in the functional will be called a goal. Whether goals are attainable or not, an objective may then be stated in which optimization gives a result which comes as close as possible to the indicated goals."

Ijiri (12) made further development of goal programming based on the foundation laid by Charnes and Cooper. He presented the definition of "preemptive priority factors", to treat multiple conflicting objectives according to their importance and suggested the generalized inverse approachas a solution method. His study was, however, primarily concerned with accounting and management control.

Although Ijiri reinforced and refined the concept of goal programming and developed it as a distinct mathematical programming technique, it was with the modified simplex method and the computer program developed by Lee (17), (19) that goal progarmming became a full-fledged management tool of decision science. Since then, goal programming model has been applied to a wide range of planning situations, resource allocation problems, and various functional areas of management including production, finance, and marketing.

The first application study of goal programming was made by Charnes, et al. (3) for adverting media planning. The model was an extension of previous linear programming models by accounting for cumulative duplicating audiences over a variety of time periods. In a subsequent paper (4), and illustrative example was provided. Charnes, et al. (6) also presented a goal programming model for manpower planning. This study was conducted in cooperation with staff members of the Office of Civilian Manpower Management, Department of the Navy.

Charnes, et al. (5) recently provided an extension to the theory of goal programming by exhibiting explicit solutions to convex goal programming. The study also indicated that the proposed computational technique is useful for other classes of problems such as interval programming. Contini (7) presented the goal programming model under conditions of uncertainty. The objective function of the model was to maximize the probability that a realization will lie in a confidence region of predetermined size. Dyer (11) presented interactive goal programming which provided a bridege between goal programming and interactive strategies for the optimization of the multiple criteria problem.

Jaaskelainen (13) applied goal programming to aggregate production planning. The model involves three separate and incompatible goals: the levels of production, employment, and inventories. Lee and Jaaskelainen (22) also presented a goal programming model for the aggregate production planning. Lee and Moore (27) developed a multiperiod production problem incorporating goals regarding inventory levels, delivery schedules, employment levels, and production costs. Lee and Moore (26) utilized the goal programming approach to the transportation problem. The model was a departure from a conventional type of transportation models where the only objective is to minimize total transportaion costs. The goals included in the model were guaranteed delivery, union agreement, and cost minimization.

Lee and Clayton (21) applied goal programming to the resource allocation problem in an institution of higher learning. The goals were defined in terms of faculty qualifications, faculty/student ratio, faculty /staff ratio, minimization of cost, etc. Solutions obtained under diffe-

rent assumptions were also presented. Lee (18) presented a goal programming model for an aggregative resource allocation in hospital administraton. The goals include securing adequate service level, adequate pay increase, and the like. Solutions obtained under simple and expanded models were presented. Courtney, Klastorin, and Ruefli (8) used goal programming in housing location preferences of students. The possible usefulness of their approach to urban planning, real estate development, and transportation systems design was illustrated.

Lee and Nicely (28) presented a goal programming model for marketing palnning through a case study. The model analyzed the effects of promotion expenditures on rate of return, the number of television sets leased, and personnel policies. Lee and Bird (20) applied goal programming to a sales effort allocation problem. The model demonstrated the advantage of using goal programming in marketing problems by employing stable empoyment level as one of its goals.

Lee and Lerro (25) presented a goal programming model for the problem of capital budgeting under capital rationing. The model consists of eight distinguishable objectives with four different priority structures. The model illustrated the divergence in goal achievement and project acceptance depending on some variations of a basic model. With these variations in mind, the model suggested that management could select the optimal solution that best suits the organizational objectives. Lee and Lerro (24) suggested a goal programming model for portfolio theory which has the effectiveness of the full covariance model of Markowitz as well as the simplified linear model of Sharpe. Furthermore, the goal programming model incorporated three other goals which are not used by Markowitz and Sharpe. They were the covariance goal, the current income goal with low risk, and the managerial goal. In the final analysis, the model demonstrated the tradeoffs between financial risk and inflation risk. It also allowed some changes in priority levels of certain goals to provide portfolio recommendations for a variety of conditions. The application of goal programming to the financial planning is made by Lee and Jaaskelainen (23). The model is designed to formulate decisions on capital structure and dividend policy with emp-

hasis on earnings growth.

Ⅳ. CONCLUSION

In today's dynamic business environment, profit maximization is not always the only objective of a firm. Firms often place great emphasis on social responsibility, industrial and public relations, etc. as surrogates to long term profit and seek power and prestige which are called psychic income. Simon (30) also argues that profit maximization is indeterminate and advocates satisficing theory of firms, behavior where firms try to reach satisfactory levels of various goals such as production, market share, profit, and the like.

If we grant that management has multiple goals to achieve, the decision criteria should also be multidimensional. For this reason, linear programming has limited value for problems involving multiple goals. The primary difficulty with linear programming is its inability to reflect complex reality due to the unidimensionality of its objective function.

The goal programming model overcomes the basic limitation of linear programming—the existence of single objective. Concurrently, as Kornbluth (16) pointed out, it restores the complexity associated with management's choice among alternative planns to its natural level. Goal programming does have limitations. As Lee and Jaaskelainen (22) explained, the most apparent one is that goal programming model simply provides the best solution under the given constraints and priority structure. Thus, the soundness of optimum solution depends primarily on that of the priority structure for goals. However, through the solution derived by the model, the decision maker has an opportunity to review the soundness of his priority structure and modify it as desired. Perhaps the most important advantage of the goal programming model is its great flexibility which allows model simulation with numerous variations of constraints and goals.

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