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Goal Programming

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Abstract: *In the last 40 years, there has been a marked transformation in the development of new methodologies to assist the decision-making process, especially in the development of procedures in multi-criterion decision-making and in multi- objective programming (MOP). Goal programming (GP) is the most commonly known model of MOP and it is today alive more than ever, supported by a network of researchers and practitioners continually feeding it with theoretical developments and applications, all of these with resounding success. This paper paints a picture summarizing the history of GP and suggests a few areas of research in this era of globalization.*

Keywords: Multicriteria Decision Analysis, Multiple Constraints, MCDA, MCDM, Lexicographic,etc.

I. GOAL PROGRAMMING

Goal Programming is an extension of Linear Programming in which targets are specified for a set of constraints. In Goal Programming there are two basic models: the pre-emptive (lexicographic) model and the Archimedean model. In the pre-emptive model, goals are ordered according to priorities. The goals at a certain priority level are considered to be infinitely more important than the goals at the next level. With the Archimedean model weights or penalties for not achieving targets must be specified, and we attempt to minimize the sum of the weighted infeasibilities.

Unquestionably, linear programming models are among the most commercially successful applications of operations research. But, one of the limitations of linear programming is that its objective function is one-dimensional, i.e., the decision maker strives for a single objective, such as profit maximization or cost minimization. To the contrary, in goal programming, the objective function contains primarily the deviational variables that represent each goal or sub-goal.

The basic approach of goal programmingis to establish a specific numeric goal for each of the objectives, formulate an objective function for each objective, and then seek a solution that minimizes the (weighted) sum of deviations of these objective functions from their respective goals.

After the II world war, the, Industrial world faced a depression and to solve the various industrial problems. Industrialist tried the models, which were successful in solving their problems. Industrialist learnt that the techniques of OR can conveniently apply to solve industrial problems. Then onwards, various models of OR/GP have been developed to solve industrial problems. In fact, GP models are helpful to the managers to solve various problems; they face in their day-to-day work. These models are used to minimize the cost of production, increase the productivity and use the available resources carefully and for healthy industrial growth.

Example

Consider the following L.P.P.:

Maximize $z = x1 + x2$, subject to the constraints:

$3x1 + 2x2 <= 12$

$x1 + x2 >= 8$

$-x1 + x2 >= 4$

$5x1 <= 10;$

$x1 >= 0, x2 >= 0$

Feasible region of the problem is given below

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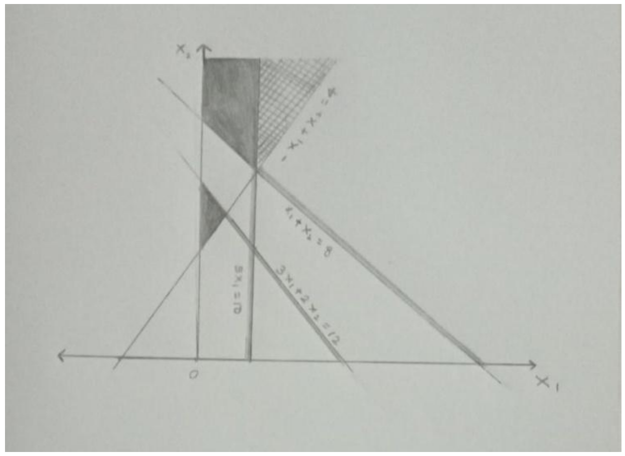

Although the three shaded areas may be considered to represent the feasible region, yet there is no common feasible region, this is so because we cannot find any point (x1, x2) to lie on both these shaded regions, thus, problem cannot be solved by usual linear procedure.

II. HISTORY

Goal programming was first used by Charnes, Cooper and Ferguson in 1955, although the actual name first appeared in a 1961 text by Charnes and Cooper. Seminal works by Lee, Ignizio, Ignizio andCavalier,and Romero followed. Schnieder jans gives in a bibliography of a large number of pre-1995 articles relating to goal programming, and Jones and Tamiz give an annotated bibliography of the period 1990-2000. A recent textbook by Jones and Tamiz gives a comprehensive overview of the state-of-the-art in goal programming.

