Multiobjective Budgetary Planning

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Nils-Göran Olve

MULTIOBJECTIVE BUDGETARY PLANNING

Models for Interactive Planning
in Decentralized Organizations

EFI

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PREFACE

This report will shortly be submitted as a doctor's thesis at the Stockholm School of Economics. The research has been carried out at the Economic Research Institute at the Stockholm School of Economics, but the author has been entirely free to conduct his research in his own way as an expression of his own ideas.

The Institute is grateful for the financial support which has made this research possible.

Stockholm, March 1977

THE ECONOMIC RESEARCH INSTITUTE
at the Stockholm School of Economics

Karl-Erik Wärneryd
Director of the Institute

Bertil Näslund
Program Director
Managerial Economics

FOREWORD

In the autumn of 1970, Professor Paulsson Frenckner suggested that a research project called Programme Budgeting for Business Firms should be started by two of my colleagues and myself. Three years later, when I finally embarked on this undertaking in earnest, the project had assumed the character of the work reported here.

In the intervening years, many people had lost faith in programme budgeting. But this was not the main reason for the change of direction. In 1973, my friend and colleague Bertil Tell and I chose to divide the study area between us, and he later wrote his dissertation as a result of his own work.[1] Professor Bertil Näslund also joined the Stockholm School of Economics, alerting us to the new science of multiobjective decision-making. Research on ways in which this could affect decentralized organizational planning seemed possible and highly relevant.

During the three years of active work on the project, Professors Frenckner and Näslund served as my advisors. Professor Frenckner, my main advisor, gave unsparingly of his time and presented me with innumerable inspiring ideas. I owe him much for this and for his rich experience in management control, while Professor Näslund introduced me to formal multiobjective methods and forced some much needed stringency on to my reasoning. Docent Ingolf Ståhl chaired numerous seminars on the project, and contributed another valuable angle to what I was trying to accomplish.

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[1] Tell (1976). As can be seen from Chapters 5 and 6 of the present study, Tell's approach and mine are to some extent alternatives.

I have had the good fortune to be surrounded by interested and sympathetic fellow researchers at the Economic Research Institute. I have already mentioned Bertil Tell, who served as an astute but encouraging critic of my many drafts. The drafts were also scrutinized with great perceptiveness by others, most notably Thomas Mossberg and Lars Sjögren. Yet others, too numerous to be mentioned here, took part in seminars and read a full-scale draft version.

I am also grateful to many of those working in the various organizations I visited as part of the project, in particular Lars Richter of the National Swedish Telecommunications Administration (known as Televerket), Lars-Gunnar Sander of Uddeholms AB, and Willy Salomon, attached at the time to the Swedish National Audit Bureau. I also received many valuable impulses from fellow teachers and participants in management courses.

Early drafts of the report were typed by Gunilla Weidenmark, among many others. The final version is the work of Barbro Orrung. Figures were drawn by Anja Gonzalez. My use of the English language was improved by Nancy Adler, whose interest in the readability of the report extended far beyond mere correctness.

The study was financed by Svenska Handelsbanken's Foundation for Social Science Research and the Swedish National Council for Social Science Research, to which are due my warm thanks.

Like most forewords, this one was the last part of the book to be written. As I complete the study, I am aware that many readers might have liked to see more concern with the philosophical, psychological, or empirical aspects of its subject matter. Let me assure these readers that I would myself be happy and interested to see this imbalance corrected in further studies.

Stockholm, March 1977

Nils-Göran Olve

CONTENTS

0. AIMS AND ORGANIZATION OF THE STUDY

It is increasingly often claimed that the heads of corporations and other big organizations must - or at least ought to - learn to relate their actions to the calls of several simultaneous objectives rather than to one overriding goal. Among the reasons given are the changing role of the corporation in modern society, and the growing demands for employee participation in decision-making. But difficulties in finding any single valid indicator of long-term profitability can also lead to similar conclusions, since action generally have to be chosen in light of their effects on several observable short-term factors. And for most non-business organizations, such as government agencies, multiple objectives appear to be even more widely accepted.

Most large organizations have a decentralized structure. This means that a central management, which is concerned with various objectives such as profit, market share, employment, environmental effects and so on, has to judge the combined effect on these factors of possible actions in several organizational units. Generally the units themselves are the best judges of what they individually are able to do, while central management alone commands sufficient perspective to tell what should be done. This means that the central body and the local units both have to contribute to planning, i.e. to the process which leads to a chosen set of plans for unit activities.

As an example let us consider the car manufacturing company which has one unit responsible for passenger cars and another one responsible for trucks. Financial objectives relevant to the survival of the company concern the combined profits, liquidity, etc. of the two units. As employees can be transferred between the units to some extent, employment effects also have to be judged centrally; this also applies to environmental impact, if the units operate in the same area. However, it is unlikely that management could decide any kind of desired "trade-off" between these objectives without first finding out about the relevant alternatives; similarly it would probably be impossible for the two units to propose any plans without knowing something about management's preferences. How should planning be organized, in order to assist the necessary interaction between management and units?

Another example concerns a public utility, and will be discussed in a later part of this study. Twenty geographical units each offer several alternatives for balancing costs against various "service" attributes of their production; in each unit this production is to all intents and purposes the same. Central management has to guide decisions about the way such balances should be struck, partly because funds are allocated centrally and partly because the service should be provided equitably throughout the country. How can a planning procedure be designed for this situation?

In both these cases it would be difficult and probably unacceptable to try to collect all the information about possibilities and preferences in one place, which means that the requisite planning will obviously have to rely on a dialogue. It is basic to the argument of this study that such a dialogue should be able to take as its starting-point some existing organizational planning dialogue, in particular that of budgetary planning.

I was introduced to this type of problem in the Swedish Army Staff. Later I was much influenced by contact with the National Swedish Telecommunications Administration (Televerket). These experiences have undoubtedly influenced my way of formulating and attacking the planning problem, and I will return to these two "case studies" in Part Three below. Nevertheless, this study is not exclusively concerned with public administration problems. I also discuss a relevant example from the private business sector, and most of the hypothetical examples in the text have a business setting.

The basic research question is:

How should budgetary planning be designed in a decentralized organization, when the organization head wants to attain several objectives simultaneously?

In this study I have tried to discuss different ways of structuring a multiobjective budgetary planning dialogue. Structure is achieved mainly through the rules for planning. I will show how such rules can be derived from theories of multiobjective decision-making and theories of planning. Each of these two groups of theories contribute some of the answers - but not all. In theories for multiobjective decision-making, the decentralized organizational setting is absent. Similarly, planning theories generally assume the existence of a single objective, since plans are generally described in terms of a unidimensional value. To some extent this study represents an effort to bring these theories together, which means that in trying to find the planning rules referred to above we have to sacrifice some of the mathematical stringency of the theories.

This combination leads to several heuristic procedures for multiobjective budgeting. They have not been tested as part of this study, but such tests would in my view be possible. An initial attempt to study the preconditions in one organization will be reported below. The intention of this study, however, is basically to show different ways of structuring the planning problem. It is hoped that this will improve our understanding of planning, and that it will alert the designer of planning systems to several alternative approaches to multiobjective budgetary planning. The choice of any one of these for a particular organization can only be discussed here in general terms.

Figure 0:1 presents the plan of the book. I have tried to illustrate the link between theories and practical planning by using the two sides of the figure.

Part One (Chapters 1 - 4) includes a presentation of the problem and a discussion of its components. In Chapter 1, the general situation is explained. Chapter 2 relates the situation to budgeting today. Chapter 3 presents the planning problem in verbal terms and the general philosophy on procedural design to be used here. Finally, in Chapter 4, the problem is given a more specific formulation, involving a set of statements about the planning situation, a mathematical formulation of the problem, and a number of planning "desiderata".

Part Two (Chapters 5 - 12) contains an analysis of the problem, in which several bodies of theory are used. After some comments on the model situation presented in Part One and a choice of general strategy (Chapters 5 - 6), the available theories within this strategy are surveyed (Chapter 7). Theories of multiobjective decision-making are then used in the formulation of two planning methods (Chapters 8 - 9). Two further methods are based on theories of decentralized economic planning (Chapters 10 - 11). In Chapter 12 a detailed comparison of the assumptions required for each of the four procedures is carried out.

The four methods differ in their approach to the planning problem, and should perhaps be described as "philosophies" rather than procedures. This also means that devices used in one of the methods could be incorporated in others, representing a compromise between them. They were chosen to provide four well-contrasted cases, involving different demands on the central management and the local units, as well as providing different degrees of mathematical stringency.

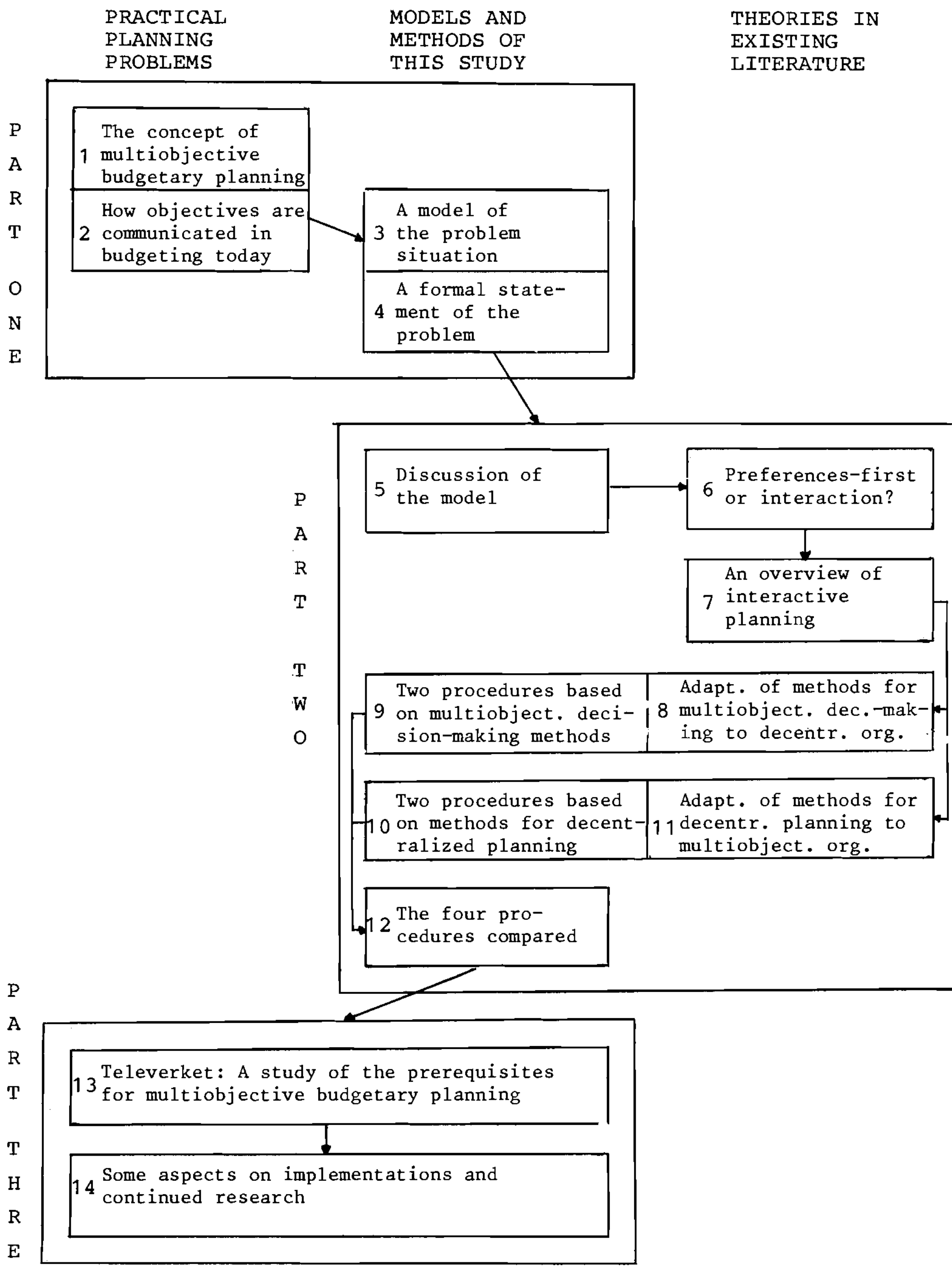

Figure 0:1. Relations between Chapters 1 - 14 of the report. Chapters 0 and 15 are general in their scope. Appendices relate to the following parts of the main text: A to Chapter 3, B to Chapter 7, C to Part Two, and D to Part Three.

In Part Three (Chapters 13 - 14) we look at some ways in which the approaches described in Part Two could be used in practice. An interview study in the National Swedish Telecommunications Administration is described in Chapter 13, while some aspects of implementation and future work related to observations of organizations are discussed in Chapter 14.

Chapter 15 provides a summary. Four appendices elaborate some topics touched upon in the study.

PART ONE
THE PROBLEM

1. THE CONCEPT OF MULTIOBJECTIVE BUDGETARY PLANNING

1.1 MULTIPLE OBJECTIVES IN ORGANIZATIONS

Human behaviour, whether individual or group, can often be described as the pursuit of certain objectives. Difficulty in finding a strict definition of "objective" (or of "goal", "aim". etc.) has resulted in a large number of suggested solutions. Instead of adding yet another to these, I will simply state somewhat more vaguely that the word is used here to denote a property or attribute (of an object, physical or abstract), which should, in the view of some observer, be changed in a specifiable direction.

This kind of objective is what Langefors (1968) has called "ultimate desires":[1]

> ... ultimate goals cannot genereally be defined in the typical multiobjective situation. What can be defined are desires, and it is possible to list desires and then to determine which are ultimate desires. Desires are not positions but only "direction" ... An important property of desires is that they are markedly questions of "what". One does not need to be an expert, nor to judge which positions are attainable.
> (Langefors, 1974, pp. 18-19; my translation)

What makes an attribute into an objective is the fact that someone - the decision-maker - takes an interest

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[1]See Langefors (1968, in particular p. 37: also pp. 56 ff., 86 ff.) In Langefors' terms, I will here use the concept of ultimate desires in the kind of planning that aims at the determination of operational subgoals. This means that operational goals will be determined as an integrated part of planning.

in its maximization or minimization.[1] The attribute thus has to be basically one-dimensional, and it should also be in some sense measurable. In addition to this, aggregation should have been carried to the point where the decision-maker feels that further aggregating is impossible without the introduction of value judgments. Such judgments would concern the trade-offs between objectives. For instance, an aggregation of divisional profits to obtain a company's profit may seem quite acceptable, while an aggregation of this with other objectives such as sales or employment would involve the kind of judgments that cannot be made in any simple way. Thus the decision-maker who has aggregated the information (the attributes) available to him and who ends up with several objectives which he would like to optimize but which he cannot reconcile, can be said to be grappling with <u>multiple objectives</u>.

This present study deals with decision-making in <u>organizations</u>:

> Formal organizations are contrived social systems designed to accomplish specific purposes.
> (Kast, 1974, p. 150)

Among the many definitions of business firms, several underline purposefulness as Kast does here, as well as the need for a coordinating control (cf. Frenckner, 1954. pp. 41-45). Here, I equate the "purposes" of Kast's definition with "objectives" as defined above. The present study could of course be relevant to government agencies, public utilities, and more temporary organizations as well. Examples of organizational objectives in all such cases are:

- Maximizing profits
- Minimizing unemployment
- Maximizing some influential member's perceived satisfaction

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[1] Objectives like "as close to xx as possible" can be changed to minimization by using the distance to xx as the variable. Also, maximization can be transformed into minimization and vice versa through sign changes.

- Maximizing the expressed satisfaction of the general public
- Maximizing readiness to handle emergencies or to change.

The first of these is a standard assumption in the part of classical economic theory that deals with business firms. The second is one of the most frequently mentioned objectives of the larger organization that we call society. The third may not originally have been intended as an objective for organizations in a democratic society; but nevertheless it is certainly a practical reality for some of them, even though it may not be their only objective. The fourth would appear to be particularly important in non-profit organizations. In common with the fifth and last, it may be difficult to measure and may require the use of indicators. Several complementary indicators are in fact often necessary, and these may sometimes assume the character of objectives.

Various circumstances may make it necessary to recognize and work with multiple organizational objectives in deciding future plans. Some of these are:

- A changing or unstable "balance of power", where different interested parties have conflicting viewpoints
- Changes in the "objective mix" over time for reasons other than the above
- The need to use indicators of the fulfilment of ultiate objectives, where the relations between indicators and objectives may not be completely known or stable.

We have assumed a coordinating control in our concept of the organization which means that in choosing plans for organizational activities, some person has to identify the objectives and balance them against one another.

If this can be done, a single superobjective has been implied. Wilhelm (1975) claims that finding such a superobjective is only a question of collecting more information.

If sufficient information is forthcoming, then some sort of composite index can be substituted for the several objectives.

Thus, one way of dealing with the multiobjective situation is to remove its multiobjective qualities after studying decision-maker preferences. If this is possible, the resulting single objective can be used in the planning process and the multiobjective characteristics can be limited to the initial phase. I will call this the preferences-first strategy.

An alternative to this involves investigating preferenes and possibilities interactively, i.e. letting the planning dialogue deal with uncombined multiple objectives, whose relations with one another become clarified during the planning process. I will postpone discussing these two alternatives until Chapters 5 and 6. But it should be pointed out that the planning dialogue explicitly concerns multiple objectives in the interactive approach only, and this is the approach to which most attention is devoted in the present study.

1.2 OBJECTIVES IN REAL-LIFE ORGANIZATIONS

On the objectives of organizations Kast writes:

> Organizations do have multiple goals that arise out of the continual learning-bargaining process of internal and external coalition members. These goals are frequently not officially stated and are often in conflict. There may be inconsistencies and ambiguities. The goal set of the organization is continually changing as a result of this learning-adapting process. (Kast, 1974. p, 154)

Thus we may expect problems when we try to identify objectives of organizations. Although knowledge of this aspect is not essential to the present study, it could be helpful insofar as we find proof of the use of multiple objectives. The actual identity of the objectives is less important in the present context, but some information about their number and general characteristics could be valuable.

That government agencies have several objectives is often apparent from the offical definition of their tasks. Even where a single task is specified, difficulties in pin-pointing its effects will often lead to the use of several indicators, which could be regarded as multiple objectives. See also Section 2.2 below, where we will return to these problems in connection with programme budgeting.

In business firms, the need for multiple objectives is less obvious. The desirability of profit-maximizing has been claimed by numerous authors from Adam Smith to Milton Friedman; for recent summaries of contrasting viewpoints, see Anshen (1974) and Baumol (1974).

Another approach is purely descriptive, asking the question: do firms seek to maximize profits? And as I am interested here in discussing planning procedures which could meet the needs of organizations rather than in recommending the number of objectives to use, this is obviously a more relevant approach than the normative one in our present context. Since Frenckner (1953) posed the question, various answers have been suggested. Baumol (1959) found sales maximization under a profit constraint a reasonable assumption, while Osborne (1964) suggested the opposite, i.e. profit maximization under a sales constraint. These authors based their findings on general contacts with business executives.

Relatively few empirical studies have been made in this field. For a review of some of them, see Bilkey (1974). Some studies concentrate on specific problems, such as investment behaviour (Hauschildt, 1973; Bower, 1970), pricing behaviour (Kaplan, Dirlam & Lanzillotti, 1958), or the behaviour of individuals (Williamson, 1964).

Heinen (1971) describes a study of 25 enterprises. Managers who considered themselves to exercise some influence on their firms' objectives were confronted with a list of objectives which they were to rank in descending order of importance. The mean and the mode of the assigned ranks are reproduced in Table 1.1. For five objectives, the ranking ranged from first to eighth. Profit had the smallest spread, ranking between first and fifth. Some respondents saw profit as a means of achieving other objectives; others held the opposite view.

Table 1:1. Ranks assigned to eight objectives for the firm in a study of 25 German enterprises. Translated from Table 1 in Heinen (1971, p. 39).

Nature of the objective	Objective rank	
	Mean value	Most frequent value
Profit	2.44	1
Security	3.24	2
Responsibility towards employees	4.51	3
Share of market	5.20	4
Independence	4.46	5
Customer service	4.50	5
Growth	4.87	6
Prestige	6.47	7

Studying business policy documents, Shubik (1961) listed 14 objectives mentioned by one or more of 25 firms. Many of these objectives are obviously related to one another and can be seen as parts of a superstructure. Ansoff (1965, Chapter 3) suggested such a "system of objectives", involving the construction of a hierarchy of objectives within which relative priorities can still change.

Most of these objectives become relevant to planning only when long-term effects are being considered. A firm's attitude to ethical matters, its recruiting policy, or its sharing of responsibility with the surrounding community, can all be expected to change fairly slowly. Likewise, changes in organization or in employee participation in decision-making will be decided as a result of special studies, not as part of the regular planning. In short-term planning such objectives merely represent constraints, while in making decisions about next year's activities there may still be a need to balance other objectives such as profitability, sales, growth, and working conditions.

In Table 1:2, I have summarized the objectives mentioned in the much-discussed corporate policy of a Swedish firm (Perstorp, 1969). I have tried to distinguish between objectives that could be relevant to optimization in short-run planning and those that seem rather to represent constraints. To what extent the policy reflects real convictions on the part of the managers, or to what extent it is a public relations activity, is difficult to judge.

In the present study we have little interest in the identification of objectives. I have nevertheless looked at some examples of business behaviour in this section because I want to support my basic assumption that organization heads may quite often perceive <u>multiple objectives without being able to state any immediate relation between their relative utilities or importance</u>. This means that in directing the activities of their organizations, management has to select plans in light of their effects on these several objectives.

1.3 EMPHASIS ON SHORT-TERM COORDINATION

There are several types of multiobjective business decisions that could well be studied. Some of these could be termed "division-of-income" problems, and are concerned with such things as the way total profits should be shared between owners and workers, the way various inescapable but negative external effects can be compensated for, etc. They often call for some sort of negotiations between the parties involved. The bargaining theories relevant to this kind of negotiation will not be discussed here.

The "division-of-income" problem cannot always be separated from the problem of identifying the most attractive mix of total profit, external effects, employment effects, etc. Here, however, we are concerned with the second problem or, more precisely, with the situation where:

Table 1:2. "Objective matrix" for Perstorp according to a 1969 corporate policy. The objective/stakeholder combinations do not show all those mentioned, but are my interpretation. Boxes that could involve short-run optimization objectives are surrounded by triple lines, constraints by double lines. Others are considered only indirectly. Based on Perstorp AB (1969).

STAKEHOLDERS \ OBJECTIVES	1. Profitability	2. Secure employment and satisfaction from work	3. Freedom of action and risk dispersion	4. Take part in and adapt to societal changes
A. Employees	Salaries, division of profit, and responsibility should be realistic	Even level of employment, avoid lay-offs if possible; achieved through D2 and personnel development	Constraints from A2	See A2, E4
B. Customers and suppliers	Growing markets, technical competence; high quality, sales/employee, level of ideas and processing		Cf. B1	Serve manifest customer needs; also see B1 and constraints from E4
C. Owners and lenders	Good performance compared to the more profitable half of Swedish industry, and growth		Liquidity requirements, good financial policies, risks have to be manageable	
D. The county	Through A1	Stay in the county; cooperate in local matters	See D2	Through cooperation, see D2
E. Society as a whole	Through A1, B1	Cooperate with organizations and others, give information	Constraints from E4 etc.	Through B4, A2; to cultivate material resources (≈B1, C1); fulfil social contract

- the existing organizational structure is accepted, and
- the intuitive balancing of objectives that the organization head must be able to perform in order to choose any one plan, is considered the best one from the organization's point of view.

Another distinction in multiobjective decision-making concerns the time horizon. For strategic, long-term decisions, forecasts in multidimensional terms are often recommended, in order to describe the firm's position in various respects. It is much less common to see similar advice concerning the annual budgetary planning, although it may be possible to choose different "balances" between objectives even in the short run.

It was postulated above that the head or management of the organization chooses a suitable balance between objectives. For long-term decisions, management can probably judge the organization's possibilities - in fact, knowledge of market developments and of financial and technological opportunities should make it easier for management to do this than it would be for the operative units. In the short run, things are different. Not only does short-term planning call for more detailed knowledge of the possibilities, but knowledge of this kind is also generally only available in the operative units themselves. Current opportunities are subject to conditions of which the units are the best judges.

Short-run planning is therefore in greater need of a planning dialogue, which in the multiobjective case has to be conducted in multidimensional terms.[1] The non-monetary effects of available plan choices would also have to be included in the dialogue. The need to consider such aspects

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[1]Unless the multiple objectives are reduced to a single one, in preparation for planning - the preferences-first approach, see Section 1.1 above.

has been frequently advocated recently in connection with ex post accounting:

> Social accounting can be defined as the reporting of accountability for all resources used by a corporation (or, for that matter, any entity). Typically, corporations have reported on the use of financial resources to the suppliers of those resources - owners and creditors. ... real social accounting must report to the suppliers of resources - and stockholders are not the suppliers of human and natural resources to the corporation. ... what the social accountant must do is break down quality of life into constituent elements and use surrogate measures. ... since they are not expressed in common measurement units, it is difficult to make rational choices based on them.
> (Elliott, 1975 (1973), pp. 15, 16, 19)

Just as this approach transforms accounting into the multidimensional description of results, so is the present study concerned with changing short-term planning and budgeting to allow for the consideration of the effects of alternative plans on a multiplicity of objectives.

Such effects will not necessarily involve external resource suppliers, as is generally the case in social accounting. Rather, they may concern any set of objectives which the head of the organization finds relevant. Essentially, during planning some exploration of possibilities and preferences is necessary in multiobjective terms, if the multiobjective decisions are to be made in a consistent and coordinated manner.

1.4 BUDGETARY PLANNING

1.4.1 Budgets and plans

We can now discuss the short-term planning and budgeting process that is sometimes known as budgetary planning. It includes roughly, the preparation of a budget, together with the planning decisions this involves.

It seems difficult to maintain any strict borderline between budgeting and planning. The terms have been defined differently by various authors. For instance, Gavatin, Magnusson and Samuelson (1973) report that U.S. firms tend to prefer the term planning, as budgeting is felt to have negative connotations connected with the idea of rigid appropriations. Taken together, I understand the two terms to mean <u>choosing and designing a particular set of activities and a particular way of performing them</u>, in preference to other sets and other ways that would have been possible.

In most discussions of this subject various characteristics that distinguish planning from budgeting are suggested. Planning may be performed in a fairly informal way, while budgeting generally obeys certain formal rules. Such rules may also demand a quantification of the consequences, possibly in monetary terms, whereas long-term plans at least can be expressed in more or less qualitative terms. Budgeting rules often refer to a formal budget dialogue between management and operating units, something which is not always considered important in planning with its generally longer time perspective.

For a review of definitions of budgeting, see Bergstrand, Gavatin, Magnusson, and Samuelson (1970, pp. 8-12). A viewpoint which appears to be fairly common is that budgeting is just a financial evaluation of chosen plans. Only if the effects of these plans on economic results and liquidity prove unacceptable can the choice of activities be questioned, in which case planning is resumed. Proponents of this view, who at the same time mention multiple objectives (e.g. Madsen, 1970), argue that the other objectives have been considered in the preceding planning.

More general defintions refer to the budget as a description of an economic position which is to a large extent quantified and which concerns future activities (Wideбäck, 1970). Greenwood (1974, p. 93), writing about General Electric is even more general. He says that there are numerous types of budgets, not all of them expressed solely in dollars and some less quantitative than others.

During the last two decades public planning has been characterized by increasing integration between planning and budgeting. Various systems of performance and programme budgeting have emphasized the importance of planning as one of the aims of the budgeting process. Schick (1969) sees this as an evolution of budgeting from an instrument of passive control to become an instrument of planning. Since I recognize no great fundamental difference between public or private multiobjective organizations, it seems to me that integration of this kind is also quite natural in business-firm budgeting.

For these reasons I have adopted here the definition used by Bergstrand, Gavatin, Magnusson, and Samuelson (see for instance Bergstrand, 1974, p. 11), but I have slightly changed the emphasis. They define budget as "a program of activities for the company based on certain explicit assumptions and expressed in economic terms". It should be observed that I understand "economic terms" to include nonmonetary factors. Multiple objectives imply that it is necessary to "economize" also with respect to factors that are not immediately possible to translate into monetary terms. (Also cf. Söderbaum, 1973, Chapter 2.)

1.4.2 Budgeting and decentralization

Budgeting is often defined as the preparation and use of budgets (Heiser, 1959, p. 3). Of these two element, only preparation could be confused with planning. In fact it is sometimes referred to as budgetary planning (cf. title of Bergstrand, 1974). This is the phase that concerns us here, although I will sometimes use the terms "planning" or "budgeting" on their own. Budgetary planning generally involves several organizational levels; it also follows certain permanent rules for the preparation and documentation of budgets. This means that the budgeting discussed here is decentralized; it leads to some sort of agreement, or "contract", between the operating units and the head of the organization.

Decentralization has been defined in two different ways in the literature. This distinction has been discussed by Heal (1971, p. 281) and by Jennergren (1974, p. 76). According to one definition, decentralization means the division of authority in an organization such that the members feel more highly motivated in their work and more involved in the activities of the organization. According to another it means the division of knowledge within an organization such that members become involved, but now for another reason: certain information exists at points away from the centre, which is needed for correct central decisions. Heal declares that this latter informational type of decentralization is the one traditionally discussed in the literature of planning. And he suggests that the former sense, geared to the division of authority, has unfortunately been neglected to a surprising extent in view of its frequent appearance in popular discussion. Despite Heal's strictures, I too have taken the informational definition of decentralization as the basis for my study.

If budgeting is being developed into a multidimensional procedure, various kinds of budgetary needs arising from the use of budgets during and after the budget period also have to be allowed for. Activities may have to be explained more fully when they are to affect several objectives, and it may be necessary to tackle the ex post analyses in new ways. These aspects will not be discussed here.

According to the above definitions, budgets can include any sort of documentation concerning planned activities, and they may consist of anything from a statement of purely monetary consequences to multidimensional descriptions. Budgets can describe all activities or only some class of activities; in the latter case, however, all the activities of that particular class will probably be included. For instance, one kind of budget consists of all the investment plans for a particular time period (cf. the term "capital budgeting").

1.4.3 Rules for budgeting

So that everyone involved in budgeting will clearly understand what budgets they are to prepare, to whom the budgets should be communicated, and so on, budgeting is subject to formal rules. These were important to my decision to concentrate on budgetary planning. A decentralized procedure is necessary in order to achieve the coordinated exploration of organizational possibilities and preferences mentioned in Section 1.3. And some degree of formalization makes it easier to guide this exploration.

Whenever the choice of one plan rather than another will affect several objectives, there are various ways of treating the expected impact on any one of the objectives:

- It can be considered and documented in the budget or activity plan
- It can be considered and documented in budget proposals, but not in the final plan or budget
- It can be discussed orally but not documented
- It can be considered intuitively by the decision-maker
- It can be neglected.

Any fairly systematic treatment of multiple objectives will obviously require the use of one of the first two alternatives, and preferably the first one since this increases the chance of achieving an organizational consensus on the objectives and of obtaining a successful ex post analysis of results. This means not only that budget formats must be made multidimensional, or that multiobjective decision rules must be drawn up; because budget decisions involve the participation of many organization members who possess a variety of knowledge, it also means that the rules must be adapted to the new multidimensional formats so that these people can readily exchange information with one another.

In developing these rules, it must be recognized that budgeting is a recurring activity, and that the rules also serve to achieve continuity from one year to another. Thus, in a multiobjective situation, rules can assume different guises. They may be:

(1) Rules for descriptions of multiobjective performance that can be used in planning discussions (and later for evaluation purposes)

(2) Rules for decision-making, in terms of the input of information and its processing by the decision-maker

(3) Rules for communications during the process, in terms of information flows and decision-making responsibility.

I would like to discuss here some different ways of structuring a multiobjective budgetary planning dialogue. Structure is achieved mainly by means of the types of rules set out above. Thus my subject in the following pages will be the derivation of such rules. The rules will be discussed for idealized and "general" situations, which means that concrete recommendations will be possible mainly for the last group (3). The ways decisions are made (2) provides an interesting field for study; this will be touched upon but not developed. The same can be said of possible descriptions of multiobjective activities (1), a subject which will be discussed mainly in Appendix A.

1.5 SUMMARY AND NEXT STEPS

This study concerns budgetary planning in organizations which have multiple objectives. Budgetary planning is the part of budgeting which deals with the preparation of a budget, i.e. the choice and design of activities for one or more future periods. Notable features of the definitions introduced in this chapter are that budgetary planning involves different levels in the organization and that it obeys certain rules, and that the final balancing of the objectives is performed by the organization head. Although it is assumed that various persons possess relevant information which they should divulge (informational decentralization), it is also assumed that authority is centralized in the person of the head of the organization.

Budgeting is usually a recurring activity which follows predetermined rules. I will concentrate here on the rules of communication during budgetary planning, and the use of the budgetary planning dialogue for exploring possibilities and preferences in a coordinated way in the course of planning activities for the next period.

In Part One we will first see how the problem of communicating objectives has been dealt with in budgeting. The problems introduced in this chapter will then be formulated in more exact terms. We will thus arrive at a model of the planning situation in a multiple objective organization. Some criteria will also be suggested for the design of a budgeting procedure suited to this situation.

2. HOW OBJECTIVES ARE COMMUNICATED IN BUDGETING TODAY

Before formulating any new procedures for budgetary planning suited to multiobjective situations, let us look at the way objectives are handled in budgeting today. As discussed in Section 1.4, traditional budgeting tends to stress monetary effects, but the probable existence of other considerations has presumably had some impact on budgetary practices. This is true particularly in the public sector, where special forms of budgeting such as programme budgeting have been tried. Programme budgeting will be discussed in Section 2.2, while Section 2.1 is concerned with the use of budgetary targets and contraints in business budgeting.

2.1 OBJECTIVES IN BUSINESS BUDGETING TODAY

During budgetary planning, objectives have to be explained to the local units (LUs) so that planning can proceed in the right direction. If there is one known and communicable objective for the activities of a local unit, this can be announced once and for all at the start of each year's budgeting. If not, more subtle guidelines may be needed.

Such budgetary objectives are part of the budgetary assumptions given to the budgeteers[1] as a point of departure, often together with management's expectations con-

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[1]The term budgeteer is here used to designate anybody involved in preparing or evaluating budgets and budget proposals.

cerning external developments. The objectives may differ in content from one type of activity to another (i.e. in different local units). An example could be sales maximization for a sales department and cost minimization for a production department. Thus, budget assumptions serve to

- identify objectives (or attributes to be used as objectives) by assigning target levels, etc. and, sometimes, to
- relate them to one another, by assigning an order of priority, restricting some of them to specific levels, etc.

Bergstrand (1973) and Budgeteringspraxis (1972) both report difficulty in giving information of this sort in areas such as administrative work and research. This has led to the use of budget constraints ("ceilings") in the assumptions document, to indicate an acceptable scale of activities for a unit. Bergstrand also found a more "selfish" attitude in these cases: lacking any meaningful indications of a unit's organizational role, the budgeteers gave vent to their empire-builder instincts. He suggests that a more careful objective-setting in the early stages of budgetary planning would save work in the later stages. This would require more effort on the part of the managers concerned. Among Bergstrand's <u>empirical findings</u> can be mentioned:

- Budget assumptions often include objectives
- These are increasingly often given as quantified targets for budget units
- Objective-setting is discussed most often as an initial or preceding stage in budgeting
- In most organizations, any revision of objectives (targets) is regarded as an exception
- Especially for less quantifiable activities, monetary budget ceilings are used by management to indicate the expected scale of unit activities.

When the targets of a unit are set in advance and are not revised during planning, the quality of the local budgets can be judged by their fulfilment of target expectations. Some authors, such as Madsen (1970), tend to limit management's role in budgeting to target-setting and checking whether local budgets are feasible, i.e. whether they fit together and result in the necessary liquidity and profitability. Budgeting is thus only concerned with planning in a lower-level sense: the determinination of a detailed plan which meets preconceived standards. These standards can be made multiple; for example, sales figures as well as market share and profit-contribution ratio could be the targets of a sales department. But the fact remains: the balance between objectives has to be identified outside (and prior to) budgeting.

Using the term introduced in Section 1.1, current budgeting practices would thus seem to have a predominantly preferences-first character, with very little interactive learning about preferences as a result of discovered possibilities. It is only when targets are revised during planning that such learning takes place.

Such target revisions are recommended by Madsen (1970) as a response to unsatisfactory plans, but he gives no rules for them nor does he report any empirical evidence. It seems to be very difficult to set meaningful targets in advance in a multiobjective situation. If a double target such as "sales = Skr 150 million and market share = 20 %" cannot be fulfilled, an operating unit needs to know the relative importance of the two objectives. This is also true when the targets can be met; how should surplus performance be allocated?

A tentative conclusion could be that a multiobjective situation requires either a more thorough ex ante analysis of preferences, so that all such situations are foreseen, or an active revision of targets during planning as an integral part of the planning dialogue. Neither method seems to be common practice today. Present-day budgeting methods may provide part of the multidimensional dialogue which could be useful, but it stops short of explicit ex ante preference studies and any subsequent systematic revision of targets.

2.2 PROGRAMME BUDGETING: A WAY OF HANDLING MULTIPLE OBJECTIVES?

The previous section dealt primarily with business budgeting, although Bergstrand (1973) included a public utility and a city government in his study, and found similar budget principles prevailing there.

The special difficulties caused by such activities as administrative work and research were mentioned above. Their effects are hard to quantify in a meaningful way, with the result that they are only described in the budgets in terms of their costs. Problems of this kind exist in business firms but are far more prevalent in the public sector, where monetary revenues are the exception rather than the rule.

In such areas programme budgeting has served as a catchword for several kinds of economic-administrative reform, sometimes lumped together as a kind of "package deal", particularly in the 1960s. An example was the Planning-Programming-Budgeting-System (PPBS) in the U.S.

Some kind of reform became necessary as governments evolved to become managing and planning bodies, no longer merely executing and controlling activities that have been decided by parliament but taking initiatives on their own. According to Schick (1969), there has been a correspondence between the aims of budgeting and the types of budgets used, reflecting a changing emphasis in the public sector:

Table 2:1.

Aim	Emphasis	Type of budget
Control	"Correctness"	Line-item budget
Management	Efficiency	Performance budget
Planning	Effectiveness	Programme budget

(Table not in Schick.)

Programme budgets do not supersede the others, as all three kinds emphasize different aims that still exist. Schick hopes for a data base that can be used for all of them.

Programme budgeting is thus concerned more than traditional budgeting with decisions similar to those featuring in this study; namely with planning in the sense of identifying plans that correspond to some given set of preferences. The "techniques" which programme budgeting uses to achieve this are programme accounting, detailed analysis of alternative ways of carrying out these programmes, and quantitative evaluation of alternatives (Merewitz and Sosnick, 1971).

At the lowest level, programme accounting means that activities in each organizational unit are divided into programme elements belonging to a particular programme. This makes it possible to sort activities (and costs) in a way suited to the necessary decision-making. According to many descriptions of programme budgeting such unidimensional effectiveness measures should be available for each programme, and the balancing of different aims or programmes is then highlighted as a central-management task (cf. SOU 1967:11, Chapters 5 and 9).

In practice, the dream of a single "best" set of programmes for sorting an agency's activities could only come true if the activities were completely separate, each affecting only one objective. In reality we are faced with multiple-objective activities which are performed in combination. This is reflected in the very wide range of principles that have come to be used for the identification of programmes. A single programme structure proved insufficient for all kinds of decisions. For experiences in Swedish public administration, see Riksrevisionsverket (1975, pp. 57-59).

The rather bureaucratic <u>analytical process</u> was also less than a complete success. In both the U.S. and Sweden, analysis was meant to include information on societal needs, performance indicators, etc., but most of the attempts made were very limited. Had such information been developed, it might have been possible to solve some of the problems caused by programme interdependencies by what has been called crosswalking, i.e. using several structures for sorting information elements by coding them in different ways. The American PPBS came to a halt when most of it was made voluntary by the Nixon administration in 1971. For some of the criticisms that preceded this step, see Wildavsky (1969). In other countries, such as Sweden, attempts are now being made to emphasize those parts of programme budgeting that budgeteers consider valuable but undeveloped, notably multiple-criteria descriptions of alternatives (see Riksrevisionsverket, 1976). In this way the multiobjective nature of individual activities, incompletely realized in programme budgeting, is coming into the focus of attention.

For the purposes of the present study, experience of programme budgeting (PB) can be summarized as follows:

- PB was directed towards the objective-balancing problem, as is the present study
- PB used a conception of organizational activiites which is here considered unacceptable; i.e. it was assumed that activities could be sorted into separate programmes suited to general-purpose decision-making
- PB attempted an analysis of alternatives which was too extensive, in view of the efforts of the lower-level information providers on the one hand and the capacities of the higher-level information users on the other
- Much of this information concerned the multiattribute effects of alternatives and was intended to serve a purpose similar to ours here, except that PB assumes a basic single-objective situation within each programme.

2.3 SUMMARY

Traditional budgeting sometimes makes use of multiattribute descriptions, but mostly to check the feasibility of the budgets in terms of predecided targets. These targets are used to coordinate the activities of different units.

