THE USE OF CONJOINT ANALYSIS IN THE DETERMINATION OF GOAL PROGRAMMING WEIGHTS FOR A DECISION SUPPORT SYSTEM

Daniel E. O'Leary
Case Western Reserve University
Cleveland, Ohio 44106

(With the assistance of)

James H. O'Leary
MPT & Associates
600 Fifth Avenue
New York, New York 10020

ABSTRACT

One of the problems of management science models is that managers don't use them. A recent trend in management science and information systems to mitigate this problem is the development of decision support systems (DSS). The purpose of a DSS is to integrate the intuition (multiple goals and judgement) and the data base of the manager into a computer model and data base to aid the decision making process.

This paper continues that trend by integrating conjoint analysis into goal programming. This forms an algorithmic approach that allows the development of models that reflect a manager's judgement and multiple goals. Accordingly, the approach of this paper can form the algorithmic core of a DSS.

INTRODUCTION

One of the trends in management science and management information systems is to make the tools of management science amenable for use by management (Little [1979] and Barbosa and Hirko [1980]). The primary focus of that research is in the development of decision support systems (DSS). This paper continues that trend by providing an algorithmic approach that can form the core of a DSS for multiple goal problems. In particular, this paper indicates that conjoint analysis can be coupled with goal programming to form a useful decision tool.

It is well known that the use of management science tools by managers has met with mixed success. As noted in Little (1970, p. 466), "The big problem with management science models is that managers practically never use them." This is due, to the lack of a correspondence between decision characteristics of management and model capabilities. In particular, management science tools have a number of limitations.

First, managers are time constrained. However, some management science tools require long time horizons to implement. Second, managers face multiple goal decision problems. Yet, many management science tools focus on a single goal. Third, managers face decision problems with goals of different units of measure. However, some management science tools are constrained to a single unit of measure. Fourth, managers have priorities associated with their multiple goals. Yet management science tools often do not allow this type of information in the model. Fifth, decision making is dynamic. Managers may change their priorities based on feedback. Many management science tools are static and do not foster feedback. Sixth, managers may need graphic decision aids to help them develop model parameters. Few management science tools are directly amenable to the use of graphics. Seventh, multiple managers at the same level in the organization may be part of the same decision making problem. Management science models need to allow for multiple inputs in the development of the priorities on the goals.

These limitations have led researchers to such tools as goal programming. Goal programming models overcome many of the limitations of management science tools. If all the model parameters are available then a goal programming problem is straightforward. Goal programming allows multiple goals of different measures and focuses on the decision maker's priorities. Interactive goal programming provides the decision maker with a dynamic tool. Finally, multiple decision makers can provide input for the priorities of the goals.

However, the numeric representation of the priorities in goal programming is not straightforward. This paper indicates that the "relative importance" measure from conjoint analysis can be used as a numerical basis to estimate the priorities. Conjoint analysis is a tool that is used to quantify the judgment of a decision maker. Conjoint analysis is easy to use, can represent multiple goals and multiple decision makers, and in many functional areas, such as marketing, it is readily acceptable by management. Accordingly, conjoint analysis can overcome many of the limitations of management science models.

This paper proceeds as follows. In the first section, the paper has provided a summary of the research problem. In the second section the paper provides a brief review of conjoint analysis and goal programming. In the third section, the paper provides an interface of conjoint and goal programming. In the fourth section, the paper analyzes the example of media selection using the model of the first three sections.

REVIEW OF GOAL PROGRAMMING AND CONJOINT ANALYSIS

Goal Programming

This paper is concerned with multiple objective linear programming, referred to as goal programming. In goal programming, each objective is multiplied by a weight (priority) and then each of the weighted objectives is summed. Goal Programming is an extension of mathematical programming that enables the user to develop models that "satisfice" (Simon [1957]). It is an attempt to include multiple objectives in the decision making process. General surveys of goal programming are given in Charnes and Cooper (1977) and Zionts (1984).

