

Interactive Multiple Goal Programming

Applications to Financial Planning

JAAP SPRONK



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1. INTRODUCTION

1.1. Motivation

This book is based on the view-point that both public and private decision making, in practice, can often be improved upon by means of formal (normative) decision models and methods. To some extent, the validity of this statement can be measured by the impressive number of successes of disciplines as operations research and management science. However, as witnessed by the many discussions in the professional journals in these fields, many models and methods do not completely meet the requirements of decision making in practice. Of all possible origins of these clear shortcomings, we mainly focus on only one: the fact that most of these models and methods are unsuitable for decision situations in which multiple and possibly conflicting objectives play a role, because they are concentrated on the (optimal) fulfilment of only one objective.

The need to account for multiple goals was observed relatively early. Hoffman [1955], while describing 'what seem to be the principal areas (in linear programming) where new ideas and new methods are needed' gives an example with conflicting goals. In this problem, the assignment of relative weights is a great problem for the planning staff and is 'probably not the province of the mathematician engaged in solving this problem'. These remarks were true precursors of later developments. Nevertheless, the need for methods dealing with multiple goals was not widely recognized until much later.

Of course, there are always early risers: Koopmans [1951] formulated the production allocation decision as a vector maximum problem, which is nowadays generally considered to be a problem in multiple criteria decision making (cf. also Chapter 3). Relatively

early too, Charnes and Cooper [1961] stressed the need to deal with multiple goals in formal decision models (see Chapter 4). Moreover, they made important contributions to meet this need by providing a new technique which was called goal programming. In spite of these early examples, however, the main part of the academic interest in multiple criteria decision making was developed in the last decade, and it is still rapidly growing.

An important impetus for this development came from the public sector. By nature, many of the decisions made there are intended to serve multiple goals. In many countries, the expenditures of this sector have grown significantly, and consequently, the desire for efficiency and equilibrium in serving the public became manifest. Discussions on political issues such as the improvement of public transport facilities, health care, aid to the Third World, and so forth need not be described here. The existence of multiple goals in the public sector is obvious.

Another impetus was given by the societal developments in the late sixties, when the role of private enterprise in society became criticized and discussed once more. Negative effects of economic growth, limits to this growth, democracy within the firm and many other topics, together with their effect on entrepreneurial behaviour, drew the attention of people representing a wide and colourful political spectrum. These discussions were obviously rather normative. They concentrated on what private enterprise's goals should be, or more often, what they should not be: in the latter case usually narrow-minded profit maximization was mentioned.

In many micro-economic approaches of the firm, it is assumed that the firm's goal is, in one form or another, to maximize profits. Depending on the point of departure chosen, profit maximization is, broadly speaking, translated as the maximization of short-term profits, the maximization of the net present value of future profits or, more generally the maximization of the wealth of current stockholders. In many economic theories these assumptions are sufficient

to lead to conclusions which can be tested empirically. These theories are generally considered worthwhile as long as their implications (and not necessarily their underlying assumptions) are not contradicted by the facts observed in reality. If the implications of these theories do not correspond to reality, one can 'identify the specific departures from the idealized conditions which give rise to various real world institutions whose functions require analysis and explanation' (cf. Copeland and Weston [1979, p. 111]).

In earlier times of economic analysis (e.g. in the days of Adam Smith) when many of the product markets were thought to be reasonably described by the model of perfect competition, it was not completely illogical to adopt the goal of profit maximization as the only objective, among other things because the actual allocation of goods and services induced by a general acceptance of this very objective was generally understood to have some well-known advantages, at least from a strictly economic point of view.

Things have, however, changed. Most markets have lost their seemingly 'perfect' character. Von Neumann and Morgenstern [1953, p. 11] have shown that profit maximization is mathematically not well-defined in oligopolistic markets (which in fact most markets are nowadays). Thus, part of the individual firm's logic to maximize profits has disappeared.