In order to deal with multiple objectives, such budgetary planning would have to be combined with an initial phase involving preference studies (preferences-first) or be developed into an interactive exploration of possibilities and preferences during planning, including the revision of targets as plan proposals are presented. Current types of budgeting only seem to include such revisions in exceptional cases. On the other hand, the use of targets and constraints to guide budget proposals indicates a readiness to develop devices of this kind.

The most important attempt so far to deal with multiple objectives in a budgeting context is programme budgeting. This has not been completely successful. It can be argued that in programme budgeting the multiobjective characteristics are disregarded in favour of an assumed single objective for each activity. It is not possible to include joint activities, each affecting several objectives in this framework.

Budgeting and programme budgeting practices have provided organizations with some experience of using multiattribute descriptions of alternatives. This means that a starting-point exists for an extension of budget practices to deal more actively with the problem of choosing the correct balance between several simultaneous objectives.

3. A MODEL OF THE PROBLEM SITUATION

In Chapters 1 and 2, an organizational planning problem has been introduced and related to current budgeting practice in organizations. The problem is believed to be a general one, in the sense that it could - and probably does - exist in many organizations.

In this chapter, the problem is presented in the form of a model which could fit several conceivable real-life situations. The model is a description of a class of situations, and it will be presented in stricter terms in Chapter 4. Its purpose is to make it possible for us to find procedures for dealing with the situations concerned. The model will accordingly be broken down into four sub-models, each applicable to one subclass of the original class of situations. This analysis will constitute the theoretical part of this study (Part Two).

This process of research may need some explanation, to clarify the relations between the various models used in the study. This explanation is given in Section 3.1. The model is presented in verbal terms in Section 3.2 and discussed in Sections 3.3 and 3.4. The important question of how the activities of operating units relate to their performance, i.e. their impact on organizational objectives, is discussed in Section 3.5. Some delimitations are given in Section 3.6.

3.1 THE ROLE OF THE PROBLEM FORMULATION

My choice of model situation for this study was strongly influenced by practical circumstances, in particular personal contacts with the Swedish Defence Organization and the Swedish Telecommunications Administration. It does not mirror any of these exactly, as I also absorbed ideas from my reading, for instance about corporate influence on the environment. The details of the model were thus a matter of choice - but only partly so, since there were several factors to take into account:

- The fact that the basic research field is multiple organizational objectives and planning in decentralized organizations
- Evidence of practical situations, particularly as regards knowledge of possibilities and preferences
- That the model should be simple and that it should not include unnecessary, or unnecessarily rigid, assumptions.

In a sense, this model provides the basis for a <u>theory</u>. The criteria of a good theory include such qualities as relevance, consistency, completeness, testability, simplicity, and clear relative centrality for each proposition contained in the theory (Argyris & Schön, 1974, pp. 197-198).[1] The assumptions of the model presented here have been chosen with such considerations in mind.

In designing a planning system for the situation depicted in the present model, another set of criteria is also important, namely the attributes desirable in a "good" planning system. <u>It is only when the model situation is combined with these desiderata that the design problem is fully specified</u>.

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[1] Centrality here denotes the number of other propositions that have to be changed when one proposition is altered. The other criteria are used in theie traditional sense.

In Part Two we will discuss various procedures for planning in organizations which fit these requirements. In order to adopt a particular procedure, further assumptions have to be added to the basic model. To put it another way, each procedure will only be valid for a subset of the situations described by the model presented in Part One. As the exact design of the procedures is a matter of choice for the researcher, we can also say that <u>the problem formulation selected in Part One is further specified in several alternative ways in Part Two</u>.

The whole process of inquiry thus involves <u>several sets of related statements</u>. If we label these sets A, B, and C, we can illustrate their relations to one another as in Figure 3.1. The basic model is given by set A. It is essentially an attempt to identify the organizational situations which are the subject of this study; it gives the characteristics that seem to me to be necessary and/or natural to expect in a decentralized organization involved in multiple objective planning, and introduces certain simplifications which will be used throughout. For instance, statements in Set A give some specification of the preference knowledge of the central unit, and describe what information exchanges can take place.

We also have set B, giving the evaluative criteria or <u>desiderata</u>. These differ from the statements in set A in that they are relative requirements. Whereas the propositions in set A should be fulfilled in a final solution, the statements in B tell us how to judge the solution in terms of such requirements as "as low demands as possible on ...", etc. The criteria I suggest here are partly chosen for this particular purpose and partly derived from other related studies. They will be presented in Chapter 4 together with the A statements. In a real-life situation, A and B sets of this kind should be identified before a solution is attempted. Such A sets would probably be more detailed than the model set, while B sets could well show more knowledge about priorities between criteria, etc.

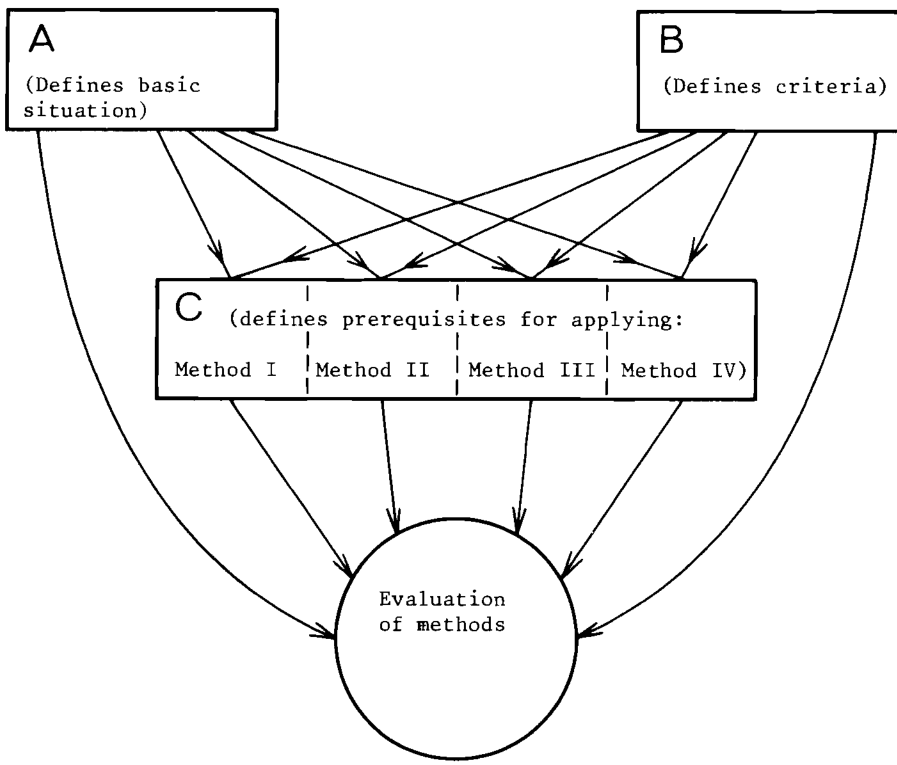

Figure 3:1. The relations between the sets of statements used in the study.

A is the set of propositions that defines the problem situation
B the criteria used in formulating and evaluating methods and
C the assumptions needed for specific methods.

Any evaluation of a method will have to consider how A, C, and the method itself affect the criteria contained in B.

Chapter 4 will also contain a mathematical formulation of the problem, which will involve some shift in emphasis. Certain of the relations between terms in the model will be more strictly specified and others less so. This seems to me to be a necessary consequence of the differences between normal and mathematical language. The two formulations should be considered as complementary; both will be used in the analysis in Part Two.

Figure 3:1 also shows a set C, containing statements relating to the different methods proposed. This set is the union of four subsets, each of which is related to one method. Many of the statements are repeated for several of the methods. They mostly concern the specific ability of the units to communicate their knowledge of preferences and possibilities. Accordingly, application of method I, for instance, requires the fulfilment of the A statements and of those C statements that are relevant to method I. The four methods thus involve the further specification of the set A model into four new models.

The C statements are chosen by the researcher in two senses:

- There are many methods that could be applied
- For each method, there may be alternative sets of statements that make it possible to apply the method.

The researcher is guided by the set B statements in making these choices. When alternative methods are later to be compared, he will also have to use the B statements. Such evaluations will mainly concern individual practical situations. In these, the B criteria will be affected by the ease or difficulty of fulfilling the requirements resulting from the A and C statements, but also from the "mechanisms" of the methods themselves. For example, the B statements dealing with information requirements will mainly relate to C statements, and the B statements dealing with the speed of the process will mainly relate to the procedure as such.

In the lists of A and C statements presented in Chapters 4 and 12, the statements will be structured as follows:

I Statements concerning the entire organization
- I.1 Organizational objectives and the planning task
- I.2 Organizational structure and authority

II Statements concerning organization units
- II.1 Central unit (impact and knowledge about impact; preferences and knowledge about preferences; information-processing ability)
- II.2 Local units (impact and knowledge about impact; preferences and knowledge about preferences; information-processing ability)

III Statements concerning inter-unit relations
- III.1 Communication possibilities
- III.2 Influence and control possibilities.

Some of the above groups are only relevant to A <u>or</u> C statements. The classification of a statement as belonging to one of the groups is sometimes somewhat arbitrary, e.g. the choice between I.2 and II.

3.2 THE ORGANIZATION MODEL: VERBAL FORMULATION

As explained in Section 3.1 the problem with which this study is concerned is defined by the model situation to be presented below together with a number of planning desiderata. The model describes an organization and conforms to the situation outlined in Chapter 1, the most important characteristics of which will be recapitulated here. In Chapter 4, a compact statement of the model assumptions will be given, together with a mathematical formulation of the model, and the set of planning desiderata.

We will discuss an <u>organization which has two or more objectives</u>, in the sense of these terms discussed in Section 1.1. Planning can be said to concern the choice of a particular plan of activities among several possible such plans for the following time period. The organization has sufficient knowledge to choose the "best" plan, but this knowledge is not - and cannot be - centralized. For an explanation of decentralization in this sense, see Section 1.4. We are concerned with the kind of budgetary planning that follows permanent rules; in other words it is not a question of once-for-all decisions, but of similar planning situations that recur.

The role of the organization head was discussed briefly in Section 1.1. In our model, the head is identified as the central unit (or CU), and we assume that the organization consists of this unit and several local units (or LUs). These make up the lower of the two levels of organization. This limitation to two levels of organization does not lessen the general nature of the case, since we could assume the existence of processes similar to the one studied here within each LU. In that case, we would naturally have to assume a single-hierarchy organization with only one superordinate for each unit; we could not assume, for instance, a matrix organization.

CU interprets the preferences of the organization. It does this in deciding the allocation of certain scarce resources, and in authorizing the various LUs to put proposed plans into action. Its authority is based on the fact that it can judge the combined impact on organizational objectives of LU activities, something these units themselves are not able to do. For this the central unit requires information from the local units, including suitable descriptions of their proposed activities. The central unit's knowledge of organizational preferences enables it to choose between alternative sets of objective values.

The LUs are the operative units of the organization, producing the goods and services it supplies. They decide which activities to propose in the plans presented to CU. They can also judge how alternative activity designs would affect the attributes included in the descriptions of plans that are presented to CU and which I have referred to above. Examples of such attributes could be product quantities, effect on those organization objectives which can be judged by the local units, or other indicators of LU impact. The LUs know which plans would be possible for different allotments of central resources, and they can propose such plans. They accept that their preferences between plans, if any, are subject to CU preferences as expressed in central resource decisions and plan authorizations. The role of LU preferences will be discussed in Section 3.4.

The CU and LU knowledge introduced here, and the attributes used in describing plans, will be discussed in Section 3.3. The results of a local unit's activities will be called production or performance, depending on whether they are described in terms of product quantities or of the attributes discussed above. Accordingly, I will use the terms production possibilities and performance possibilities for the sets of available alternatives.[1]

The attributes are thus the variables used by the local units in describing their plans, obviously chosen so as to enable CU to judge the impact that the combined plans will have on organizational objectives. It is assumed that CU is able to make this choice. Performance is the outcome of LU activities, as described in terms of these attributes.

To summarize, we thus have a situation where the CU directs planning for the organization's several objectives, letting its preferences represent those of the organization. For planning within each LU, the agreed set of attributes for describing plans becomes a set of objectives. Local units possess knowledge of possiblities which the CU does not possess, but their own preferences are not necessarily correct from the organizational point of views.

Planning will have to rely on interaction between central and local units, if an optimal or near-optimal

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[1] A different way of explaining it would be to show the feasible set in production (product) or performance (attribute) space. As discussed in Appendix A, Section A.7, performance can sometimes be regarded as caused by production. This assumption is used in the numerical example in Section 3.5 below.

solution is to be found.[1] In this dialogue, messages are exchanged between CU on one hand and the local units on the other. In line with probable real-life circumstances, we will assume this dialogue to be limited to between two and five rounds or iterations. Few organizations use more than two or at most three iterations (Bergstrand, 1973), but if we include preliminary rough proposals and the more intense exchanges made possible by budget simulation, a few more than this seem a realistic possibility. This implies that an optimal solution cannot be guaranteed - the "best" near-optimal solution will have to do.

3.3 ON THE NATURE OF MULTIOBJECTIVE CHOICE[2]

According to the model described above CU assesses LU plan proposals on a basis of plan descriptions expressed in terms of attribute values. In its simplest form, this judgment concerns the choice of the preferred combination of LU plans from among several alternatives. Thus, CU receives multicriteria information and we assume that it wants to maximize multiple objectives; nevertheless it has to make an inherently unidimensional judgment in choosing one set of plans.

This assumed situation is an example of the working of what have been called implicit preferences (cf. Geoffrion & Hogan, 1972, and Jennergren, 1971, p. 12). A person can judge multidimensional information in a consistent way by indicating the existence of preferences, but without being able to communicate these preferences or make them explicit in any simple way.

For instance, central management may be able to choose between plans presenting different balances between employ-

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[1]Even in the preferences-first approach (cf. Section 1.1) some interaction is needed for finding the best resource allocation. This would involve an interactive exploration of possiblities, but not of preferences.

[2]The reader is referred to Appendix A for a more detailed discussion.

ment effects and profitability, but be unwilling or unable at the same time to announce such a desired balance, except indirectly through its choices.

In the same way the local units are assumed to possess implicit knowledge of their own possibilities. As in the case of implicit preferences, this involves the existence of a feasible set about which the LUs have similarly limited explicit information. For instance, it may not be possible for a local unit to say exactly what it knows about the "cost" of employing more people; but it could suggest alternatives that indirectly imply the existence of such knowledge. It will be assumed below that each LU can propose one non dominated (efficient) plan for each resource allocation.

CU's assessment of LU proposals can be said to include two basic steps. First, CU finds the combined impact that LU plans would have on each of the multiple organizational objectives. In simple cases, this can be done by adding together the various units' contributions to some objective such as profit; in more complex cases CU will need to know something about the interaction of different LU effects. Thus this step can involve more or less explicit elements. There may often be less controversy and fewer value-laden judgments about the degree of fulfilment of individual organizational objectives than there is about striking the final balance between these objectives.

After evaluating the LU plans in terms of their impact on objectives (i.e. establishing the organizational performance that the plans would result in) CU reaches the second step. This involves weighing the objectives against one another and choosing the preferred combination of LU plans. This is the step where the evaluative and intuitive properties of CU preferences will be most needed.

The sequential character of the assessment process described above is important in predicting what kind of preferences CU will exhibit. The greater the number of steps involved, the more complex is the dependence of the final choice on individual LU plan attributes likely to be. There is fairly strong evidence from psychological studies that preferences often conform to quite simple mathematical functions, in particular to linear functions (cf. Appendix A, Section A.5). In spite of this, the sequential nature of CU assessments, together with our intention here to assist rather than predict or simulate behaviour, makes it reasonable for us to assume that nonlinear preferences could appear in the model situation.

Recommendations about the choice of attributes, and a discussion of their relation to LU activities, appear in Appendix A (Sections A.6 - A.8).

3.4 THE ROLE OF LU PREFERENCES

Assuming that CU preferences are those that should ultimately prevail, we should still remember that the local units may well have preferences too. These may not necessarily involve the same attributes of LU plans, and the resulting ranking of possible LU plans may agree or conflict in varying degrees with the judgment that the CU would arrive at. We have assumed here that the CU acts as interpreter of organizational objectives and, if this is accepted by the LUs, then the latters' preferences should represent their idea of CU objectives. Since one reason for assigning this role to the CU was the inability of the local units to command an adequate overview, only by coincidence will such an approximation to CU preferences correspond to the preferences CU actually holds.

In this study we disregard behavioural factors (cf. Section 3.6, below), which means that we ignore the "cheating" problem whereby procedures aimed at optimizing central preferences are more or less efficiently sabotaged as a result of local self-interest. But even apart from this, there are several other ways in which LU preferences can have implications for our problem.

The most limited of these is to let an LU use its preferences as a decision rule to direct local search during the early stages of planning. LU preference functions should to some extent reflect central preferences; they could also be expected to be geared to the relative advantages of the different units. In these ways, they could be superior to arbitrary choice rules in finding initial solutions. CU would still have the opportunity to impose its will on the organization during later iterations.

Quite often, however, CU may want to give some weight to LU preferences in its own preferences. In other words, LU satisfaction may be one of the organizational objectives. The model of Geoffrion and Hogan (1972), to be discussed in Chapter 8, uses this approach in defining CU preferences over LU-satisfaction values only. This means that even in a model with centralized authority, LU satisfaction could be one of the attributes of an LU plan to be considered by CU. In order to use such an approach, it has to be possible to measure or identify "satisfaction" in some way. If this can be done, CU can balance the measure of satisfaction against other objectives, or perhaps apply some other rule such as minimum requirements for LU satisfaction.

According to this approach, a desire to fulfil LU wishes does not conflict at all with a centralized model. The important point is that CU has the last word, and the relative satisfaction of the different local units is decided by CU and not, for example, in the course of inter-LU bargaining.

3.5 THE RELATION BETWEEN ACTIVITIES AND PERFORMANCE

The term LU performance was used (see Section 3.2) to indicate a set of values for the attributes used in describing LU plans. An LU plan is thus presented to CU in terms of the performance it would generate. CU receives a vector of values for variables such as LU sales, profit contribution, rate of employee turn-over, etc.

"Production" or "activities" are probably more basic concepts than "performance" for the local units of most organizations. In assuming that the units can describe their plans in performance terms, we are expecting them to know how production affects all the attributes that are relevant to the organizational objectives and that have been agreed upon between CU and themselves.

In evaluating the effects of alternative plans on the attributes, the units will often have to look beyond cases of which they have direct experience. They will have to make assumptions about the relations between the attributes and activities such as "the production of a certain product". Such assumptions will probably be fairly simple. It may even be possible to assume linear relationships over the relevant range, in describing the combined effects of different activitiy combinations on such things as pollution or customer recognition. Thus, estimating a unit's impact on several objectives may involve a <u>transformation of the feasible set from product space into performance space</u>. Transformations similar to those introduced here are used by Wilhelm (1975).

The justification for carrying out such transformations is that a discussion in performance terms is likely to be more attractive to CU than a discussion in product terms, and that knowledge about the way individual products or productive activities will affect attributes is likely to be better in the local units than in CU. Divisionalized firms tend to exert control in terms of a limited number of attributes applying to all divisions (cf. Mossberg, 1977). A preference for performance space descriptions rather than those using product space has also been mentioned in Geoffrion, Dyer and Feinberg (1972, p. 361), in view of the generally smaller dimensionality of the former.[1]

To <u>illustrate</u> this, let us consider a hypothetical LU which can produce any combination of two products, A and B, constrained on the one hand by the raw material requirements and the number of machine-hours needed, as follows:

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[1] Geoffrion et al. use the terms "criterion space" and "outcome space".

$$\left.\begin{array}{r} A + \ \ B \leq 10\ 000 \\ 6A + 4B \leq 50\ 000 \end{array}\right\} \text{ or } \begin{pmatrix} 1 & 1 \\ 6 & 4 \end{pmatrix}\begin{pmatrix} A \\ B \end{pmatrix} \leq \begin{pmatrix} 10\ 000 \\ 50\ 000 \end{pmatrix} \qquad (3\text{-}1)$$

where A and B designate product quantities, and on the other by the nonnegativity constraints.

$$A,\ B \geq 0, \quad \text{or} \begin{pmatrix} 1 & 0 \\ 0 & 1 \end{pmatrix}\begin{pmatrix} A \\ B \end{pmatrix} \geq \begin{pmatrix} 0 \\ 0 \end{pmatrix} \qquad (3\text{-}2)$$

The attributes that have been agreed for the local units' description of its possibilities to CU, are its contributions to organizational profits and its strategic value. The latter is an index of its impact on customer good-will, and both are assumed to derive directly from the sales of the two products.

Both products show positive contributions to the firm's overheads and profits, A with 3 dollars and B with 5 dollars per unit. The strategic value per unit is 8 for product A and 4 for product B. To find out the performance alternatives open to the unit, it is advisable to transform the feasible product-space region in Figure 3.2 (formed by the above constraints) into the performance-space feasible region in Figure 3:3. This transformation can be made, if we note that profit (P) and strategic value (S) depend on A and B as follows:

$$\left.\begin{array}{l} P = 3A + 5B \\ S = 8A + 4B \end{array}\right\} \text{ or } \begin{pmatrix} 3 & 5 \\ 8 & 4 \end{pmatrix}\begin{pmatrix} A \\ B \end{pmatrix} = \begin{pmatrix} P \\ S \end{pmatrix} \qquad (3\text{-}3)$$

This is a linear transformation, and the matrix is nonsingular (cf. Noble, 1969, p. 15). By finding the inverse matrix or solving the system of equations, we find that

$$\begin{pmatrix} A \\ B \end{pmatrix} = -\frac{1}{28}\begin{pmatrix} 4 & -5 \\ -8 & 3 \end{pmatrix}\begin{pmatrix} P \\ S \end{pmatrix} \qquad (3\text{-}4)$$

which, inserted into the production constraints (3-1) and (3-2), gives us the following performance constraints:

$$2P + S \leq 140\ 000 \quad (3\text{-}5)$$

$$4P + 9S \leq 700\ 000 \quad (3\text{-}6)$$

$$4P - 5S \leq 0 \quad (3\text{-}7)$$

$$-8P + 3S \leq 0 \quad (3\text{-}8)$$

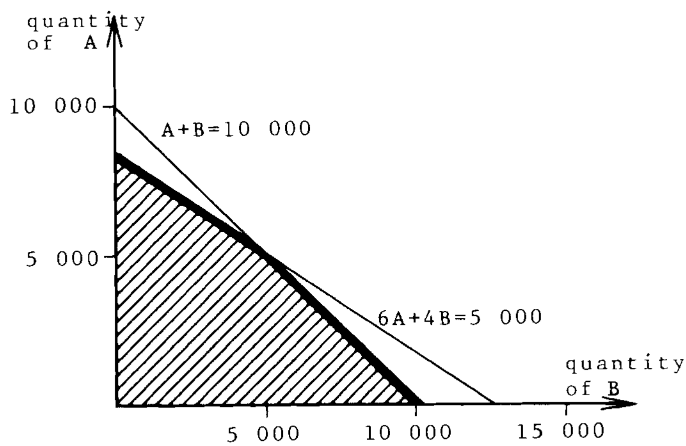

Figure 3:2. Feasible region for product mix with the linear constraints (3-1) and (3-2) (see text).

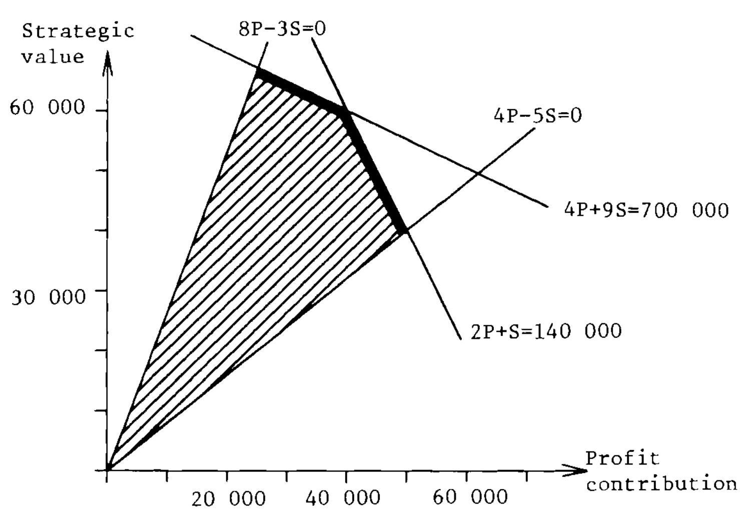

Figure 3:3. Feasible region for performance, derived from Figure 3:2 using the transformation (3-3) in the text. Dark lines indicate efficient performance.

The best plan from the organizational point of view must be one of the nondominated ones, i.e. it must lie on the dark lines in Figure 3:3. For linear preferences, one of the three corner points (25 000, 66 667), (40 000, 60 000), and (50 000, 40 000) is the best one, for nonlinear preferences possibly one on the lines between these. This will of course also depend on CU's evaluation of the combined effect of all the local units.

The point of this example is to show that even in this very simple case the exact range of efficient plans is not altogether obvious from what is known of the production possibility set and the transformations. It also shows how such knowledge can be used in the search for possibly efficient plans. This is more important in the multiobjective case than in traditional planning, where there are unidimensional criteria for judging plans, and it is therefore possible to use some kind of utility functions already in Figure 3:2.

Theoretically, an alternative would be to transform information about preferences into the product space. Given our model situation, this is less attractive and would not always be easy. A prerequisite would of course be that CU objectives had a known relation to LU-plan attributes. This approach would show the relevant objectives less clearly, as planning would no longer emphasize objectives or attributes. In the interactive version of planning (but not in the preferences-first version described in Section 1.1), preference transformations would have to be made repeatedly.

This is because CU can only give an incomplete account of its preferences, and planning would have to be based on approximations of these. Finally, the number of products will often be greater than the number of attributes or objectives, which means that the dimensionality is increased in the transformation.

The feasible region transformation may also involve problems of differing dimensionality. In general, the following factors should be considered:

- Dimensionality of production space
- Form of the feasible region (in the linear case, number of binding constraints)
- Form of the transformation (e.g., linear or not)
- Dimensionality of performance.

The example showed a very simple situation: a quadrangle feasible region in two-space and a linear transformation into another two-space. A linear transformation such as (3-3) will obviously change any line into another line, preserving the general shape of the original feasible region (e.g., the number of binding linear constraints). This is also true for cases of higher dimensionality, except that, in making a transformation into a space of lower dimensionality, we can look upon the result as a projection of the feasible space that we would have received if the dimensionality had been preserved. Cf. Noble (1969, p. 471). As a result, points on the boundary of the lower-dimensional representation must still correspond to points on the boundary of the representation we would have had in the case of full dimensionality. If the transformation is linear, these points correspond in turn to points on the boundary of the original feasible space, since one line is changed into another in a full-dimensional representation.

This means that plans leading to efficient (nondominated) performance will always lie on the surface of the product feasible space, if the transformation is linear. Nonlinear constraints combined with linear transformations will obviously be similarly represented with their characteristics preserved - a circle becoming an ellipse, for instance. On the other hand, nonlinear transformations could result in very big change in performance feasible spaces. In this case, we could not even be sure of finding solutions on the boundary of the product feasible space.

Incidentally, this provides one more reason for preferring transformations of production spaces into performance space, rather than transformations of preferences into production space. It would obviously be difficult for the LU to go back to the product or activity space representation of possibilities, and to find out which activities give a particular desired performance. Because of differences in dimensionality, several alternative production plans will often result in the same performance in terms of attributes or fulfilment of objectives.

3.6 SOME DELIMITATIONS AND SIMPLIFICATIONS

In this section some delimitations will be introduced into the model. In a sense the characteristics of the model as presented in Section 3.2 also represent delimitations in our model as compared with the class of all organizations. The difference is that those characteristics define the study area by concentrating on the essential traits of a subset of organizations, while the characteristics introduced here constitute some more artificial simplifications introduced to facilitate the analysis.

First among these is the assumption that the performance possibilities of any one LU do not depend on the performance of any other LU, except indirectly as a result of central resource allocations affecting either of them. This makes it unnecessary for one unit to be informed about other units' plans.

On the other hand, the utility to the organization of the first unit's performance will of course depend on the utility of the performance of other units, since total fulfilment of an objective depends on their combined efforts. This assumption clearly represents a major simplification, which probably reduces the relevance of this study to certain types of organizations. Cf. the discussion in Section 14.2 below.

I also assume that behavioural aspects of the planning problem can be more or less ignored. In particular, what is generally called the cheating problem will not be considered until Section 14.4. However, some factors of this kind do come into the discussion of the ability of organization members to communicate their knowledge. See in particular Appendix A.

The next assumption is that this knowledge is not subject to any uncertainty. As planning deals with future events, this is obviously impossible; but it seems a natural simplification for an initial formulation of multiobjective budgetary planning methods. It can also be noted that most budgeting tends to follow a similar implicit assumption, in the sense that budgeteers provide only one estimate of expected consequences, and the final budget often includes only one value for each outcome.

This assumption too will be elaborated in Section 14.4.

In Section A.3 of Appendix A, alternative relations between objectives and LU plan attributes are shown. For the sake of simplicity, we will disregard the possibility that any one objective may require more than one attribute from a local unit. That is, we assume that a local unit, which affects a particular objective, reports one attribute only for that organizational objective.

This attribute need not be of the same type in all units, nor will there necessarily be more than one LU affecting the objective. I have introduced this assumption because CU will find it difficult to know which attributes to suggest changes in, if the fulfilment of an objective is too low or too high. With only one attribute per LU for each objective, such recommendations will be obvious; with several attributes, no clear-cut rules could be given. I believe this difficulty could be overcome, but any such discussion lies outside the scope of the present study.

Thus, each objective is evaluated by using one attribute from each LU. This combination of LU plans will be shown as a summation in the diagrams used in Part Two. This simplification is not generally assumed in the text, as it seems quite probable that effects such as diminishing marginal utility will be involved in the combination.

However, local units must know enough about the relation between attributes and objectives to propose a non-dominated attribute combination, i.e. to recognize a plan as efficient. The importance of this was underscored by the example in Section 3.5. In the model, it is assumed that the units are able to do this. This means that they have to know the "desirable direction of change" for each attribute.[1]

This is connected with the function of the attributes as objectives in LU planning, and makes them correspond to our definition of objective in Chapter 1. It thus seems necessary to assume that <u>a greater attribute value always gives greater objective fulfilment</u>, for such attribute values as are relevant to the planning situation.

As we are not interested here in mathematical formulations as such, the shape of implicit preference functions and performance possibility sets will not be analysed in detail. In general, it will be assumed that <u>CU preferences conform to a differentiable concave increasing function of the objectives, and also of LU attributes</u>. It will also be assumed that <u>LU feasible sets are compact and convex</u> when expressed in terms of performance possibility.

3.7 SUMMARY

In this chapter a model has been presented of the situation to be studied below. It will be specified more exactly in Chapter 4, and will then be used as a basis for our discussion in Part Two.

The design of the following inquiry was discussed in Section 3.1. It involves a gradual narrowing of scope, from the general situation of Chapter 1 to the prerequisites of alternative procedures in Part Two. This is portrayed in several sets of statements, or models, of which the one discussed in verbal terms in this chapter is the most fundamental.

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[1] The assumption that a local unit can find <u>some</u> LU-efficient plan, does not necessarily mean that it knows this direction for <u>all</u> possible attribute vector values. It seems difficult to use this modification in any strict way.

Section 3.2 provided a compact description of this model. A central unit (CU) and several local units (LUs) interact in order to combine central knowledge of organizational objectives with local knowledge of possible plans. As this knowledge cannot be centralized and, in part, is only available in implicit form, recommendations for the planning process are not obvious. The nature of this knowledge was discussed in Section 3.3, where it was noted that the probably sequential nature of CU's evaluation of LU plan proposals made it resonable to expect that CU preferences may be nonlinear.

This study is not concerned with the serving of LU interests, except if CU chooses to accept them (Section 3.4). In Section 3.5, a numerical example was used to show the importance of our assumption that the planning dialogue concerns attributes, i.e. LU performance in terms of objectives rather than in terms of activities or product quantities.

Finally, Section 3.6 introduced a number of delimitations and simplifications: for instance, we assume certainty; we ignore the possibility of LUs affecting one another's possibilities; we disregard behavioural considerations; we limit ourselves to certain relations between attributes and objectives; and we make assumptions regarding the shape of preferences and possibility sets.

4. A FORMAL STATEMENT OF THE PROBLEM

4.1 INTRODUCTION

In this chapter, the problem introduced in earlier chapters is given its final and more exact formulation. This is done in three closely related ways:

1. By giving a list of statements that define the problem situation (set A, given in Section 4.2)
2. By giving a mathematical formulation which shows the relations between the terms of these statements (Section 4.3)
3. By giving a list of statements that define the criteria for an evaluation of planning methods (set B, given in Section 4.4).

I have preferred the word "statement" here as a more general alternative to "proposition", "assumption", or "requirement" - the statements contain examples of each. Individual statements may therefore be referred to later by the alternative terms. The relations between the sets of statements were discussed in Section 3.1.

In its more exact formulation here, little has been added to the model as it was presented in Chapter 3. Discussion of the statements can accordingly be reduced to a minimum. The statements will be structured as indicated in Section 3.1.

4.2 THE MODEL ASSUMPTIONS ("A-STATEMENTS")

I. Statements concerning the entire organization

I. 1 Organizational objectives and the planning task

(A1) There are two or more objectives for the organization[1]

(A2) The organization is to choose a particular plan of activities for the following period

(A3) There are several possible plans for the period concerned

(A4) In principle, sufficient information for identifying one preferred plan among those possible is available to the organization

(A5) The knowledge referred to in A4 cannot be centralized

(A6) Similar planning decisions recur for each planning period, i.e. this is not a once-for-all type of decision

(A7) The organization's knowledge is complete, i.e. not subject to any uncertainty

(A8) The only behavioural factors to take into account are the exact degrees of explicitness in CU and LU knowledge

I.2 Organizational structure and authority

(A9) There are two levels of organization (or, in generalized terms: there is a hierarchy of organizational units, such that the overall organizational planning problem can be decomposed into a sequence of two-level problems, each corresponding to our situation as defined through the A-statements)

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[1] Certain basic terms are assumed to be defined outside these statements. For instance, organization and objective were defined already in Section 1.1 above.

(A10) There is only one organizational unit at the upper level, known as the central unit or CU

(A11) CU is considered to be the "interpreter" of the organization's overall preferences

(A12) There are at least two units on the lower organizational level, called local units or LUs.

II. Statements concerning organizational units

II.1 Central unit

(A13) CU controls
- the allocation of certain resources (or other scarce commodities, such as authorization to hire additional employees)
- which proposed plan an LU is authorized to put into action

(A14) CU is able to judge the combined impact of LU activities on organizational objectives, provided it is presented with suitable descriptions of planned activities in all LUs.

(A15) CU is able to rank any two plans for organizational activities, described by means of their sets of values for the fulfilment of organizational objectives

(A16) The CU preferences which are implicit from A14 and A15 conform to a differentiable concave increasing function of CU objectives, or of the attributes of the descriptions referred to in A14

(A17) CU preferences do not change during the planning of an individual period's activities

II.2 Local units

(A18) Each LU controls its choice of activities in the plans that are presented to CU

(A19) Each LU is able to judge how alternative activity combinations, resulting in different product volumes, affect the LU plan attributes used in the descriptions referred to in A14. The set of possible plans is referred to as production possibilities or performance possibilities, depending on whether it is described in terms of product quantities or in the terms of statement A14.

(A20) The feasible set of an LU, expressed either as its production or its performance possiblities (cf. A19), is constrained by local conditions

(A21) For each LU, certain allocations of central resources would further constrain the feasible set

(A22) An LU's feasible set is not affected by the plans chosen by other LUs

(A23) LU feasible sets, expressed in performance possibility terms (cf. A19) are compact and convex

(A24) The activities of each LU affect more than one organizational objective

(A25) Each LU is able to propose at least one nondominated (i.e. LU-efficient) plan for each received resource allocation

(A26) For each organizational objective, there is one corresponding element in the attribute vector of each LU that affects the objective

(A27) The relation between an LU plan attribute and the corresponding organizational objective is such that a greater attribute value always gives greater objective fulfilment, for such attribute values as are relevant in the planning situation

III. Statements concerning inter-unit relations

III.1 Communication possibilities

(A28) Messages can be sent from CU to the LUs or from the LUs to CU

(A29) CU can send different messages to each LU

(A30) The number of iterations or, equivalently, the number of CU or LU messages during the planning of an individual period's activities, is limited to between two and five

III.2 Influence and control possibilities

(A13) See above

(A31) CU is able to choose the variables for which the LUs communicate values, cf. A14 and A26

(A32) CU terminates planning when further iterations are considered impossible or not worthwhile, by announcing the final plan decision

4.3 A FORMALIZED MODEL

In this section, I will use a mathematical formulation to show the relation between the terms of the model more clearly. In some respects, the A-statements in Section 4.2 provide a more basic form of our model, since they contain some elements not actually assumed in the model. For instance, it seems easier to show CU preferences mathematically as a preference function, although I have not actually assumed such a function but only an ability to order any two alternatives.

The aim of this section is to make the structure of the model more understandable, by indicating more clearly the relations between its elements. Sections 4.2 and 4.3 are complementary, the differences in emphasis depending mainly on the differences between the two languages used. For similar reasons, both formulations will be used in the analysis in Part Two.

In the presentation of the model in this section, the final formulation appears in formulas (4-8) to (4-12), and the discussion that precedes it is intended to tie it in with the various points that we have made in the earlier chapters. A list of symbols is given after formula (4-12). Vectors are indicated by underlining.

The planning choice centres on the activities of the individual LUs. If LU number i chooses a vector of acitivites $\underline{x}^i$, it has to make sure that this vector is possible, given its production possibilities with current allocations of the organization's total supply of scarce resources. This allocation is denoted $\underline{y}$; $\underline{x}^i$ then has to obey the production possiblity constraints (4-1), where we let $\underline{x}^i$ be a description in activity or product quantity terms:

$$\underline{g}^i(\underline{x}^i, \underline{y}) \leq 0 \tag{4-1}$$

We have seen that CU is interested in a description of activities in what we have called performance terms. As $\underline{x}^i$ is given in activity or product volume terms, a transformation of product quantities into performance is required, in which the latter is described by the vector-valued function $\underline{f}^i$:

$$\underline{f}^i(\underline{x}^i, \underline{y}) \tag{4-2}$$

Each $\underline{f}^i$ vector value is a description of a particular plan of activities for LU number i, using performance attributes. In planning, the only interesting vectors of this kind are the nondominated ones, i.e. those on the efficient frontier:

$$Z^i(\underline{y}) = \left\{ \underset{\underline{x}^i}{\text{Max}}\ \underline{f}^i(\underline{x}^i, \underline{y}) \right\} \tag{4-3}$$

where maximization is obviously a task for the LU, which controls its own choice of activities and knows its own possibilities. For the LU, the $\underline{y}$ values are given. For each $\underline{y}$ value, there will generally be several nondominated plans to choose from, i.e. the set in (4-3) will have more than one element for each $\underline{y}$ value. These constitute the efficient LU performance possibilities for that resource allocation. Information about this set $Z^i(\underline{y})$, containing descriptions in multidimensional performance terms of LU-efficient plans for different resource allocations, is the i:th LU's contribution to planning.

CU needs information about some of the possibilities in Z^i so that it can choose:

- A resource allocation $\underline{y}^*$ such that Z^i will contain as attractive plans as possible
- The preferred plan from the several possible plans in $Z^i(\underline{y}^*)$.

To be able to judge individual plans in Z^i, CU has to combine all the results from the plans adopted by all the LUs. For the reasons given in Chapter 2, this can be described as a two-stage sequence. First, CU is able to foresee how all the LU plans together will affect the several organizational objectives. Secondly as the evaluator of organizational good, CU can choose between alternative LU plan combinations.

The first of these steps involves a transformation of the descriptions of plans into performance terms which are contained in $Z^i(\underline{y})$. We can denote the operation (which we assume CU is able to perform) as H, and write it as:

$$H:\quad Z^1(\underline{y}) \times Z^2(\underline{y}) \times Z^3(\underline{y}) \times \ldots \times Z^m(\underline{y}) = \qquad (4\text{-}4)$$

$$= \mathop{\times}_{i} Z^i(\underline{y}) \longrightarrow V_H(\underline{y})$$

This means that each total plan can be seen as a Cartesian product of plans from all LUs, and that the performance possibilities Z^i of all LUs combined will result in organizational plans whose range, in terms of their effects on organizational objectives, is given by V_H. As an alternative, we can show this as:

$$\left[\underline{z}^1(\underline{y}),\ \underline{z}^2(\underline{y}),\ \underline{z}^3(\underline{y}),\ \ldots,\ \underline{z}^m(\underline{y})\right] \longrightarrow V_H(\underline{y}) \qquad (4\text{-}5)$$

In this formulation, lower-case letters indicate that <u>one</u> plan $\underline{z}^i$ from each possibility set Z^i is combined with <u>one</u> plan for each of the others, giving us one of the total plans in V_H, similarly denoted by a lower-case letter. It has to be remembered that a different resource allocation $\underline{y}$ would change the possibilities of the LU and, thus, of the organization.