Interactive goal programming starts with equal weights on all the goals. Then the weights are changed to reflect feedback to the decision maker. The Zionts-Wallenius approach to the interactive multiple objective linear programming model can be described as follows (Zionts [1984, p. 3])

> In our framework a numerical weight (arbitrary initially though generally chosen equal) is chosen for each objective. Then each objective is multiplied by its weight, and all the weighted objectives are then summed . . . Using the composite objective, we solve the corresponding linear programming problem. The solution . . . is presented to the decision maker in terms of the levels of each objective achieved. Then the decision maker is offered some trades from that solution . . . (of) the form "Are you willing to reduce objective 1 by so much in return for an increase in objective 2 by a certain amount, an increase in objective 3 by a certain amount and so on?"

Review of Conjoint Analysis

The objective of conjoint analysis is to determine the utility associated with each of a set of stimuli. Conjoint analysis quantifies judgemental data by using rank ordered input to develop interval scaled output data.

"An important special case of conjoint measurement is the additive model, which is analogous to the absence of the interaction in the analysis of variance involving two (or more) levels of two (or more) factors in a completely crossed design" (Green and Rao [1971, p. 355]). This paper is concerned with the additive model for two primary reasons. First, previous researchers (Green and Rao [1971]) have used it successfully, in the representation of many decision problems. Second, it is used because the additive model has additive utility measures. This allows the use of the utility measures in the objective function in a goal program and in situations where multiple managers can provide input to the priorities. The primary use of conjoint analysis has been to analyze the joint influence of independent variable factors on the ordering of a dependent variable. For example, Green and Tull (1978) describe the choice of an automobile (dependent variable). The independent variables include years of warranty, miles per gallon, and price. This paper adapts the factor-based, conjoint analysis discussion in Green and Tull (1978) to a goal-based analysis. For example, rather than the factor of miles per gallon, the decision maker can analyze goal levels exceeding some given average mile per gallon.

Conjoint Analysis and Decision Characteristics

One of the contentions of this paper is that conjoint analysis can be a useful aid to decision making. Accordingly, the remainder of this section relates conjoint analysis to the decision characteristics developed in the first section (table 1).

Table 1. Decision Characteristics of Conjoint Analysis and Goal Programming.

Decision Characteristics	Conjoint Analysis	Goal Programming
Multiple Goals	Multiple Goals	Multiple Goals
Different Measures	Part-Worth	Goals of Different Measures
Dynamic Decision Making	Changes in Part-Worths	Interactive Goal Programming
Priority Assignment	Relative Importance	Priorities of Goals
Time Constrained	Multiple Goal Evaluation Method	Given parameters - just solve
Naive/Sophisticated Decision Makers	Graphic Presentation	-----
Horizontal Decision Making	Multiple Managers	Reflected in Weights
Satisfice	-----	Partial Goal Attainment (Deviation)

Part-worths. In the analysis of multiple goals, conjoint assumes a prior identification of the goals and the levels of performance associated with those goals. The levels may be numeric or simply "yes or no". In addition, different goals can utilize different units of measure.

The problem in conjoint analysis is to assign to each level of each goal a utility number called a part-worth. A number of algorithms have been developed to determine the part-worths based on a ranking of the alternatives (Catlin and Wittink [1982]).

Changes in part-worths. There are two primary situations which can lead to changes in the values of the part-worths. First, changes in the rankings of the alternatives will cause a change in the part-worths. Second, changes in the goals or in the definition of levels may result in a change in the part-worths because of a corresponding change in rankings. This is discussed in more detail later in the paper.

Relative importance. The derivation of the part-worths allows the development of what is referred to as the "relative importance" of each goal. This is measured by subtracting the smallest part-worth from the largest part-worth for each goal. The relative importance reflects the priority associated with the goal.