In a discussion on *laissez-faire*, Keynes [1926] argued that 'One of the most interesting and unnoticed developments of recent decades has been the tendency of big enterprise to socialize itself. A point arrives in the growth of a big institution at which the owners of the capital, i.e. the shareholders, are almost entirely dissociated from the management, with the result that the direct personal interest of the latter in the making of great profit becomes quite secondary'. Indeed, modern enterprise has become a complex organization in which many factors other than profit alone play a role. In empirical studies, the goal of profit maximization -

in a variety of manifestations - is seldom mentioned as the only one. And if it is, there is generally a multiplicity of subgoals, though seldom with an exact definition of the relationships between these subgoals and the main goal.

The problem of the firm's goals has engaged many prominent researchers. To mention just a few, the work of Simon [1958], Cyert and March [1963] and Williamson [1974] is well-known. Until now, the academic world has reached little consensus on the nature and role of the firm's goals. Nevertheless, because the firm in general has multiple parties to serve, and because the claims of each of them change over time, it is clear that the firm has to deal with a complex of multiple goals, also changing over time.

A firm which should be aiming at such a dynamic goal complex and which uses decision techniques designed for profit maximization only runs the risk of neglecting the interests of some of the parties involved. Unfortunately, most of the formal decision methods and models are based on precisely this assumption. In our opinion, multiple criteria decision methods offer a closer correspondence to decision making in practice. Therefore, we hope to contribute to the use and understanding of multiple criteria decision methods, not only in the public sector but also in the realm of the private enterprise.

1.2. Scope of the Study

The main purpose of this study is to investigate the usefulness of multiple criteria decision methods for capital budgeting and financial planning. Both the private and the public sector have to undertake capital investment projects. Obviously, in order to choose the 'right' projects, the effects of the proposed projects must be evaluated. In the public sphere, the existence of multiple goals in project selection has been recognized for a long time, as is

witnessed by the widespread use of cost-benefit and cost-effectiveness analyses.¹⁾ In this study we will mainly focus on the private sector. As indicated in the preceding section, we are taking the position that private decision making in general, and private project selection in particular, should be aimed at the fulfilment of multiple goals. The question now arises whether existing methods for private project selection are well suited to deal with this multiplicity of goals.

An important theoretical framework for private project selection is being offered by the discipline of finance, which starts from the *a priori* position that the firm's single goal should be to maximize the wealth of its current stockholders. For quoted companies, stockholders' wealth is being determined on the stock exchange by means of supply and demand for the firm's stock. As described by finance theory, the stock value depends on the expected levels and the risk characteristics of the future streams of income which will be distributed among the stockholders, and on the interest rate of a risk-free asset. Since the decision rules for project selection have been placed in an equilibrium framework, they have been subject to revolutionary changes.

However, the theoretical background of these decision rules as such is far from complete. The underlying capital market model has not been extended to the multiperiod case (at least not in a generally accepted way). In addition, severe problems arise in applying these rules.

If other goals are involved, they can, within this approach, be only accounted for by formulating criteria (or restrictions) and applying them to the set of alternative investment proposals before the mentioned goal of wealth maximization can be served.

We will investigate whether such an approach can be used safely to maximize the stockholders' wealth and whether other goals can be incorporated in an adequate way. Our position will be that neither

1) See Nijkamp [1979] for a critical discussion.

the first nor the second question can be answered affirmatively except in some very sophisticated, theoretical cases.

Next we will examine whether existing multiple criteria decision methods can offer some help. In doing so, we will conclude that the existing set of methods shows a gap. We will try to fill this gap by proposing a new, interactive variant of one of the existing methods, viz. goal programming. It will be shown how this new variant can be used within capital budgeting and financial planning.

The same approach will prove to be applicable to other fields of interest, both inside and outside the realm of project selection. In fact, we will show that, compared with existing methods, the proposed technique is applicable for a broader class of problems.

1.3. Outline of the Contents

In this section we present a brief description of the contents of each of the following chapters.