The range of total plans V_H will obviously contain a large number of plans, as there are several possible plans in each Z^i and these can be combined in different ways. Some of all these total organizational plans will be dominated, i.e. not efficient from the organizational standpoint, although they involve LU-efficient plans. This means that planning should concentrate on the vector-maximal $\underline{v}_H$ values. The set of these will be called U:

$$U(\underline{y}) = \left\{ \underset{\underline{z}^i}{\text{Max}}\ \underline{v}_H(\underline{y}) \right\} \tag{4-6}$$

This maximization is performed by CU by making a suitable choice among the plans in the various Z^i. For the moment we will disregard the question of how this choice can be made.

$U(\underline{y})$ indicates the organization's performance possibilities, defined in objective space and excluding dominated, nonefficient alternatives. (It has to be remembered that the assumed impossibility of centralizing information makes it impossible to observe more than part of $U(\underline{y})$.) CU choice of one preferred plan for the total organization should be made from this set:

$$\text{Max } P \left[\underline{U}(\underline{y}) \right] \tag{4-7}$$

$$\underline{y} \in Y,\ \underline{u}(\underline{y}) \in U(\underline{y})$$

Here we write $\underline{u}(\underline{y})$ for the objective fulfilment values of a particular plan. The maximization is performed by CU in accordance with its preferences (as shown by the function P). It involves not only the choice of one resource allocation $\underline{y}$, but also the choice of one plan $\underline{u}(\underline{y})$ from the set $U(\underline{y})$ for the $\underline{y}$ value. The choice of $\underline{y}$ alone would not identify $\underline{u}(\underline{y})$. CU also has to identify the LU plans from which the total plan $\underline{u}(\underline{y})$ would result. This means that the final outcome of the planning should be a resource allocation, together with identification of local plans in attribute terms (the corresponding $\underline{z}^i$ values). CU has only discussed plans in these terms, leaving it to the LUs to "translate" these descriptions back into activity information.

To summarize the problem in compact form, we have:[1]

$$\underset{\underline{y} \in Y,\ \underline{u}(\underline{y})}{\text{Max}}\ P\left[\underline{u}(\underline{y})\right] \qquad (4\text{-}8)$$

("achieving effectiveness") where

$$\underline{u}(\underline{y}) \in U(\underline{y}) = \left\{\underset{\underline{z}^i}{\text{Max}}\ \underline{v}_H(\underline{y})\right\} \qquad (4\text{-}9)$$

("achieving organizational efficiency"),

$$\left[\underline{z}^1(\underline{y}),\ \underline{z}^2(\underline{y}),\ \ldots,\ \underline{z}^m(\underline{y})\right] \curvearrowright \underline{v}_H(\underline{y}) \qquad (4\text{-}10)$$

("finding combined impact of LU plans"), and

$$\underline{z}^i(\underline{y}) \in Z^i(\underline{y}) = \left\{\underset{\underline{x}^i}{\text{Max}}\ \underline{f}^i(\underline{x}^i,\ \underline{y})\right\},\ i = 1,\ \ldots, m \qquad (4\text{-}11)$$

("achieving LU-efficiency"),

$$\text{s.t}\quad \underline{g}^i(\underline{x}^i,\ \underline{y}) \leq 0, \qquad i = 1,\ \ldots, m \qquad (4\text{-}12)$$

("production possibilities")

The symbols used here are:

P the preference function of CU (and, therefore, of the organization) defined on the vector $\underline{u}$ of objective fulfilment values

$\underline{y}$ the vector of resource allocation values (or similar variables) controlled by CU

Y the set of available choices for $\underline{y}$

$\underline{u}(\underline{y})$ the vector of objective fulfilment values for a particular combination of plans for all LU, which is efficient from the organization's standpoint for that $\underline{y}$ value

$U(\underline{y})$ the set of such plans, described through their $\underline{u}(\underline{y})$ vectors, i.e. the set of efficient performance possibilities for a particular $\underline{y}$

---

[1] Terms used in the parentheses (efficiency, effectiveness) will be discussed in Chapter 5.

$\underline{v}_H(\underline{y})$ the vector of objective fulfilment values, for a particular combination of plans for all LUs, which are all efficient from the respective standpoints of the different LUs for that $\underline{y}$ value

$V_H(\underline{y})$ the set of such plans, described through their $\underline{v}_H(\underline{y})$ vectors. $U(\underline{y})$ is the efficient (nondominated) subset of $V_H(\underline{y})$

$\underline{z}^i(\underline{y})$ a particular plan for LU number i, described by means of the attributes agreed between CU and the LUs, and efficient from the LU standpoint for that $\underline{y}$ value

$Z^i(\underline{y})$ the set of such plans for LU number i, described through their $\underline{z}^i(\underline{y})$ vectors

H a transformation which combines one $\underline{z}^i$ vector for each i value, i...m, and describes the total effect of all these plans in objective fulfilment terms

$\underline{x}^i$ the vector of decision variables (for instance product mix) of LU number i

$\underline{f}^i$ the vector-valued function of plan attribute values, as agreed between CU and LUs, for LU number i if it chooses $\underline{x}^i$ when the CU decision vector is $\underline{y}$

$\underline{g}^i$ the vector of constraints for LU number i, external as well as internal (i.e. depending or not depending on $\underline{y}$)

m the number of LUs

n the number of objectives

Vectors are shown as underlined, lower-case letters. For vectors relating to the individual LUs, superscripts show the LU number. Subscripts will be used later to indicate elements in vectors.

In this formulation the following steps can be distinguished:

(1) (Formulas 4-11 and 4-12). For each LU, the production process is constrained by $\underline{y}$ and by local factors. There are several efficient combinations of values for the attributes that are used in the dialogue, as decided by CU. The assumptions tell us that the LUs contribute to the planning their knowledge of the possibilities and their actual plan proposals.

(2) (Formulas 4-9 and 4-10). An evaluation is made in multidimensional terms (fulfilment of different objectives) of the combined effect of all m LUs. For each $\underline{y}$ value, this results in several alternative total plans. This combination is performed in our model by CU, whose knowledge thus has to include transformation H of the formulas.

(3) (Formula 4-8). Finally, the alternatives are subject to a unidimensional evaluation, based on their fulfilment of the objectives. It is assumed that the preferences needed for this are possessed by CU.

The reasons for separating the last two steps were discussed in Section 3.3.

4.4 CRITERIA FOR BUDGETARY PLANNING SYSTEMS ("B-STATEMENTS")

The design of new budgetary methods requires a number of criteria for identifying "good" systems of budgetary planning. This problem has been studied by Samuelson, whose criteria include the effect of the process design on creativity, prognostic ability, and the realism of proposals (Samuelson, 1973, p. 77). Some of these seem intimately related to the design of budget documents and the choice of information elements in a given situation - aspects that are not directly relevant to the present study.

The requirements given below should not be regarded as a complete list of all possible desiderata. They are simply those that were used in designing the methods proposed in Part Two, and they could also be evaluated in an actual application using these criteria.

This list was inspired by the discussions of multi-objective decision-making in Näslund (1974) and Hemming (1975), where some criteria are given, and by the planning study presented in Ljung and Selmer (1975). Some of the statements in the list are relevant only to potential applications, but it seemed better to give the entire list here than to split it between Parts One and Three.

When these criteria are used for judging alternative ways of handling the planning situation, they become the objectives in the problem analysis in Part Two. Since we assume loyal organization members and centralized authority (Sections 3.2 and 3.4), the quality of the solution can be judged from the CU viewpoint only. Otherwise, we would also have to make these judgments multidimensional, corresponding to different interests in the organization.

Even in its present form the list is already multidimensional, since there is no "supercriterion". The final evaluation of a method using the criteria will have to consider the situation and the desires of the users.

The criteria are given here in the form of statements, to indicate their contents more clearly. They are divided into four broad groups.

I. Ease of use

(B1) Only a small number of plans should have to be investigated

(B2) Demands regarding CU knowledge of preferences should be low

(B3) Demands regarding LU knowledge of possibilities should be low

(B4) Demands regarding CU and LU information processing ability should be low

(B5) The iterative planning process should be compatible with traditional iterative planning, i.e., in most organizations, budgetary planning

II. Incentives

(B6) Participants should find it easy to understand what to do at each step during planning

(B7) Participants should find it easy to understand the general meaning and importance of what they do

(B8) Participants should feel confident that the plan identified through the planning is better than alternative plans which could be found ad hoc

III. Solution quality

(B9) The plan identified through the planning should be close to the optimal plan which could be found through a hypothetical centralized solution

(B10) The planning procedure should converge rapidly

(B11) A truncated procedure should give a feasible and useable plan

(B12) Errors in estimates made by CU or LUs should not drastically affect the procedure

IV. Other uses of planning information

(B13) The planning procedure should form a good basis for control and analysis during and after implementation of the plan

Comments. The four headings cover most of the aspects that are to be found in other lists, such as those referred to above. B1 accounts for the amount of work, B2 to B4 for the demands it makes on the planners. B5 adds the consideration of "newness" and consequent changes in other related activities, by demanding compatibility between the new methods and earlier ones.

To some extent, B6 could also be said to deal with ease of use, but it has been included in the "incentives" group because a clear understanding of what is expected of them will increase the planners, motivation. (Most of these criteria could of course also affect the quality of the solutions.) B7 demands that participants not only understand what to do, but also why they do it - which is obviously conducive to better planning. If B8 is not fulfilled, it might well be impossible to introduce the planning methods, and if the planners' lack of confidence is justified, then of course it ought to be impossible.

Criterion B9 will have to be judged indirectly, since according to our definition of the planning problem the centralized solution is not available. Even if it were, the difference between the identified plan and this perfect solution could not be evaluated unidimensionally. B10 complements B1 and is related to B11. Such considerations were discussed by Ljung and Selmer (1975, Chapter 8). Statement B12 seems necessary as the type of knowledge assumed to exist in CU and the LUs could not be expected to result in exact estimates. This statement would also guard against voluntary misinformation, had we not already decided to disregard that possibility.

Although we concentrate otherwise on budgetary planning (cf. Section 1.4), B13 has been included here as a reminder that later uses of the budget could affect the way planning is organized.

4.5 SUMMARY

The problem introduced in the earlier chapters has now been given its final formulation, in three separate but closely related ways:

(1) A set (A) of statements, defining the planning situation basic to the study

(2) A mathematical formulation, indicating the relations between the terms of the A statements

(3) A set (B) of statements, indicating the criteria by which planning methods should be judged, and in this way also serving as objectives in designing such methods.

All three will be used in the analysis and practical discussions of Parts Two and Three.

PART TWO
THE THEORIES

5. DISCUSSION OF THE MODEL

5.1 CONTENTS OF PART TWO

In the four chapters of Part One, the problem of decentralized planning in multiobjective organizations was given a formulation which was summarized in three closely related ways:

(1) The A-statements of Section 4.2
(2) Formulas 4-8 to 4-12 in Section 4.3
(3) The B-statements of Section 4.4.

In Part Two, four planning methods will be developed to handle this situation. I shall rely in this part on theories borrowed from the fields of economic planning and multiobjective decision-making, as these seem to be the most likely to provide analogies with the present situation.

This first introductory chapter discusses certain aspects of the basic model which concern the role of the resource vector, as introduced in the basic model (Section 5.2) and the strategy for approaching the planning problem.

The three steps identified at the end of Section 4.3 will be used here as a point of departure. They can be restated thus:

(1) The LUs find nondominated (LU-efficient) plans

(2) These are adjusted so that their combined effect is a total organizational plan which is nondominated (organization-efficient). This may involve CU, in order to identify the combined effect of all LU plans.

(3) LU plans, and the resource allocation they are based on, are adjusted so that their combined effect is optimal for the organization. This requires that CU selects a resource allocation, <u>and</u> a particular set of LU plans among all those that give an organizationally efficient total plan.

These three steps (or four, counting the two decisions in (3) separately), are used below to structure planning in the two strategies briefly introduced in Section 1.1: preferences-first and interaction. This involves an analysis of the relation between the steps, and the steps and LU activities, which is given in Sections 5.3 - 5.5. The two strategies are formulated in Section 5.6 and compared in Chapter 6.

5.2 THE ROLE OF THE RESOURCE VECTOR

The control vector $\underline{y}$ of formula 4-8 has a very general purpose in our model. In statement A13, it is expected to include different interpretations of the "resource" concept. To simplify the argumentation, it will henceforth be assumed (except in method I, Section 9.2) to contain <u>only one type of resource</u>, which can be seen as a fixed amount <u>shared between all LUs</u>. I believe that the procedures which will be discussed below could be generalized to apply to several resources and perhaps even to resources whose total amount depends on LU activities. But these complications will not be discussed in the present study. To repeat:

> There is only one type of common resource, which is allocated between the LUs. To allocate some of this resource to one LU means that it can be used only by that LU. Thus, the $\underline{y}$ vector consists of the allocations y_i, i=1. ..., m, to the different LUs.

There are several different ways of treating such a constraint during planning, and these will be discussed in greater detail in Section 6.3.2. The main alternatives are to use <u>prices</u> (scarcity values) to compel an LU to plan for a reasonable resource use, or to make <u>trial alloca-</u>

tions. The first alternative turns resource requirements into another attribute of LU plans, which means that "minimum resource use" will appear as an additional objective for the internal planning of the LU concerned. That it is a constraint and not an objective for the organization can be seen from the fact that CU has preferences about it, so long as the total constraint is met.

Trial allocations will of course be able to fulfil the given sum total constraint. For these, the LUs plan as well as they can, indicating in the process their suggestions for changes in resource allocation. Compared with resource pricing, trial allocations highlight the difference between the resource variable and the plan attributes. It is also much closer to budgetary practices, where "budget ceilings" are often used. As one of our aims is to adapt to budget practices, this alternative will be assumed in three of the methods:

> Resources are allocated by CU as preconditions for planning. For each LU, the allocation becomes a constraint on plan proposals.

This also corresponds closely to formulas 4-8 to 4-12, where plans are chosen by the LUs from among those existing for a particular $\underline{y}$ value. It corresponds to the "partitioning" or "projection" approach to mathematical optimization in Geoffrion (1970).

To be consistent with this, the third step identified in Sections 4.3 and 5.1 will henceforth be divided into two: finding the best resource allocation, and finding the preferred set of plans, given the allocation.

5.3 LU EFFICIENCY AND ORGANIZATIONAL EFFICIENCY

In its formalized version (formulas 4-8 to 4-12), our planning model involves two vector maximizations. These were explained as excluding all dominated, nonefficient alternatives, following a common definition of efficiency:[1]

> A point $\underline{f}^*$ is <u>efficient</u> if and only if there is no other point $\underline{f}$ such that $f_j \geq f_j^*$ for all j, with $f_j > f_j^*$ for at least one j.

Following Charnes and Cooper (1961, p. 321), a plan can be called functional-efficient or just efficient if it results in objective value combinations that are efficient. Fandel (1972, p. 15) calls the enumeration of all efficient points a "complete" solution to a vector maximum problem. This would give us what we could call the performance possibility (p-p) surface or, in our two-dimensional graphs, the p-p curve.

Our two vector-maximum problems (formulas 4-9 and 4-11) represent the finding of LU efficiency and of organizational efficiency respectively. With the LU problem formulated in attribute terms, a particular LU can judge which plans are efficient from its own standpoint. It can easily be shown that these are not necessarily part of total plans which are efficient. In Figure 5.1 the "diagram assumption" of additive attributes introduced in Section 3.6 is used. The shapes of the p-p curves for LU number 1 and LU number 2 have been chosen so that we can see more easily how they add up to the organizational performance possibility curve in the third graph. The latter results from combining LU-efficient plans, but all combinations of such LU plans do not give organizationally efficient plants. Without additional guidance, the LUs cannot tell the subset of organizationally efficient LU plans from those that are LU-efficient.

With additive attributes as in Figure 5:1, an obvious way of giving such guidance is to use objective weights or trade-offs. The efficiency definition above can be shown to be equivalent to (cf. Koopmans, 1951, p. 61; Kuhn & Tucker, 1951, p. 482, and Philip, 1971):

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[1] This concept of efficiency is closely related to Pareto-optimality and seems to have been introduced by Koopmans (1951). Vector maxima were first discussed by Kuhn and Tucker (1951).

A point $\underline{f}^*$ is efficient if there exists a vector $\underline{\lambda}$ with its number of elements p equal to that of $\underline{f}$, such that $\underline{f}^*$ is the solution of $\mathrm{Max}\sum_{j=1}^{p} \lambda_j f_j$, subject to $\underline{\lambda} \in R^p$, $\lambda_j \neq 0$, $j = 1, \ldots, p$.

Each efficient point corresponds to a particular vector $\underline{\lambda}$ of weights or prices. If we think of our interactive planning in these terms, CU could call for LU plans that result in different plans on the possibility line in Figure 5:1 (c) by giving the right $\underline{\lambda}$ vector. Such weight or price vectors could be introduced even where CU did not yet know its preferences exactly, just to guide LU planning in such a way that organizationally efficient plans emerge.

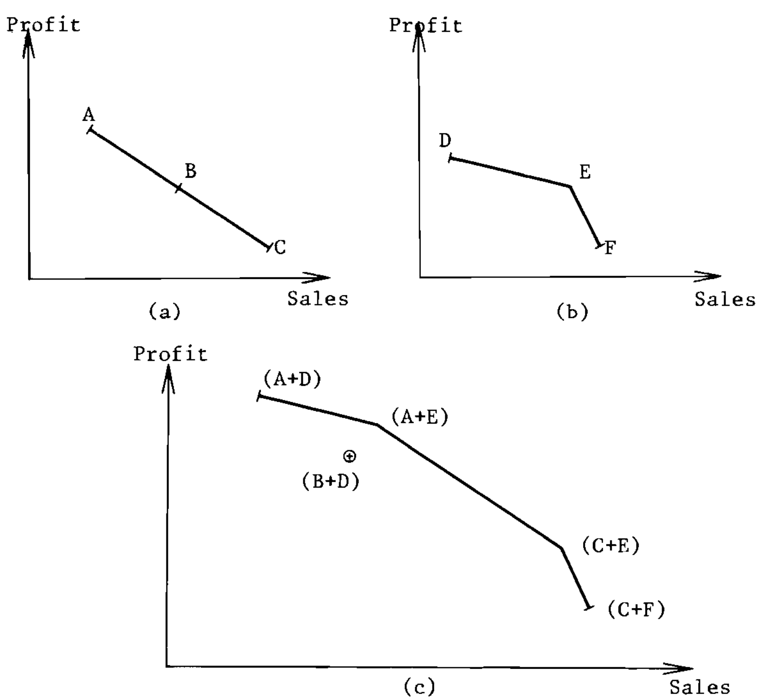

Figure 5:1. All LU-efficient plans cannot be combined into an organization-efficient one

If CU's transformation of attribute information into objectives fulfilment is more complex, it becomes difficult to use weights. In graphical terms, the slope of all LU p-p curves need not be the same for plans which combine into an organizationally efficient plan. However, equality will be a logical necessity whenever a given change in the attributes of an LU has the same effect on the objective regardless of which LU it concerns. This extends the applicability of weight vectors to include the case of an objective which depends on the square root of the attribute sum, for instance.

Wherever an organizationally efficient plan requires different trade-offs in different LU, it will be impossible to weight the objectives unless CU is familiar enough with the transformation from attributes to objective-value, to be able to change the weights accordingly. Suppose, for example, that an objective such as delivery time were evaluated as the weighted average of delivery time in all LUs. As the weights used in averaging would certainly be known, the value of one day's improvemenet in the different LUs could be registered and adjusted to allow for the effect of the weights used in averaging.

Thus, we clearly have to bear in mind the two concepts of LU efficiency and organizational efficiency, of which the former is a necessary but not a sufficient condition for the latter. To identify such LU-efficient plans as will together provide a plan that is organizationally efficient it will sometimes be possible to use equality between objectives trade-offs or similarly, equality between the weights attached to the objectives. This becomes possible as soon as a unit change in attribute value has the same effect on the corresponding objective regardless of where (in which LU) the change takes place.

5.4 CHANGES BETWEEN ORGANIZATIONALLY EFFICIENT PLANS: EFFECTIVENESS

An organization's performance-possibility surface will usually consist of more than one point. In other words, there will be more than one plan which is organizationally efficient. Each such plan corresponds to a particular trade-off between objectives, i.e. a particular set of preferences. We will call the organizationally efficient plan which agrees with CU preferences the effective plan. Note that effectiveness requires both that the optimal resource allocation is found and that the optimal plan is chosen among the organizationally efficient ones made possible by this resource allocation (cf. formula 4-8).[1] In this section we consider the latter problem.

Moving from one plan to another on the organization's performance-possibility surface involves sacrificing some fulfilment of one objective for as much compensation as possible in the fulfilment of others. In the simple case of Figure 5:1, there is only one other objective to improve, but in general it is not obvious which objective(s) should be improved if we do not have access to any preferences.

In Figure 5:1, we also note that a decrease in profit from point (A+D) could be effectuated by letting LU 1 move towards B, or by letting LU 2 move towards E, or by a combination of both these moves. The rule of sacrificing profit for as much compensation as possible means that we must choose the second of these options. This is why (B+D) is not organizationally efficient: LU 2 can provide more improvement in sales for a unit decrease in profit.

In a two-dimensional additive case like that of our figure, the organization's performance-possibility curve can be found by first maximizing one objective and then trading on the margin by changing the mix of objectives in that LU which provides the best marginal rate of transformation of the maximized objective for the other objective. The same holds for two-dimensional movements along a surface of higher dimensionality, provided it is still an additive case. As the slope will always equal the least slope of any LU's curve, concave LU functions together give a concave organizational curve. From this follows that if the LUs have convex feasible sets, the organization's feasible set will also be convex.

If we abandon the additive case, we no longer have any

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[1] Similar distinctions between efficiency and effectiveness are often made in American public administration literature. Efficiency is then given the meaning of maximal output, and effectiveness that of maximal objective fulfilment, or output worth, in each case related to available resources. In a multiobjective context, a natural analogue seems to be the usage proposed here: any nondominated plan (in performance terms) is called efficient, and the one that agrees most closely with the preferences is called effective.

such guarantees. It is still enough to consider only the performance-possibility curve of each LU, but certain transformations can combine these into an organizational curve with little resemblance to the original curves.

5.5 INTERDEPENDENCE BETWEEN CU AND LU DECISIONS

In our model, we assumed that an LU's feasible set (and the location of its performance-possibility surface) depends on the resource allocation. Let us take a simple continuation of the graphical example to show the effect of this.

Assume that LU 1 and LU 2 both depend for their performance on the sales axis on a common resource, perhaps a licence that they must have before production can be started. The total number of licences held by the organization is a constraint on organizational action, as is shown by the vertical line sales = s in Figure 5:2 (c). In the graphs (a) and (b), LU 1 has received y_1s of the total amount s, and LU 2 $y_2s = (1-y_1)s$. Depending on the choice of y_1 and y_2, different parts of the LU performance-possibility (p-p) curves then become feasible.

If organizational preferences are as indicated by the iso-preference curves PP, the optimal plan among those that are potentially feasible, i.e. those meeting the licence constraint, is (B+E). Only one allocation of resources makes B and E attainable at the same time. Thus, in this case, CU must arrive at exactly this allocation of resources if the optimal plan is to be possible.

In the figure we could use the symbols of Section 4.3 and denote the LU p-p-curves to the left of the (sales = y_is) lines $\underline{Z}^i(y)$. The $\underline{U}(y)$ set, on the other hand, will consist of points, most of which are on the potential organizational p-p-curve and all of them to the left of sales = s. For all choices of $\underline{y}$ except the optimal one some of the points on the potential organizational p-p-curve, but still to the left of (sales = s), may be organizationally-efficient for these $\underline{y}$ values.

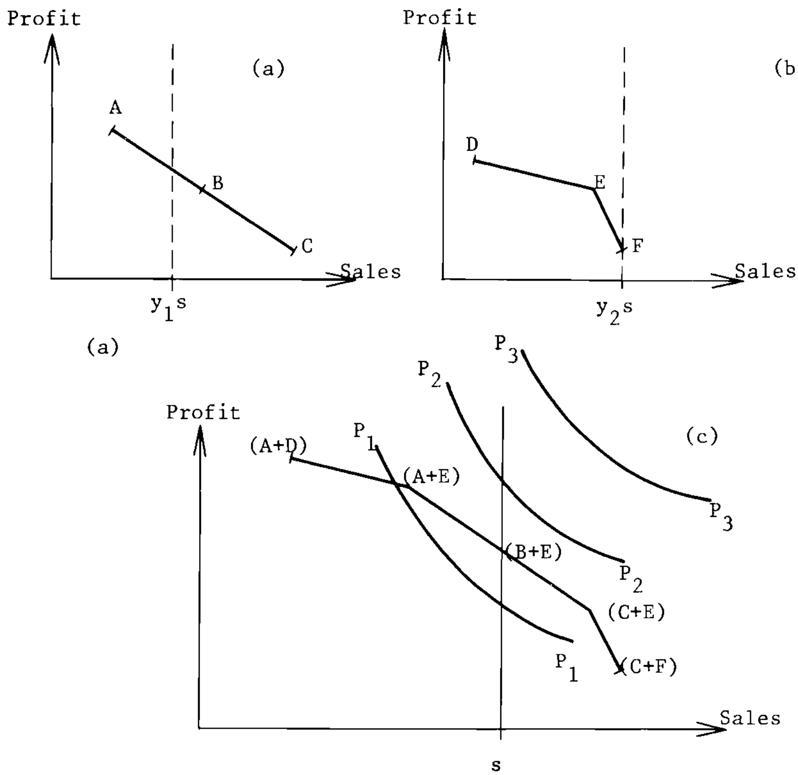

Figure 5:2. A two-LU, two-objective organization with a common resource which has to be allocated in one exact way if it is to be possible to choose the optimal plan

In Figure 5:2, the resource allocation thus affects the part of the potential performance-possibility curve of the organization that will become feasible. A more general case is that the location of the curve changes for different resource allocations, as the resources affect several of the objectives.

Let the shaded area in Figure 5:3 represent all feasible combinations of LU-efficient plans for a particular $\underline{y}$-value, using the H transformation of formula 4-10. We have seen (Section 5.3) that it is difficult to get the LUs to propose plans that could be directly combined into organizationally efficient plans. Thus a first set of LU plans will probably together give an interior point in the shaded area of the figure, for example G.

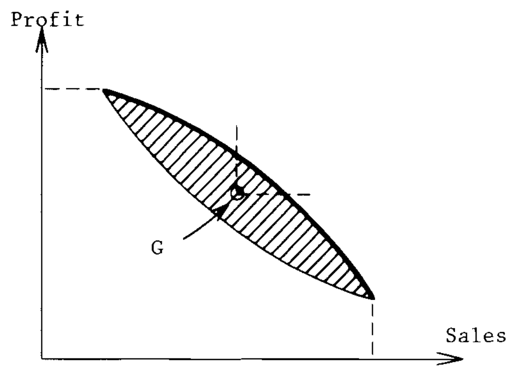

Figure 5:3. From the organizational plan shown as G, desirable changes could involve finding dominant plans for unchanged resources, i.e. within the shaded area, or finding a resource allocation which makes preferred plans possible.

If this is the case, then there will be two alternative ways of improving organizational performance. There are feasible plan combinations for the same $\underline{y}$ that dominate G, shown as points to the right and above G. But there could also be improvements from a change in resource allocation $\underline{y}$, as the entire shaded area could perhaps be moved out from origo.

Different allocations can only be compared in terms of the organizational performance which they make possible. Ideally, we should therefore identify the preferred point among the feasible ones for each and every resource allocation; or at least we should not change to another allocation before exploring completely the possibilities of a previous one.

Given the limited number of iterations we have assumed to be possible (A30), this would probably not be a wise policy. The difficulties involved in finding LU plans which amount to an organizationally efficient plan may well be greater than those involved in changing resource allocations.

The important point to note is the existence of two basic alternatives for improving an organizational plan, and these are of course directly related to the two ways in which our CU influences planning: through its resource allocations and through its choice of LU plans among the possible plans for each resource allotment (A13).

5.6 TWO ALTERNATIVE PLANNING STRATEGIES

In Sections 5.3 to 5.5, I have dealt briefly with the relations that exist in the model between LU efficiency and organizational efficiency and between LU plan choice and CU resource-allocation choice. LU efficiency was found to be a precondition of organizational efficiency, and ideally the organization's preferred plan should be found for each resource allocation before the allocation is changed. Note that this follows the assumption introduced in Section 5.2 that CU allocations of resources are a precondition of planning.

The essence of the decentralized situation is that both the LUs and CU have to contribute to the solution, i.e. to the choice of plan. The concept of implicit knowledge was introduced to describe the inability of the units to communicate a "global" statement of their preferences or possibilities.

Given this, there are <u>two</u> ways of approaching the problem, as we have already seen in Section 1.1. One is to use the fact that any final choice of an alternative must involve some superobjective, as soon as there is any conflict between the multiple objectives. In our case this superobjective is the preference function discussed in Section 3.3, which was suggested as a way of "explaining" CU's ability to choose between alternatives. If this superobjective could be <u>identified before studying available plan alternatives</u>, using the decision-maker's imperfect ability to communicate these preferences, plans could be evaluated directly for their effect on the superobjective.

This *preferences-first strategy* would mean that the multiobjective situation is reduced to a traditional, single-objective one. In the planning process CU will then be able to present unidimensional objectives to the LU right from the start. The problems of LU efficiency and organizational efficiency disappear (cf. Sections 5.3 - 5.4 above), and it becomes possible to use classical planning theory which concentrates on the resource allocation problem. The complications arising from multiple objectives would be limited to the preceding phase, in which CU would have to make its implicit preferences explicit.

A flow-chart for this planning strategy is illustrated in Figure 5:4. It should be noted that the exact design of the steps can be made in many ways. Different methods for (centralized) multiobjective decision-making could be used in Step 1. Different (single-objective) planning methods could be used in Steps 2 - 5, where only our decision to use resource allocations to partition the planning (see Section 5.2) constitutes a restriction on the choice of method. The preferences-first approach will be considered in greater detail in Chapter 6.

The *alternative* is to keep the different objectives separate during planning, and let their relative importance be revealed only as part of the actual process. No super-objective is stated before planning starts as in the preferences-first approach, and it is not necessarily explicit even at the end of planning, except to the extent it is reflected in the choices made during planning. This is the *interactive exploration of possibilities and preferences*, for which a flow-chart is illustrated in Figure 5:5.

In Figures 5:4 - 5:5, I have indicated two logical sequences of steps. These are based on the discussion in this chapter, especially in the case of the interactive approach in Figure 5:5, where we need our understanding of the relation between the two sorts of efficiency and effectiveness.

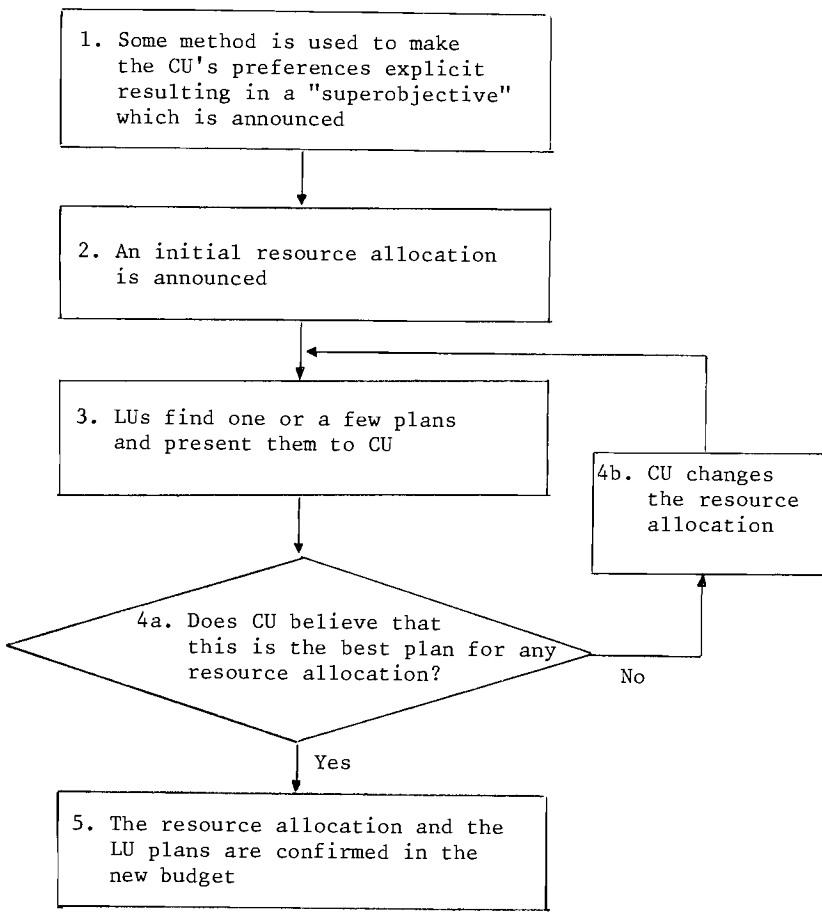

Figure 5:4. A preferences-first strategy for decentralized (multi-objective) budgeting

However, these sequences could not be used in practice unless several methodological questions about the way individual steps should be performed had first been answered. Let us consider some of the steps shown in Figure 5:5. The others do not invite any general comments.

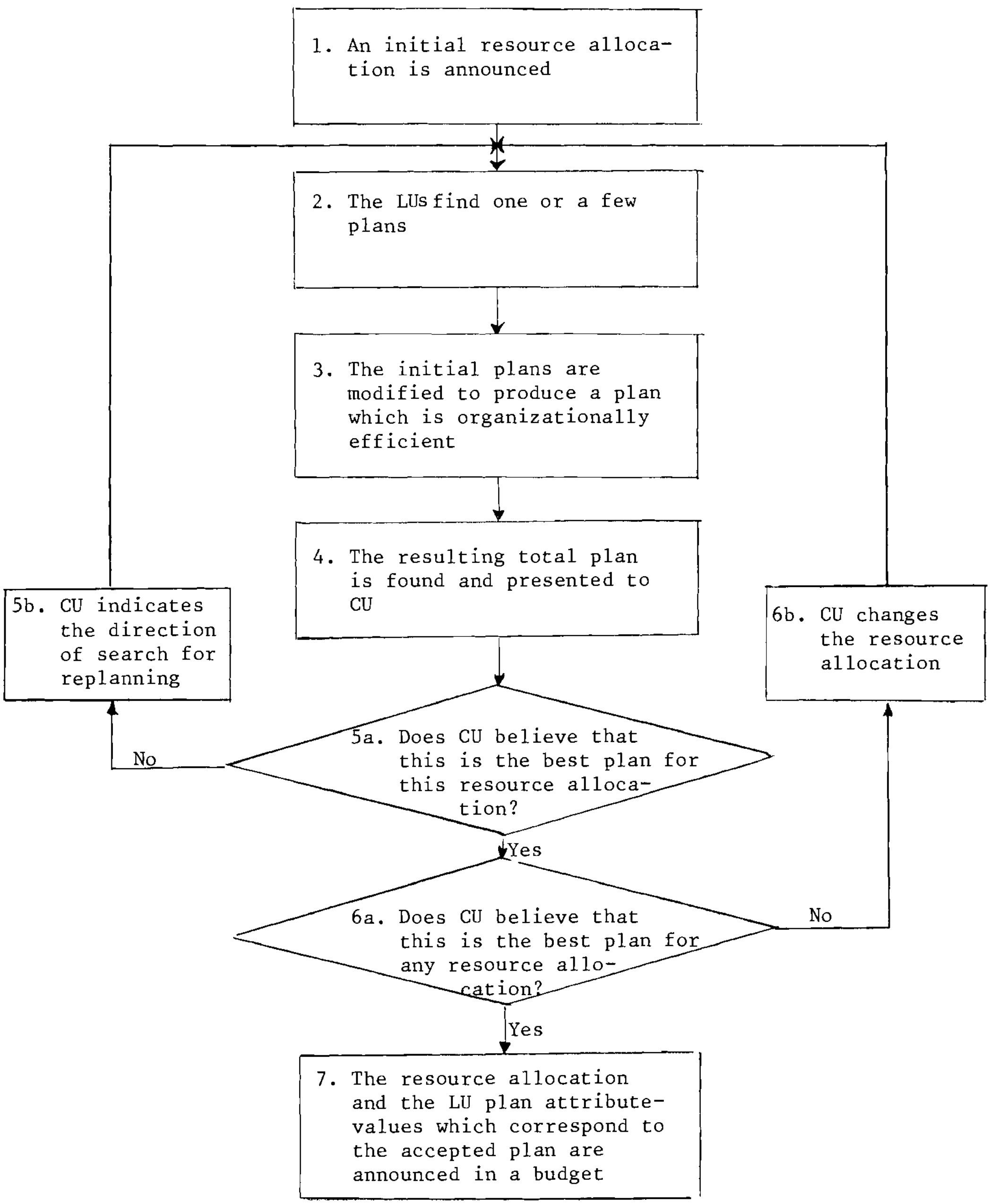

Figure 5:5. An iterative strategy for decentralized multiobjective budgeting

Step 2. With the assumptions introduced in Section 5.2.1, only LU-efficient plans should be communicated. It was assumed (A25) that the LUs can find one such plan for each resource allocation. In finding an LU-efficient plan, an LU could either use an arbitrary weight vector for its attributes and maximize for the weighted sum, or it could use some other approach. I will not discuss alternative methods here, as that type of choice is in no way specific for this study. In the formal terms of Section 4.3, we try instead to find one value for each $\underline{z}^i(\bar{\underline{y}})$, where $\bar{\underline{y}}$ is the current allocation.

Step 3. Where changes of attribute values in all the LUs have the same impact on the corresponding objective (cf. Section 5.3), equalization of all LU marginal rates of transformation (MRT) between attributes becomes necessary. For each pair of organizational objectives, the MRT between the corresponding attributes should be the same in all LUs. For more complex transformations, there is no obvious way of achieving a similar equalization. In formal terms, we try to find one $\underline{u}(\bar{\underline{y}})$ value.

Step 5. CU here uses its incomplete knowledge of its own preferences in some as yet undetermined way, to answer the question which in formal language is: Is this $\underset{\underline{z}^i(\bar{\underline{y}})}{\text{Max}}\ P\left[\underline{u}(\bar{\underline{y}})\right]$? If the answer is No, CU also has to give some indication of what changes it wants. The simplifying assumption (Section 3.6) of correspondence between objectives and attributes helps here, but CU still has to know which objective changes it wants and which of the LUs should make the corresponding changes in attributes.

Step 6 (and Step 4 of the preferences-first strategy). Almost the same comments apply here as for Step 5, where the formal question is: Is this $\underset{\underline{y}}{\text{Max}}\ P\left[\underline{u}(\underline{y})\right]$? We do not yet have any way of answering this.
Only one $\underline{y}$ value will have been used in the preceding steps, so a strict comparison between P-max for two $\underline{y}$ values will not be immediately possible. Of course we could try any

other y value and see if it brings any improvement, but this would obviously be a very wasteful way of using the few iterations.

Step 7. If the LUs are to know what to do, they will have to know the expected attribute values (performance) and their own resource allotments. If these are the same as in the latest iteration, Step 7 is not necessary.

Both the interactive and the preferences-first strategy will be discussed further in Chapter 6, where a choice between them will also be made in preparation for our subsequent analysis.

5.7 THE BASIC PROBLEMS

The analysis in this chapter has served to improve our understanding of the steps presented in Section 4.3 and repeated in Section 5.1. These three steps were increased to four by the decision in Section 5.2 to treat resource allocation separately. They can be named:

(1) LU efficiency
(2) Organizational efficiency
(3) Effective use of resources
(4) Optimal resource allocation.

The first of these, LU efficiency, does not seem to cause any problems special to the multiobjective planning situation. Dominated plans are never desirable, and all that is required here is that the LU find a non-dominated plan. This is an ability we have already assumed in statement A25.

Let us instead take a closer look at the other three:

(1) Organizational efficiency: to get the LU to find plans such that, given a certain resource allocation, they can be combined into a total organizational plan which is organizationally efficient

(2) Effective use of resources: to get the LUs to find plans such that, given a certain resource allocation, they can be combined into a total organizational plan which

is preferred to any other that is possible for this allocation.

(3) Optimal resource allocation: to find the resource allocation which makes possible a total plan which is preferred to any other that is possible for other resource allocations.

Note that the first of these three is a necessary but not a sufficient condition for the second, and that the second and the third together guarantee an optimum.

The problems are illustrated in Figure 5:6. In (a) we can see two LU performance-possibility curves for a given resource allocation, and the resulting organizational curve. The LU know some LU-efficient plans, such as $\underline{z}^1$ and $\underline{z}^2$, but initially no point on the organizational performance-possibility curve is known. $\underline{z}^1$ and $\underline{z}^2$ combine into $\underline{v}$, assuming additivity as in previous figures.

The first problem concerns what is shown in Figure 5:6 (b): finding plans $\underline{z}^{1'}$ and $\underline{z}^{2'}$ such that together they give $\underline{v}'$, which is organizationally efficient and which can also be called $\underline{u}'$ in accordance with the symbols given in Section 4.3.