The GP is one of the many models which have been developed to deal with the multiple objectives decision-making problems. This model allows taking into account simultaneously many objectives while the decision-maker is seeking the best solution from among a set of feasible solutions.

According to Hwang et al. (l980) and Evans (l984), the variants of GP could be classified into four categories depending on when we introduce information regarding the decision-makers preferences. These categories are as follows:

- No articulation of the decision-makers preferences: these methods do not take explicitly into account thedecision-makers preference structure;
- A priori articulation of the decision-makers preferences by way of utility or value functions;
- Progressive articulation of the decision-makers preferences by using an interactive procedure;
- A posteriori articulation of the decision-makers preferences where he expresses his preferences for the efficient solutions generated by an algorithm.

III. STEPS TO FORMULATE A LINEAR GOAL PROGRAMMING

Step 1: Identify the decision variables of the key decisions

Step 2: Formulate all the objectives or goals of the problem, these are generally determined by:

i. The desire of the decision maker

ii. Limited resources

iii. Any other restriction either explicitly or implicitly placed on the desire of the decision maker

Step 3: Reduce the number of goals eliminating a few negligibly important or redundant goals

Step 4: Express each goal in the form of constraint equation by introducing a negative and positive deviation variable (denoted by d+ and d- respectively)

Step 5: Assign the goals to priority levels. All absolute goals (i.e., di- = 0 or di+ = 0), if any exist, are assigned to top priority.

Step 6: Establish the achievement function. The priorities associated with each objective, along with the deviation variables are used to form what we call the achievement function.

IV. DEFINITION

Decision Maker(s): The decision maker refers to the person, organization, or stakeholder to whom the decision problem under consideration belongs.

Decision Variable: A decision variable is defined as a factor over which the decision maker has control.

Criterion: A criterion is a single measure by which the goodness of any solution to a decision problem can be measured. There are many possible criteria arising from different fields of application but some of the most commonly arising relate at the highest level to

- Cost
- Profit
- Time
- Distance
- Performance of a system
- Company or organizational strategy
- Personal preferences of the decision maker(s)
- Safety considerations

A decision problem which has more than one criterion is therefore referred to as a multi-criteria decision making (MCDM) or multi-criteria decision aid (MCDA) problem. The space formed by the set of criteria is known as criteria space.

V. NEW DEVELOPMENT IN GOAL PROGRAMMING

Goal Programming (GP) is a powerful and flexible technique that can be applied to a variety of decision problems involving multiple objectives. It should, however, be pointed out that GP is by no means a panacea for contemporary decision problems. The fact is that GP is applicable only under certain specified assumptions and conditions. Most GP applications have thus far been limited to well-defined deterministic problems. Furthermore, the primary analysis has been limited to the identification of an optimal solution that optimizes goal attainment to the extent.

Possible within specified constraints. In order to develop goal programming as a universal technique for modern decision analysis many refinements and further research are necessary.

VI. COMPUTER SOFTWARE SUPPORTING GP SOLUTION ANALYSIS

In S.M Lee's 1972 GP book, Goal programming to for Decision Analysis, the computer coding for a FORTRAN program presented the first published source of software for all the various types of weighted and preemptive linear GP models. Other mainframe computer-based systems, like Ignizio's MAINFRAME code that came later helped to broaden software capabilities to included LP algorithms as a part of a package of software. Other specialized computer codes whose ability to deal with a smaller subset of GP problem solving have been developed over the years.

Software	Publisher	System Features
AMPL	Boyd&fraser pub	Linear GP, integer GP, Nonlinear GP, Duality, Sensitivity Analysis
Extended LINDO	Lindo systems	Linear GP, Integer GP, Nonlinear GP, Sensitivity Analysis
Solvers	Frontline Syst. Inc.	Linear GP, Integer GP, Nonlinear GP, Duality
XPRESS-MP	Resource OptimInc.	Linear GP, Integer GP, Nonlinear GP, Duality, Sensitivity Analysis

VII. APPLICATIONS OF GOAL PROGRAMMING

As an extension of linear programming, it is assumed that goal programming can readily be adapted to the solution of educational problems previously utilizing linear programming techniques, but it appears that a greater value of goal programming lies in its facility for providing a more realistic model of the decision environment than has previously been possible with linear programming.