Collection of conjoint data. The data from which the part-worths and the resulting relative importance are constructed are rank order data, derived from either two-goal evaluations or multiple-goal evaluations.

The simplest way to obtain judgemental tradeoff information involves comparing two goals at a time as in figure 1. The two goal approach is both simple and makes few demands on the manager. However, it is also tedious and time-consuming. If there are six components, each with three levels, then the two goal approach requires analysis of (6x5)/2=15 of the 3x3 tables.

Figure 1. Two-Goal at a Time Evaluation.

	Goal 1		
	Level A_1	Level B_1	Level C_1
Level A_2			
Level B_2			
Level C_2			

"For each combination of goals rank your choices from 1 to 9. Your first choice should use a 1."

Figure 2. Multiple Goal Evaluation.

	Scenario 1	Scenario 2
Goal 1	Level A_1	Level B_1
.	.	.
.	.	.
.	.	.
Goal n	Level C_n	Level A_n

An alternative is the multiple goal approach, which compares different scenarios (see figure 2). Each scenario reflects a different combination of goal and level pairs. The scenarios are then compared and the manager ranks all the scenarios from most preferred to least preferred. Assuming six goals, each with three levels, the multiple goal approach, with a statistical factorial design, requires the ranking of eighteen scenarios. Accordingly, the multiple goal approach can require minimal time participation by the manager.

Graphic presentation of goals. Graphic presentation of goals can be integrated in the use of conjoint analysis in order to develop the part-worths. As noted in Green and Tull (1978, p. 487), in the discussion of conjoint analysis, "whenever possible, visual props can help in transmitting complex information more easily and uniformly than verbal description." This approach may yield both greater managerial acceptance and understanding of the management science model and its objectives.

Multiple managers. The additive nature of conjoint analysis indicates that the part-worths for the same level of the same goal can be added together and averaged for multiple managers. This allows two or more managers to establish an average utility curve and a corresponding, average relative importance measure. Thus, the model can account for more than a single manager's priorities.

DSS Chauffeurs and Conjoint Analysis

An important aspect associated with some DSS is the role of the "Chauffeur" (Keen and Scott-Morton, 1978). The chauffeur is an intermediary between the DSS and the decision maker. As noted in Keen and Scott-Morton (1978, p. 158), "The agent obviously needs many skills: to be familiar with the DSS; experiences in problem formulation, analysis and interpretation of the data; and responsive to the user's needs and moods . . . however individuals with all the needed abilities are hard to find and generally aim at far more senior jobs."

Conjoint analysis provides an alternative approach. Conjoint provides the chauffeur with a quantitative expression of the decision maker's judgment. This can have two primary affects. First, this may improve the chauffeur's responsiveness to the decision maker. Second, the quality of the chauffeur required to meet the needs of the decision maker may be reduced.

The chauffeur's responsiveness may improve because conjoint can give an explicit map of the decision maker's concerns. Since such a map is available, the chauffeur will not need to be as familiar with the manager's needs.

CONJOINT ANALYSIS AND GOAL PROGRAMMING: THE INTERFACE

Conjoint analysis can be used in conjunction with goal programming in at least two ways. First, conjoint analysis can be used to provide a set of starting priorities on the goals. Second, conjoint can provide an alternative means to alter the priorities on the goals.

In interactive goal programming (Zionts and Wallenius [1976]), the user is presented with an initial solution that has equal weight on each of the goals. Conjoint analysis provides an alternative. The relative importance estimates of conjoint analysis can be used to provide a good starting point for those weights.

In interactive goal programming, the user can directly change the weights on the goals. Conjoint analysis offers an alternative. As noted above, a change in the ranking of the objectives changes the part-worths and the relative importance. Changes in the rankings generally occurs with either changes in the goals or changes in the levels on which the rankings are based. If an initial set of weights, based on conjoint, is unappropriate to the decision maker, then either of the changes may be indicated.