In the second problem, described in Figure 5:6 (c), preferences PP etc. enter into the picture. We want to find $\underline{z}^{1''}$ and $\underline{z}^{2''}$ that combine into the preferred point on the organization's performance-possibility curve.

In the preferences-first strategy, both these problems are removed and we are faced with the potentially difficult initial preference study. In the interactive approach, they correspond to Steps 3 and 5 in Figure 5:5, respectively.

Finally, we have the third problem. If there is a change in the resource allocation which alters the organizational performance-possibility curve as shown in Figure 5:6 (d), this should be identified, as well as the consequent optimal LU plans which are not shown in this figure. In the preferences-first approach of Figure 5:4 and the interactive approach of Figure 5:5, the third problem corresponds to Steps 4 and 6 respectively.

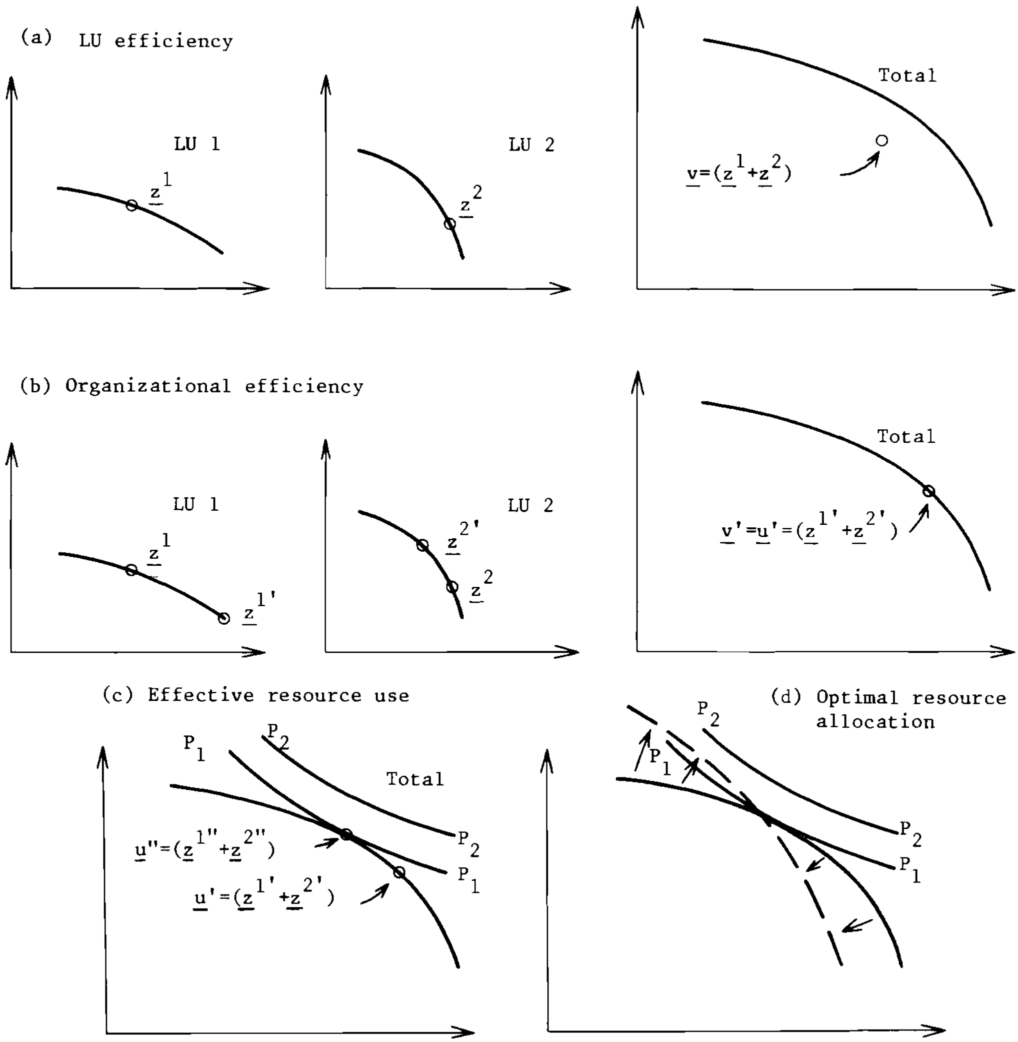

Figure 5.6. Three basic problems illustrated for a two-LU, two-objective case. According to the basic model, (a) can be performed by the LUs. (b), (c), and (d) require some sort of procedure. See text for symbols etc.

5.8 SUMMARY

In this chapter we have introduced the simplifying assumptions of a single central resource constraint and the exploration of one resource allocation at a time. Analysis of the Part One model led to two basic strategies as shown in Figures 5:4 and 5:5. These represent alternative philosophies, each leading to a sequence of steps, for most of which we still lack any exact rules. Considering the initial assumptions, the main problems here can be labelled:

- Organizationally efficient use of resources
- Effective use of resources
- Optimal resource allocation.

Only the interactive strategy involves dealing with all of these during the planning dialogue. A preferences-first strategy removes the first two by stating a super-objective from the beginning.

The two basic strategies will be discussed further in Chapter 6.

6. PREFERENCES—FIRST OR INTERACTION?

6.1 INTRODUCTION

This chapter deals with the choice of approach, preferences-first or interaction, presented in Sections 1.1 and 5.6. The preferences-first method, in which preferences are made explicit as a preparation for a planning process which can then be geared traditionally to single objectives, is discussed in Section 6.2. The alternative to this, namely an interactive exploration of possibilities and preferences together, is discussed in Section 6.3. In Section 6.4 I explain the choice I have made in the present study.

In the subsequent analysis, we will rely on analogies with several mathematical theories. In preparation for this, we will look at some general problems in deriving normative theories from mathematics in Section 6.5.

6.2 THE PREFERENCES-FIRST STRATEGY

In the preferences-first strategy, the multiobjective situation is reduced to a traditional, single-objective case, so that CU can give unidimensional objectives to the LUs at the start of planning. Classical planning theories can be applied, and any complications arising from the existence of multiple objectives can be limited to a preceding phase, in which CU has to make its implicit preferences explicit. (See also Section 2.1 on budgetary practices.)

6.2.1 Making preferences explicit

How can CU state its preferences as an explicit objective, perhaps together with one or more constraints? Some methods are mentioned in Appendix A, Section A.5. Most of them aim at the construction of a linear function of the original objectives, i.e. a weighted sum of the fulfilment values of these objectives is used as the new value.[1]

The methods mostly rely on some form of questioning of the decision-maker (here CU, or its representative). The decision-maker is often confronted with hypothetical choices which get him to disclose his intuitive weights. For examples of this, see Tell (1976, Chapter 2). This procedure could be said to simulate the simultaneous exploration of preferences and possibilities that takes place in the interactive strategy.

The choices have to be found within the expected range of relevant variables. In the situation we are considering here, weights that would be useful to the LUs would have to be in terms of attributes. Thus, if such methods are to be applied here, both steps in the CU evaluation of LU proposals would have to be taken into account, i.e. the combining of attribute information (the H transformation of formula 4-10) and the application of preferences (formula 4-8). The CU representative would be shown attribute value vectors; he would then make choices which the analyst could use to formulate a synthetic superobjective.

6.2.2 A single-objective planning method

To illustrate the many methods that have been suggested for planning in organizations and national economies, I have chosen the interpretation of the Dantzig-Wolfe algorithm discussed in Ljung and Selmer (1975). The planning situation is characterized by block angularity: "blocks" of

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[1]This applies by and large to methods based on goal programming as well, although these enable the decision-maker to use a more complex objective, including even a ranking of objectives. See Section 7.4 and Appendix B.

constraints and planning variables can be identified, while interdependence is limited to certain common connecting constraints. (See Figure 6:1.)

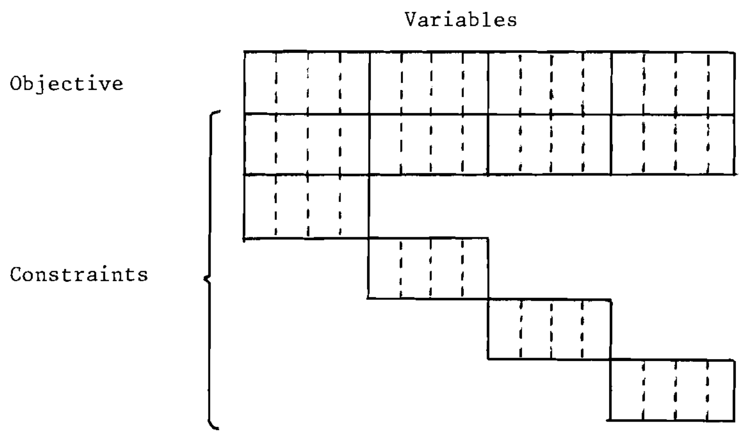

Figure 6.1. Block angularity: constraints involve only specific groups of variables, thereby indicating separable blocks. Adapted from Ljung and Selmer (1975, p. 19).

Using the terms suggested in Section 4.3, we can say that each block is formed by the $\underline{g}^i$ constraints for some i, except for any constraints that depend on $\underline{y}$. Taken together, the latter form the common constraints in Figure 6:1. If this approach is to be applied to our model, the multiple objectives will first have to be transformed <u>either</u> into a single objective <u>or</u> into a single objective plus one or more common constraints. If we let $\underline{y}$ stand for a multi-dimensional resource allocation, we can then include several common constraints.

By equating the binding common constraints of Figure 6:1 with the allocation $\underline{y}$ of scarce resources, an important logical identity is indicated. Ljung and Selmer suggest three ways of handling a common constraint which indicate this identity (Ljung & Selmer, 1975). For each planning iteration, always using the single objective as the point of reference, the LUs can <u>either</u> be allotted a part of the scarce resource, or be given a resource price to be observed in planning, or be assigned revised prices for their products based on their use of resources and the current state of resource scarcity. From the LU viewpoint, these alternatives would be experienced as a fixed appropriation, or a change in production costs, or a change in objective-function respectively.

Thus, a single objective combined with constraints can result in LU objectives that change between iterations, reflecting the constraints. The distinction between an objective and a constraint may therefore appear rather small. We will make use of this fact in one of the procedures to be formulated below.

6.2.3 The preferences-first strategy and linearities

The preferences-first strategy seems particularly appropriate where preferences conform to a linear function of attributes. Linear preferences are easier to model, and linear objective functions in planning models are considerably more common than non linear ones. Non linear preferences would be more complex to make explicit, and a superobjective based on them would be more difficult to use in a planning dialogue.

A substantial body of research suggests that linear models can adequately predict human judgments based on multiple criteria. Even where a nonlinear judgment could be expected, or is claimed to have taken place, linear models are more consistently successful than human decision-makers in making correct decisions (Goldberg, 1968, 1971).

Linearities are important in the present case, and not only because a simple relation of this kind is easier to identify than more complex relations would be; the LUs would actually find it difficult to use nonlinear weights. If for instance the CU preference function contains interaction between total profit and sales values, an LU would need more than a nonlinear objective function; it would also have to have some information on the performance planned by other LUs. Linear weights could of course provide good local approximations of nonlinear preferences, but new approximations would then have to be announced for each iteration of the planning dialogue, referring to a non-linear and previously declared superobjective.

The two-stage nature of the CU assessment process may make a nonlinear evaluation more likely. Although human decision-makers may not be able to handle several attributes at once in any consistent way except by making a linear combination of their values, psychologists seem to accept that we can experience nonlinear utility for single attributes (cf. the oft-quested law of diminishing marginal utility). This could mean that an objective-fulfilment value resulting from CU's study of LU-plan attributes would not necessarily be a linear function of these attributes. A case of this sort would correspond to the additive model described in Tell (1976, p. 19), where the overall preference value is a linear combination (weighted sum) of unidimensional utility values for each attribute. This closely resembles our problem formulation, except that the multi-LU situation means that we have to combine attribute values in order to find the objective-fulfilment values.

The additive model was used successfully by Tell. In our case, nonlinearity in each objective's utility function means that the preference function is nonlinear in the LU attributes, even if the objectives are weighted linearly. If they are, it becomes impossible to give the LU any directives in attribute terms in the form of a linear objective function, except as a temporary approximation (cf. above).

As an example, let us consider a company which cares about environmental effects. This concern is one of its objectives. LU plans involve the emission of various substances. CU tries to evaluate the combined impact of these and assesses this impact in terms of the company's environmental objective. Here, a meaningful measure of objective-fulfilment which could be combined with profitability, market share, and other objectives would quite probably involve nonlinear evaluation of the reported LU attributes.

This could be the result of technical considerations (how much emission can nature absorb) and of concern about what society will tolerate. Neither nature nor society reacts linearly.

Even if profitability, market share, and environmental effect are then combined to reveal linear preferences, any attempts to tell the local units what to do will necessarily use emission quantities as its "language", assigning weights to these quantities to make them comparable with other attributes of the plans. Because of the nonlinearities the weights will only be local approximations which will have to be changed if, for instance, another LU drastically changes its values.

Thus, in the case described above, we have an additive separable preference function, in which the separable parts contain nonlinear elements. This type of case is also discussed in Wallenius (1975, p. 104), where it is suggested that the objectives could be modified in some way, by taking the square-root of profits instead of profit itself, for instance. In a multi-LU situation, this kind of new substitute objective would obviously not be possible.

Another complication may be the nature of CU's knowledge. We have assumed CU knows its own preferences <u>implicitly</u>. Would the hypothetical choices made during the pre-planning identification of preferences activate this knowledge in the same way as the real choices that have to be made in the actual process of planning?

Another important question concerns our attitude to <u>inconsistent behaviour</u>. One explanation of the excellent performance of linear models in predicting choice that is sometimes suggested is that irregularities (probably unwanted) in human judgment are ironed out when a formal model is used. This more than compensates for any loss of "real" nonlinearities (cf. Tell, 1976), which could be a point in favour of the preferences-first approach. However, there is also a counter-argument here: inconsistencies sometimes show that preferences are not quite definite, in which case the use of any exact model could be dangerous (Montgolfier & Tergny, 1971). CU might put too much faith in the model as a reflection of a "true" balance between the relevant objectives.

6.2.4 Conclusions

A preferences-first strategy could follow any of several single-objective planning methods, some of which would give the LU an impression that objectives changed. Essentially, however, it requires the initial establishment of a single objective, possibly together with some constraints, as a way of indicating CU preferences. There are several methods, based on implicit knowledge of preferences, by which this can be done. The most usual approach is to ask questions about hypothetical choice situations.

The preferences-first approach seems appropriate mainly where preferences conform to a linear function, or where no great loss is incurred by approximating them by such a function. Some other considerations affecting the choice between a preference-first or an interactive strategy will be discussed in Section 6.4.

6.3 INTERACTIVE EXPLORATION OF POSSIBILITIES AND PREFERENCES

Some exploration of both possibilities and preferences takes place in most planning. Any consideration of preferences, however, is generally very informal. A group of theories for the combined exploration of both possibilities and preferences have generated what are known as the interaction methods for multiobjective decision-making, which will be described in Section 6.3.1 and used extensively later in this study. The theories lack the organizational context necessary for our aims. An organizational theory that has much in common with the interactive approach is Johnsen's theory, to be discussed in Section 6.3.2. It might also be possible to incorporate some of these ideas in certain classical economic planning methods.

6.3.1 Interactive methods for multiobjective decision-making

In the field of multiobjective decision-making various interactive methods are probably those which have aroused most interest in recent years. For surveys of the subject, see Näslund (1974) and Tell and Wallenius (1976). The methods are characterized by an iterative dialogue between the decision-maker and a computer. Information about the feasible range of solutions (alternatives) is fed into the computer, which then presents possible solutions to the decision-maker during the dialogue. At each step, the decision-maker reacts to the proposals in a way that enables the computer to propose at the next iteration a solution which the decision-maker prefers to the previous one. It is assumed that the decision-maker has some implicit knowledge of his own preferences, and the aim of the method is to use this knowledge as efficiently as possible in finding the preferred direction of change between steps. The various methods suggested use different information and computational procedures to arrive at increasingly attractive solutions and ultimately, to approach an optimum.

This kind of dialogue is very similar to the dialogue in the interactive strategy between CU and the local units. If there were only one LU, the methods could be used as they stand. All that would be needed would be to insert the LU instead of the computer, provided the LU had the computational ability required. In such a situation all the jointly available resources would go to the single LU, and there would be no resource-allocation problem. Likewise, there would be no need to combine the performance of several units so that LU efficiency and organizational efficiency would be identical.

The main problem for us in using interactive methods is that we cannot restrict ourselves to the one-LU case in constructing a theory of multiobjective budgeting planning. The interactive methods would have to be "decentralized" before they could provide a solution to our planning problem.

6.3.2 The "search-learn" approach to organizational planning

Johnsen (1968, 1973) argues in favour of a search-learn approach to planning, where objectives are reformulated as search discloses new information about possibilities. Johnsen's main preoccupation seems to be with the organizational setting of such processes. In reporting practical experiences in a recent paper, Johnsen concludes:

> 1. People are normally not aware of their objectives but need them in the managerial process;
> 2. People are willing to and able to cope with objective problems as a link in a normal problem-solving process formed as combinations of analysis, interaction and search-learning;
> 3. Objectives change all the time, partly due to the situation, and partly because people become more aware of their "true" objectives through the process;
> 4. Objectives become meaningful only in a process in which they interact with means;
> 5. The objective-setting process never stops, but it can change its outer form all the time.
>
> (Johnsen, 1976, pp. 150-151)

Especially 1, 2, and 4 show how necessary it is that preferences be clarified in some sort of interactive process. Whether this should be a "real" interaction during the actual planning or the "simulated" interaction of the preferences-first approach is less clear, although obviously statement 2 above could be understood as referring to a real ("normal") process.

The changeability of objectives might appear to conflict somewhat with our assumption (A17) about the stability of preferences during the planning of one period. However, even Johnsen would have to "freeze" objectives at some point during planning, as the final plan has to be chosen with some set of objectives in mind.

Johnsen's formal model (1968, Chapter 10) is not altogether suitable to our planning problem, nor was it probably meant as a recommendation for practical planning. Nevertheless, its central idea of a search-learn process seems very attractive even in the context of our model.

6.4 PREFERENCES-FIRST OR INTERACTION?

In this study, I have chosen the interactive rather than the preferences-first strategy. We will study possibilities and preferences together, instead of first removing the multiobjective problem in preparation for planning. It should be noted that the framework of some of the classical planning methods discussed in Section 6.2.2 could be relevant even in an interactive approach. The essential difference lies in whether the decision-maker is made to reveal his preferences in advance or whether this becomes part of the planning itself, in which case real plan proposals are used rather than hypothetical ones.

My choice does not reflect any conviction that interaction is always preferable. It merely seems to be worth investigating. In coming to this decision, I have considered the following arguments.

Nonlinearities can be expected. A basic question seems to be: does nonlinear judgment exist? If it does not, the preferences-first approach seems preferable. If it does, then the interactive strategy offers certain advantages but may also be more expensive as it involves a more complex planning process. We have already mentioned the views of several psychologists, which suggest that the answer is "yes" but that the nonlinear elements are not very important. This runs counter to such bodies of theory as utility theory and classical economics, where a diminishing marginal utility has an important role. Mathematical programming theories, such as goal programming, also constitute attempts to include nonlinear preferences. This seems to me to indicate an interest in the development of nonlinear planning theories.

Should normative theories allow for nonlinearities? The advantages of using linear models in predicting choice does not necessarily mean that they are also superior in normative theories. CU might perhaps like to use its real nonlinear preferences, as yet unrevealed, but it has difficulty in doing so. This difficulty shows itself in inconsistent behaviour that makes linear models preferable in predicting the choices. Perhaps we should therefore design a procedure which could assist nonlinear judgment, rather than fall back on linear approximations.

Costs. It is not possible to know in advance exactly what value combinations, for objectives and attributes, will become relevant during the planning process. Preferences would therefore have to be studied over a greater range of value combinations than will actually be needed. If LU planning can be directed reasonably correctly in an interactive strategy, we can expect fewer CU choices and a consequent saving in costs.

It could be argued that the preference study could be made once and for all, but the quotation from Johnsen in Section 6.3.2 suggests rather that such studies would probably have to be repeated every year.[1] Compared to the cost of these, one has to set the costs generated by the (smaller) preference study which is "integrated" in the interactive strategy. These could turn out to be greater than those of the preference-first method, because of the need to involve the entire organization in a multidimensional dialogue.

Would CU want to communicate its preferences? It would be quite natural for CU to have less than complete confidence in any "representation" of its implicit preferences, or at least to want to reserve the right to revise its opinion. This could result in a reluctance to show any set of LU weights to the LU, and a preference for some other form of LU guidelines. There could even be political motives for this sort of behaviour. The preferences constitute a

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[1]The identity of objectives probably changes less often than the desired balance between them. Thus it might seem natural to include only their identity in permanent routines for budgetary planning, adding "this year's objective weights" each year. Nonlinear preferences could motivate different weights for successive iterations. This seems potentially confusing and difficult for the LU to accept, as well as being costly.

unique CU competence, the basis for its position in the organization.

This reluctance could also serve to reduce conflict. Even if such political reasons may seem rather dubious in a normative theory, at least a desire to be able to revise preferences in the light of more information should be considered legitimate.

CU could of course keep the revealed super-objective to itself, using it only as a parallel check on its intuitive judgments during a multiobjective dialogue. To me this seems just a special case of the interactive strategy.

Amount of information exchange. Even where a super-objective could be found, it would probably not be the only description of LU plans required by CU. CU and the local units will probably prefer to use other information as well, with more obvious interpretations such as observable attributes of performance etc. In this way CU can check that plans conform to given constraints, that they do not fall outside the foreseen value ranges, etc.

If the information exchange is thus still multidimensional, and if it makes use of something similar to the performance attributes of our model, then there will be no advantages in this respect in following the preferences-first approach rather than the interactive alternative.

"Correctness" of plan choice. As a preference study made in advance would probably be more extensive than a study integrated with the planning, the final choice of plan according to the preferences-first method might be more "correct" in the sense of being "consistent with preferences as revealed by questioning". There is always the risk of arbitrary errors in isolated CU reactions during the interactive strategy. On the other hand, the validity of ex ante preferences is difficult to prove. If in doubt, CU can use an interactive strategy combined with a parallel check against revealed preferences.

Conclusion. The preferences-first method would be appropriate mainly for linear preferences, and in such cases might even be preferable to the alternative approach. There is theoretical evidence that linear preferences are "sufficient", in a certain sense. But there are also indications that people believe in nonlinear preferences and try to use them. For this reason it seems to me that a planning approach based on the alternative interactive strategy is motivated. It would more nearly meet the requirements of such situations as were discussed in Chapter 1 above and in Johnsen (1976). In view of the character of implicit preferences, it seems better to treat the balancing of different objectives as part of the actual planning than as a hypothetical exercise preceding it.

For these reasons, the interactive strategy will be used in this study.

6.5 ON ORGANIZATIONAL VS. MATHEMATICAL PLANNING THEORIES

The procedure adopted in this study and presented in Section 3.1 is to reduce a conception of a real-life problem into fairly formal alternative models. In the process we make use of analogies with existing theoretical proposals for planning and decision-making. But what we are looking for is not new mathematical algorithms. Rather, the analogies with formal methods are used to suggest rules for practical budgetary planning. The conclusions that can be drawn in this way are subject to considerable limitations. This has been discussed in Kornai (1975, Chapter 30), where a distinction is made between <u>three interpretations of mathematical planning methods</u>:

(1) Mathematical computational procedure
(2) Descriptive theoretical model of planning
(3) Method recommendable for practical planning.

Kornai regards it as dangerous to generalize from A to B:

> From the number of iterations and operations required by the direct simplex method or the DW algorithm, nothing follows for the <u>economic</u> theory of planning.
> (Kornai, 1975, p. 509)

Even numerical examples fail to tell us anything, as they do not consider indivisibility, increasing returns, uncertainty, distortion of information, etc.

Interpretation C is said to be rarer and even more misleading. Mathematical models cannot cope with the simultaneous information flows in all directions which are often desirable in order to reduce uncertainty (Kornai, 1975). There is also the behavioural aspect: "People may not be classified as 'peripheric equipment' of the computer, as a data input or result-evaluating device". (Kornai, 1975, p. 516)

Yet Kornai means that mathematical models should be used along with other planning. In national planning, markets should be used for short-run choice. Models should only be used for medium-range and long-range planning, and they should include seemingly redundant information and take care to adapt to the desires of their users. The result could be "a multi-level planning system such that men and machines, planners and models cooperate on every level. They do so without rigid formalities - although not merely improvising, but in a pre-meditated and organized way." (Kornai, 1975, p. 523)

Other writers, notably Weitzman (1970), seem to envisage a rather more direct type of learning from theoretical models for application in practical situations. Weitzman claims that his procedure would be relevant even if certain approximations were introduced. This is more or less the way I have used the formal methods, and in doing so have obviously laid myself open to the dangers described by Kornai. On the other hand, real-life applications of my proposals would aim at an organized cooperation between methods and man rather similar to that described by Kornai. The procedures would structure the approach to the problem in a way that is lacking in unguided multiobjective planning.

An alternative could be to formulate an organizational theory rather than a mathematical one, starting from observations of actual situations and concentrating on characteristics such as "actual knowledge of preferences" etc. The present study contains elements of this approach, in the background provided by my own experiences (cf. Section 3.1). I believe that an interaction between both types of analysis can be fruitful. The researcher's perception of the problem situation is expressed in a model, from which tentative conclusions are drawn. In this process he is assisted by the use of analogies with other models. When the conclusions are confronted with reality the models may have to be changed. This later stage is touched upon in Part Three below.

However, the analysis presented below is already partly "organizational" rather than "mathematical" in that it takes the "B-statements" (see Section 4.4) as criteria of quality and does not rely solely on the quality of the solution. Also, heuristics are used when algorithmic exactness seems difficult to achieve. It seems to me that more "correct" procedures would be too limited in their applicability in such cases.

Any exact formulation of the steps of a procedure represents a choice of a particular trade-off among the B-statements on the researcher's part. This makes it difficult to compare different procedures, as these would have to be evaluated multidimensionally, and the evaluations would also have to take the user situation into account.

For these various reasons I have decided here to present several approaches without recommending any one in particular. By this I emphasize that they represent different ways of attacking the planning problem, where the details of each approach could have been designed in several ways. Any detailed formalized statement of a method that I give should be understood in this spirit. It serves to explain the general approach or philosophy by illustrating one way in which it can be made precise.

7. AN OVERVIEW OF INTERACTIVE PLANNING

7.1 DIFFERENT FORMS OF INTERACTIVE EXPLORATION

In Section 6.4, I explained my decision not to approach the planning problem by reformulating the multiobjective case as a single-objective problem, although such a "preferences-first strategy" could have provided one way of attacking the problem. The original model assumptions (specifically A5) also exclude another possible approach: namely transforming the multidivisional situation with decentralized information into a situation that allows for centralized planning by assembling all LU information and CU preferences at one place. This approach would have made it possible to use the interactive methods introduced in Section 6.3.1 in their original form here. And, in fact, some promising examples of using an interactive approach to multiobjective centralized planning have been reported by Wallenius and Zionts (1975).

If we disregard the preferences-first approach and various "centralization" strategies, we are left looking for a "solution" containing elements of interaction and keeping to the decentralized structure of the model. I have not found any procedures which meet these requirements and which are also explicitly concerned with multiple central objectives. However, several theories exhibit most of these qualities. Those which appear to merit consideration, and which will be discussed in Chapter 8 onwards, are:

- Interactive methods for multiobjective decision-making (cf. Section 6.3.1). These deal with the relations between a decision-maker and a computer.

- Some theories of decentralized economic planning. These deal mostly with the relations between a central planning board and several producing firms, and can often be applied to business situations. The difference from our model generally seems to be that the central board knows more about its superobjective, and it is often assumed that the activities of individual firms each only affect one objective.
- Goal programming is a mathematical technique which has been applied to organizational planning. Thus, it has the decentralized structure, and it assumes a form of multiobjective situation. Its relation between objectives, i.e. its implied preference function, has to be formulated in a particular way which is not immediately possible in our model.

All these approaches deviate somewhat from our present model. One lacks the decentralized structure, another the multiobjective impact of activities; two imply a knowledge of preferences which does not quite conform to our model situation. Could these differences be overcome and the approaches used to discover possible methods suitable to the situation described in our model?

7.2 INTERACTIVE METHODS FOR MULTIOBJECTIVE DECISION-MAKING

Interactive multiobjective decision-making models (see Section 6.3.1) would have to be "decentralized" to be appropriate to our model situation. Only one method has been adapted in this way (Geoffrion & Hogan, 1972), which makes it natural for us to consider it in some detail. A problematic feature is the heavy call it makes on information. CU is expected to provide objective trade-offs in the form of marginal rates of substitution (MRSs).[1]

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[1]Throughout this report, the term marginal rate of substitution or MRS denotes a preferential relationship, and the term marginal rate of transformation or MRT a technological relationship. Knowledge of MRS is thus a type of preference knowledge, and that of MRT a kind of possibility knowledge. Unless otherwise indicated, these rates relate here to trade-offs between attributes or objective fulfilments.

This is not required in other, as yet "undecentralized", methods. Some methods (the STEM method of Benayoun, de Montgolfier & Tergny, 1971; the Exterior Branching method of Aubin & Näslund, 1972) require the decision-maker to respond by selecting, at each iteration, the objective which has so far been most adequately met. This, and their use of an "ideal point" (to be explained in Section 8.3), make them interesting in our context, since practical equivalents are easy to find.

Hemming (1975) and Wallenius (1975) let the decision-maker rank a small number of proposals - three in Hemming's method, two in Wallenius'. These seem more difficult to translate into an organizational setting, since they are basically ways of finding which proposals the decision-maker should consider out of those available according to a formal model of the feasible set. Such a selection of proposals should of course be made in an efficient way. In the absence here of any formal model of the feasible set, it seems unclear what could be learnt from these methods in the present context.

7.3 THEORIES OF DECENTRALIZED ECONOMIC PLANNING

Planning methods for decentralized single-objective organizations were introduced briefly in Section 6.2.2. Some of the best-known of these are concerned with national planning rather than business or agency planning, but this difference does not affect our aims. Similarities include a decentralized structure, where the local units know the production possibilities but not the complicated interrelations which would be necessary if they were to choose plans themselves.

In these models, national objectives should be maximized through the choice of plan. Objectives are interpreted by a central planning bureau. Kornai (1975) suggests that several plans, representing different trade-offs between objectives such as final consumption and the trade balance should be shown to the decision-makers, who then make the final choice. Otherwise, it is assumed in these models that the situation is more or less the same as in our Figure 6:1, and that the aim of the planning is to allocate limited resources in an optimal way under consideration of a single explicit objective.

This is achieved by means of an iterative dialogue. Earlier writers usually stressed the tâtonnement process, in which each iteration corresponds to one period of actual implementation. The contributions to be reviewed in the present study, on the contrary, all deal with iterations simply as a way of planning, while only the final plan is actually implemented. This kind of solution to the planning problem is sometimes motivated by the decentralized nature of the information; sometimes it is seen as a computational device to facilitate the solution of very large problems, for example the planning of nation's total production and consumption (after it has first been described in an econometric model).

Early writers such as Walras and Barone developed the foundations for the theories now associated with the names of Lange (1938) and Lerner (1944). In these theories, planning in an economy is regarded as analogous to the working of a perfect market. The central planning board (comparable to our CU) sets prices for resources and commodities produced. Producing units react to these prices, and as CU changes the prices in the light of proposed plans, the economy is led towards an optimum (in the social-welfare sense) by means of an iterative process. This is the price-adjustment approach. As an alternative to prices, later methods also use information about quantities.

The vast literature on this subject has been surveyed by Hurwicz (1973), Jennergren (1974, pp. 61-90) and others. Jennergren distinguishes three main approaches:

(1) Centralizing the information, which is not in keeping with our original problem definition but which is claimed by Jennergren to be the true consequence of some of the methods proposed (1974, p. 68).

(2) Using an iteration mechanism to build gradually a CU approximation of the organization's feasible set,

which makes central plan-decisions possible

- Using an iterative mechanism where LU decisions are "coordinated" through central information. This corresponds to a partitioning or parameterization of the total problem, which is decomposed so that LUs can make decisions.

The first of these alternatives is obviously ruled out by our assumptions. The second deviates from the model in that it implies CU knowledge of possibilities. As a limited amount of such knowledge could indeed exist (we have neither assumed its presence nor its absence), a version of this approach will be included later (Weitzman, 1970).

The third group makes use of allocation vectors and/or prices to decompose the problem. Formulas 4-8 to 4-12 and Figures 5:4 - 5:5 have already introduced the use of allocations. Formal algorithms were proposed by Kornai and Lipták (1965) and others. Prices were used in the early Lange-Lerner formulations and by many later authors, such as Malinvaud (1967), whose method develops the Dantzig-Wolfe approach.

Some combinations have also been presented. In commenting on his price-directed method, Malinvaud suggests that in practice production targets could serve to supplement prices, since they help to identify the correct scale of activities. In this way, information which is unnecessary from the theoretical standpoint may have practical value: "These targets would a priori eliminate proposals which would be completely unusuable from the point of view of the plan being developed" (Malinvaud, 1967, p. 206). The budget allocation approach developed by Ståhl and Ysander (see Jennergren, 1971, pp. 69-76) uses price vectors and budgets.

Most of these methods deal with a known central preference function. The need for a dialogue stems from the resource-allocation problem, not from this problem plus the balancing of objectives as in the present study. Nevertheless, this important class of methods seems to merit closer consideration.

7.4 PLANNING WITH GOAL PROGRAMMING[1]

Goal programming (GP) is a mathematical programming technique in which the objective is to minimize a weighted sum of the deviations from some pre-determined target levels of several objectives. These objectives can also be ranked, so that the most important are attended to first, while the less important are only considered if there remains a choice between alternatives after fulfilling those that were ranked higher. Thus we can see that GP is concerned in a way with multiple objectives, but it requires the decision-maker to draw up a ranking list with weights for objectives that have the same rank, as well as supplying target levels for the objectives.

Decentralized planning methods based on GP have been proposed by Ruefli (1971, a, b, c) and by Freeland and Baker (1975). These represent preferences-first methods, in that the CU objective has to be formulated (as explained above) before planning starts. The planning dialogue is concerned with the way in which the central targets should be decomposed, and the LUs report prices so that CU can revise LU targets iteratively. These methods could thus be considered as a special class of the kind described in Section 7.3.

For several reasons I will <u>not put forward any procedure based on GP</u> in this study. One reason is the essential <u>preferences-first</u> character of GP. An attempt to formulate interactive GP has been made (Monarchi, Weber & Duckstein, 1976) but it seems difficult to reformulate it for a decentralized situation. Also, any such reformulation would begin to resemble the interactive methods of Section 7.2, in particular those that make use of ideal points.

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[1]Also see Appendix B.

Another reason is that the predominant characteristic of a budgetary planning system based on GP would be a reliance on targets as a way of communicating possibilities and preferences during planning. This is also a notable feature of the Weitzman model mentioned in Section 7.3, on which a procedure will be based below. If we chose to base a procedure on GP, its main line of thinking would be very similar.

Perhaps the strongest reason against using GP here, is the unclear consequences of the existing decentralized GP planning methods already mentioned. It seems that the plans arrived at by using these methods constitute a compromise between the CU and LU preferences which deviate from one another; CU then optimizes a weighted sum of LU dissatisfactions. This kind of non-cooperative organization (see Freeland & Baker, 1975, p. 675) may have a good deal of practical relevance but does not fit our model assumptions. The same is true of a somewhat similar proposal made by Rasmusen (1974).

For all these reasons, I do not find the inclusion of a GP procedure justified here. On the other hand, in some multiobjective situations it might be possible to use a preferences-first approach to make preferences explicit enough for the Freeland-Baker or Ruefli methods to be followed. CU would then have to accept the kind of optimization performed by these methods. Since GP can be seen as an alternative way of handling our problem, Appendix B is devoted to a discussion of this method and of the Rasmusen method, showing their relations to the procedures described here.

7.5 FOUR ALTERNATIVE APPROACHES

We can now summarize briefly the four types of interactive strategy that will be used for formulating methods in the remaining chapters of Part Two. All four start from the problem presented in Part One and all follow the principle of the interactive exploration of possibilities and preferences, for the reasons given in Section 6.2. As explained in Section 6.5, I will also draw on analogies with existing theoretical procedures for the development of methods. The four approaches derive from the brief examination of various bodies of theory undertaken in the present chapter.

The first approach is based on the method proposed in Geoffrion and Hogan (1972). This is the only decentralized multiobjective planning method already formulated that is known to me; but its assumptions differ significantly from the model introduced in Part One above. It could therefore be interesting to compare this approach with our model situation, to find out whether - or how - the method might be useful here despite differences in assumptions.

Geoffrion and Hogan represent one type of interactive multiobjective decision-making model. The other that appears promising in our context (cf. Section 7.2) uses infeasible targets or an "ideal point" to direct planning. This would imply a different "philosophy" from the Geoffrion-Hogan method if it could be used in decentralized planning, and has therefore been chosen as our second approach.

Among methods for decentralized economic planning (Section 7.3), the main types involve either a CU approximation of LU possibilities, or a decomposition of the problem by means of allocations or prices. The first kind gives us our third approach, taken mainly from Weitzman. It differs from the other three in not allocating resources on a trial basis, and in allowing for a gradual process of learning about possibilities in the CU.

The fourth approach allows for the decomposition of the problem by means of prices and allocations. The important role of resource allocations was recognized already in Chapter 5; they appear in all the approaches except the third one. Prices were used also by Geoffrion and Hogan, but as their method derives from a somewhat different background (being an adaptation of a (centralized) multiobjective decision method), it seems relevant to include a discussion of this fourth approach as well.

The four approaches will be discussed in the following chapters. In Chapter 8, we will examine the theories of interactive (centralized) multiobjective decision-making that form the basis of the first two approaches. This will bring us to a description of two planning methods in Chapter 9. In Chapters 10 and 11, the other two approaches, based on economic planning theories, will be similarly examined.

8. ADAPTATION OF METHODS FOR MULTI— OBJECTIVE DECISION-MAKING TO DECENTRALIZED ORGANIZATIONS

We have now seen that one way of finding methods for decentralized and multiobjective exploration of possibilities and preferences could be to study some existing methods of decentralized multiobjective decision-making that rely on interaction between man and computer. From our point of view, the main component missing in these methods is the decentralized knowledge of possiblities, which in our model is lodged in the LUs.

In Section 7.2, two approaches were selected: Geoffrion's and the "ideal-point" approach. In the present chapter we will look at these more closely, before turning in Chapter 9 to some related methods.

8.1 THE GEOFFRION APPROACH

If we use symbols corresponding to the model in Chapter 4, we can write the "centralized" problem which is tackled by interactive methods as:

$$\max_{\underline{x}} P \left[\underline{u}(\underline{x})\right] \tag{8-1}$$

$$\text{s.t. } \underline{g}(\underline{x}) \leq 0 \tag{8-2}$$

P is the preference function, $\underline{x}$ the vector of activity values or product quantities, $\underline{u}$ the objective values resulting from a certain activity vector, and $\underline{g}$ a vector of constraints. This formulation corresponds to formulas (4-8) to (4-12), less all the parts of the earlier formulation that resulted from the decentralized setting. Among these is the allocation of resources. Resources devoted to different uses within a single LU could be introduced as a control device, but the allocation of resources that is characteristic of our planning model obviously has no place when there is only one resource user in the organization and there is no alternative use for the resources outside.

Geoffrion, Dyer, and Feinberg (1972) proposed a method based on the Frank-Wolfe algorithm. Their method can be used in situations such as those illustrated in formulas (8-1) and (8-2), in cases where the $\underline{u}$ functions and the feasible set are known explicitly but P is only known implicitly. It is assumed that the feasible set is compact and convex and that P is concave and differentiable. According to Geoffrion et al., this is the case if P is concave and each u_j is linear, or if P is concave increasing and each u_j is concave.

The procedure is then to:

- Choose an initial feasible point $\underline{x}^1$
- Let the decision-maker estimate the trade-off between different criteria or objectives at this point, i.e. the value of the gradient of P at $\underline{x}^1$
- Use this information to find another feasible point, with the help of the algorithm
- Let the two points define a direction in which $\underline{x}^1$ should be changed in order to increase $P\left[\underline{u}(\underline{x})\right]$ as much as possible
- Determine, by asking the decision-maker, the optimal step-size for this change. A new $\underline{x}$ value $\underline{x}^2$ is then given by $\underline{x}^1$, the direction of change, and by the size of the step
- Repeat the procedure for $\underline{x}^2$ etc., until no further improvements are possible.

What is required from the decision-maker is the gradient and the size of the step. He can evaluate the former by using an estimate of the marginal rates of substitution (MRS) between pairs of objectives that the decision-maker experiences at the proposed points.[1] For deciding on the size of the step, graphical displays of how various objectives are affected by steps of different sizes are recommended.

The process converges, and it is claimed by its authors to be quite robust even in the presence of approximation errors.