- **A.** The earliest example of goal programming implementation in financial management is in the field of budgeting. They used goal programming formulation to show the balance sheet of break-even analysis
- **B.** Applied goal programming to small-firm financing decisions'

VIII. GOAL PROGRAMMING VS LINEAR PROGRAMMING (ALIKE)

- Both require the formulation of a model for transforming a real-world decision problem into a prescribed format.
- Both are concerned with goal or objective achievement.
- Both represent a systematic attempt toward rationality in decision making.
- Both are adaptable to analysing decisions.

IX. GOAL PROGRAMMING VS LINEAR PROGRAMMING (UNLIKE)

- Goals- The goals of a particular problem are modelled as constraints although they may be statements (written in the same format as constraints) which are not restrictive or descriptive of limited resources: but positive in nature, representing a desirable condition.
- Objective function- In goal programming the objective function usually contains no choice variables, but rather is made up of the deviational variables contained within the goals. When multiple goals are thus represented in the objective function, it is said to be multidimensional.

X. CATEGORIZATION OF GOAL PROGRAMMING

The goal programming problem may be categorized in terms of how the goals compare – non-emptive and pre-emptive. When all the goals are of roughly comparable importance, goal programming is known as non-preemptive. In case of a pre-emptive goal programming, the goals are assigned priority levels. The goals are ranked from the most important to the least important and the objective function coefficient assigned for the variables representing goal i is Pi, it is assumed that P1 >>> P2 >>> P3 ….>>>Pn, where the symbol >>> means 'more important than' a lower priority goal is never sought to be achieved at the expense of higher priority, thus a higher priority goal is considered first.

XI. PREEMPTIVE METHOD

In the preceding example we assume that all the goals are of roughly comparable importance. Now consider the case of *preemptive* goal programming, where there is a hierarchy of priority levels for the goals. Such a case arises when one or more of the goals clearly are far more important than the others. Thus, the initial focus should be on achieving as closely as possible these *first-priority* goals. The other goals also might naturally divide further into second-priority goals, third-priority goals, and so on. After we find an optimal solution with respect to the first-priority goals, we can break any ties for the optimal solution by considering the second-priority goals. Any ties that remain after this re-optimization can be broken by considering the third-priority goals, and so on.

When we deal with goals on the *same* priority level, our approach is just like the one described for non-preemptive goal programming. Any of the same three types of goals (lower one-sided, two-sided, upper one-sided) can arise. Different penalty weights for deviations from different goals still can be included, if desired. The same formulation technique of introducing auxiliary variables again is used to reformulate this portion of the problem to fit the linear programming format.

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XII. CONCLUSION

Goal programming is an extension and modification of linear programming which allows the educational manager to more closely simulate real-life situations. Both linear and goal programming are optimization techniques which lend themselves to increasing the rationality of decision-making. The foremost value of goal programming is in its facility for solving problems with hierarchically arranged, conflicting goals. While there are presently certain limitations of goal programming which may slightly narrow the scope of its feasible applications, it is believed that its potential for educational problem solving is vast.

Virtually all models developed for managerial decision analysis have neglected the unique organizational environment, bureaucratic decision process, and multiple conflicting natures of organizational objectives. In reality, however, these are important factors that greatly influence the decision process. In this study, the goal programming approach is discussed as a tool for the optimization of multiple objectives while permitting an explicit consideration of the existing decision environment.

In the nearly half century since its development, goal programming has achieved and maintained its reputation as a "workhorse" of the multi-objective optimization field. This is due to a combination of simplicity of the form and practicality of approach.

This paper conceptually described the relationship of goal programming (GP) within the subject area of multi criteria decision making (MCDM). Furthermore, we have discussed a variety of GP methodology. Included algorithms and methodology designed to obtain a basic or primary solution for a problem. These primary types of methods included linear GP, integer GP and nonlinear GP. Each of these types of methodologies was subdivided into various other existing methodologies. This paper also discussed secondary GP methodologies including duality and sensitivity analysis. List of computer software supporting GP solution are also included in this thesis.

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