An Adjunct to Interactive Goal Programming

Conjoint analysis can form an adjunct to interactive goal programming. The first step in the process is to have the decision maker develop the part-worths. The multiple goal scenario method provides a timely process. The development of the goal scenarios can be computer-based and may feature graphic representations of goals. The resulting part-worths can be used to develop the relative importance of the goal, which can be used as a weight on the goal in the goal programming model.

If an appropriate solution is found then the process can stop.

Otherwise, the decision maker can either reevaluate the rankings or review the goals and the levels of the goals and then reevaluate the rankings. The reranking will lead to the development of new part-worths and relative importance measures. However, it may be that the rankings won't change. If the solution is unappropriate then the more direct approach of Zionts and Wallenious (1976) would then be used.

Contributions

The methodology proposed in this paper has three primary contributions. First, it focuses on getting the decision maker's judgement into the goal programming model, rather than the chauffeur's. Second, even for those decision makers directly involved in the process, the approach provides a good starting point for the weights for the interactive process. Third, the approach provides a means to change the starting point.

APPLICATION: THE MEDIA SELECTION PROBLEM

One of the first applications of goal programming was the media selection problem (Charnes et al. [1968a] and [1968b]). Similarly, conjoint analysis has received attention in a number of marketing problems (Green and Rao [1971] and Green and Tull [1978]). Accordingly, both tools have developed acceptance in the marketing community. In particular, conjoint analysis has received broad acceptance (Cattlin and Wittink [1982]).

However, the two have not been interfaced in marketing models. The above discussion indicates that conjoint analysis can form a basis for the estimate of the priorities on the goals in a goal programming model. The purpose of this section is to develop a goal programming model, that uses conjoint analysis to derive the weight on the objective, for the media selection problem.

Literature Review: The Media Selection Problem

Media selection is an integral part of developing the advertising plan. It involves selecting advertising media, the number of advertisements to be placed in the media, the size of advertisements and other concerns.

Models of media selection. As noted in Calantone and Brentani-Todorovic (1981, p. 491) "Media planning has attracted a larger number and a greater variation of model building efforts than any other single problem in marketing." A number of reviews of media selection models are available (Calantone and Brentani-Todorovic [1981] and Gensch [1968] and [1973]). These reviews summarize a wide variety of approaches including Simulation, Dynamic Programming, Non Linear Programming, Linear Programming, and Goal Programming.

Typical of the reported success of these models is Compass. In 1965, ten U. S. advertising firms banded together to develop this joint project. As reported in Calantone and Brentani-Todorovic (1981, p. 522), that project is not yet operational.

The failure of projects such as Compass occur for a number of reasons including,

- attempting to be all encompassing instead of exploiting a particular problem situation as suggested by Little (1979) and
- ignoring the utility function of the manager and instead using the chauffeur's function.

This paper will circumvent these causes of failures by focusing on a particular problem and by integrating the decision maker's utility function into the model via conjoint analysis.

Linear programming and goal programming models. The media selection problem was formulated as a linear program as early as 1961. However, as summarized in Gensch (1968), the use of linear models in media selection has some important limitations. One of the primary limitations is that linear programming assumes repeat exposures to an advertisement have the same effect.

The linear programming model was then extended to goal programming by Charnes et al. (1968a). That research focused primarily on the exposure goal (see below). Another limitation of that research was that the choice of the weights on the goals received only limited attention.

The limitations of these previous models are mitigated in this paper by the delineation of a specific problem for which the number of exposures is approximately linear, the specification of multiple goals for the media selection problem and the discussion of the use of conjoint analysis to aid in the choice of the weights.

A Goal Programming Model for the Media Selection Problem

Unlike previous models for the media selection problem this paper is concerned with a specific media selection setting. However, the generality of the situation suggests that the setting is of interest to a number of other firms.

The particular firm has a chain of retail stores in which they sell their product. The product is a mature product, that is generally purchased when it is needed. On average, a typical customer purchases the product within ten days of the decision to purchase. The firm has a budget for the purchase of newspaper advertising to meet media selection goals.