To translate Geoffrion's method into the terms of a one-LU organization will not require any major changes. CU assumes the role of the decision-maker. The MRS-estimation introduces an element which is problematic. An estimate of MRS involves asking questions such as: "How much more sales would exactly compensate a drop in profit of 1 000 dollars?" or "What balance between sales and profits would be ideal, if both could be expanded from their current level?"

According to our model CU is not able to react so exactly to individual proposals; it can only choose between pairs of total plans. Nevertheless, since the required estimates are only local ones and do not require a complete identification of a preference function as in the preferences-first strategy, we could perhaps accept this as an additional assumption.

The decision about the size of the step involves a choice between alternative plans, such as we assume our CU is able to make. We also assume that the LUs are able to propose an efficient plan, which is here synonymous with the first $\underline{u}(\underline{x})$. But it seems doutbful whether the LU would be aware of possible trade-offs etc. in sufficient detail at this point to use the algorithm for finding another point, as can be done in the man-computer dialogue where the computer possesses full information about the feasible set. The LU would be required to estimate all derivatives $\partial u_j/\partial x_k$, where j and k indicate elements of the $\underline{u}$ and $\underline{x}$ vectors, at the points $\underline{x}^1$ etc.

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[1] Also see Appendix C, Section C.3.

The LU's difficulties are obviously related to those of CU. Both concern communicating their implicit knowledge. The ease or difficulty of judging trade-offs was discussed in Wallenius (1975, Chapter 3), where it was recommended that MRS estimates should if possible not be asked for.

8.2 THE GEOFFRION-HOGAN EXTENSION TO SEVERAL LOCAL UNITS

In a multi-LU reformulation of the Geoffrion method, Geoffrion and Hogan (1972) first use one unidimensional objective function f_i for each LU. In the terms of our formulas (4-8) to (4-12), this means that instead of (4-9) to (4-11), we have:

$$u_i(\underline{y}) = z_i(\underline{y}) = \max_{\underline{x}^i} f_i(\underline{x}^i, \underline{y}), \quad i = 1, \ldots, m \tag{8-3}$$

where a single attribute is now used to express the performance of LU number i. In other words there is one organizational objective per LU, which means that f_i, the attribute corresponding to this objective, can be used instead of $\underline{f}^i$. Such an LU objective would correspond to its "main task", besides which its impact on other objectives is secondary or even negligible. No combined effect of the activites of several LUs is relevant to any objective, so there is no need for a CU transformation. The multiobjective characteristics of the situation are restricted to CU's preferences in balancing the scales of activity in different LUs. Each LU can judge for itself which of its plans is organizationally efficient and effective.

Geoffrion and Hogan show that this situation can be handled by their method, using basically the same steps as in the Geoffrion method. Each LU chooses its $\underline{x}^i$ itself, and the Geoffrion technique is used for CU's choice of $\underline{y}$. With a unidimensional objective for each LU, the choice of $\underline{y}$ will completely determine performance.

The modified method requires information similar to that of the original, except that LU estimates now concern values and derivatives of all f_i and $\underline{g}^i$ functions, for $\underline{x}^i$

as well as for $\underline{y}$. In real-life situations this probably means that a formal model of the activities and their impact on the relevant objective, on constraints, and on resources, has to be available.

What makes it possible to use the Geoffrion method with these modifications, is the assumption that CU preferences are defined over a unidimensional objective for each LU. When Geoffrion and Hogan proceed to introduce multiple criteria for each LU, they have to combine these criteria into a unidimensional function in order to retain a defined LU objective. They assume that each LU has an implicit preference function, and it is the value of this which enters into the CU preference function. This could be the case in our model if we change formulas (4-9) and (4-10) into:

$$u_i(\underline{y}) = \underset{x^i}{\text{Max}}\ L_i(\underline{z}^i), \quad i = 1, \ldots, m \tag{8-4}$$

where L_i is the implicitly known preference function of LU number i, defined over the attribute values of LU-efficient plans. This time we would keep the original formula (4-11), using an attribute vector $\underline{f}^i$ to describe LU performance.

As the LU preference functions L_i are only known implicitly, no actual u_i values are available for use in CU decisions. Each LU can use the original Geoffrion method to solve its own problem, which of course requires extensive information about the feasible set. Geoffrion and Hogan also introduce further assumptions so that CU can act _as if_ it had access to some measure of LU-objective fulfilment (see Geoffrion & Hogan, 1972, Section 2.3).

The first Geoffrion-Hogan procedure is a drastic simplification of our original problem. It corresponds to complete specialization in all LUs, or to a situation in which CU has allotted a certain objective function to each LU once and for all. The latter case could arise if a firm wants to use fixed transfer prices to achieve a "profit-centre" situation, and if different transfer prices for different LUs make it necessary to keep the objectives separate in the CU decisions.

The second formulation is closer to our model. But the assumption that CU judges the LUs on the grounds of some implicit preference values or LU-satisfaction values still seems unconvincing. It might sound more realistic if these values were understood as the "pressure" applied by the head of an LU in arguing for more resources, but this would involve us in a bargaining situation where quite different theories would probably be needed. The formulation might be attractive in cases where CU has delegated judgment to the LUs, but with our model's assumption of centralized authority we would expect CU to want some other way of influencing local choices apart from through the allocation of resources. In Chapter 9, I will discuss whether control devices of this kind could be included in the $\underline{y}$ vector, although Geoffrion and Hogan exemplify its role only by discussing resource allocations.

A basic difficulty with the Geoffrion-Hogan approach is the heavy demand it makes on non-trivial estimates. It may be possible for the CU to answer such trade-off questions as we quoted above. In this case, however, it would also seem possible to employ other, more traditional planning methods (cf. Chapter 10 below). The LU requirements seem to demand formal models of performance possibilities, which would make a centralized solution feasible - in contrast to what we assume in our model.

8.3 "IDEAL-POINT" METHODS

In this section we will look at some interactive methods that include the concept of an "ideal point". The method presented in Benayoun, de Montgolfier, and Tergny (1971), called the Step Method or STEM, is based on linear programming (LP). As before, it is the way preferences etc. are communicated rather than the actual computations which interests us here. The procedure is:

- Use LP to find the points in the feasible set that maximize each of the objectives. Together, the maximal fulfilment of all objectives give an "ideal point" which is not feasible (except by coincidence)

- "Normalize" the objective scales by using weights proportional to their value ranges.
- Find a feasible minimax solution, i.e. minimize the maximum distance over all normalized objectives to the "ideal point"
- If the decision-maker is not satisfied with this solution, he selects one objective in it whose value can be reduced, in order to raise some others. He also announces the amount of this reduction, perhaps with the help of sensitivity analysis
- The reduction in the value of one objective constrains the feasible set. For all other objectives, only improvements from the previous proposal should be considered. In the reduced feasible set, a new minimax solution is found. The last two steps are then repeated until no further significant improvements are possible.

An equivalent to STEM that would be suitable to a hypothetical one-LU organization would require the LU to maximize its contributions to each organizational objective in turn. It seems that the fundamental ideas of the method would survive, even if the LU did not have access to an LP formulation. As long as CU is able to reduce one objective at a time, any planning procedure could be used in the LU to find the plan which, in a minimax sense, is closest to the ideal.

In the multi-LU situation, some new problems arise. CU could derive an organizational ideal from the LU ideal points. But LU choice would still need some of the guidance that ideal points can give, and the LU points would now no longer necessarily be representative of the "organizational good". We will investigate this problem in connection with STEM and Exterior Branching (see below) together in Section 8.4.

In many ways the <u>Exterior Branching</u> method proposed by Aubin and Näslund (1972) resembles STEM. (Other methods such as Fandel's (1972, pp. 56 ff) also use similar approaches.) It shares the ideal-point concept, but instead of a minimax choice of plan proposals, it solves for the minimum Euclidean (sum of squared deviations) distance from the ideal points. Unlike STEM, it does not require linearity. Another difference is that the decision-maker specifies only which objective is to be relaxed, and not by how much. This is because Exterior Branching moves the ideal point instead of gradually delimiting the feasible set.

When an objective is relaxed, its value in the most recent proposal is substituted for its previous value in the ideal-point vector. For the changed ideal point, the minimum-distance rule is used to select another proposal, and the process is repeated.

As in STEM, a one-LU interpretation requires correspondence between attributes and objectivs. Also, it seems probable that here too the formal choice of proposals could be approximated in the LU by some other planning method which in some way used the minimum-distance idea.

The introduction of more LUs raises the same sort of problem as it does for STEM, as regards interpreting the ideal point and finding LU equivalents that represent the direction of changes in plan which are desirable from the organizational point of view.

8.4 "DECENTRALIZING" IDEAL-POINT METHODS

We will use a simple two-LU, two-objective example to illustrate the problems of attempting to decentralize STEM and Exterior Branching. The resource-change problem will not be shown; on that question the methods have no solution to offer. Nevertheless, it could be interesting to see whether the basic thinking as regards ideal points and "objectives to be relaxed" could be transferred to the organizational situation, since the information requirements would be comparatively modest and certainly less than those of the Geoffrion method.

In Figure 8:1 we use two additive objectives for illustrative purposes, as we did before. The objectives have not been named, as their wide range of possible variation would probably not occur in practice.

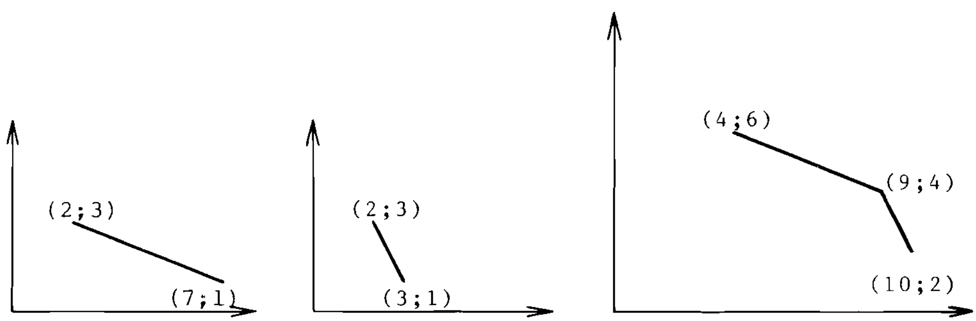

Figure 8:1. A two-LU, two-objective organization

If we used STEM for the centralized problem, the result could be represented by Figure 8:2. First, the feasible set is normalized so that the value ranges of both objectives are equal (= d). Next, the ideal point A is found, and the feasible point (B) for which the maximal deviation from the ideal in any single objective is at its minimum. This is then "denormalized" and presented to the decision-maker. Let us then suppose that it is not considered necessary to attain more of the horizontal objective and that some relaxing of its present level could even be accepted. The decision-maker can then suggest a maximal value for this objective, which is used as a constraint on the feasible set (as indicated by the line CC in the figure). After this, the process returns to the normalized situation to find which point in the reduced feasible set is the new minimax solution, and the process is repeated if necessary.

Figure 8:3 illustrates Exterior Branching whereby an ideal point A is found in the original objective space and the point B with a minimum Euclidean distance to A. Supposing as before that some of the horizontal objective can be sacrificed, the decision-maker no longer has to announce

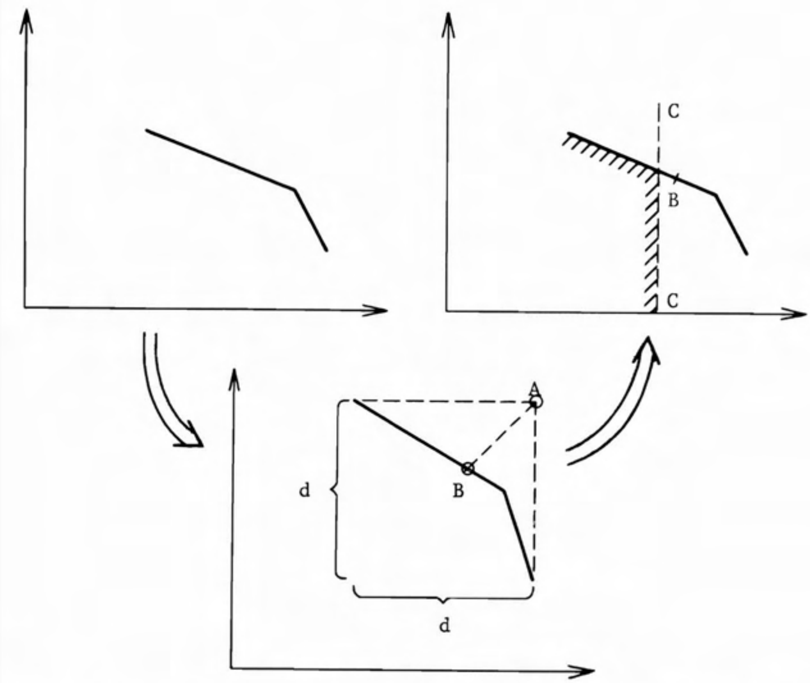

Figure 8:2. A centralized STEM procedure for the problem of Figure 8:1.

the amount of any reduction. The ideal point is automatically redefined as A^1, using the horizontal objective value of B. From the new ideal point, a new minimum-distance solution follows, to which the decision-maker can be supposed to react in the same way, and the process is repeated if necessary.

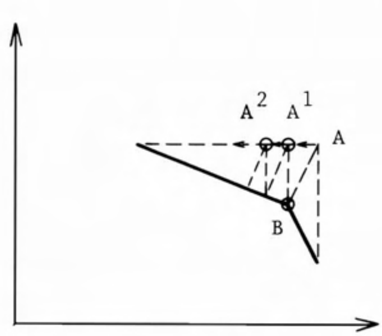

Figure 8:3. A centralized Exterior Branching procedure for the problem of Figure 8:1.

In both STEM and Exterior Branching, the need to have an ideal point to guide the new proposals is more obvious in the case of a large number of objectives. This offers more alternatives for how a reduction of one objective can be combined with increases of others.

The decision-maker will ultimately find that no further improvement is possible - perhaps, in our example after reducing also the vertical objective's value during some of the iterations. Throughout, only solutions on the efficient performance-possibility curve are used.

Turning now to the <u>decentralized</u> situation, we can try to divide a similar process between the LUs. This turns out to be difficult. If both our LUs normalized their performance possibilities as in <u>STEM</u>, they would both propose the mid-points of their own performance-possibility lines: (4.5; 2) and (2.5; 2), respectively. The resulting total performance (7; 4) is clearly not organizationally efficient. (The organizational p-p-curve in Figure 8:1 passes through (7; 4.8).) If the "central" normalization weights were used, the result might be somewhat better - roughly (7.2; 4.3) - since these normalization weights reflect the total organizational situation. But this is still not efficient from the organizational point of view. And if a reduction in the value attached to one of the objectives is desired, there is no way of knowing which LU or LUs should undertake this.

The situation is not much better in <u>Exterior Branching</u>. If ideal points are used for both LUs without any normalization, the result will be the same as that shown in Figure 8:4: an organizationally inefficient total plan. If CU then wants to relax the horizontal objective, it would be natural for this to be interpreted by each LU as a new LU ideal, where the horizontal objective is now given the value of the latest proposal. But it is not at all obvious that both LUs should change in the same way, although it seems to work quite well in our illustrative example. LU 2 would move quickly towards (2; 3), which is its organizationally efficient plan for the preferences that we indirectly assumed above when we let CU lower its ambitions for the horizontal objective. Then the remaining adjustment of plans is made by LU 1.

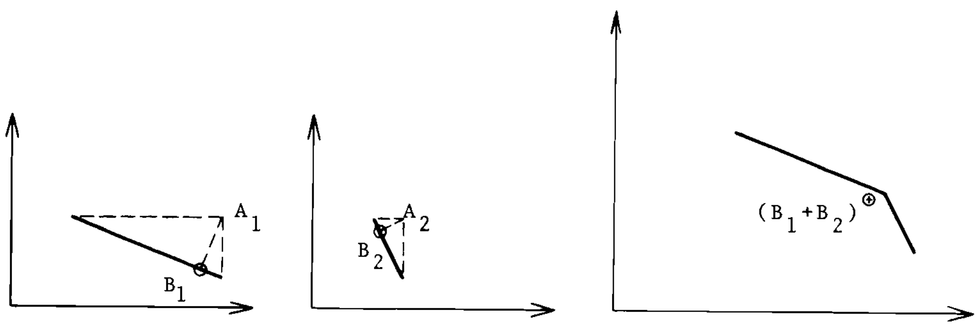

Figure 8:4. An attempt at decentralized Exterior Branching in the situation illustrated in Figure 8:1. $B_1 \approx (6.4;1.2)$, $B_2 \approx (2.3;2.5)$.

However, to be able to evaluate this approach, we would have to simulate a great many cases, using realistic assumptions about number of objectives, number of LUs, performance-possibility curves, and preference functions. Obviously we have too little knowledge about typical conditions in real-life situations to make such an exercise worthwhile.

Instead we have to conclude that not only the resource-allocation problem (which we have not discussed in this section) but also the problems of organizational efficiency and effectiveness are left unanswered by our attempts to decentralize ideal-point methods. This is regrettable since ideal-points and "objectives to be relaxed" seem easy to translate into practice, and are certainly easier to handle than the derivatives required by the Geoffrion-Hogan method. But we have also found that in the case of STEM, normalization according to central weights could be expected to approximate organizational efficiency better than unaided LU planning. It seems to me that the general lessons to be learnt from these attempts are:

- Identification of an organizational ideal point may make it easier for CU to give some directives about further LU planning
- Before they can serve as planning guidelines, LU ideal points should be supplemented by some information on the organizational situation in general, such as the "central" normalization weights discussed for STEM above
- Identification of an "objective to be reduced" should be combined with a differentiation of the reduction required in different LUs, at least if any amount is to be given for the reduction.

Finally, the resource-allocation problem is not helped by these methods. It might perhaps be possible to start with some "favourable but reasonable" allocation in finding the ideal points for all LUs. If some of the points arrived at in this way are "unrealistically ideal", this should not greatly affect their later use as reference points in planning.

8.5 A COMPARISON OF DECENTRALIZED INTERACTIVE METHODS

The comparison in this section will simply serve as a summary of the arguments already presented above. A real comparison is obviously not possible between an exact procedure for a special case of our problem (Geoffrion-Hogan), and two less successful attempts at transferring ideas from interactive methods to a decentralized situation (STEM and Exterior Branching). In Table 8:1, the problems stated in Section 5.7 are brought together in an overview of the difficulties and the (partial) solutions.

We are left here with the following ways of using interactive methods:

- Simplify the basic situation. This may involve extending our assumptions of what LUs and CU can do, and/or introducing basic changes in the assumed situation, such as allowing each LU one objective only. Both

Table 8:1. Some interactive methods and their difficulties in a decentralized situation

	Geoffrion-Hogan	STEM, attempted decentralization	Exterior Branching attempted decentralization
Organizational efficiency	Unidimensional objective for each LU, i.e. only one efficient resource allocation. Alternative solution: LU preferences unknown to the CU, are accepted for making the LU objective unidimensional.	"Ideal points" for each LU do not guarantee organizational efficiency. In determining minimax distance to ideal, STEM includes a normalization. Perhaps the central unit's ideal plus central normalization weights would give an acceptable approximation.	As in STEM, the central unit's ideal point should probably be used. But outcome would not be organizationally efficient.
Effective use of resources	As noted above, only one efficient solution exists for each resource allocation, eliminating this problem.	When CU reacts to the first plan by reducing one objective by a given amount, we need a rule to divide this change between LUs so that we achieve the greatest impact on other objectives.	Unlike in STEM, the CU decides which objective is to be reduced, but not the amount of the change. Ideal is then changed, reintroducing the above problem.
Optimal allocation of resources	Various derivatives and an estimate of desired "step-size" are used to translate unidimensional response information from the LUs into comparable information concerning the effects if a particular LU is given more or less of the resource.	Not solved.	Not solved.

these adjustments are required by Geoffrion-Hogan. Other methods could probably be formulated for similarly simplified situations, using other assumptions.

- Accept approximative solutions, and concentrate on the way in which less-than-exact decision-rules could help in a practical situation.

The emphasis in this study is on budgetary planning, not on formal algorithms in well-structured situations. The model assumptions include a strictly limited number of iterations. The way we use these is obviously the most important consideration. We could formulate analytical or simulated approaches to the problem of truncated search, but in view of the limited knowledge we have about the actual problem situations corresponding to our model, the idea is not very attractive.

This means that recommendations have to remain heuristic, involving something of each of the above alternatives. This is why I have chosen a rather imprecise approach, proposing two procedures for multiobjective budgeting which combine various features from the methods discussed here. These will be described in the next chapter.

9. TWO PROCEDURES BASED ON MULTI— OBJECTIVE DECISION-MAKING METHODS

9.1 INTRODUCTION

In Chapter 8 we found it difficult to adapt the interactive multiobjective methods to the decentralized structure that is inherent in our planning problem. Only the Geoffrion method exists in a decentrilized version, and even this differs from our model in two vital respects:

- The character of the multiple objectives
- The assumed ability of CU and LUs to provide information.

The comparison of methods and problems summarized in Table 8:1 left several problems unsolved. Nevertheless, it seems to me that the underlying principles have something interesting to offer. I will now describe two procedures based on the interactive methods and supplemented by heuristic components to "fill in" where these methods provide no solution.

One method, presented in Section 8.2, is an adaptation of Geoffrion and Hogan, but one which assigns a stronger role to CU. The second method, described in Section 8.3, is based on the ideal-point methods. It demands less strong assumptions than the first, but at the same time provides less formal exactness.

In presenting these and later methods, I will first discuss and describe them in verbal terms as a sequence of steps. As far as possible, these will be related to the basic interactive method illustrated in Figure 5:5.

To show how the steps could be specified, I will suggest a mathematical formalization of each method. This should not be regarded as the only possible formulation or, indeed, as a "definitive" statement of the method. Our main interest here is not the mathematical properties of the methods. What is interesting, on the other hand, is that the methods point to different approaches to the planning problem, and these formalized versions make it easier to see what operations the methods involve and which assumptions may be necessary for each procedure.

Together the assumptions form the C set of statements discussed in Section 3.1. These will be compared for all methods in Section 12.4.

9.2 METHOD I: SINGLE LU OBJECTIVES AND ADAPTIVE CONSTRAINTS

In Section 8.2, we discussed two versions of a method proposed by Geoffrion and Hogan, which I will refer to as the GH method (Geoffrion and Hogan, 1972). The heavy demands on information that this method involves and the fact that CU was required to accept LU preferences or to assign a unidimensional objective to each LU, raised some problems.

In the GH method CU control is exercised through a vector $\underline{y}$ which Geoffrion and Hogan interpret as resource allocations. Even if CU is unable to state single LU objectives (which would imply almost a preferences-first approach), it might nevertheless be willing to indicate such objectives provided it could add some constraints on attribute values, and provided it would later be allowed to revise these during the planning process. During planning the LU objective would thus be an assumption and if the maximization of this "objective" results in unacceptable values for certain attributes, then CU can exert a direct influence on the values concerned.

Could such constraints be added to the GH method, thus reducing one of our objections to it? The resulting procedure would still make demands on information that we find unacceptable, but it could perhaps be regarded as a formalization of an approach to the planning problem which in itself seems fairly realistic: the allocation to each LU of a main task, together with certain constraints. The main task cannot be pursued regardless of its side effects, but these are constrained mainly by means of central directives which are adapted in the light of possible plans.

9.2.1 Adaptive constraints and optimality

In the GH method organizational efficiency and effectiveness are achieved as a result of the one-objective-per-LU assumption. LU efficiency becomes identical with organizational efficiency, and effectiveness results from the balance between LUs that CU achieves, using resources to improve or lower the value of their performance. In such a case an optimal resource allocation will automatically lead to effectiveness. CU shifts resources between LUs, noting how its own preference value will change as a result of changes in LU fulfilment of objectives.

If CU asks for a specification of the values attached to the variables, we could say that CU is determining the levels of some attributes in the LU attribute vector $\underline{f}^i$, instead of limiting its interest to some element f_i or a function $L_i(\underline{f}^i)$ (cf. Section 8.2). This implies that the situation deviates from the one assumed by Geoffrion and Hogan. A desire to constrain individual attributes of LU plans presupposes that at least one organizational objective depends on more than one LU (without being separable into main LU tasks), or that there are other objectives apart from the main LU tasks. In this way the argument put forward in Section 5.3 becomes relevant, and CU no longer has a guarantee that objectives and constraints will yield an optimal plan.[1]

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[1]The situation resembles that described in Krouse (1972), which includes target values for LU attributes that are relevant to objectives other than those assigned to the LUs in question. This is based on identifiable interdependencies and explicitly known preferences.

Let us consider an example based on the situation shown in Figure 5:1. For various reasons the main task of LU 1 is profit maximization, while that of LU 2 is sales (revenue) maximization. As LU 1 also has an impact on sales and LU 2 on profits, CU tries to constrain their plan choices by announcing a sales value for LU 1 and a profit value for LU 2. If the preferred plan combination is B+E, then we need to know the LU 1 sales level and the LU 2 profit level.

The added constraints would thus require some changes in the GH method so that the constraints would be set correctly. There are various ways in which this could be attempted.

One way would be to include the constraints in the CU control vector $\underline{y}$, requiring the LUs to include derivatives for these "new" $\underline{y}$ elements in their reports as well. But the "new" elements differ from the "old" resource-allocation elements: a change in the new elements is not linked to any common constraint, thus forcing CU to make the opposite change in other $\underline{y}$ elements; instead it has a direct impact (via the H transformation of formula 4-10) on some organizational objective which has not been assigned to any LU as its main task. The GH method for $\underline{y}$ revision would therefore have to be changed, so that these "direct" benefits from constrained attributes could be taken into consideration when constraints are being chosen. This would probably be possible but the need for information would obviously be considerable. For this reason, I do not suggest this kind of method here.

Another way would be to leave the GH method as it is, but to supplement it with informal considerations in the form of constraints. This would probably be feasible, at least when the constraints concern matters of general policy and are somewhat separate from the main tasks of the LUs. Planning in accordance with GH could then start with one set of constraints, which is changed in an informal way when the results of planning become available.

As an example, let us consider a multi-LU firm where each unit has a main task, and CU wants to balance these against some other objective such as to provide employment, which is not any one LU's main task but which is affected by several LUs. By announcing a trial constraint for each LU, CU can keep a check on the LU's pursuit of this additional objective. When changing the constraint later, CU will benefit from what it has learnt about organizational possibilities and preferences from these interactions.

Although such changes would be informal, the LUs could try to provide some information about their impact. In this way, CU could get to know what someone has called "the price of its values", and could judge how much sacrifice in terms of main tasks seems relevant. Thus this approach differs from the first one in that no attempts is made to find a formal algorithm for changing resources and other constraints together; instead we let the GH process be combined with more or less informal changes in constraints. There is then a risk that the process will not converge. However, CU would only apply constraints when an unconstrained GH process does not seem likely to yield acceptable plans because of its failure to take all objectives into account. In this case the approach should represent an improvement.

To summarize: Planners would be provided with an imperfect objective and some constraints (not only resource constraints) that could be revised in later iterations. This has obvious parallels in real-life planning, which is why the method has been included in this study.

The informal constraints added to the GH method do not guarantee organizational efficiency. However, if they have the "general-policy" character envisaged above, organizational efficiency and LU efficiency should not be too far away from each other. Organizational effectiveness is achieved mainly by influencing the fulfilment of main tasks by means of resource allocations, but also partly by changing the constraints. Resource allocations are improved by using the Geoffrion-Hogan method. (Cf. also Table 8:1.)

9.2.2 Choice of main tasks and constraints

Targets and constraints can be used in different ways to influence local choices. Some of these ways are discussed in Appendix C. Where an important aim of budgetary planning is to encourage efficiency (cost minimization for a given performance, etc.), the use of constraints seems to be very widespread. Examples can be found in the Swedish defence organization (Section 14.2, below) and in other sectors of the public administrations. In business planning they are often used for objectives such as liquidity, personnel turnover, etc., instead of a "full" multiobjective dialogue. Similar reasoning can also be found in theories of national planning (Chapter 10; Kornai and others).

Constraints that change during planning have obvious connections with the concept of aspiration levels (Simon, 1955). Their use in a multiobjective organization would benefit from some guiding principles, or a logical procedure, even if it is impossible to decide constraint levels by any formal method.

Rules for selecting LU objectives and constraints are seldom given in the theories presented in the literature. Discussions of internal transfer pricing (e.g. Arvidsson, 1971) and programme budgeting (cf. Section 2.2) provide some guidance. Obviously the simplest way is to choose one LU-plan attribute as the objective of that LU, and set constraint values for all other attributes.

The choice of initial constraint values is important, particularly because it affects the length of the necessary adjustment cycle. With the few iterations that are available, it will also affect the quality of the solution. This is particularly important, if the rules for changing the constraints are imperfect.

Some attributes can be constrained at identical levels for all LUs, while others may have to be differentiated between LUs to reflect differences in potential. For instance, profit constraints would probably reflect the assets of the LUs (return on investment).

As mentioned above, the job of changing constraints is not without its problems. The already heavy demands on information from the LUs become even greater, as CU tries to discover the effects on LU objectives of changes in the constraints.

9.2.3 Verbal statement of method I

Step 1. CU identifies an objective for each LU's planning, together with such constraints[1] as CU believes will make it acceptable for the organization that the LU plans for this objective only. An initial resource allocation is also determined on the basis of experience. The objective, the constraints, and the resources all serve as planning assumptions in a first iteration.

Step 2. Each LU plans in accordance with the information generated in Step 1. If the constraints do not allow for any feasible solution, CU has to reconsider them before Step 2 can be executed.

Step 3. As mentioned above, organizational efficiency would result only if CU preferences can be divided perfectly into parts assigned to the LUs. The need for constraints and the single LU objectives together indicate that this is not the case. CU therefore has to choose constraints in such a way as to approximate organizational efficiency. No formal rules for this will be given here, but it can be noted that at this stage CU should be able to get some information on possible "voluntary tightening" of constraints.

Step 4. Every LU communicates its solution to CU, together with any available indications of the effects of changes in resources and constraints.

Step 5. CU may find it worthwhile to explore the present resource allocation further, for instance if the

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[1] Targets could also be used, by following techniques similar to those applied in goal programming, cf. Appendix B.

LU reports at Step 4 show possible improvements from a change in constraints that are more advantageous than the improvements from a change in resource allocations. In this case constraints are changed and the process returns to Step 2. Otherwise, continue to the next step.[1,2]

Step 6. CU alters the resource allocation (and possibly the other constraints), basing its decisions on information derived from Step 4. Then return to Step 2. If CU does not believe that a better resource allocation exists, it continues instead to the next step.

Step 7. CU confirms the final plans, announcing their resource values and LU-attribute values if necessary.

9.2.4 "Formalization" of method I

The steps described in Section 9.2.3 can be formalized in different ways. As I explained in Section 9.2.2, I am not going to attempt to give formal rules for CU's control constraints. Nevertheless, I find the following rather more formal expression helpful, in relating the method to the model described in Part One.

Step 1. CU: Identify one attribute in each LU-attribute vector $\underline{f}^i$ which the LU in question is to maximize. This attribute will be written f^i_t (or more precisely $f^i_{t(i)}$). Decide realistic values for the constraints:

$$ {}_{*}\bar{f}^i_j \le f^i_j \le {}^{*}\bar{f}^i_j \;, \; j \neq t, \; i = 1, \ldots, m \qquad (9\text{-}3)$$

for all attributes that CU wants to influence. Probably only lower or upper bounds will be considered relevant for any particular attribute. Also decide a resource allocation $\bar{\underline{y}}$. Announce $t(i)$, ${}_{*}\bar{\underline{f}}^i$, ${}^{*}\bar{\underline{f}}^i$, and $\bar{\underline{y}}$ to the LUs.

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[1] "Stopping rules" are intentionally given a vague form. I can only suggest subjective rules for Step 5, while Step 6 will obviously depend on the number of available iterations, and the satisfaction achieved.

[2] As in Step 3, the changes in constraint of Steps 5 and 6 have not been given as formal rules.

Step 2. LU: $\max\limits_{\underline{x}^i} f_t^i(\underline{x}^i, \bar{\underline{y}})$, s.t. $\underline{g}^i(\underline{x}^i, \bar{\underline{y}}) \leq 0$ (9-4)

and constraints (9-3) above. If no feasible solution exists, CU must first repeat Step 1. Otherwise, continue to Step 4.

Step 3. For reasons discussed in Section 9.2.2, no rules for this step are given here.

Step 4. LU: Communicate to CU the values of f_t^i and $\underline{g}^i$, and their derivatives with respect to $\underline{x}^i$ and $\underline{y}^i$ at the proposed point, and also the derivatives of f_t^i with respect to $_{*}\bar{\underline{f}}^i$ and $^{*}\bar{\underline{f}}^i$.

Step 5. CU: Combine the LU plans received, in order to establish organizational performance. If some of the $\partial f_t^i / \partial\, ^{*}\bar{f}_j^i$ or $\partial f_t^i / \partial\, _{*}\bar{f}_j^i$ received indicate trade-off opportunities that seem attractive in the current situation, change the corresponding constraints by a small amount. Then return to Step 2. If no changes in constraints seem needed, continue to next step.

Step 6. CU: Use the GH method to change $\bar{\underline{y}}$. This involves:

- Judge all $\partial P/\partial u_j$, and derive from these all $\partial P/\partial f_t^i$
- Apply GH algorithm to these and the LU information on f_t^i, $\underline{g}^i$, and their derivatives (see GH for details). This gives the direction of the steepest-ascent change of $\underline{y}$ from $\bar{\underline{y}}$, $\overline{\Delta \underline{y}}$.
- Decide a suitable step-size for $\overline{\Delta \underline{y}}$
- Compute a new $\bar{\underline{y}}$ as the old $\bar{\underline{y}} + \overline{\Delta \underline{y}}$.

Then return to Step 2. If no change in $\bar{\underline{y}}$ is desired, go to next step. (On stopping rules, see note 2 to Section 9.2.3.)

Step 7. CU: Announce the final budget as the $\underline{f}^i$ and the resource allocation from Step 4.

9.2.5 Assumptions

This formal statement of my version of the GH approach would require the following:

- Inclusion of the assumption, introduced in Section 5.2, that resources represent a precondition for planning
- When supplied with additional constraints on the feasible set and the identification of one of its attributes as its "main task", the LU can find the plan which leads to the maximum value on the attribute so identified.
- It is possible for all LUs not only to estimate the values of their own attributes, but also:
  - to find out whether or not each constraint on the feasible set is binding
  - to calculate the derivatives of its main task with respect to activity variables and central-control variables
  - to calculate the derivatives of the LU-constraint variables with respect to activity variables and central-control variables.

(These requirements could perhaps be summarized equally well as follows: LUs have to have a mathematical model of their performance possibilities, their activities, and the way these depend on control variables.)

- CU has to be able to:
  - formulate unidimensional LU objectives
  - provide constraints which make single-objective LU planning acceptable
  - change the constraints, using LU trade-off information
  - estimate marginal rates of substitution between objectives
  - use GH techniques for changing resource allocations
  - decide whether planning should be continued.

If it is not possible to use the GH method because of lack of data (CU estimates of MRS, LU estimates of derivatives etc.), approximations of the procedure still require that the LUs:

- Can take central constraints into account as well as local ones
- Can maximize for selected attributes
- Can give some indication of how a proposed plan could be changed in the case of slight changes in resources allocations and/or central constraints,

and that CU:

- Can select one attribute for each LU to maximize
- Can use information from the LUs about proposed plans and expected results from changes in constraints and resources, in deciding these changes.

9.2.6 Discussion

This version of GH seems to present formidable problems on account of its extensive information requirements, particularly because CU has been given more opportunities for influencing LU choice by means of adaptive constraints than in the original. Considering the small number of iterations available in real-life planning, it seems unlikely that it could ever by fully implemented. And in view of the lack of revised decision rules, even then it would not lead to the optimum $P(\underline{u})$.

Where formal models of possibilities are available, such as in budget simulation, a decentralized solution like this would probably anyway be unnecessary. Such models could solve the LU-information problem but would still leave us needing a CU which could provide utility trade-offs (MRS estimates) for each solution presented.

There remains the possibility of approximating the basic sequence of steps in an informal way.

This method shows how our problem can be converted into constrained single-objective optimization for each LU. This kind of approach seems to me to have practical relevance, as do the "adaptive constraints" which it generates. For these reasons I decided to include the method in this study, in spite of the reservations I have mentioned concerning its usefulness as a formal method.

9.3 METHOD II: MRT APPROXIMATIONS AND IDEAL POINTS

In Chapter 8, it was found that the "ideal-point" multi-objective methods could not be easily adapted to a decentralized planning situation. In this section a method will be presented in which heuristic elements are used to attack the problems raised in Section 5.7. The method is based on the structure illustrated in Figure 5:5. As the main advantage of the ideal-point methods is the simple character of the responses required of the decision-maker (here CU), the heuristics have been designed to preserve this simplicity.

As before, it is assumed that the attributes have been chosen before planning starts. The three questions asked in Section 5.7 are answered in the following ways:

Organizationally efficient use of resources: We found in Section 5.3 that this involves equal marginal rates of transformation for all LUs between pairs of attributes that correspond to the same objectives, provided attribute changes in all LUs are valued equally by CU. This means that by introducing some necessary assumptions (see Section 9.3.3 below), we can use MRTs to achieve efficiency.

Effective use of resources: This involves CU preferences. In order to avoid demands for preferential trade-offs between objectives, an "objective to be relaxed" as in the ideal-point interactive methods is used.

Optimal resource allocation: Lacking the CU preferential trade-offs that would enable LUs to estimate a unidimensional value for an increase in resources, we have to use the latest MRT values as an approximation.

A practical example of such a planning process could be as follows: CU sets infeasible "ideals" as a first indication of a desirable mix of objectives, and later "freezes" one objective at a time at the lower levels that turn out to be possible as planning proceeds. Responsibility for the objectives is relocated between LUs according to their reported trade-off opportunities. The latter are also used to reallocate resources.

9.3.1 Verbal statement of method II

Step 0.[1] Each LU finds its ideal point (cf. Section 8.3), assuming a favourable resource allocation.

Step 1. The CU decides upon a resource allocation, based on the revealed potential of the LUs. If possible, it should also assign planning targets to the LUs, based on the ideal points.

Step 2. LUs use CU targets and/or their own preferences in selecting a first proposal, which must be possible within the proposed resource allocation.

Steps 3 and 4. LUs estimate trade-offs (note, "technological" not preferential, i.e. MRT rather than MRS[2]) at the proposed points. For each objective pair, the CU receives information on the corresponding trade-off opportunities in all LUs and suggests suitable changes until trade-offs for all LUs are approximately equal.[3]

Step 5. If the combined organizational plan is not considered by CU to incorporate the best balance between objectives, all LUs will be required to reduce fulfilment of one objective by a specified amount. The objective will be selected by CU, and the required reduction in the value

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[1] This step was not included in Figure 5:5. Other step numbers are taken from this figure.

[2] See also note 1, p. 104.

[3] This could also be achieved through direct contacts between LUs: cf. Jennergren's "profitable trades", which here concern contributions to objective fulfilment. (Jennergren, 1971, pp. 53-55)

of the corresponding attribute becomes a constraint on LU planning. The LUs find new plans, whereupon Step 5 is repeated. If the reduced attribute generates only negligible improvements in other attributes in any one LU, that LU should stick to its earlier plan.

Step 6. If CU believes that the combined organizational plan could be improved by trying another resource allocation, the LUs are asked to state how much their resource requirements would change as a result of a slight (specified) increase or reduction in performance (evaluated with the help of the trade-offs in Step 4). Resource allotments are then changed in accordance with these values, and a new iteration from Step 2 follows.

Step 7. The final plan is announced when CU finds (in Step 5 or 6) that further iterations are either unnecessary or impossible.

9.3.2 "Formalization" of method II

As in the case of method I, the computational rules suggested here are not the only ones that could be used to implement the above approach. Furthermore, in this case they are not motivated by any formal algorithm but have been chosen as possible rules which require few assumptions about the abilities of the units.

Step 0. LU: $\max\limits_{\underline{x}^i} f_j^i(\underline{x}^i, \underline{y}^i)$ for $j = 1, \ldots, n$ (9-5)

$\underline{y}^i$ = a $\underline{y}$-value which LU i considers favourable but realistic

Communicate the maximal elements f_j^i.[1]

[1] If the initial resource allocation is to be decided according to the formula in the note to step 1 below, all $\underline{f}^i$ values that contain some maximal f_j^i should be communicated.

Step 1. Decide a resource allocation $\bar{\underline{y}}$ and communicate it.[1] If possible, CU should also provide a target for LU planning. The use of targets is discussed in Appendix C. The ideal point $\underline{f}^{i*} = (f_1^{i*}, f_2^{i*}, \ldots, f_n^{i*})$ of LU number i could serve as its targets, but CU should reduce the f_j^{i*} values if it seems obvious that lower values are sufficient. The decided targets $\bar{\underline{f}}^{i*}$ are communicated to LUs.