In Chapter 2 we give some reasons for considering capital budgeting and financial planning as decision problems involving multiple goals. We do not claim to offer any new insights into the firm's behaviour. On the contrary, we try to synthesize some almost generally accepted and sometimes old ideas into a frame of reference which can serve for the evaluation of the normative decision models being developed in subsequent chapters. Within this framework, we try to integrate the goal of the firm as it is seen in financial theory. We are then able to formulate some desiderata for decision methods which could possibly serve to support the capital budgeting decision, and financial planning in general.

In Chapter 3 we give a brief account of normative decision making, including its way of thinking in terms of 'means and ends' (or 'instruments and targets') and its possibility to incorporate concepts as 'uncertainty' and 'fuzziness'. We then turn to a brief overview of multiple criteria decision methods with some special emphasis on programming techniques. In doing so, we also elucidate

a number of concepts and definitions used in the multiple criteria decision making literature.

Chapter 4 is devoted to one of the earliest methods in this field. This is goal programming, established and further developed mainly by Charnes and Cooper. In our opinion, it is to this day one of the stronger methods available. We will show that it has some properties which are in close agreement with decision making in practice. Furthermore, many goal programming problems can be solved by means of linear programming, a well-known technique for which many excellent software packages are available. However, depending on the problem formulation, other solution procedures (e.g. generalized inverses) may also be used. In this chapter we try to give an impression of the variety of problems which can be handled by goal programming.

An important drawback of goal programming is its need for fairly detailed *a priori* information on the decision maker's preferences. As will be shown in Chapter 5, we agree with those scholars advocating interactive approaches to the goal programming problem. These are based on a mutual and successive interplay between decision maker and expert. They neither require an explicit representation or specification of the decision maker's preference function nor an explicit quantitative representation of trade-offs among conflicting objectives. A sample of interactive goal programming methods will be presented and discussed.

It appears that the evaluation of an interactive decision model is itself a multiple criteria problem. In order to illustrate this statement we shall propose some criteria which may be important in evaluating interactive decision models. We will see that most of the usual interactive approaches lack some of the advantages of 'traditional' goal programming, such as for instance the possibility to include pre-emptive priorities. Furthermore, in contrast with most existing interactive methods, goal programming is particularly suitable in situations of satisficing behaviour. This situation, combined with the repeatedly shown power of the traditional approach to inclu-

de piecewise linear functions (cf. Charnes and Cooper [1977]) justifies the effort to seek an interactive variant of this approach.

In Chapter 6, we present a detailed description of a new method which we have termed Interactive Multiple Goal Programming (IMGP). This method includes all advantages of goal programming. For instance, pre-emptive priorities and piecewise linear functions can be handled in a straightforward way. Furthermore, the interactive process imitates practice in formulating aspiration levels, assessing priorities, seeking a solution and readjustment of the aspiration levels. The method needs no more *a priori* information on the decision maker's preference structure than other interactive multiple objective programming models. However, all available *a priori* information can be incorporated within the procedure.

In Chapter 7, to illustrate the properties of IMGP, we describe a number of possible applications in various fields of decision making. In order to give an impression of the 'game of questions and answers' induced by this procedure, we introduce an 'imaginary decision maker'. With the help of this fictitious creature we are able to discuss the convergency properties of the method.

In Chapters 8 and 9, we describe how IMGP can be used in capital budgeting and financial planning. In Chapter 8 we first review some applications of multiple criteria decision methods in capital budgeting and financial planning, as reported in the literature. We then list a number of general problems occurring in these applications and demonstrate how IMGP might help.

In Chapter 9, we present a detailed example of a financial planning model with multiple goals. We show how such a model can be handled within the Interactive Multiple Goal Programming framework, while the possible (dis)advantages of such an approach are also exposed.

The final chapter deals with an evaluation of the properties of interactive multiple goal programming, especially when applied to capital budgeting and financial planning.

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