The media selection problem is an ideal problem for goal programming because there are a number of goals of concern to management, including exposure, intensity, budget, competition and sales goals.

Exposure/coverage. The exposure (coverage) level refers to the number of individuals who will see an advertisement. In general, this is a non-linear process. However, a linear model is appropriate for this media planning setting because the product is purchased so soon after the need is recognized. Management is interested in maximizing the number of exposures.

Budget. Generally, management focuses on using the entire budget to ensure a similar or larger budget in future years. However, management is concerned also with not exceeding the budget. As a result, management generally minimizes the amount by which the budget is exceeded.

Intensity. Intensity refers to the impact of the advertisement. Intensity can be measured by the size of the advertisement for newspaper media. Management is interested in maximizing the intensity of the ads for the newspaper media.

Competition. Competition refers to the actions of competitors. Any of a number of dimensions of competition may be important. This paper assumes management is interested in trying to match or exceed the media purchases by competitors.

Sales. The sales goal is designed to tie the amount of advertising to the estimated sales due to the advertising. Management wishes to maximize sales.

Variables. The variables used in the model are as follows:

j	Newspaper (Media) j
k	Intensity level
Y_r	Goal r, r = E, B, C, I, and S.
Q_r^+ (Q_r^-)	The positive (negative) deviation associated with goal, r.
E_{jk}	Amount of exposure in media j at level k.
B_{jk}	Cost of media j at intensity level k.
C	Amount of media purchases by competition (= Y_C).

I_{jk}	Intensity level k of media j.
S_{jk}	Estimated sales per ad in media j at level k.
X_{jk}	Amount of media j purchases at level k.

Constraints. The constraints in a goal programming model reflect the goals of the model. Other constraints can be implemented to ensure that certain minimal values are exceeded or that certain maximal values are not exceeded.

The exposure constraint can be formulated as follows:

$$Q_E^+ - Q_E^- = Y_E - \sum_{j,k} E_{jk} \; X_{jk}$$

The budget constraint can be formulated as follows:

$$Q_B^+ - Q_B^- = Y_B - \sum_{j,k} B_{jk} \; X_{jk}$$

The competition constraints can be formulated as follows:

$$Q_C^+ - Q_C^- = Y_C - \sum_{j,k} X_{jk}$$

The intensity constraints can be formulated as follows:

$$Q_I^+ - Q_I^- = Y_I \quad \sum_{j,k} I_{jk} \; X_{jk}$$

The sales constraints can be formulated as follows:

$$Q_S^+ - Q_S^- = Y_S - \sum_{j,k} S_{jk} \; X_{jk}$$

The objective function. The objective function in the goal programming model will mirror the goals and reflect the importance of the goals as measured in the conjoint analysis. Let,

W_E	be the importance associated with over-attainment of the exposure goal Q_E^+
W_B	be the importance associated with minimizing the over-attainment of the budget goal Q_B^+
W_C	be the importance associated with the over-attainment of the competitive goal Q_C^+
W_I	be the importance associated with the over-attainment of the intensity goal Q_I^+
W_S	be the importance associated with the over-attainment of the sales goal Q_S^+

Thus, the objective function can be stated as:

$$\text{MAX } Z = W_E \; Q_E^+ - W_B \; Q_B^+ + W_I \; Q_I^+ + W_C \; Q_C^+ + W_S \; Q_S^+$$

Conjoint Analysis and the Media Selection Model

Conjoint analysis can be a useful tool in the media selection problem. Conjoint analysis can capture, quantitatively, the judgement of the Director of Media or other company management. The goal programming model can utilize the relative importance of the goals as priorities. Lower level media buyers (chauffeurs) can use the model as a basis of media purchases. This approach can ensure that media buyers are aware of the priorities of management, while still allowing the media buyers a certain level of independence.

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