Step 2. LU: $\underset{\underline{x}^i}{\text{Min}}\ L_i\left[\underline{f}^i(\underline{x}^i,\bar{\underline{y}}),\ \bar{\underline{f}}^{i*}\right]$, s.t. $\underline{g}^i(\underline{x}^i,\bar{\underline{y}}) \leq 0$ (9-6)

The L_i functions measure the distance from the target $\bar{\underline{f}}^{i*}$, for instance as the distance:

$$L_i = \sum_i \left|\bar{f}_j^{i*} - f_j^i(\underline{x}^i,\underline{y})\right| \qquad (9\text{-}7)$$

If no $\bar{\underline{f}}^{i*}$ has been given in Step 1, the LU can use the unrevised ideal point $\underline{f}^{i*}$ which it will know from Step 0.

Step 3. LU: Find $\partial f_j^i/\partial f_1^i$ at the solution point from Step 2. Communicate these trade-offs (MRT:s) to CU.

Step 4. (a) CU: Calculate the average MRT:s as a "price vector" $\bar{\underline{p}}$, where

$$\bar{p}_j = \frac{\sum_i (\partial f_j^i/\partial f_1^i)}{m}, \quad j = 2, \ldots, n \qquad (9\text{-}8)$$

(b) LU: $\underset{x^i}{\text{Max}}\ \bar{p}'\underline{f}^i(\underline{x}^i,\bar{\underline{y}})$, s.t. $\underline{g}^i(\underline{x}^i,\underline{y}) \leq 0$ (9-9)

where $\bar{p}'$ is a row vector. Communicate the solution.

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[1] This could be based on experience. Otherwise, each LU could receive, for instance, the relative share of resources that corresponds to its average potential contributions to the objectives, i.e.

$$\bar{y}_i = \frac{\sum_j \dfrac{f_j^{i*}}{\sum_i f_j^{i*}}}{n} \cdot \sum y_i, \qquad i = 1, \ldots, m$$

where f_j^{i*} is LU number i's value for attribute j of its attribute vector if it optimizes for this attribute, n is the number of attributes, y_i are the resources aloocated to LU number i, and $\sum_i y_i$ are total resources. It is assumed that there is only one type of resources, cf. Section 5.2.

Instead of involving CU, the LUs can achieve a similar result by trading among themselves. The present formulation seems more convenient.

Step 5. (a) CU: Find the $\underline{u}(\bar{\underline{y}})$ vector resulting from the solutions in Step 4 (b). If this is satisfactory for resource allocation $\bar{\underline{y}}$, go to Step 6. If not, select one objective r for which a slight reduction in value could be accepted, provided other objectives are unchanged or improved. Constrain f_r^i to be for instance 95 % of its earlier value, for all i.

(b) LU: Repeat Step 4 (b), but with the r constraint from Step 5 (a) added to the $\underline{g}^i$ constraint vector. Communicate the new solution and repeat step 5 (a).

Step 6. (a) CU: If the $\underline{u}(\bar{\underline{y}})$ value resulting from the last LU plans is considered satisfactory as an organizational plan, go to Step 7. If not, go to Step 6 (b).[1]

(b) LU: Find the per cent change s_i in alloted resources $\bar{y}_i$ which makes possible a performance improvement of five per cent (an arbitrary figure, but the same for all LUs) as evaluated by formula (9-9). The constraints from Step 5 should no longer be used here. If it is easier to evaluate a disimprovement, this could be used instead. Communicate s_i.

(c) CU: Calculate $\overline{\Delta y}_i = k(\frac{\Sigma s_i}{m} - s_i)$, where k is a small number.

LUs that have not received any resources before have to be handled specially, as do cases where a negative $\overline{\Delta y}_i$ could lead to negative allocations. A new allocation $\bar{\underline{y}}'$ is found as $\bar{\underline{y}} + \overline{\Delta \underline{y}}$ and communicated, and the process returns to Step 2.

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[1]No formal stopping rules are proposed. In a planning situation with 2 - 5 iterations, such decisions will probably remain intuitive.

Step 7. CU: Announce the final values of $\bar{\underline{y}}$ and $\underline{f}^i$ as the budget for the next period.

9.3.3 Assumptions

Method II uses the two simplifying assumptions from Section 5.2.

In addition to the assumptions of the basic model about the relation between objectives and attributes (A26 - A27), one more statement is needed:

- If an LU makes a change of a certain magnitude in the attribute corresponding to a particular organizational objective, the impact on that objective will be the same regardless of which LU institutes the change (cf. Section 5.4).

The rest of the assumptions that have to be added to our original model all concern the abilities of CU and the LUs. As no advanced computations are required, all assumptions deal with the information that can be provided.

- We assume that CU
  - can adjust LU ideal points to serve as targets (or accept them unadjusted)
  - can react to a proposed total organizational plan by selecting the objective which has been most adequately met so far
  - can judge whether or not better plans should be sought for a certain resource allocation
  - can judge whether or not better resource allocations should be sought.

In view of the small number of iterations available, the last two points would probably require some assistance which is not part of the method.

- We assume that an LU:
  - can find the ideal point
  - can use this point, or the CU target, for choosing a plan that comes close to the ideal

- can find technological trade-off possibilities between attributes at the proposed points
- can use given attribute prices in choosing a plan[1]
- can incorporate constraints on some attributes in its planning.

9.3.4 Discussion

Method II is an attempt to use the approach of the ideal-point multiobjective methods (see Sections 8.3 - 8.4) for handling the problems described in Section 5.7, with the necessary addition of heuristics. The method is considerably less precise in its details than method I, based on Geoffrion and Hogan. At this cost we have arrived at a procedure which makes far less controversial demands on the central and local units. There may seem to be an excessive number of steps compared with usual budgetary procedures, but in practice some of the steps could of course be further approximated.

The main difficulty will probably be to find technological trade-offs between objectives. The need for an ideal point, and for a CU target derived from it, raises fewer problems, since the choice of plan cannot be very sensitive to estimation errors.

The problem of stopping rules, i.e. CU's ability to choose between further iterations or continuing to the next step at Steps 5 and 6, has its counterparts in all methods. Rules that have been suggested include one stating that improvements should diminish at each iteration until progress comes to a more or less natural stop (see Ljung and Selmer, 1975, pp. 97 ff, for heuristic rules). It is doubtful if this rule could be applied in a budgetary-planning situation; instead, however, CU is sure to have

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[1]Note that an ability to perform Step 6 (b) follows from this and from the assumption that LUs can find efficient plans for every resource allocation (A25).

certain expectations about the benefit further iterations should yield.

Enforcing CU preferences by five-per-cent reductions in selected attributes, as in Step 5, has its risk. There is no guarantee that the right LUs will be affected by the cuts, and the cuts themselves could prove too extensive. If CU is doubtful, it could of course choose a lower percentage; it should also perhaps be possible to reverse the cuts if other attributes do not improve as expected. The last of these problems arises in the STEM method as well. Further heuristics could be suggested: for instance, letting some LUs stick to their previous plans if the cuts do not "pay off".

Given "well-behaved" forms of the functions, the process will probably converge. Non-convergence could only result from loops involving Step 5 or Step 6. In either case, CU will only accept LU plans that result in an organizational plan which is an improvement on previous plans. With the functional forms relevant here, such improvements are certainly not unlimited. If improvements cease, the process will of course be terminated.

It seems somewhat irrelevant to discuss convergence, when we only have between two and five possible iterations. Unfortunately we cannot predict what values to expect at the end - using this or any other methods - except by means of extensive simulations.

9.4 SUMMARY

In this chapter we have examined two procedures based on the interactive methods presented in Chapter 8. The first of these was based on the Geoffrion-Hogan method. It represents a formal version of the practical solution of supplying each LU with an objective, together with constraints derived from other objectives. While the basic philosophy here is obviously relevant to many planning situations, the Geoffrion-Hogan method would require a considerable amount of data that could probably only be procured if a formal model existed of each LU's activities and of the impact of these activities on objectives. In such a case, planning could just as well be centralized. Also, CU has to provide MRS estimates.

The second method presented here is based on some of the fundamental ideas of ideal-point methods, supplemented by various heuristics. The resulting procedure, whose efficiency is as yet untried, does at least seem to offer an orderly way of handling our present planning problem. It demands less sophisticated estimates than the procedure based on Geoffrion and Hogan. Its basic philosophy is also different: instead of converting each LU situation into constrained unidimensional optimization, the dialogue explicitly concerns multiple objectives, and the only "price vector" used is derived from technical trade-off possibilities, rather than from preferences.

10. ADAPTATION OF METHODS FOR DECENTRALIZED PLANNING TO MULTIOBJECTIVE ORGANIZATIONS

10.1 INTRODUCTION

A short introduction to the literature of economic planning was given in Section 7.3, based mainly on Hurwicz (1973) and Jennergren (1974). It was concluded that two approaches should be attempted for our planning problem as presented in Part One above: the "central-approximation-of-local-possibilities" approach represented by Weitzman (1970), and a variant of price decomposition. In this chapter we will examine these two alternatives in more detail, as a preparation for the presentation of methods III and IV in Chapter 11.

The reader is reminded that my present intention is not to contribute to the theoretical literature. The reason for discussing these methods is that they add two distinct cases to the two philosophies of multiobjective planning already represented by methods I and II. All four will be summarized and compared in Chapter 12.

10.2 BUILDING A CU APPROXIMATION OF ORGANIZATIONAL PERFORMANCE POSSIBILITIES

In our basic model, and in the two methods described in Chapter 8, CU has almost no knowledge of LU possibilities before planning starts. In method I, the CU is only required to find a main task for each LU and some constraints, which can be rather "loose" at the outset. Method II requires literally no such knowledge on the part of CU: a target is derived from what the LUs know about their own possibilities.

But there is an important planning philosophy that runs counter to this: CU does have ideas about what should be possible, and planning is mainly concerned with lowering these expectations until agreement is reached. In other words CU's knowledge of the feasible set improves. One of the better-known proponents of this approach is Weitzman (1970). In several important respects, his discussion resembles our model formulation more than most planning theories do.

Weitzman's CU (which in his case is a central planner dealing with the firms in an economy, rather than with local units) has implicit knowledge of a social-welfare function or utility function, which is defined over the goods that can be consumed.

The arguments of the CU utility function are the sums of all firms' production quantities of each good, augmented by the initial stock of this good. The function is assumed to be continuous and defined for all production values, but it is not restricted to being concave. The CU also has some idea about the possibilities of each firm, perhaps based on the previous year's production. The firms (LUs) know their own production possibilities implicitly, being able to find relevant plans on the efficient frontier "if they were asked to do so in an operationally meaningful way" (Weitzman, 1970, p. 53).

If we compare this with our situation and translate it into our terms, we find that a firm's production of a good corresponds to an LU's attribute value. Furthermore, the fact that CU preferences are defined over aggregated quantities means that the corresponding case for our model would be one of additive attributes, which together would provide an objective value for the organization. This is one of the additional assumptions that would be needed to bring our model into line with Weitzman's.[1] Also Weitzman

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[1] It will be remembered that additivity was introduced in Section 5.2 for the diagrams only.

assumes that CU has some knowledge about each firm's possibilities - it is "acquainted with at least a broad picture of current possibilities" (Weitzman, 1970, p. 54).

We could even claim that Weitzman's model uses a multiobjective formulation, as knowledge is assumed to be implicit. However, it does not provide any assistance to CU in using this implicit utility function; the assumption is that although the function is implicit, it can be used in some unspecified way in choosing the preferred plan among those believed to be possible.

It is assumed by Weitzman that CU's initial approximation of the feasible sets will be too optimistic and will overestimate the possibilities. This means that a first set of production targets decided by CU (a production plan for each firm, given in terms of product quantities) cannot be fulfilled. For each firm, a target such as C in Figure 10:1 leads to a response from the firm in the form of a proposed feasible plan, i.e. one on the p-p curve AA. (Weitzman gives reasons for restricting search to this curve segment. See Weitzman, 1970, pp. 56-57.) If the firm considers B to be the feasible plan "nearest" to C, it should respond by communicating B and its price vector $\underline{p}$ to CU. CU can use this information to exclude all points outside TT from its approximation of the firm's possiblities. If it is not satisfied with B, it can then propose a new target from the reduced approximation of possibilities.

A firm's choice of one plan on AA could be reached in various ways. Weitzman calls a rule of Euclidean distance to C "needlessly difficult" (1970, note to p. 56) and recommends that the prices implied by the central choice of C should be passed on by CU to guide the choice of plan in the LUs. Thus information about both targets and prices would be communicated in both directions. But Weitzman also shows that any point on AA (i.e. what he calls efficient with respect to the target C, or C-efficient) will be acceptable in his method.

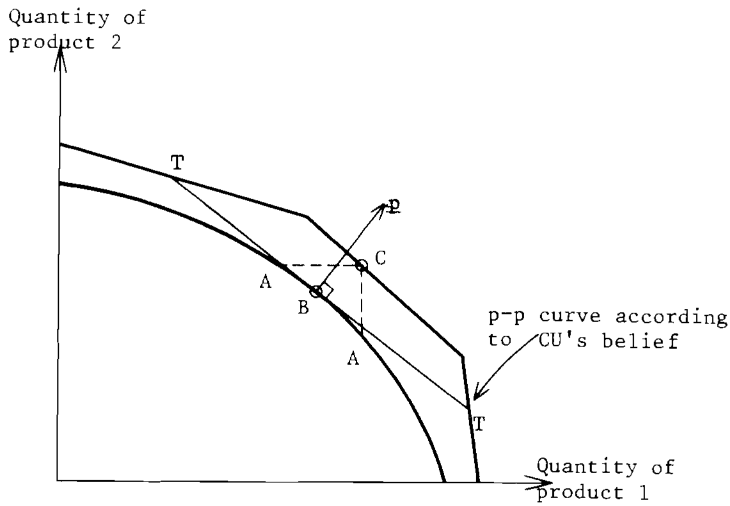

Figure 10:1. For an over-optimistic target C, a feasible point somewhere on the curve segment AA should be chosen, for instance B. This implies a price vector p which also identifies the tangent plane TT. (Adapted from Weitzman, 1970, p. 55.)

If we translate this model into terms of performance rather than production, do we achieve a method that can solve the three problems posed in Section 5.7? First we must note the additional assumptions of Weitzman's model: some CU knowledge about LU possibilities, and additive attributes.

On the other hand, Weitzman treats central resources as additional products, whose LU production values can assume negative values in the case of resources. This means that the assumptions we accepted in Section 5.2 are not relevant here. Although Weitzman's model deviates on this point from the other procedures (and from the structure in Figure 5:3), I do not see any reason to bring it into line with our assumptions here.[1] CU issues targets for LU's

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[1]This could probably be done, but I do not want to change Weitzman's formulation in this respect, as I keep close to it in others. CU would still determine the resource allocation in the same way, as it expects its target to be feasible. The difference lies in whether LUs are allowed to violate the target or whether the target acts as a constraint. The problem of not using the target as a constraint, is that LU plans need not add up to a feasible total plan.

use of resources, and these fulfil a function very similar to trial resource allocations. The difference is that, in Weitzman, LU proposals that come close to the target may involve exceeding the target for use of resources.

Does the Weitzman process, interpreted in this way, lead to organizational efficiency? It does, given the rule suggested by Weitzman whereby CU provides the price vector implied by the target proposals. With additive attributes, this leads to equal MRTs in all LUs. By means of the gradually improved CU estimates of LU possibilities, it also leads to organizational effectiveness, since the balance between products or objectives will ultimately correspond exactly to CU's choice. At this late stage of convergence, both these conditions will be fulfilled for arbitrary LU choice among what Weitzman calls C-efficient points as well. The resource allocation problem is not relevant here, as resources are treated as additional attributes.

A negative aspect of the method for our purposes seems to be its information requirements. Weitzman claims that the formal procedure could be approximated by verbal descriptions in an institutional setting, if that served to "correct the center's exaggerated notion of their /the LUs'/ technology sets in a way that leads to convergence" (1970, p. 64). But he does not discuss the problems of choosing targets for all LUs so that they reflect, for instance, the same relative value of products.

It is also difficult to understand how CU's implicit knowledge of preferences works. Can CU really state a price relation, or an MRS value, for the preferred point in what it believes to be the combined feasible set? CU preferences can not give any indication that relates to the sets of individual LUs, so CU would either need some initial approximation of the organization's total set, or it would have to be able to add together its approximations of LU sets. As we have seen in Section 5.3, it is not obvious even with the additivity assumption which points in the LU sets should be combined to find the organizational set.

In addition to this, after a preferred total plan in the believed set has been found, this has to be decomposed into LU plans. This is not very difficult if we use an implied price vector, but in order to do this we have to assume either that because CU has implicit knowledge of preferences it is able to state MRS, or because CU has knowledge of approximate possiblities it can state MRT.

At this point we may well feel that rather too many additional assumptions are being introduced into our original model - Weitzman's notion of implicit knowledge seems to be more extensive than our assumptions. We may feel similar doubts about the LUs, who can provide the price vector implied by their proposals as a matter of course. If Weitzman's model is to be applied to our problem, we would probably have to find ways of helping CU in particular with its choice of targets, or we would have to accept very uncertain estimates.

10.3 PRICE AND QUANTITY DECOMPOSITION

10.3.1 Price decomposition

The basic framework of the methods that involve the price decomposition of the total planning problem has already been presented in Sections 6.3.1 and 7.3. In the original price-adjustment methods, LUs respond to CU prices by demanding certain resources, whereupon CU changes the prices in proportion to the excess of demand over available resources. The Dantzig-Wolfe algorithm has also been applied to this type of problem.[1] A much-quoted method belonging to this group is to be found in Malinvaud (1967). Weitzman regards his production-target approach and Malinvaud's price approach as in several respects each other's duals (Weitzman, 1970, p. 62).

Malinvaud's method, like most price-governed planning methods, assumes a more restrictive form of organizational

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[1] Cf. Section 6.1.1. Dantzig-Wolfe's algorithm can be said to involve a local CU approximation of possibilities, based on gradient information from the LUs. This should be compared with Weitzman's method (Section 10.2).

objective than Weitzman's. This places the method even further from our multiobjective situation, since there would probably not be a valid linear objective formulation if CU felt that multiple objectives were necessary (cf. Chapter 6 above).

A price-decomposition planning method for quadratic objective functions has been developed by Hass (1968). According to this method, the contributions of individual products to the organization's profit can depend on the quantities of these and other products, perhaps reflecting imperfect competition in the organization's markets. This means that CU cannot quote separate prices for each product as planning guidelines for the LUs. Instead the LUs are given "demand curves", where the value to the organization of additional units of a product is expressed as a function of the total quantity produced. If necessary, the function for a demand curve will include a term showing the effect of interdependencies with other products.

If this formulation is used, CU will have to know the demand relations between products. This may be possible in Hass' model, which deals with the product line of a decentralized organization, but if we try to equate the quadratic objective function with the implicitly known preference function of our model, the assumptions necessary appear forbidding.

Hass uses linear constraints for his feasible sets. The problems connected with price-guided resource allocation in a completely linear economy has been discussed by many authors (see Jennergren, 1971, p. 37 ff., for references). Furthermore, this case can result in price schedules rather than prices, i.e. prices that depend on the quantities included in plans.

10.3.2 Allocation decomposition

According to Jennergren's survey (1974, pp. 70 ff.), an alternative to price allocation in decomposing the total problem is to use tentative allocations of central resources.

This is a dual formulation to the one considered earlier, because now the LUs evaluate the marginal utility of resources with reference to their objectives. The LU objectives obviously have to reflect the organization's objective, and an explicitly recognized organizational objective function becomes necessary. This means that complete reliance on this approach is only relevant in the case of a preferences-first strategy. On the other hand, the assumption (see Section 5.2) that resources have to be a precondition for planning means that we use allocation decomposition as <u>part</u> of our various methods.

Among the supporters of this approach is the Hungarian economist Kornai, who also discusses the relation between formalized planning and objectives that change or are incompletely known. I will examine some of Kornai's views on planning below, although no method will be based explicitly on Kornai's work here. On the other hand, his views do provide direct parallels with our present planning problem. (See also Section 6.2 above.)

Kornai has extensive practical experience from national planning in Hungary. The best-known method which he has proposed (Kornai & Lipták, 1965) uses CU production targets, and reports from LUs on shadow prices associated with LU optimizations. However, this - like the Dantzig-Wolfe method - was found too slow in practice (Kornai, 1975, p. 447), and a "naive heuristic variant of the Dantzig-Wolfe decomposition algorithm" (Kornai, 1969) was used instead.

In most of the Hungarian planning experiences reported in Kornai (1975), it is assumed that the objective function is known explicitly: cost minimization, with final consumption of various goods as constraints, and with given prices. In the "naive" method, however, alternative local plans were found, which made it possible to have discrete plan alternatives corresponding to <u>different objectives</u> or, in the Hungarian context, different economic policies. These are described as clear-cut optimization of single objectives, such as the trade balance with communist or capitalist countries for example. For each such optimization, it is possible to demonstrate the trade-offs between objectives that result (see Kornai, 1975, pp. 459-460). This integration of exploration of preferences on the one hand and planning on the other is explicitly recommended by Kornai:

> Planning is one of the control processes of the economic system. It is a cognition process, where economic policy-makers and planners explore the possibilities, their own intentions, the consequences of implementing alternative objectives of economic policy.
> (Kornai, 1975, p. 427, note)

Discussing this process in more detail, Kornai suggests that the actual possiblities are never exactly known to the central planners. What they definitely know to be possible is really only a subset of the true feasible set. This can be contrasted with Weitzman's over-optimistic planners (see Section 10.2). The initial situation can be illustrated as in Figure 10.2, where the only available knowledge about preferences has also been introduced in the form of two minimum requirements.

The planners' aim, unlike that of our CU, is here only to satisfy the politicians; thus they can now choose any point on AA. Local planning may then reveal even better opportunities.

The possibilities become increasingly clear as planning continues. This means that the planners or the politicians can revise the minimum requirements. The aim, according to Kornai, is not to find the preferred plan, but rather to generate a large number of efficient programmes for the politicians to react to. The process terminates when the decision-makers consider the identified programme to be satisfactory.

Kornai's conception of planning thus includes a strong flavour of interactive search and learning (cf. Section 6.4 above). For the national planning problems that are his subject, he claims that a complete preference function is impossible (1975, p. 417). As a result some objectives have to be turned into constraints or minimum requirements (1975, pp. 403, 422), which can then be changed in light of the possibilities available.

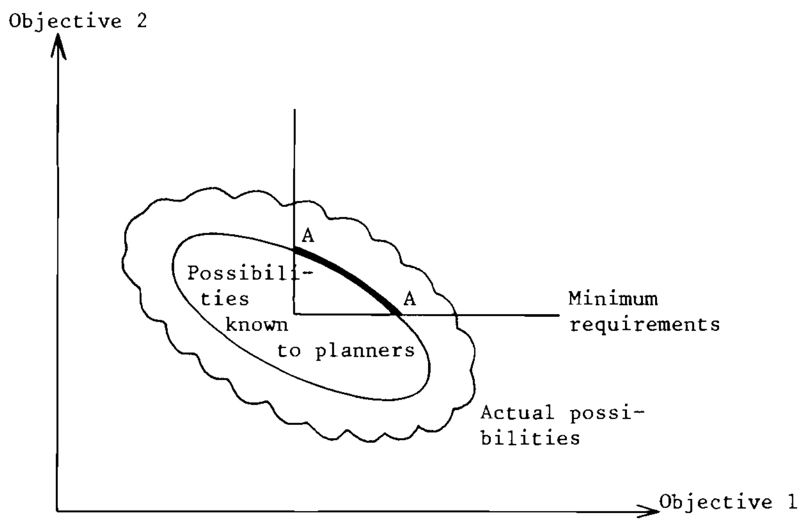

Figure 10:2. As minimum requirements are gradually revised, there will be a range of known possible plans to choose from. (Adapted from Kornai, 1975, p. 420.)

Kornai's discussion of the general role of formal planning has already been quoted in Section 6.2. It would be difficult to use his general argument in the construction of any specific planning procedure. His own suggested methods are obviously intended as part of man-method interaction processes, whereas our methods are attempts to structure such a process in its entirety.

I have reproduced Kornai's views here for two reasons. One is that his general preference for the use of methods to provide decision-makers with alternatives rather than to "solve" their problems, seems worth bearing in mind. The other is that his gradual tightening of minimum requirements has obvious similarities with some of the interactive methods for multiobjective choice reviewed in Chapter 8, and in particular with the approach used in method I (Section 9.2).

10.3.3 Decomposition using prices and allocations

As we have seen, most methods for decentralized planning assume an explicit preference function which can be decomposed and presented to the LUs in the form of prices or quantity targets. The problem caused by our multiobjective situation is the essential indeterminacy of the preferences.

In the case of nonconvex feasible sets, however, even an explicit objective function can yield several solutions. If this happens in an LU, it will not be possible for the LU manager to select the "correct" solution to present to CU. Nonconvexities result from increasing returns to scale in certain products. It is the problem addressed by Heal (1971, 1973). Heal shows that two questions have to be answered: Which resource allocation, and Which product mix? If we read "performance" for "product", we can see that these are similar to our problem, although in our case we have argued that it is the degree of explicit knowledge about preferences which is the problem and not the shape of the functions.

Heal solves the problem by handling each question separately. Resources are allocated by holding the output mix constant, while a unidimensional "worth" is computed for the marginal resources. As a second step, the resource allocation is assumed to be fixed, while the output mix is changed. Heal (1971) shows that the process converges.

Up to now preference-based prices have been avoided in our methods, as they seem to require greater knowledge of preferences than has been assumed in our model. However, as their use is so widespread, one method in which they are assumed to be possible will be included. According to the basic interactive strategy, the prices provided by CU during one iteration represent only a local point on CU's own imaginary preferences function - other prices, as yet unknown, may result from other objective values. Following the basic strategy shown in Figure 5:5, tentative resource allocations will be used.

This brings the approach which we will be using later in method IV directly into line with the method Heal has proposed (although he suggested it for other reasons).[1]

A major addition to our assumptions will be necessary before we can use this approach, or something similar to it. This is that CU is able to provide prices (or MRS) - in Heal's original, for the products in the organizational objective function; in our model, for the objectives that have the corresponding role. The relation between objectives and LU attributes also has to satisfy some additional requirements. In Chapter 11, despite these difficulties, we will look further into the question of what procedure this would lead to.

10.3.4 Concluding comments on price- and quantity-allocation methods

Jennergren (1971, pp. 83-84) in his survey of single-objective planning concludes that three procedures could be recommended:

- "Divisional trading" (Jennergren, 1971, pp. 53-54), a rather informal reallocation of initially allocated resources as LUs find that it benefits their combined result
- The price-adjustment approach, which he recommends mainly in situations where many iterations are possible
- The Dantzig-Wolfe method for decomposition, but this is more complicated and less natural

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[1] Another method that combines information about prices and allocations is the "budget allocation" proposed by Ståhl and Ysander (1968). This differs from our situation in that LU objectives are explicit, but a price list for central resources and a total budget for their purchase are varied by CU. In the assumed one-resource situation (Section 5.2), this is obviously not relevant, but for the case of multiple resources, the similarities could be investigated. However, Jennergren (1971, p. 76) considers the adjustment phase of the Ståhl-Ysander method less clear, regarding it as possibly a special case of price adjustment.

It should be stressed that the Dantzig-Wolfe method can be used for price or allocation decomposition. The price-adjustment approach referred to here is the one defined in Section 10.3.1.

Divisional trading is essentially identical to the MRT equalization used in Step 3 of our method II (Section 9.3). Price-adjustments, although less relevant in the multi-objective case, will be used in our method IV (based on Heal). Dantzig-Wolfe's algorithm will not be used, as our main interest is not the mathematics of planning. On the other hand, rather similar ideas for constructing a CU approximation of LU possibilities form the basis of method III, and are also used in the algorithm underlying step 6 of method I.[1]

The most important ideas embodied in these methods thus seem to have been included in one or other of the methods considered here.

10.4 CONCLUSION: RELATION BETWEEN THE METHODS REVIEWED HERE AND OUR PROBLEM

We have seen that single-objective planning methods can be designed in various ways, combining price and quantity information and using various mathematical methods which we have not attempted to discuss here. Several authors (e.g. Weitzman, Heal) suggest that part of the information used may be known only implicitly to the actors in the planning. Despite this, few of the methods allow much room for a simultaneous exploration of preferences and possibilities, such as we need for the multiobjective problem. Kornai (quoted in Section 10.3.2) mentions the need for such an exploration. He recommends planning with a successive revision of constraints, or a final choice between several alternative economic policies. He does not suggest any

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[1] Geoffrion and Hogan use the Frank-Wolfe algorithm in changing resources (CU control vector value), based on CU MRS estimates and LU reports of $\underline{f}^1$ and $\underline{g}^1$ values and gradients: cf. Sections 8.1 and 9.2 above.

guiding principles for how this should be accomplished. Weitzman's and Heal's proposals go further in that respect, at least if interpreted in "performance" rather than "product" terms.

It is interesting to note the basic similarities between the various multicriteria methods on the one hand (cf. Chapter 8) and the national planning methods on the other. These can be explained in part by the related mathematical techniques that are used. The concordance becomes apparent if we compare the methods of Malinvaud and Geoffrion, both of which explore the feasible set from the inside, with those of Weitzman and Aubin-Näslund, both of which start from the outside.

We also find strong parallels between these planning methods and the approaches chosen in the two procedures proposed in Chapter 9. To start with, both belong to the general class of allocation-decomposed methods, in view of our decision (see Section 5.2) to treat resources apart from the attribute vectors of the LUs. In method I (our interpretation of the Geoffrion-Hogan approach), the allocation not only includes resources but it also implies a responsibility to fulfil the objectives that have been transformed into constraints. The latter is very close to Kornai's ideas, although these are not included in his formal methods. The LUs report back "prices" in the form of derivatives, just as in other allocation-decomposed methods.

In method II the targets based on ideal points resemble to some extent certain aspects of Weitzman's approach, although in our case no central approximation is built up. Our MRT equalization device corresponds to Jennergren's divisional-trading concept, except that it trades responsibility for the different objectives rather than resources.

There remain two approaches on which methods III and IV, to be presented in Chapter 11 will be based: central approximation-building and price-decomposition.

To be able to build a central approximation, CU has to have some initial idea of organizational possibilities. It seems difficult to combine this with the basic idea of resource allocation which we have otherwise maintained throughout. In spite of this, we will investigate in Chapter 11 whether the Weitzman method could be applied to our problem, if it were supplemented by some of our knowledge of multiobjective decision-making is reported in Chapter 8.

Price-decomposed planning requires CU to make estimates of MRS or of prices. Estimates of this kind were also necessary in the Geoffrion-Hogan method. As we want to stick to the resource-allocation idea, we will employ a method that uses both prices and allocations when we look more closely at some approaches of this type in Chapter 11. Heal's method provides a good point of departure here.

11. TWO PROCEDURES BASED ON METHODS FOR DECENTRALIZED PLANNING

In Section 10.4 our discussion of methods for decentralized planning led us to the conclusion that the Weitzman and Heal proposals would suitably be used in formulating multi-objective planning methods. It is still not my intention to make any claims about the formal properties of the resulting procedures. Weitzman's and Heal's proposals simply illustrate alternative philosophies which it seems promising to apply to our problem.

I will follow the same pattern here as in Chapter 9: First each procedure will be described verbally and in more formal terms, after which the assumptions will be listed. The role of this formalization is also the same, meaning among other things that the procedures vary in their algorithmic correctness according to their different backgrounds, even if all the assumptions are fulfilled.

11.1 METHOD III: CU TARGETS BASED ON BELIEVED POSSIBILITIES

Weitzman's method (see Section 10.2) deals with the determination of product output and input quantities in a multi-LU organization, where CU has some initial optimistic idea of production possibilities. On a basis of this initial overestimation and of an implicitly known utility function defined over the product quantities, CU decides on plans for all LUs. Since the plans are overestimates, they can only be used as targets. LUs respond with proposals that come as close as possible to the targets, and by showing the MRT for the proposals, they correct to some extent CU's estimate of production possibilities. This means that even if CU does not accept the proposals, a new iteration can start from new and better knowledge of the possibilities, and the process will gradually converge.

It is fairly easy to translate this into terms of objectives instead of products. As was explained in Chapter 10, this gives us a planning philosophy which has obvious practical relevance: planning as a way of correcting exaggerated expectations, expressed here in CU targets, and of finding a feasible set of plans.

Some problems are present already in the original version, and these become more obvious in our translated formulation: (i) CU has to combine its approximations of all LU possibilities, because the utility function is defined over combined output; (ii) in choosing one total plan from this combined possibility approximation, some way of using the implicit utility knowledge is needed; (iii) the combined plan must then be divided into LU plans, which means that CU has to "remember" which local plans correspond to the total plan.

The choice of a total plan (ii), is exactly the type of problem to which the multiobjective decision methods reviewed in Chapter 8 are suited. The combined possibilities of Weitzman's model constitute a set delimited by linear constraints, such as most of the interactive methods assume. Furthermore, Weitzman's CU has the type of knowledge required for answering the necessary questions. Some sort of interactive multicriteria method could be used already in Weitzman's original product context, but it becomes even more natural where the fulfilments of objectives constitutes the criteria. As the linear set must be well specified in order to solve the other two problems mentioned above, we could even use the Wallenius (1975) method, which makes very little demand on the decision-maker. He has only to answer yes or no to the questions put to him.

The other two problems, (i) and (iii), are closely connected with the relations between LU attributes and organizational objectives. These were discussed in Section 5.4 where we made a verbal analysis. For the sake of simplicity, I will use an algebraic formulation below, which is a possible formulation only under certain conditions. In other cases it should be possible to approximate the basic ideas in various ways, but we will not consider these here.

11.1.1 Verbal statement of method III

Below is a multi-objective analogue to Weitzman's approach. It uses similar step number as in earlier methods and apart from interpreting the method in terms of multiple objectives and following the structure illustrated in Figure 5.5, only the suggestion about using a multicriteria method at Step 1 has been added to the proposal in Weitzman (1970).

Step 0. The initial CU proposal makes it necessary to have a step 0 here. CU starts with some idea of each LU's performance possibilities. This is assumed to be an overestimation.[1] CU uses this knowledge to make an approximation of the combined performance possibilities of all LUs, i.e. of the entire organization. This will obviously be much simplified by our assumptions (A26 - A27) about relations between attributes and objectives.

Step 1. Instead of simply announcing a resource allocation, CU uses its approximation of the organization's possibilities from Step 0 to help in finding a preferred point, i.e. a combination of the values attached to the objectives in the believed feasible set. As this is a "centralized" multiobjective problem, one of the interactive methods for multicriteria decision-making can, if desired, be used here. The resulting organizational plan has to be decomposed into LU plans, relying on CU's knowledge of the combination process it has used in Step 0. The LU attribute values and resource allotments that result are announced

[1] If CU has no knowledge on this point, it can always choose some arbitrarily large performance set (cf. Weitzman, 1970, p. 54.)

to the LUs.

Step 2. As the CU decisions in Step 1 are based on an exaggerated idea of LU possiblities, the proposal will not usually be feasible. Each LU reacts by finding a feasible plan that is strictly dominated by the CU proposals, i.e. all its attribute values should be equal to, or worse than, the CU proposals; its resource requirements should be the same or greater.

(Step 3. It might be worth approximating Step 3 in our basic procedure (see Figure 5:5), as organizational efficiency is not guaranteed by Step 2. This has not been done here as adjustments result from the following steps.)

Step 4. The LU plans from Step 2 are reported to CU, together with the technological trade-offs (MRTs) between attributes.

Steps 5 - 6. If CU finds the combined effect of the Step 4 proposals satisfactory,[1] Step 7 can follow. Otherwise, the proposals and the trade-offs provide new information about the real possibilities which can be incorporated into the approximation of organizational possibilities used in Step 1. With the new reduced set of (believed) possibilities, CU returns to Step 1 to perform another iteration.

Step 7. When CU has accepted a set of proposals, the LUs are authorized to put these into action. It is interesting to note that if individual LUs have come close to CU expectations, CU could decide to accept their plans, and let later iterations involve only the remaining LUs. On the other hand, an "optimal" balance between objectives cannot be achieved in this way, as the preferred attribute balance in an isolated LU cannot generally be decided until the total organizational picture is clear.

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[1]The comments on stopping rules given in connection with methods I and II also apply here: with few iterations, there seems to be little point in suggesting formal rules.

11.1.2 "Formalization" of method III

The following is not the only alternative; it was chosen for reasons of clarity. It is substantially different from Weitzman (1970).

Step 0. CU: Find a linear approximation of each LU's feasible set:

$$\underline{A}^i\underline{e}^i \leq \underline{b}^i, \quad i = 1, \ldots, m \tag{11-1}$$

where $\underline{A}^i$ and $\underline{b}^i$ define linear constraints on the values assumed by the $\underline{e}^i$ vector; the dimension of $\underline{b}^i$ is here quite small. The vector $\underline{e}^i$ corresponds to LU number i's attribute vector $\underline{f}^i$, with resource requirements added as further attributes. In the one-resource case assumed in Section 5.2, this means that we can think of the last element in $\underline{e}^i$ as being $-y_i$. We will use this assumption here as well. The minus sign is used to achieve a similar "direction of positive change" for all elements.

CU can use his knowledge of the H transformation in formula (4-10) to deduce from (11-1) an approximation of the feasible set of the organization. For the sake of simplicity, we assume fulfilment of an objective to be the sum of the corresponding attribute values, i.e. believed organizational performance possiblities are given by the sum of the $\underline{e}^i$ vectors. If left-inverses to $\underline{A}^i$ exist,[1] we have:

$$\sum_i \underline{e}^i \leq \sum_i \left[(\underline{A}^i)^{-1}\underline{b}^i\right] \tag{11-2}$$

Step 1. CU: Use the implicitly known preference function P to find the preferred point in the feasible set

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[1] Concerning the existence of inverses, see for example Noble (1969, p. 135). In the many cases where this way of finding the organizational feasible set is not possible, it could probably be deduced from (11-1) in other ways.

defined by (11-2). The first n elements in the $\sum_i \underline{e}^i$ vector give the fulfilment of the organizational objectives, while the element (n+1) gives the total resource demand which has to fulfil the central resource constraints. This further delimits the feasible set.

To choose one point in this linear set, use e.g. the method proposed by Wallenius (1975). The $\underline{e}^i$ vectors of the chosen point, to be denoted $\bar{\underline{e}}^i$, are announced as targets for LU planning.

Step 2. LU: If there is a plan in the feasible set

$$\underline{f}^i\ (\underline{x}^i,\ y_i \mid \underline{g}^i(\underline{x}^i,\ y_i) \leq 0)$$

with the attribute and resource requirement values of $\bar{\underline{e}}^i$, this is the LU proposal for Step 4. If not, the proposal is any solution to:

$$\max_{\underline{x}^i, y_i} \quad \underline{f}^i(\underline{x}^i,\ y_i) \text{ s.t. } \underline{g}^i(\underline{x}^i,\ y_i) \leq 0$$

$$\text{and} \begin{pmatrix} \underline{f}^i \\ -y_i \end{pmatrix} \leq \bar{\underline{e}}^i \qquad (11\text{-}3)$$

i.e. any LU-efficient plan which does not exceed the target for any attribute and which uses a resource allocation which is the same or greater.

(Step 3 is not necessary - cf. the verbal description above.)

Step 4. LU: Find the MRTs corresponding to the proposal from Step 2, which we can call $\bar{\underline{f}}^i$. The MRTs define the price vector $\bar{\underline{p}}^i$ in the point $\bar{\underline{f}}^i$. Communicate $\bar{\underline{f}}^i$, $\bar{y}_i$, and $\bar{\underline{p}}^i$.

Step 5 and 6. CU: If the objective values $\sum_i \bar{\underline{f}}^i$ are satisfactory <u>and</u> the combined resource requirements $\sum_i \bar{y}_i$ are less than available resources $\sum_i y_i$, go to

Step 7. If not, add the constraints

$$(\underline{\bar{p}}^{i})' \; \underline{e}_i \leq (\underline{\bar{p}}^{i})' \; \underline{f}^{i}, \quad i = 1, \ldots, m, \qquad (11\text{-}4)$$

to the constraints in (11-1) and find the corresponding feasible set, as in formula (11-2). Return to Step 1.

Step 7. CU: Announce the latest $\underline{\bar{f}}^{i}$ vectors and the corresponding $\bar{y}_i$ values as the official plan.

If the end is not reached in the few iterations available, CU may, at Step 1 in the last iteration, constrain LU planning in Step 2 to use exactly the resource allocation of the target plans. This will guarantee an organizational plan which is at least feasible.

11.1.3 Assumptions

In the formalized version, the following assumptions are needed (in addition to those of our basic model as presented in Chapter 4):

- Attributes have to be additive, as stated in Section 11.1.2, Step 0.
- Only one resource is allocated centrally as in Section 5.2, except that LUs are now not required to plan for specified resource allotments (unless possibly in the final iteration).
- The feasible performance set of an LU has to be closed and convex; it must be bounded from above, and it must contain all plans dominated by some plan in the set. (These requirements are taken from Weitzman, 1970, p. 52. Cf. Section 4.2, statement A 23).
- It is assumed that CU can
  - . define a believed set of performance possibilities for each LU which:

    includes all possiblities that are not regarded by CU as totally unrealistic

    is closed, convex, and bounded from above by linear constraints includes the whole of the LU's true set

- Incorporate specified additional linear constraints in the believed LU sets
- Aggregate the believed sets for all LUs to find the believed organizational performance possibilities
- Use its implicitly known preferences to choose one plan in this believed organizational set
- Disaggregate such an organizational plan, using its knowledge of the way LU sets were combined into an organizational set
- Judge from LU proposals received whether planning should be continued or terminated

- It is assumed that each LU can:
  - Use CU targets, expressed as infeasible value combinations of LU attributes and resource requirements, in order to find an LU-efficient and feasible plan close to the target and dominated by it
  - Find the trade-offs between individual attributes and resource requirements for such a plan

Even in an informal version, the assumptions would have to include:

- The same demands on the true LU feasible sets as above
- Roughly the same CU requirements, except that linear approximations could be changed to any vague knowledge that enables CU to set meaningful targets, and to revise them in light of new information
- The first of the LU requirements, and the ability to communicate restrictions on the feasible set in some way to CU during the iterations

11.1.4 Discussion

Weitzman (1970, p. 64) obviously expects his main ideas to be useable in practice, although he would then "dispense with such an exact formulation. ... The basic idea is that the firms must correct the center's exaggerated notion of their technology sets in a way that leads to convergence." His proposal is attractive, particularly because it allows for the fact that CU activity during planning is largely determined by expectations about possibilities. Such expectations were not included at all in the procedures considered in Chapter 9.

The most difficult assumptions to fulfil among the "new" ones introduced here, seem to me to be the aggregation and disaggregation that CU has to perform. The linear approximations of LU sets can always be found by choosing rather higher performance values than CU has experienced in the past, and by assuming some rough technological trade-off values around these. Once the linear approximation of the organizational feasible set is achieved, it should not be too difficult, using one of the interactive methods, to choose one plan from the set.

A good choice here will obviously depend on the approximation of the organization set not being too exaggerated, so that realistic preferences are "activated". There is obviously a risk that the sum of believed LU sets may yield a completely unbelievable organizational set. And in a not fully formalized version of the method, it may sometimes be difficult to find the corresponding LU plans.

I think these problems could be overcome and that, together with the Wallenius (1975) method mentioned above, for instance, this procedure could be suitable as the basis for a computer-aided system of target-setting and target-revision for use in the actual planning.

11.2 METHOD IV: PREFERENCE-BASED CU PRICES

Heal's method (1971, 1973) was introduced in Section 10.3.3. Heal's aim was to handle nonconvex feasible sets in some LUs, which make the traditional price-adjustment schemes unusable. But its interest for our planning problem derives from quite different considerations: if price-adjustments are added to the basic procedure presented in Figure 5:5, separating choice of objective mix and resource allocation the result is very like Heal's approach. The major characteristic of Heal's method, however - a fixed objective mix during the resource reallocation - is not needed here. It does not seem necessary unless the nonconvexity problem is introduced.

Thus the method described below has been inspired by Heal's method, but it by no means follows Heal in detail. Also in the present formulation, the multiple-choice objects are represented by the fulfilment of objectives rather than by Heal's product quantities. Of Heal's two formulations (Heal, 1973), it resembles the first formulation most closely: what he calls price-and-quantity planning.

Using this procedure, the following are the answers to the three problems raised in Section 5.7.

<u>Organizationally efficient use of resources</u>: As soon as the process gets started, CU's estimates of MRS are used as prices.

<u>Effective use of resources</u>: Use of CU's prices will achieve this as well.

<u>Optimal resource allocation</u>: Resources are changed, using current CU prices.

In most linear situations, price-adjustments are not possible according to Jennergren (1971). In our case, there is no reason to expect linearity - rather the opposite. Jennergren also mentions that a truncated process does not yield a feasible solution. This problem could probably be overcome by changing resources separately, as any resource allocation that is announced will always be feasible.

Heal's method alternates between changes in resources and changes in product mix, although in principle several consecutive changes of each might be profitable. Thus the answer to the question about how many times each loop in Figure 5:5 should be repeated, is to decide arbitrarily to observe each once at a time. This is also what we will do below.

11.2.1 Verbal statement of method IV

Step 1. CU announces a tentative resource allocation. If desired, some rule such as that included in method II (note on p. 141) can be used here.

Step 2. LUs determine LU-efficient plans, which they recommend. If desired, CU can provide targets to help this step, as a better choice of plan will obviously reduce the adjustment process.

Step 3 is not used here, as equivalent adjustments result from Step 5.

Step 4. The LUs present their proposals.

Step 5. (a) CU combines LU proposals, and judges the "weights" of all objectives in the achieved total plan, according to its own preferences. This corresponds to an MRS estimate, which can be issued to the LUs as prices for the objectives.

(b) LUs use the prices to revise their Step-2 plans, and report the result to CU. They also identify the improvement in performance that would result from small changes in resource allocation, as evaluated with the prices, and report this "resource worth" to CU as well.

Step 6. (a) CU combines the revised plans. If the "resource worth" is roughly equal for all LUs and the total plan is acceptable, the process should be ended by proceeding to Step 7. Otherwise, CU reallocates a portion of used resources, guided by the "resource-worth" figures.

(b) LUs take the new resource allocation and the Step-5 prices as a starting-point for finding new plans. Steps 5 and 6 are repeated.

Step 7. The process is concluded with a CU announcement of the final plans as those which are to prevail.

11.2.2 "Formalization of method IV"

Step 1: CU: Announce an arbitrary $\underline{y} = \bar{\underline{y}}$, with the allocations $\bar{y}_i$ to different LUs as its elements.

Step 2: LU: Find $\max\limits_{\underline{x}^i} L_i \left[\underline{f}^i(\underline{x}^i, \bar{y}_i)\right]$, s.t. $\underline{g}^i(\underline{x}^i, \bar{y}_i) \leq 0$,

where L_i is an arbitrary LU preference function.

(Step 3 is not used.)

Step 4. LU: The maximal plan from Step 2 is communicated.

Step 5 (a) CU: Assuming additive attributes, CU can combine LU proposals by summation. The resulting total plan is used to find a price vector $\bar{\underline{p}}$, with elements proportional to $(\partial P/\partial u_j,\ j = 1, \ldots, n)$ at the achieved value for the objective fulfilments u_j. Communicate $\bar{\underline{p}}$.

(b) LU: Find $\max\limits_{\underline{x}^i} \bar{\underline{p}}'\underline{f}^i(\underline{x}^i, \bar{y}_i)$, s.t. $\underline{g}^i(\underline{x}^i, \bar{y}_i) \leq 0$.
The consequent $\underline{f}^i$ vector is denoted $\bar{\underline{f}}^i$. Also find the value of "resource worth",

$$V_i(\underline{p}, y_i) = \frac{\partial\left[\max \bar{\underline{p}}'\underline{f}^i(\underline{x}^i, \bar{y}_i)\right]}{\partial y_i}$$

which can in practice be approximated by repeating the maximization of $\bar{\underline{p}}'\underline{f}^i$ for a slightly larger or smaller y_i than $\bar{y}_i$ and relating the improvement or disimprovement to the change in y_i. The revised proposal $\bar{\underline{f}}^i$ is reported to CU, together with the resource worth.

Step 6 (a) CU: Combine the revised proposals as $\sum\limits_i \bar{\underline{f}}^i$. If this is an acceptable total plan and the V_i values are similar for all i, go to Step 7. Otherwise, change the resource allocation so that LU i's allotment is changed by

$\overline{\Delta y}_i = k(V_i - \bar{V})$,

where $\bar{V}$ is the average value of all V_i and k is a small constant. This can be chosen so that the maximum reallocations are of suitable size. Communicate the new $\bar{\underline{y}}$.

(b) LU: Use the new resource allocation for finding the maximum $\bar{\underline{p}}'\underline{f}^i$ value, using the $\bar{\underline{p}}$ from Step 5. Communicate the corresponding plans and return to Step 5 (a).

Step 7. CU: Announce the final plan and resource allocation.

11.2.3 A note on excess resources

In Step 5 (b) above, and elsewhere, $\underline{f}^i$ and $\underline{g}^i$ have been written as using $y_i = \bar{y}_i$, tacitly assuming that all resources will be used. This will obviously be the most common case, and assumption A21 probably can be understood as a binding resource constraint. Otherwise, the $\underline{f}^i$ and $\underline{g}^i$ can be seen as requiring $y_i \leq \bar{y}_i$, with excess resources being returned to CU.

If there are surplus resources, method I should be able to deal with it, as the Geoffrion-Hogan approach requires LUs to report whether constraints are binding or not. In method II no similar provisions were made, as the changes in resources are heuristic. In method III, successive iterations should gradually reveal LU possibilities, including opportunities to use less resources.

In method IV, excess resources mean that $V_i = 0$, resulting in a diminished y_i. A more efficient change would probably be to reallocate all unused resources at an early stage, perhaps following some simple rule such as a proportional increase for all LUs for which $V_i > 0$.

However, if we look at this as an approximation of what happens in real-life budgetary planning rather than as a mathematical model, excess resources do not seem likely to constitute a major problem.

11.2.4 Assumptions

In its formalized version, this method is based on the following assumptions:

- The two assumptions from Section 5.2 and additivity of attributes as in method III. (If Heal's way of changing resources is preferred, performance possibilities need not be convex.)
- To avoid the problems associated with price-adjustment methods (see Jennergren, 1971, p. 37), constraints and preference functions should not be linear.
- It is assumed that CU can:
  - . judge utility trade-offs between objectives
  - . judge whether a total plan is acceptable or whether planning should continue
- It is assumed that each LU can:
  - . use an arbitrary preference function or choicerule to suggest a first LU-efficient proposal
  - . find the "resource worth", possibly in approximate terms
  - . use CU prices for an optimization of performance

An informal version of the method would require at least:

- the assumptions given in Section 5.2 plus additive attributes
- that CU can state objective prices or weights
- that LU can use these weights
- that LU can communicate some indication of resource worth which can be used by CU

11.2.5 Discussion

This method, like method I based on Geoffrion and Hogan, strains our original assumptions about CU knowledge by introducing estimates of prices or MRSs. As we noted in connection with Geoffrion's method (Section 8.1; also cf. Appendix C, Section C.3) these can assume the form of simple questions, but the evidence seems inconclusive as to the decision-makers' ability to answer them. Also, it could be claimed that in a "true" multiobjective situation, such answers would not be available.

The method has been included here because it represents one of the most classical approaches to planning: price adjustments. Heal (1971, 1973) reverses the order of changes in resources and changes in objective mix (or, in his version, product mix) which probably makes no difference once the process is under way. For his case of nonconvex possibilities, he has to use a constant product-mix during the resource change, rather than the derivative used in Step 6 above. If preferred, this alternative could of course be used here as well.

11.3 SUMMARY

In this chapter we have examined two procedures based on theories for decentralized economic planning and resource allocation. The _first_ of these is an adaptation of Weitzman's method, representing the class of planning methods in which CU forms a successively improved approximation of LU possibilities. CU sets targets based on this approximation, and the LUs respond by suggesting feasible plans which are close to these targets.

Compared to our original model, _CU's approximative knowledge of LU possibilities_ represents a new element, and there are also new requirements about what CU is able to do. However, in determining the mix of objectives, I have suggested that CU could be helped in its exploration of the central approximation of performance possibilities by one of the interactive methods for multiple objective decision-making which were presented in Chapter 8. The similarity between Weitzman's model and certain forms of practical budgetary planning, and the possibility it offers of incorporating a multiobjective decision-making method, makes it an attractive alternative to the planning procedures discussed in Chapter 9.

The <u>second</u> procedure is less complicated. It is an adaptation of price adjustment methods, and resembles a method suggested by Heal. All price adjustment schemes take prices as a basis for finding the best resource allocation. Because of the indeterminacy of preferences in our situation, plans also have to be revised for each allocation to conform with preferences. This means that CU has to react by repeatedly revealing its preferences at local points, in the form of <u>objective weights or prices</u> that are synonymous with MRS ratios.

The mathematical properties of this method in its present form have not been investigated; however, it uses concepts which are "classical" in planning theory. Although the need for MRS estimates (also present in method I) is not attractive, prices are so basic to many types of theoretical and practical planning methods that this procedure can be considered a realistic alternative to the other three approaches we have studied.

12. THE FOUR PROCEDURES COMPARED

12.1 THE FOUR APPROACHES: A RECAPITULATION

In this chapter, the four procedures introduced in Chapters 9 and 11 will be compared. It will be remembered that they represent the main alternative ways, that I have been able to deduce from related theories, of handling the problem presented in Part One.

I have stressed several times that the procedures should not be seen primarily as algorithmic solutions to a maximization problem. Rather, they represent four different philosophies that can be applied in the outlined situation. This becomes clearer if we consider the most characteristic traits of each method.

Method I (single LU objectives and adaptive constraints). The multiobjective problem is partially avoided. CU lets each LU perform single-objective constrained maximizations, where all objectives except one are turned into constraints. As CU discovers what can be accomplished, these constraints are reconsidered. The philosophy is thus that each LU has a main task for which it plans, and that CU interactively sets its aspiration levels as regards each LU's effects on other "secondary" objectives; CU then balances the main tasks by means of the resource allocations.

Method II (MRT approximations and ideal points). CU can only set tentative targets and resource allocations, and identify an "objective to be relaxed" as a reaction to LU proposals. LUs therefore have to rely on ideal points derived from existing possibilities, and on a comparison of

MRTs to find an acceptable solution. This portrays a situation where the multiobjective situation cannot be reduced, and CU can provide very little guidance except by its fairly simple reactions to LU information. In this situation, the best we can do is to try to approximate the basic steps formulated in Figure 5:5.

Method III (CU targets based on believed possibilities). CU sets targets based on expected LU performance possibilities. CU improves its knowledge of these possibilities in a dialogue with the LUs, so that in the end it knows almost enough to select LU plans itself. The LUs "teach" CU the true possibilities, by cutting down CU proposals into feasible plans. This approach is based on the idea that CU knows something about actual possibilities and can select what it wants. However, the dialogue is needed to reduce the visions to feasible plans, and this is where multiobjective planning comes into the picture.

Method IV (preference-based CU prices): CU knows its own preferences in considerable detail, and is consequently able to issue prices or weights for the various objectives. The LUs plan for a weighted sum of activities. As plans are presented, the weights are adjusted. No central approximation of possibilities is formed. This involves a different kind of CU knowledge than method III: CU's rather controversial ability to state prices or weights means that it can always reduce LU planning so that it finally concerns a single (weighted) objective.

In this chapter we will compare the properties of these approaches in various respects: the information exchange involved, the similarities in the means they use, and their underlying assumptions. But before embarking on this comparison we can note that the basic differences in philosophy, i.e. in the kind of situation the methods seem to presuppose, seem to be manifest in the roles played by CU and the LUs.

Method I describes a special case of multiobjective organization, in which a high degree of specialization makes it possible for CU to balance objectives mainly by balancing

LUs. This specialization makes planning fairly easy for the LUs.

In method II - III, the multiobjective qualities of the planning situation receive more emphasis: there are several, potentially equally important objectives for each unit. In method II both CU and the LUs are fairly ignorant and have to rely to a great extent on heuristics. Their reactions occur almost exclusively in relation to plans presented, or to ideal points (which also derive from possibilities).

In methods III and IV, on the other hand, far greater knowledge on the part of CU about possibilities and preferences respectively, is the pivot of the whole approach. This somewhat reduces the role of the LUs.

CU and LU characteristics can thus be summarized as in Table 12:1.

Table 12:1. The most important characteristics of the initial situations that are implicit in the four planning approaches

	Initial CU knowledge	LU:s are able to plan for
Method I	"Main task" identified for each LU, with tentative constraints for its effects on other objectives	Single objectives subject to central constraints
Method II	Nothing that can be communicated	Distance to own ideal point subject to central constraints
Method III	Expectations concerning LU possibilities as prices	Distance to CU targets
Metod IV	Preferences that can be communicated	"Weighted" performance, given different prices

To some extent the four methods presented here represent approaches that could be combined in various ways. This does not mean that the mathematical procedures are easy to blend. But, as we can see in Table 12:1, the approaches are based on four assumptions about what CU is able to do, and on three or four about what the LUs can do. These are really extreme cases; in real life something in between can readily be envisaged. And if, for instance, some prices can be communicated in a situation which otherwise resembles that of method II, this should probably be allowed. (Also cf. Appendix C.)

12.2 INFORMATION EXCHANGES

In Table 12:2 the communications made by CU and the LUs are listed for each of our four methods. The compact form used here makes exact definitions impossible, and the reader who seeks clarification is referred to Chapters 9 and 11.

Table 12:2. Summary of the information exchange in the four procedure

Method	CU communicates	CU varies	LU communicates
I (Single LU objectives and adaptive constraints)	The single objective selected for each LU Constraints on other objectives Resource allocation	Constraints Resources	Attribute values Constraint values Derivatives with respect to activities and to central resources and constraints
II (MRT approximations and ideal points)	Target for each LU, derived from "ideal" Resource allocation Later: Average MRTs "Objective to reduce"	Resources	Attribute values (incl. "ideal point") MRTs Later: Resource worth
III (CU targets based on believed possibilities	Target for each LU, incl. resource worth	Targets	Attribute values Resource requirements MRTs
IV (Preference-based CU prices)	Resource allocation Prices attached to objectives	Resources Prices	Attribute values Resource worth

12.3 SIMILARITIES

In this section, in order to increase the reader's understanding of the four procedures, I will examine in greater detail some characteristics that recur in several of the methods but not all.

Two of the methods include some form of CU approximation of LU possibilities. This is most apparent in method III, where CU choices are based on its view of LU feasible sets. But method I also has something of this characteristic, in that a good deal of information about derivatives and so on is used by CU to form a local approximation of possibilities so that it can find the direction of change for the control vector.

In methods I and IV CU is expected to provide MRS between objectives, or equivalent information. In method IV the main idea is that in this way CU finds weights for the objectives that it can issue to the LUs. In method I, similar information is needed to find changes in the control vector.

In all the methods except the fourth, LUs are called on to provide MRTs between attributes, or equivalent information. This reflects a belief that it should be easier for LUs to find such ratios by inspecting alternative plans, than it is for CU to provide MRSs. MRTs and MRSs are used in very different ways, and assume different forms. In method I, the derivatives given by the LUs contain equivalent information. In method II, LUs explicitly try to equalize MRTs, although this can perhaps be done in less formal ways. In method III, equivalent information is used by the LUs to "teach" CU what the real possibilities are. In method IV MRTs are not needed, as planning always uses the MRS dictated by CU, and MRT necessarily becomes approximately equal to MRS.

MRT and MRS as discussed here refer mainly to objectives or attributes, excluding resource requirements. The demand in methods II and IV for an estimate of resource worth is closely related to MRT, since it involves an aggregate measure of the yield of marginal resources in terms of performance. The use of a central approximation seems to eliminate the need for such an estimate; consequently it is only necessary to estimate resource worth in methods II and IV. As method IV was the only one not requiring MRT, it is interesting to note that it would still be necessary here to have this related information. The explanation is that we wanted to design a price-and-quantity approach, which did not include resources in the price vector.

The methods that call for estimates of resource worth also require that LUs can optimize performance for a given price vector (objective weights). In method II this is because of the "equal-MRT" step that leads to organizational efficiency; in method IV it results from the general price-adjustment approach. Note that method I also requires "prices" of a kind (MRS), but these are used only by CU.

As we will see in Appendix C, there are other ways of guiding LU choice. Two methods use constraints on attribute values. In method I, these are part of our additions to Geoffrion and Hogan, and they are intended to strengthen CU's role. By means of the constraints, CU can influence local search more than it could by identifying single LU objectives. In method II, the role of constraints is somewhat different. Here, they represent the only way for the "ignorant" CU to convey to the LUs its reactions to their plan proposals.

The last way that we examine of guiding LU choice is by providing infeasible targets. This is the way in methods II and III, where the targets are based on rather different knowledge of possibilities.

Finally, CU learning exists in methods II and III. In method III, the gradual improvement in CU knowledge of LU possibilities is important. In method II, the gradual delimitation of the parts of the LU feasible sets which are to be investigated further, can be regarded as a kind of learning. The other methods do not seem to require any similar accumulation of information.

12.4 PROCEDURE ASSUMPTIONS ("C-STATEMENTS")

In Chapter 4, the assumptions that form part of the basis of this study were introduced. Already in Section 3.1 it was mentioned that certain additional assumptions would characterize individual procedures. These "C-statements" (where A-statements defined the model and B-statements the aims of designing the planning procedures) consist of the assumptions made in Section 5.2 and in the discussion of individual methods in Chapters 9 and 11. They will now be restated. I will follow the grouping presented in Section 3.1 and already applied to the A-statements in Section 4.2. Thus we are reminded that a planning situation which can be handled by a certain method should correspond to the description provided by the A-statements <u>and</u> by the relevant C-statements. As many C-statements refer to certain methods only, they will be followed by numbers in parentheses which designate the relevant method.

I. <u>Statements concerning the entire organization</u>

I.1 Organizational objectives and the planning task

(C1) There is only one common resource which is allocated among the LUs. To allocate some of the resources to one LU means that it can be used only by that LU. Thus the $\underline{y}$ vector consists of the allocations y_i $(i = 1, \ldots, m)$ to different LUs. (II, III, IV)

II. <u>Statements concerning organizational units</u>

II.1 Central unit

(C2) CU preferences do not conform to a linear function. (IV)

(C3) CU is able to use LU ideal points in selecting targets for LU planning. (II)

(C4) From a set of LU proposals, CU is able to choose one objective which it thinks could be somewhat reduced provided other objectives are unchanged or improved. (II)

(C5) CU is able to provide LU attribute constraints and later to change them during planning in response to LU trade-off information, in a way which makes single-objective LU planning acceptable. (I)

(C6) CU is able to formulate unidimensional LU objectives for planning. (I)

(C7) From a set of LU proposals, CU is able to judge the relative importance of the different objectives according to its preferences (i.e. the ratios between their marginal utility, or the marginal rates of substitution). (I, IV)

(C8) CU is able to define a believed set of performance possibilities for each LU which:

- includes all possibilities that are not regarded by CU as totally unrealistic
- is closed, convex, and bounded from above by linear constraints
- includes the whole of the LU's true set. (III)

(C9) CU is able to revise the set described in C8, by incorporating specified additional linear constraints. (III)

(C10) CU is able to aggregate the sets described in C8, to find the believed organizational set. (III)

(C11) CU is able to choose one plan in the believed organizational set of C10 as the preferred plan. (III)

(C12) CU is able to disaggregate the organizational plan chosen in C11 into LU plans contained in the LU sets of C8. (III)

(C13) CU is able to perform the computations and the step-size choice required by Geoffrion and Hogan (1972). (I)

(C14) CU is able to judge whether planning should continue. (I - IV)

(C15) CU is able to judge whether planning should continue for a certain resource allocation. (II)

II.2 Local units

(C16) LU feasible sets contain all plans dominated by some plan in the set. (III)

(C17) LU feasible sets are bounded from above by non-linear constraints. (IV)

(C18) If an LU makes a change of a certain magnitude in the attribute corresponding to a particular organizational objective, the impact on that objective will be the same regardless of which LU institutes the change. (II-IV)

(C19) The relation between an LU attribute and the corresponding organizational objective is such that a summation of LU attribute values gives the objective fulfilment value. (III, IV)

(C20) Each LU is able to incorporate specified CU constraints in its knowledge of its own feasible set. (I, II)

(C21) For each LU attribute, the LU is able to find the plan in its feasible set which maximizes that attribute's value. (I, II)

(C22) Each LU is able to use an infeasible target for finding a feasible plan close to it. (II, III. In III the target includes resources.)

(C23) Provided with a set of prices or relative weights for its plan attributes, an LU is able to identify the feasible plan which is the best one if evaluated according to these prices. (II, IV)

(C24) For each plan it proposes, an LU is able to judge technological trade-off possibilities between attributes (i.e. marginal rates of transformation). (I , since this follows from C25; II; III where attributes include resources)

(C25) For each plan it proposes, an LU is able to give values and derivatives of attributes and constraint variables, with respect to activities and CU's control variables. (I)

(C26) Each LU is able to estimate "resource worth". (II, IV. This actually follows from A25 and C23.)

III. Statements concerning inter-unit relations

III.1 Communication possibilities

(C27) All information which CU and the LUs can "judge" etc. according to other relevant C-statements, can also be communicated by them to each other (i.e. by CU to the LUs and vice versa). The requirements that this raises in procedures I - IV were summarized in Table 12:2. (I - IV)

III.2 Influence and control possibilities

(C28) Resources are allocated by CU as preconditions for planning and are not considered as one of the attributes which are "balanced" against each other by the LU in proposing a plan. (I, II, IV)

12.5 COMPARISON OF ASSUMPTIONS

Significant differences between the assumption sets that are required for our methods mainly concern what CU and the LUs are able to do. We will consider these in turn, returning also to the original set-A assumptions of our model presented in Section 4.2.

12.5.1 Central-unit abilities

In statements A14 - A17, our model's basic demands on CU were stated. CU should be able to judge LU plans in combination and rank the alternative total plans thus generated in a consistent way. We also assumed that the implied preferences should be of a certain form. The C-statements add to the knowledge of preferences thus assumed in two ways, in one instance demanding nonlinear preferences (C2), and demanding throughout a greater ability to use the preferences.

Differences between procedures mainly concern this ability. C3 deals with a reaction to infeasible ideal points, but otherwise differs little from C4. Once CU has some total plan available (perhaps the last period's), C5 and C6 also resemble C3 and C4. All concern a revision of plans by setting constraints on one or more objectives.

This clearly requires a good deal of knowledge about preferences, although probably less than C7, the demand for MRS statements, would do. The latter can be regarded as a complete disclosure of CU preferences around the currently achieved plan (objective values). In Figure 12:1, this would mean that a CU which knows implicitly the preferences shown by the iso-preference curves P_1P_1, P_2P_2, etc. should react to a proposal A by communicating its "price vector" $\underline{p}$ or, alternatively, by indicating the slope of the tangent.

It seems a less difficult requirement to find, for instance, the objective to be relaxed (C4). The relative importance of objectives can vary a good deal, still leaving the same objective as the one that is "best off". In other words, such indications of the preferred direction of change can be made with much less exactitude than that demanded by the estimation of MRS. (Also see Appendix C on different ways of indicating preferences.)

However, if we choose one of the less demanding ways of indicating preferences, such as identifying a reduction objective (C4) or supplying a set of constraints (C5), we will in fact be introducing a need for some <u>knowledge of possibilities</u> on the part of CU. A price vector will steer the LUs in approximately the right direction, even though CU knows nothing of the broken-line possibilities shown in Figure 12:1. On the other hand, if constraints are to be applied, CU must have some idea about the direction in which a better solution should be sought.

Assumptions C8 - C12 constitute a group of additions unique to method III. They require, unlike our original model, that CU should possess knowledge of possibilities. It seems quite probable that the CU may have some such knowledge, but even an intuitive approximation of what is intended by these statements may seem to CU to be quite demanding.

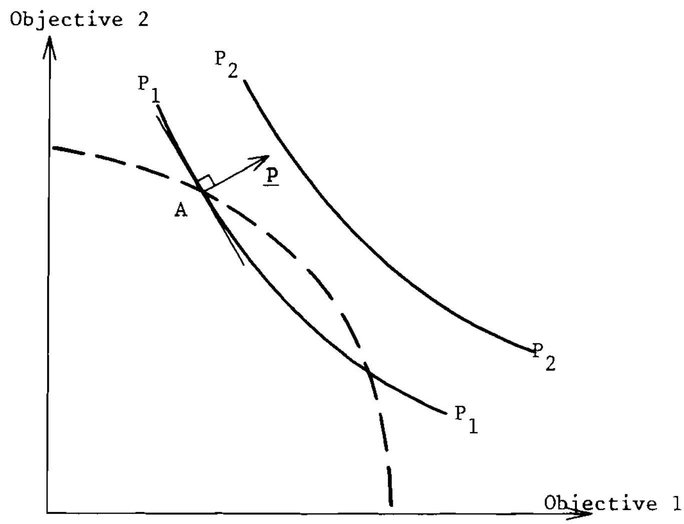

Figure 12:1. Illustrating CU knowledge of its own preferences when confronted with a plan A

Perhaps some of them can be regarded as computational requirements, as C13 also can. Stopping rules (C14, C15) will not be discussed here in any detail, as a fixed limit will probably exist in practice, and the number of iterations assumed to be possible in A30 (between two and five), will certainly all be needed.

12.5.2 Local-unit abilities

In the A-set, we learn only that for each LU there exists a feasible set in performance-possibility terms with certain properties (A19 - A24) from which the LU can select plans (A18), and that the LU is able to propose an LU-efficient plan (A25). We obviously could desire considerable additions in the way of LU knowledge about possibilities.

Assumptions C20 - C26 all concern alternative ways of bringing in such additional knowledge. The most far-reaching is C25, which requires what amounts to a mathematical model of possibilities around the proposed point. C24 (MRT estimates) is a subset of C25. C23 - C30 are related to the different ways in which CU can direct local search: by means of constraints by introducing single-objective maximization (perhaps as part of finding ideal points), targets, or prices. C26 (resource worth) is also a subset of C25.

The relation between the various estimates that LU might be required to wake, can be shown as in Figure 12:2. The two performance-possibility curves are the efficient frontiers for two different resource allocations. A demand for MRT estimates for a proposed plan such as B will mean that LU must know the slope of the curve at B (in the figure indicated by the tangent). In method III, and perhaps elsewhere, this is best communicated as the corresponding price vector $\underline{p}$.

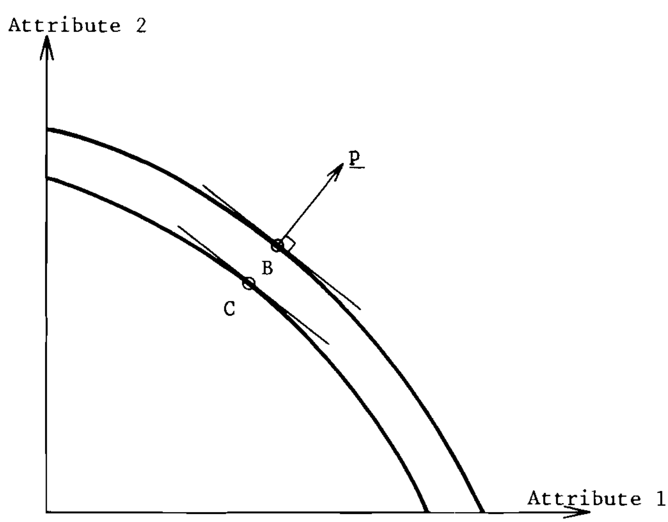

Figure 12:2. Illustrating LU knowledge of its own possibilities

When MRT has to include resources as an additional element in the attribute vector, we will add a third dimension to the case illustrated in our figure. This will not involve any particular problems, except that the LUs may experience a certain lack of comparability between attributes and resources.

For this reason it might be easier to ask for the almost equivalent combination of attribute MRTs and a separate resource-worth measure. The latter could be found by repeating LU's plan-search, given a slight change in resource allocation and an unchanged target, or unchanged prices for the objective. If resources are reduced by five per cent, the new recommendation may be a point such as C in Figure 12:2, instead of B. The difference now has somehow to be evaluated unidimensionally, using MRS or MRT prices if these are available.

The functional forms of the constraints (C16 - C17) and the relations between attributes and objectives (C18 - C19) are rather similar in all the methods, although the assumptions grow stronger in the later methods.

12.5.3 Summary

Each of the four procedures has its individual "mix" of assumptions, with none of them clearly dominating or nearly dominating when it comes to the hope of fulfilment. Perhaps method I comes closest to being dominated by another method (IV): its LU assumptions, especially C25, are very extensive, and CU has not only to find unidimensional LU objectives but also to supply MRSs.

Method IV also uses MRSs. The LUs have rather more difficult decisions here than in method I: optimization of a weighted sum of objectives rather than a single objective. But the LUs only report their plans and do not have to find derivatives. Of course the assumption of additive attributes means that the model becomes less generally applicable. This last assumption could be removed from method IV, but C18 ("identical impact for all LUs") could not.

A reason for rejecting method IV could be a desire to avoid MRS estimates. Among the remaining two procedures, method III has the better theoretical basis. The controversial requirement here concerns CU's knowledge of possibilities. Even if this knowledge need only be fairly general rather than an exact approximation of true possibilities, CU will simply be changing one difficult estimation for another.

On the other hand, perhaps an informal variant of this method could be about as attractive as method II. If we only look at the list of assumptions, we could easily believe this method to be preferable to the others. But its more heuristic nature is partly responsible for this advantage, and if method III were to be altered in the same sort of way, these two procedures could perhaps be more accurately compared. Method II seems to require less knowledge on the part of CU than method III, but more on the part of LU.

But the conclusion has to be that a strict comparison is pointless. The methods are based on situations that differ in important respects, and even if one method requires less assumptions of one kind, there is always a price to pay in the form of other assumptions or a less exact procedure. The last points in particular have not been sufficiently considered here. Only if we had information about the characteristics of a large number of real-life situations would it be possible to claim that one method is useable more often than another. And even then, recommendations for individual situations would have to be based on the nature of the situations in question.

PART THREE
THE PRACTICAL OUTLOOK

13. THE NATIONAL SWEDISH TELE— COMMUNICATIONS ADMINISTRATION; A STUDY OF THE PREREQUISITES FOR MULTIOBJECTIVE BUDGETARY PLANNING

13.1 INTRODUCTION

13.1.1 The case of the National Swedish Telecommunications Administration (Televerket)

In this chapter I will report the results of my contacts with Televerket, during which I tried to compare their situation with the general situation assumed in our model in Part One, and with the alternative approaches to multiobjective planning developed in Part Two.

As mentioned already in Chapter 0, I had been in touch with Televerket at an early stage of the present study. As these contacts may have influenced my problem formulation, this chapter should not be regarded as a formal test of the models. I hope instead that it illustrates the basic approach used in multiobjective budgetary planning by relating it to a concrete example. It also shows the initial stage in any implementation of this kind of planning: i.e. a study of the relevant conditions, to discover something about:

- The desirability of a multiobjective approach to budgetary planning in the current case
- The feasibility of the alternative approaches.

My choice of Televerket for this discussion was governed by several considerations. As a public utility, it may be more conscious of having several objectives than a business firm might be, which made it easier to discuss such problems with the people concerned. In the case of Televerket, profitability had also been much stressed as a guiding management principle, which made for a closer resemblance to a business firm. Its decentralized structure also seemed suitable. In addition to this, I had already been in contact with many people in the organization, which made it possible to select for interviews those best qualified to answer my questions, and also to formulate questions of practical relevance even at the earliest interviews.

During the interviews and talks with representatives of the organization on which this chapter is based, few spontaneous attempts at multiobjective budgetary planning were discovered. I personally hold the view that such attempts should be made, even if the methods discussed in Part Two would prove impossible to use in any strict form. This bias may of course have had some influence on my reasoning.

13.1.2 How to study the feasibility of multiobjective budgeting

In Chapter 12 we made a theoretical comparison of the four procedures formulated in Part Two. In Part Three, we will be concerned with recommendations for the type of situations we can expect to meet in practice. The problem formulation in Part One, which we have used as our point of departure, was meant as a general description of the problem situation discussed in this study, i.e. the situation in which some form of multiobjective budgeting seems desirable. In a practical situation, the first step should therefore be to compare the situation with the original model from Part One, to find out how similar it is to the kind of situations to which this study is primarily addressed. This involves asking:

- Are the A-statements a relevant description of the situation?

and perhaps also trying to collect some evidence of the "fit" of the formulas (4-8) to (4-12).

If the general approach is relevant, the next step must be the choice of one of the four alternatives in Part Two, or possibly some modified compromise between them. According to the argument in Section 12.5.3, the four procedures could all be relevant to different practical situations, depending on how the additional assumptions introduced by each of them are met in the particular case. In fact, a choice involves the following steps:

- Find out which methods, if any, are possible, i.e. for which methods are those requirements that are contained in the C-statements and that are relevant, fulfilled by the actual situation?
- Evaluate the difficulty of fulfilling the statements, using the criteria under B - information can perhaps be provided, but only with considerable effort on the part of the units involved.
- Find out how other properties of the method affect the criteria in the situation in question.
- Combine the criteria values from the preceding two steps. The resulting evaluation may quite often in itself be a multiobjective problem.

An evaluation like this could only be attempted for specific applications. Only if a method behaved worse in every conceivable case could a general judgment be passed, or if its requirements (C-statements) could never be met. Further development of the approaches thus seems to require investigation of some real-life situations. The Televerket study is an example of this. Some less extensive "mental applications" are reported in Chapter 14. General methodological comments are made in Appendix D, to which the reader is referred for a discussion of case studies in general, and of the Televerket interviews in particular.

Throughout, it is the present situation in Televerket which I am discussing, although the design of a planning system also has to take into account possible future situations. Forecasts of these could only be based on current views, present knowledge, etc.

13.1.3 Plan of the chapter

In Section 13.2, the reader is introduced to the organization and its general planning situation. The desirability of an attempt at multiobjective budgeting is discussed in this context, and also the fulfilment of the A-statements and those C-statements that concern the general situation. In Section 13.3 we will discuss Televerket's CU against the background of the A-statements and C-statements about CU capabilities, and in Section 13.4 the LUs are subjected to the same examination. As differences between our four methods almost exclusively concern such capabilities, a comparison can then be made in Section 13.5 between the suitability of the four alternatives in the present case. Section 13.6 contains an outline of a possible multiobjective planning approach, and Section 13.7 some concluding comments.

13.2 THE PLANNING PROBLEM

13.2.1 The general planning task

The Swedish National Telecommunications Administration, known in Swedish as Televerket, is a state-owned monopoly firm for the provision of telephone, telegraph, and related services throughout Sweden; it also constructs and manufactures much of the equipment itself. Like similar organizations in other countries, profitability is an important result criterion. Charges are partly controlled by the government (and the Riksdag), but Televerket has to generate sufficient funds to pay interest on its equity capital to its owners. Following a recent reorganization, including the introduction of a new system of economic and financial control, profit has been stressed as the main yardstick in identifying efficient behaviour.

Societal utility is not synonymous with this profitability-based efficiency concept, especially not in a monopoly. Therefore, several other criteria have to be considered in selecting future plans. Some of these appear as constraints, such as the public's need for certain unprofitable services like telegrams, and public control of charges and employment plans. Even within such constraints, the preferred design of services could not be completely determined by profit considerations. Profits in excess of the required interest on capital are not desirable per se, at least not in the long run. Rather, a number of service criteria are used in the organization to describe the level of service. These will be discussed in Section 13.2.4 below.

This chapter concentrates on how the annual budgetary planning of activities related to telephone services could be changed to include more formal consideration of service qualities. As in Parts One and Two, planning for the next year will be emphasized. To concentrate in this way on one year among the six years covered in the present budgetary system, is somewhat questionable. Changes in service often take several years, as they may involve changes in personnel and equipment. Such decisions normally deal with a desired future state, rather than the "next period" of our model.

Further periods could probably be added to our chosen methods, in order to include planning over several years. But in the present case, discussions about service in Televerket are essentially concerned with the balance between service and profits in one of the later years of the six budgeted, and the rate of progress towards that state of balance. It seems possible that this desired balance is the only one that could be relevant to discuss as part of the annual budgeting, and it does not really require a multiyear planning design (or at least not one concerned with more than two years, the next one and the final "balanced" one). In the following argument, we will assume that some solution to this problem is possible, which would leave us with a one-year budgeting situation. For instance, it may turn out to be possible to discuss next year's possibilities and preferences, bearing in mind that the justification for current choices may lie in longer-term ambitions.

I turn now to two questions: Who supplies the societal preferences, i.e. who plays the role of CU? In what terms should possibilities be described? These will be discussed in Sections 13.2.2 - 13.2.4.

13.2.2 The division of authority

Televerket's organization can be summarized for our purposes as follows. Twenty Telecommunication Areas (Tele-Areas) serve the customers; these operate on budgets of their own. Budgets are decided in a planning dialogue with the central management. In the terms of this study, the Tele-Areas are the LUs and the central management the CU.

Our basic model in Part One assumes a central authority, with CU acting as "interpreter" of the organization's overall preferences. In Televerket these preferences derive from societal considerations. When Televerket decides to let summer-house subscribers wait longer for delivery than permanent residents, this is an interpretation of societal preferences. Such interpretations are not made in a consistent way, as the balance between objectives is the result of many decision-makers' opinions at various times, and of the past history of the various Tele-Areas.

There are several candidates for making these interpretations: the government, Televerket's central management, and the individual Tele-Areas. The government can be disregarded, as there is little sign that alternative service possiblities are ever discussed in its dialogue with Televerket. Changes are made only to maintain a service which is considered acceptable in view of tradition, public pressure and Televerket's own opinion. All this means that Televerket is left with the task of <u>interpreting societal needs itself</u> within its sphere of activities, either centrally or in the various Tele-Areas. To look after the public interest within its own sphere is one of the tasks of any Swedish public agency or utility. But as the budget is authorized by the government, we could not really have taken it for granted that Televerket would have so little discussion about services with its principal .

This is a key factor in deciding whether or not multiobjective budgeting is desirable. Only if CU preferences have to be combined with LU knowledge of the possibilities can it be warranted.

There remains the division of authority within Televerket. There are two major reasons why the Tele-Areas themselves should have considerable influence over their own performance. First, the area management has the best knowledge of its own customers, and regional needs may differ between, for instance, a densely populated city and a mainly rural area. Secondly, there may also be differences in the marginal cost of improved service (given the same initial level of service) because of local geographical or demographical conditions.

On the other hand, a strong role for central management could be justified on the grounds that it knows more about the total perspective: long-term ambitions in Televerket; customer views, as revealed in polls, that could be more representative than any that direct contacts in the local area could reveal; insight into national and international experience of possible approaches, and so on.

Perhaps even more important is the basic egalitarian policy which is revealed in the system of charges. These are uniform everywhere in the country, with some reduction in long-distance rates for people living in Northern Sweden. This means that it is an established policy that city subscribers are not served at the low prices that would be possible in their particular case, nor does it seem desirable to let them receive service that is incomparably better in quality. But exactly how this collective responsibility should be allocated, in terms of the costs and the service provided to subscribers in different regions, should perhaps be subject to central decisions. As one Tele-Area representative said in the interviews, we cannot have "twenty separate Televerkets".

Although central management has not laid down any decisions about LU service, similar decisions used to be made at the intermediate level of geographical districts, each of which embraced four or five Tele-Areas. The aim was to coordinate activities, so that similar service levels would be attained. In the recent reorganization the districts disappeared, but their tasks can be expected to reappear to some extent among those of central management.

Interviews in the central administration and in the Tele-Areas point strongly to a need for central guidance, so that regional differences can be planned and motivated rather than allowed to develop as the result of tradition and external factors. This is not the same as instituting identical service everywhere. Furthermore, the central role could include experimenting with different solutions and communicating the results achieved in various places. It would probably be more fruitful to compare parts or aspects of different Tele-Areas rather than to compare areas as a whole. Subjects at the interviews mentioned, for instance, the possibility of studying urban conditions in several areas and issuing targets for the service to be supplied there, diverging from the standards applying in rural parts.

We can therefore conclude that the Tele-Areas and the central management should both be involved in planning, which suggests that our type of planning would be _desirable_ in Televerket. The alternative would obviously be that central involvement was limited to deciding profitability requirements, while the LUs chose the balance in services entirely on their own. But the influence of central management and the Tele-Areas on the services both seem necessary, even complementary. I therefore _conclude_ that the situation in Televerket resembles that discussed in Part One above: the central management (CU) has the final word, but it can allow the Tele-Areas (the LUs) fairly extensive authority of their own. Moreover, in both cases it is the balance between several objectives (different kinds of service _and_ profitability) that has to be decided in the planning.

13.2.3 Relations between LU attributes and organizational objectives

Technological externalities were excluded from our basic model (A22)[1], as they are from most planning theories (cf. Heal, 1973, p. 221- 223). In the national (inter-area) communications network, such externalities occur when several areas share the responsibility for the equipment that is necessary for a long-distance telephone-call. This necessitates central decisions, but these will be disregarded here. Ideally they should be included in some sort of dialogue, so that the areas could contribute their knowledge of alternative uses for the personnel and resources involved in improving inter-area communications.

There still remains the greater part of the telephone service, where the only interaction between the different areas is preferential. For instance, a long delivery-time in area A is considered less acceptable if the service is being improved in other areas. Such preferential interaction results from the fact that a positive value is attached to equality as such, apart from the service levels attained.

In Part Two various assumptions were introduced about the relations between attributes and objectives. For instance, if objective-fulfilment can be calculated as the sum of LU attribute values (C19), identical objective/attribute prices can be communicated to all LUs. This is rather difficult to reconcile with the situation in Televerket, where the national counterparts to the yardsticks applied in the Tele-Areas mainly consist of the weighted averages of the local measures. However, central management would still be able to deduce the impact that changes in the area measure would have on the national one, and it could communicate attribute prices which allowed for the different "weights" of the different areas. There may still be areas where a higher or lower level of service can be motivated by the local conditions of demand, and where such simple

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[1]Numbers within parentheses refer to the A-statements in Section 4.2 and the C-statements in Section 12.4.

adjustments are not possible. In the following argument, I assume that problems of this kind can be overcome.

13.2.4 The identity of objectives, attributes and resources

Total profit is a constraint from the organization's point of view. However, profits in excess of the required interest on state-owned capital could be desirable in the short run - at least, such profits have existed in the last few years and have been regarded as proof of managerial efficiency. The profit requirement for an individual area will be regarded as the central resource allocation. The logic of this becomes clear if one considers the fact that a decrease in the profit requirement means that more resources become available for the area to spend to improve its performance.

Other objectives all probably constitute criteria of service. About thirty yardsticks of this kind are used quite regularly in the organization, although others exist and those that can be considered as the major indicators are much fewer. They have been in use for a very long time - "ever since Televerket started its operations", according to one subject. Long-term central targets have been announced for the service criteria, but they are commonly considered unrealistic and probably not even desirable. Some typical values for the most important of these are shown in Table 13:1.

Other criteria concern:

- Delivery times for other types of equipment
- Time for connecting certain calls (inter-area calls, excluded from our consideration above; S-O-S calls, and calls to sales and service departments)
- Share of repairs made within 40 working hours
- Number of repairs per year and 1,000 telephones
- Frequency of nonconnection for nonlocal calls,

Table 13:1. Some important service criteria in Televerket

	Central target	Typical current levels	Long-term ambition for one Tele-Area[*]
Mean delivery time for telephone sets (weeks)	2	3- 6	3
Relative share of repairs made within eight working hours (per cent)	90	45-75	60
Relative frequency of non-connection for local calls due to overload (per cent)	0.5	$\lessgtr$ 0.5	0.5

[*]Budget for 1976/1977, same year as the central targets, in an area with good profitability but intentionally moderate service quality.

For our present discussion - and apparently in Televerket too, when only a general picture is needed - a short list including, perhaps, profit and the three criteria in Table 13:1, is sufficient for use as attributes in planning.

13.2.5 The general planning situation and the basic model

The A-statements and C-statements were divided into three groups:

(1) Statements referring to the entire organization
(2) Statements referring to individual units (CU and the LUs)
(3) Statements referring to inter-unit relations

In this section, I will discuss the model "fit" in the case of the first and last groups; we will examine the middle one in the following sections.[1]

In these groups there are only three C-statements, but seventeen A-statements. This reflects the fact that the latter identify the general problem, while the C-statements introduce additional assumptions that are needed for individual procedures.

Some of these have already been discussed in Sections 13.2.1 - 13.2.4. We found there that planning cannot perhaps

[1] For the full statements, the reader is referred to Section 12.4. Short descriptions will be given in the text, together with statement numbers.

be strictly regarded as a matter of choosing a plan for the next period (A2). Nevertheless, the dialogue does mainly seem to concern a single balance between objectives, rather than several balances for different years. On the other hand, the authority relations (A11) and the basic single-resource situation (C1) seem to be reasonable approximations.

Of the remaining statements in these groups, my impression is that all proved more or less reasonable during my interviews. Some call for a few comments:

- Could information be centralized (A5)? Both Tele-Area and central management representatives claim that central knowledge of local possibilities is very limited today, and that there is a definite need for local knowledge. And given the special studies often required to identify local possiblities (cf. Section 13.5.3 below), it does not seem likely that future CU attempts to improve its knowledge could make centralized planning a real possibility.
- The number of iterations could be more than one, and for formal iterations less than six (A30). In the present system, there are face-to-face meetings between CU and LU representatives which could be regarded as a great number of messages, i.e. as iterations of a kind, but normally the LUs present two or three alternatives only during any one meeting. More substantial replanning would require one of the "formal" iterations, so I conclude that the severely limited number of iterations is basically true.
- CU's ability to select attributes (A31) has never really been tested, due to the traditional nature of these (cf. Section 13.2.4). As CU prepares the forms to be used, this influence seems clear.
- The statements regarding uncertainty and behavioural aspects (A7 and A8) were meant as simplifications from the start, but do not seem inappropriate in the Televerket case. In the present planning system, at

Televerket, differences in risk or provision for uncertainty are not discussed. The stable character of production and demand helps here. As for behavioural factors, our subjects did not seem very conscious of tactical budgeting, the motivational aspects of targets, etc. Disregarding such factors always involves an approximation; in the present case it seems less objectionable than in most.

As mentioned in Section 13.2.2, I consider that the desirability of attempts at multiobjective budgeting follows from CU's multicriteria preferences and the decentralized nature of the information that is relevant to planning.

13.3 TELEVERKET'S CU AND THE RELATED ASSUMPTIONS

CU's exercise of control depends on its knowledge of preferences, and on its ability to determine resource allocations and to select a final plan for the organization (A13). Televerket's central management obviously has these capabilities. Application of one of our procedures would further depend on the exact form of the preference knowledge, on the existence (if any) of possibility knowledge, and on the fulfilment of some technical requirements.

13.3.1 CU's knowledge of preferences

The combined impact of the activities of several LUs was discussed in Section 13.2.3 above. CU is certainly able to judge this (A14), for instance by calculating averages and dispersion-measures for such criteria as those in Table 13:1. As the period of budgetary planning is short compared to the long-term perspectives that the technology imposes, it also seems reasonable to expect preferences to remain stable during planning (A17) (which is perfectly reconcilable with the fact that preferences become clearer and more explicit in the course of the interaction).

The statements about CU's ability to use or communicate its preference knowledge (A15, C3 - C7), and the "true" nature of these preferences (A16 and C2), proved more difficult to check. The central management has not yet had an opportunity to choose between alternative service profiles, let alone to indicate their preferences in any more exact way. Instead, I had to investigate indications of such an ability.

As mentioned in Section 13.2.2, before a recent reorganization there were regular attempts to equalize the level of service in the different LUs. However, this did not really require any preferences, so more will be needed to justify multiobjective approach. Let us look at the alternatives. Could CU use "ideal points" to find targets (C3)? Targets are part of Televerket's present budgetary planning system, although they seem too optimistic to do much good. As the kind of targets discussed in C3 are not expected to act as more than general indications, it should be possible to find similar ones in Televerket.

My suggestion that they should perhaps provide more nearly feasible targets met with a certain reluctance from central management's representatives: upper and lower bounds were considered more practicable. Could these lead to a situation where single-objective planning is possible (C5 - C6)? For short-run planning, possibly "yes": particularly determined efforts may be needed during one period, for instance. For "service-mix" decisions that concern the "steady state" to be arrived at in the longer, run such guidelines seem less relevant. They could perhaps be used to guide replanning, but probably not with the same objective in several iterations.

Finding a reduction objective (C4) is a related approach, although here the problem is the opposite: to find out which objective is most adequately met. Our interview subjects thought it would be possible to answer such a question but obviously this should be test in a real situation. The most demanding of the assumptions about knowledge of preferences is C7, where CU is required to supply weights for the objectives or to disclose its MRS. Central decision-makers felt that it would be possible to answer questions such as: "How many days' speeding-up of deliveries would be worth the same as a 1 % decrease in the share of repairs that are completed within 8 hours?" but that it would also be artificial.

I conclude that, as far as can be judged from questioning some of the people who would have to make judgments like these, none of our statements about CU's knowledge of preferences appears totally unfeasible; C7 seems to be the most difficult to fulfil and C3 and C4 the easiest. At the moments CU preferences are rather rudimentary and undeveloped, which makes it difficult to pass any judgments on what could be achieved with regular use. The use of constraints, differentiated for different parts of the various areas, was however considered particularly attractive.

13.3.2 CU's knowledge of possibilities

The assumptions that deal with CU's knowledge of possibilities (C8 - C12) are relevant to one only of our four procedures. In the original model, CU's knowledge of possibilities was not included. In Televerket, central management may know more about the possibilities of individual LUs than CUs generally do, as the feasible sets can be expected to change rather slowly. Even so, CU will have experienced only a small number of service "mixes" in recent years' planning. To use this knowledge to "build" an approximation of LU possibilities such as we proposed in method III, may seem somewhat far-fetched. However, in his original method, Weitzman (cf. Chapter 10) claims that such knowledge would be sufficient, although it would probably increase the number of necessary iterations.

I conclude that the extensive knowledge of possibilities that could motivate the use of procedure III is not present in Televerket; on the other hand, its use should not be absolutely out of the question either.

13.3.3 Technical requirements

Assumption C13 was not tested at all, as it concerns the application of specific techniques where nothing is revealed by questioning.

Concerning stopping rules (C14 and C15), there is hardly more evidence. Successive planning iterations have so far always dealt with different resource allocation (profit requirements), as CU has not tried to affect the service mix chosen. The acceptance of a final plan, which has ultimately followed, can be seen as proof of ability to fulfil C14, although lack of time has generally led to a natural termination of the planning process. In this respect, little change could be expected to follow the introduction of multiobjective budgetary planning.

13.4 TELEVERKET'S LUs AND THE RELATED ASSUMPTIONS

In our model the LUs contribute their knowledge of possibilities. We have already seen that this also applies to the LUs in Televerket. Nevertheless, if we are to investigate the "fit" of our model and our procedures, we must look into this question in greater detail. Critical factors here are LUs' ability to select plans and to judge their impact, LUs actual performance possibilities, and LUs' knowledge of their own possibilities.

13.4.1 LUs' ability to select plans and to judge their impact

According to statement A18, every LU controls its own choice of activity levels in the plans presented to CU. In A19, an LU is said to be able to judge the impact of various LU-activity combinations on its own performance. In a Tele-Area, this control over performance is limited by two factors: market demand, and integrated production.

Market demand governs LU choices to a considerable extent. With no influence of its own on charges, a Tele-Area can do little to regulate the volume of traffic. But given the resources needed (especially personnel) and time for adjustment, the relevant service criteria can be affected by various designs of maintenance, construction, etc. The different policies in various Tele-Areas prove that there is some freedom of choice, as indeed the area representatives claim. Thus market demand acts mainly as a local constraint.

Integrated activities. Until recently, employees engaged in construction and maintenance work were specialized in such a way that different service criteria described the results of separate activities. Studies have been made where the cost of improving the share of repairs completed within a certain number of hours (cf. Table 13:1) from 50 % to 55 %, from 55 % to 60 %, etc., were found for a typical area. Although it would probably require special studies of this kind, it would be possible to gather similar information about individual criteria, since the necessary changes in activities can be identified.

Recently, some attempts at job enlargement have been made. A system of integrated activities has been introduced, whereby the employees themselves assume the responsibility for several types of service for a group of customers. Wage plans etc. may make certain activities more attractive to the employees, and this may make it difficult to control the final service mix. Of course, a Tele-Area manager can demand that services comply with certain norms, but integrated activities may still make it more difficult to foresee the impact of plans on performance.

With this reservation, however, the relation between production (activities) and performance seems to be known to the LUs. LU heads are therefore apparently able to formulate fairly exact expectations about the effects of alternative plans on performance, as well as about the effort needed to change performance. I conclude that statements A18 and A19 appear to be valid in Televerket.

The relation between attributes and objectives is the subject of assumptions A26 - A27 and C18 - C19. This problem was discussed in Section 13.2.3. It would probably be possible for CU in the present case to establish this relation well enough to be able to use some of our procedures.

13.4.2 Real LU performance possibilities

Local constraints on a Tele-Area's feasible set (A20) depend on the equipment in the area, on the number of employees that can be hired and on the skills the latter possess. In some areas it is difficult to attract skilled personnel, and would be so even if the necessary resources were present, i.e. if central management would accept a budget which included staff increases. This also points to CU constraints on LU possibilities (A21). I have already mentioned the current emphasis on profit-centre thinking, and that profit requirements can be said to provide the CU with a control possibility similar to a central resource allocation. This means that CU can influence LU possibilities in a general way: authorization to reduce profits can be used by an LU to improve its service performance in several alternative ways.

It was not possible in my interviews to test whether the feasible set was compact and convex (A23), but the marginal cost of improving a particular type of service was said to be increasing with successive improvements, which at least is consistent with this.

C16 indicates that from any feasible plan, you could always make any arbitrary decreases in one or more attributes. This is probably not true of a Tele-Area. Although most service criteria correspond to specialized activities, some of them could not be assigned very low values without others being affected at the same time. On the other hand, C16 could probably hold over the range of values that is relevant to practical planning. That constraints are not linear (C17) in real life seems probable.

Thus, to summarize the Tele-Areas seem to correspond more or less to our model as presented in Part One. Although the functional forms could not be tested, there is nothing to suggest that the procedures are likely to be less appropriate in this context than in most others.

13.4.3 LU's knowledge of possibilities

LU's knowledge of possibilities is an important part of our model. Together with CU's knowledge of preferences, it motivates our approach to the budgetary planning problem. In the basic model, only statement A25 dealt with this point. In the procedural assumptions, seven alternative statements (C20 - C26) refer to LU's abilities to make judgments.

Strictly speaking, even the A25 assumption that LU is able to find a non-dominated, LU-efficient plan is doubtful. This implies that LU should know exactly what could be accomplished in the absence of any slack at all, and this is something which could hardly be expected in any organization.

However, we can look at the sense of this formulation instead, which is that the proposed plan should be the best known one for an arbitrary trade-off between objectives. If there is no known way of reducing slack, it will perhaps not be correct to say that the feasible set really includes the maximally efficient, zero-slack plans. This points to a reduced concept of efficiency: the only criterion of efficiency is that an alternative must not be dominated by any of the other known alternatives. In these terms, a Tele-Area could certainly be said to believe that its proposals were efficient.

In most organizations it would be necessary to add reservations here about the tactics of budgeting, as studied by Hitch and McKean (1960) and Wildavsky (1964). It is not my impression that Televerket has an exceptional amount of such tactics, compared to other organizations.

All the C-statements considered here refer to LU's ability to select particular plans (rather than the arbitrary, efficient one discussed above), and to provide further information on chosen plans as well as describing them in attribute terms.

If CU issues specified constraints on attribute values, the LUs should be able to obey them (C20). In fact, to do this LU only needs to be able to find some feasible plan to propose among the remaining ones, and this seems possible for the Tele-Areas. My interviews indicated that people in the areas are quite ready to accept constraints on the quality of their service from the central management.

It may be more difficult for Tele-Areas to maximize individual service criteria (A21). However, if we interpret this requirement in terms that are rather less absolute and rather more practical, we may find it more acceptable: a Tele-Area could probably tell what a concentrated effort to improve each service criterion would mean for that criterion, and for others. This would be enough to provide CU with a sort of ideal point.

Use of a nonfeasible target for planning (C22) exists already, as can be seen in Table 13:1. Tele-Area decision-makers would have preferred a target closer to the feasible set. They also preferred this to objective weights or prices (C23). Although the criteria are expressed in quantitative terms, and the existence of some implicit trade-off is obvious, the idea of optimizing some composite index seemed strange to the people interviewed. Nor did they find a less exact variant attractive - i.e. to receive instructions to devote 25 % of their efforts to objective i, 50 % to objective j, etc. Realistic targets or lower bounds were much preferred.

It was possible, with some effort, to indicate technological trade-off possibilities (MRTs) from the proposed plans (C24) by developing alternative plans some distance apart. But this would require planning throughout the Tele-Area, starting at the lowest organizational echelons. Most areas already do present a few alternatives for performance in the next period to the central administration. A real example is:

(1) Reduction in repairs service, unchanged delivery time, unchanged profits

(2) Improved delivery time, unchanged repairs service, reduced profits

(3) A compromise between (1) and (2)

Such alternatives suggest that trade-off studies are possible, as was also mentioned in Section 13.4.1. But it would probably be very difficult to provide the full information on <u>derivatives</u> needed for the Geoffrion-Hogan method (C25). Approximative information of this kind could perhaps be provided by the budget simulation models now being introduced. These have not yet been developed to include full information on the service supplied but they indicate that this information may become easier to supply in the future.

Estimates of <u>resource worth</u> (C26) would require that the Tele-Area used some sort of performance index, as discussed in connection with C23 above. The same problems would also arise.

I <u>conclude</u> that at the present stage of development, objective prices and more extensive information about derivatives probably cannot be used in Televerket. On the other hand, <u>some</u> trade-off information could be provided, and Tele-Area representatives thought that realistic targets could be recommended as a way of indicating CU's preferences during planning.

13.5 SUMMARY OF THE "TEST" OF ASSUMPTIONS

Our survey of the A-statements and C-statements in Section 13.3 - 13.4 has now prepared us for an attempt to evaluate the general "fit" of the model and the procedures. As mentioned in Section 13.1, we cannot expect absolute agreement. It is rather a question of trying to find out which of the procedures - if any - seems to provide the most promising basis for further work in Televerket.

To this end, I will now summarize my comments on the A-statements and the C-statements, including those which I have not found any reason to review above as their fulfilment seemed obvious. This summary appears in Tables 13:2

and 13.3. The capsule versions of the statements included here are intended solely as a reminder, not as formulations equivalent to those given in Section 4.2 and 12.4.

Table 13:2. Summary of the Televerket study: the A-statements

Statement description	Comment on statement's chances of fulfilment
A1 Several objectives	Yes
A2 Next period's plan only	Problematic, but planning may yet concern one "balance" only
A3 Several possible plans	Yes
A4 Sufficient information	Assumed in all planning
A5 Decentralized information	Yes
A6 Planning recurs	Yes
A7 No uncertainty	Conscious simplification
A8 No behavioural aspects	Ditto
A9 Two-level organization	Yes, but sublevels within lower level
A10 One CU	Yes
A11 CU preferences valid	Yes (see discussion)
A12 Several LUs	Yes
A13 CU controls exist	Yes
A14 CU can judge fulfilment of objectives	Yes
A15 CU can rank plans	Yes
A16 CU preferences are concave etc.	Unknown
A17 Preferences stable during planning	Probably
A18 LU controls activities	Yes
A19 LU can judge activities' impact on attributes	Yes (see discussion)
A20 Local constraints exist	Yes
A21 Centrally given LU constraints exist	Yes
A22 No technological interdependence	If we concentrate on local telephone service
A23 Compact, convex feasible sets	Unproved but possible
A24 Multiobjective LU impact	Yes

(cont.)

(table 13:2, cont.)

Statement description	Comment on statement's chances of fulfilment
A25 LU-efficient plans can be found	In a modified sense
A26 One attribute per organizational objective	Yes
A27 Monotonous attribute-objective relationships	Possibly
A28 Messages between CU and LUs	Yes
A29 Diversified messages	Yes
A30 Two to five iterations	Possibly
A31 CU chooses attributes	Yes
A32 CU terminates planning	Yes

Table 13:3. Summary of the Televerket study: the C-statements

Statement descriptions	Needed for method no.[1]				Comments on statement's chances of fulfilment
	I	II	III	IV	
C1 One resource only		+	+	+	Reasonable approximation
C2 Non-linear CU preferences				+	Yes
C3 CU can use ideal points		+			Yes
C4 CU can select objective points to be reduced		0			Possibly
C5-C6 CU can give constraints and find single LU optimization objectives	-				Not in general
C7 CU can judge MRS	0			0	May be possible but thought "artificial"
C8 CU knows approximate LU possibilities			0		Not "natural" but may prove possible
C9 CU can revise the approximation from C8			0		Ditto
C10 CU can aggregate C8 approximations			(-)		Ditto
C11 CU can select plan in the C10 aggregation			(-)		As C8, etc.

(cont.) [1]Footnote se following page.

(table 13:3, cont.)

Statement descriptions	Needed for method no.[1]				Comments on statement's chances of fulfilment
	I	II	III	IV	
C12 CU can divide C11 plans into LU plans			(-)		Ditto
C13 CU can use GH algorithm	?				Unknown
C14 CU can judge whether planning should continue	0	0	0	0	In practice yes, but with unknown "decision quality"
C15 Ditto, for unchanged resources		0			
C16 The value of any LU attribute can be decreased			0		Not quite true
C17 Nonlinear bounds on LU feasible sets				+	Probably
C18 Different LUs have same impact on an organizational objective		0	0	0	Not really, but relation probably traceable
C19 Additive attributes			0	0	
C20 LU can use CU constraint	+	+			Yes
C21 LU can find ideal points	+	+			In a modified sense
C22 LU can use infeasible target		+	+		Yes
C23 LU can use prices		-		-	Not attractive
C24 LU can judge MRT	0	0	0		Only by developing alternative plans
C25 LU can judge derivatives	-				Difficult
C26 LU can judge resource worth		-		-	Not attractive
C27 Above judgements can be communicated	+	+	+	+	Yes - only such judgments are observable
C28 Resources are precondition for planning	+	+		+	Yes

[1]A mark in a column signifies that the statement is needed for the corresponding method. For easy overview, the "degree of fulfilment" is summarized using +, 0, and -. Absence of any mark indicates that the corresponding statement is irrelevant to the method in question.

Table 13:2 summarizes the verdict on the relevance of our model to the Televerket situation and this is mainly positive. From Table 13:3 we can get some indication of which approach might be possible. But it is not enough simply to count pluses and minuses; the methods differ in their other properties, and there are effects from using them that can not be predicted. But some comparative notes are now possible on the strengths and weaknesses of the alternative approaches.

<u>Method I</u> (single LU objectives and adaptive constraints) was found already in Section 12.5.3 to demand extremely strong assumptions. The Televerket case proves this once more: The central management thought it would be difficult to provide the Tele-Areas with constrained optimization planning tasks, while the MRS judgments might be possible but were considered artificial. In addition to this, the Tele-Areas would have to make derivative judgments that could only be based on guesses, or on an impossible large number of plan alternatives.

<u>Method II</u> (MRT approximations and ideal points) derived from STEM and similar methods, fares somewhat better. This was perhaps to be expected, as its heuristic character brings it closer to current practice, with consequent losses of computational qualities. Its greatest problem here would be the LUs' reluctance to use objective prices, which are needed in order to equalize MRTs. If this problem could be surmounted, there is nothing in the A-statements and the C-statements to discourage attempts to use this approach.

<u>Method III</u> (CU targets based on believed possibilities) uses a continuously improved CU estimate of LU performance possibilities. Not unexpectedly, this feature presents the only problems here. The initial approximations would have to be extremely crude, as the central administration knows only one, or at least not many, plan alternative based on the experience of recent years'. The revision of the estimates could follow the formal rules proposed by Weitzman, but the relative difficulty of this has not been

investigated. Perhaps this approach would be more warranted if CU began with a good idea of LU possibilities. In other words the procedure might well become more attractive if the central administration gains more experience.

Method IV (preference-based CU prices) meets with the same problems as method II, when it comes to LU's use of objective prices. And this time the problem is more serious as the method is entirely based on this device, whereas in Method II it is used only to achieve organizational efficiency. Central management's view that the use of prices is "artificial" points to the same problem as the Tele-Areas' reluctance. A lot of "selling" would obviously be necessary before area planners would accept to optimize a weighted composite index of very different types of criteria or to adapt their plan proposals to announced trade-offs between such criteria.

I would not, however, consider this a permanent obstacle. In other contexts, it has proved possible to develop and use similar indices (Baumol, 1975). Perhaps the fact that the index would have to change during the planning process robbing it of its air of "truth", would appear suspect to planners?

Unless such problems can be overcome, methods II and III seem likely to be the easiest to use. Of these, the dependence of method III on CU's knowledge of possibilities makes it less promising as yet.

Perhaps the MRT equalization in method II could be dispensed with, as it seems awkward to apply in the present case. In Televerket, not much would be lost. It is a step that is concerned with the achievement of organizational efficiency - here, for instance, ensuring that the best national averages of all LUs' delivery service and repairs service have been achieved. This could well turn out to be less important than the overall balancing of different kinds of service.

13.6 OUTLINE OF A HYPOTHETICAL APPLICATION TO THE TELEVERKET CASE

To illustrate how method II might perhaps be applied to the Televerket case, I will now present an "imaginary application". Its point of departure is that central management tries to assume a rather more influential role as regards service than it has now. See Section 9.3 for the original description of Method II.

First, the attributes (criteria of service) to be used and the planning horizon are established (on the dynamism of this planning situation see Section 13.2.1). Each Tele-Area estimates the maximal values for each attribute, given that they received as much resources as they want from central management. This would still not mean immediate delivery or any other kind of "perfection" as there are local conditions which would preclude this, and no area representative would interpret a maximally favourable budget in such terms.

These ideals help CU to set realistic targets and a tentative resource allocation (Step 1 of method II). This is the sort of information that the area representatives interviewed said would be valuable, and they would therefore probably be able to respond by giving the first outline of a budget in terms of the attributes (Step 2). Trade-offs between impact on the objectives of the total organization should now be evened out (Step 3). In Televerket this step could perhaps be dispensed with (cf. Section 13.5 above).

For each Tele-Area, central management would next identify the attribute which seems most adequately met (Step 5). Comparisons with other areas should make this possible. Replanning instructions could be issued in the shape of questions such as: What would happen if you increased delivery time by a week and used your employees for some other jobs, assuming that your target and tentative resource allocation remain the same?

After one or a few such replanning steps, central management would probably find that further improvements required a change in the tentative resource allotments (Step 6). As noted in Section 9.3, it is difficult to do this in an exact and formal way. The difficulties involved in having weights attached to the objectives also complicate matters.

By asking Tele-Areas how much more resources they would need in order to reduce by a certain amount the gap between the target and their latest plans, it would be possible to arrive at comparable estimates of the value to the various areas of additional resources . Approximate estimates of this kind could be made, even if the distance measure used would have to remain entirely intuitive. Central management could then change resource allotments in response to these values, whereupon a new iteration would begin.

During the following iterations, the process could be stopped at any set of area proposals which is deemed acceptable by central management. Note that any such solution would still mean that Tele-Area preferences exerted considerable influence, since only a large number of iterations could compel the areas to follow central preferences in detail.

13.7 SOME CONCLUDING POINTS

As I have shown in the preceding sections, I consider that the implementation of some sort of multiobjective budgetary planning in Televerket would be possible. Its general desirability was discussed in Section 13.2.2, but this would obviously also depend on how successful any one of the possible approaches could be expected to be in this particular case. Naturally the costs (in a broad sense) should not be allowed to exceed the gains.

To judge the desirability of a method in this sense, we need an evaluation using the B-criteria listed in Section 4.4. The interviews gave some indications about this as well.

The attitude to this kind of central involvement will mainly depend on what relations are desired between central management and the Tele-Areas. Some of our respondents expected future increases in charges to be quite small, which would mean that carefully thought-out decisions about what service is "acceptable" would become increasingly important. For some years now, high profits have made the need for external (state) financing insignificant - Televerket has even "paid back" some of its equity! As the profitability requirements are based on the capital invested by the state, this should mean that the profit requirements will in time become easier. It should then become possible for central management to devote more attention to service decisions. The growing maturity of the new economic system introduced recently should also help.

Naturally I do not posit this optimistic scenario as a prerequisite for central management's future interest in the quality of service. In fact, the reverse developments could motivate similar conclusions. If Televerket is faced by a more difficult economic "climate", it could be compelled to devote more consideration to questions of service.

At the same time the areas are not interested in strong central control. "Friendly but firm" directives are much preferred. Respondents in the Tele-Areas also point to the opportunity to "experiment" with different service profiles and different ways of designing activities in different districts as an advantage of a less rigid control system.

It is my belief that even the more centralized among the procedures outlined in this study would leave sufficient scope for this sort of freedom, as long as the possible number of iterations is as small as it is.

Finally, I should make some comments on the B-statements from Section 4.4. The requirement that plans should be few in number (B1) and that demands on CU and the LUs should be light (B2 - B4) cannot be evaluated objectively. Some sort of organizational "tolerance" would have to be found. I think the dialogue discussed in Section 13.6 is compatible with the planning and budgeting procedures being used at present, although the service criteria are not very prominent in these procedures (B5). The reactions of the participants are difficult to forecast (B6 - B8), although it seems reasonable to expect that the more open expression of the motives behind the activities chosen has a positive value.

The most important function of these B-statements, like those concerning the quality of solutions (B9 - B12) were of course to guide the formulation of procedures in Part Two. Their relative importance in Televerket cannot be ascertained from the interview material. The last B-statement concerns ex post analysis (B13). Here there would not be much change, as the districts already have local norms for service. In the new system these would derive from the budget process.

To summarize, there are indications that multiobjective budgetary planning is desirable in Televerket in a general sense. I consider it probable that one of the approaches described in Part Two could be used, although this has not been proved in any strict sense and some modification (approximations) would certainly be needed. Whether the implementation should also be considered desirable, considering the costs involved, cannot be decided. But, taking the desiderata introduced in Part One into consideration, no definite problems were foreseen.

14. SOME COMMENTS ON IMPLEMENTATIONS AND CONTINUED RESEARCH

14.1 INTRODUCTION

The Televerket study reported in Chapter 13 is the most extensive investigation that has so far been made of the prospects for implementing a version of multiobjective budgeting. There are several points to be added in connection with some of the statements, and these will be the subject of this chapter. The discussion will be based mainly on my own practical experiences.

The aim of this chapter is to provide some additional perspectives on the model used in this study, to indicate where I think it would be applicable, but also to suggest what changes would be needed in certain other cases where it might not be appropriate as it stands. This is particularly important if we are to identify suitable directions for further work.

To achieve the aim, I will concentrate on some key statements from Chapter 4, concerning the organizational structure, the informational structure, "imperfections" (uncertainty and behavioural factors), and relations to present budgetary planning. As before, we will be looking for indications of the <u>feasibility</u> and <u>desirability</u> of multiobjective budgetary planning, and will now relate these to certain properties of the planning situation.

14.2 THE ORGANIZATIONAL STRUCTURE AND MULTIPLE OBJECTIVES

The two-level organization assumed in the basic model is characterized by LUs that are independent as regards their activities, except that the central unit may issue commands that reflect common constraints. At the same time, the LUs have a joint impact on the various organizational objectives.

Thus, if there is technological interdependence in a situation where multiobjective budgeting is desired, the problem becomes difficult to handle (cf. statement A22). To some extent, this problem is analogous to that of setting up a profit-centre organization. The major difference between the independence for LUs assumed in such an organization and in our case, is that the multiobjective model dispenses with the assumption of a single measure of achievement (profit) for individual units. This complicates inter-unit relations where, in the profit-centre case, the single-measure assumption is used to find transfer prices. Multi-objective LU performance could easily require multidimensional transfer prices.

An exception occurs, of course, when inter-unit services or deliveries affect only one of the multiple objectives and can accordingly be evaluated in a single dimension. It may be that a market price obtains, and no significant impact on LU attributes other than profit can be expected. Such cases will probably be rare.

Apart from this special case, there are still a few alternative ways of modifying our model slightly (unless we are prepared to revise it extensively). One is to deal only with situations that, in a narrow sense, correspond to the model: that is to say, there is no significant technological interdependence between LUs. This should be true in the case of parallel activities in different regions that have to be coordinated, as in the Televerket example; or in the case of a product organization in which the LUs produce and market different goods. In many diversified corporations, it is probably true in the case of top-level control.

Another possible modification is to make the interactions subject to central management control, i.e. among the plan attributes reported by an LU are the demands it makes on other LUs, or perhaps its plans are based on tentative central decisions about inter-LU deliveries. However, this could strain the one-resource-only assumption that is included in several of our methods.

A third possibility is to set up some kind of planning sequence among the LUs, where LU j's (multiattribute) plan choice is allowed to affect LU j + 1's possibilities. This is in fact what does happen in many organizations already, when the sales budget is taken as input in the production budget.

Some additional comments appear in Section 14.2.1 below, where I review the planning situation of a major Swedish company. Interrelations between LUs are prominent features of other models with somewhat similar aims, notably Carlsson (1975). However, I do not know of any model geared explicitly to the balancing of objectives in such situations.

Another aspect of the organizational structure is the comprehensiveness of the organization, in the sense of the scope of the activities included in its planning. This will be discussed in Section 14.2.2.

14.2.1 The Uddeholm case: How to deal with a multiobjective matrix

Technological interdependence between LUs often calls for inter-unit cooperation and shared responsibility for plans. In certain cases, LUs may be required to identify areas of mutual concern in the form of a matrix. In Uddeholms AB, a major Swedish industrial company (1975 sales in excess of Sw. Cr. 2 100 millions), the Swedish steel-producing divisions and the international subsidiaries - each of which is in general responsible for sales in a certain part of the world - are dependent on one another in this kind of way. As Uddeholms set up planning targets for several objectives, we have here a case of a matrix planning situation combined with multiple objectives. For the year 1977, targets were set for profits, liquidity ratios, solvency ratios, capital turnover rate and employment.

While most of these objectives were the same for all LUs, profit targets were given for divisions and subsidiaries, as shown in Table 14.1. Representatives of these units would meet to agree on plans for the "matrix elements" of Table 14.1, assuming joint responsibility for these plans, or more exactly for the row and column sums resulting from them.

Table 14:1. Principles of profit targets in Uddeholms AB. Targets T_i are given by the central management; "row" and "column" representatives agree on matrix elements (profit contributions, and corresponding plans)

SUBSIDIARY (MARKETS)	DIVISION (PRODUCTS) A	B	C	D...	Common costs of each subsidiary	Subsidiary targets
1						T_1
2						T_2
3						T_3
. . .						. . .
Common costs of each division						
Division targets	T_A	T_B	T_C	T_D...		

During budgetary planning for 1977, this set-up was used for the first time, and it seems too early to evaluate it yet. The completed plans failed to meet the targets announced for profits and for some other objectives and, when planning was already under way, liquidity emerged as the dominating problem. In a situation which is financially problematic for the company, to find any feasible plan is difficult enough. Other objectives, related to more long-run concerns, seem less important. How far they can actually be neglected is of course also a multiobjective problem, but it seems reasonable to suppose that it is less urgent for management to enter upon an interactive dialogue for establishing this sort of minimum standards than to balance objectives at a higher level of fulfilment.

It is hoped that this situation will change in future years, and it will probably become necessary to seek an optimal balance between the objectives; fulfilment can then be considered partly in terms of the matrix of Table 14:1. This would mean that the general situation would parallel that of our problem, except for the interdependence. How could multiobjective budgetary planning be designed in such a situation?

The solution attempted at Uddeholms AB has been to organize interaction systematically (the matrix), which should mean that divisions and subsidiaries negotiate problems caused by the interdependencies before proposals reach CU. The intention is that it should be possible for CU to exercise control entirely in terms of division and subsidiary performance - so far most obvious in the profit targets of Table 14:1. At least in certain respects, CU should be able to treat these LUs independently, just like the CU of our model.

This makes possible several of the suggestions we made in Part Two above. For instance, a first planning iteration could lead to a set of proposals in which central management wants a change in emphasis, for instance:

- Greater emphasis on CU's views about employment which directly affects the production (divisions) and indirectly the sales (subsidiaries)
- Greater stress on CU's views about a desirable world-wide product-line profile, which directly affects sales and, indirectly, production
- Acceptance of the subsidiaries' wish to expand sales and acquire markets, at the cost of some sacrifice in liquidity; this also affects production

These changes in the trade-off between organizational objectives for the budget year all involve both the divisions and the subsidiaries. By relying on the matrix (by letting "rows" and "columns" negotiate), it might prove possible to let CU react to individual LUs in much the same way as in our our methods.

The main difficulties here might spring from the fact that, although the LUs can negotiate a plan, it would probably not be possible to ask them to supply alternatives or trade-off information. In fact both these kinds of information would be rather difficult to define in the given situation. For instance, a division's chances of substituting more employment for a reduction in profits will depend on its interaction with several subsidiaries. This means that the trade-off possibilities shown by an LU could be misleading, unless they are related through the matrix to several other units. Even if CU was able to organize the dialogue as if the LUs were independent (for instance, presenting them with independent demands for replanning), the necessary information as recommended in several of our methods would be difficult to find.

Another way of looking at this is to say that any trade-off will reflect some constraint which is binding in the situation of the suggested plan, i.e. trade-offs describe the boundary of the feasible set. Naturally this will sometimes depend entirely on a market constraint, or a production constraint, and these could provide trade-off values that are independent of production and sales consederations, respectively. But where both kinds of influence interact, trade-offs may prove too complex to handle.

Nevertheless, the methods could provide a general framework for the kind of dialogue which, at present, is not much in evidence at Uddeholms. This year there were two iterations, and some new planning directives issued in between, but there was no revision of the targets. A revision of this kind seems called for, if the targets are considered as a means of indicating preferences. It may have been that because of the economic situation this year, the real meaning of the targets was not very clear: were they CU's estimates of possibilities (cf. method III in Section 11.1), were they real requirements (constraints, as in method I in Section 9.2), or did they represent some sort of "ideal" (cf. method II, Section 9.3)? The various objectives were ranked, but it was not clear whether the ranking really gave the order in which targets should (if necessary) be violated or, if so, by how much.

To conclude: The matrix used by Uddeholms AB seems a promising way of handling LU interdependence also in a multiobjective context. It might prove possible for CU to give planning directives to individual LUs, relying on the units to interact in the matrix, in this way sorting out their mutual dependence. It would still be difficult to define the possible trade-offs between objectives as presented to CU, and this would make several of our methods awkward to apply. On the other hand, some of our basic structure still seems relevant, such as the way preferences are communicated to the LUs, and the way CU reacts to LU proposals. That multiobjective budgeting would be desireable in this context seems clear, at least before considering the likelihood of its success (using the B criteria, Section 4.4). Whether it would also be possible, cannot be answered until further attempts have been made.

14.2.2 An "incomplete" organization: state employee lunches

In this section, I will deal with a planning problem that is of small economic significance compared with those discussed in Chapter 13 and in the sections above. My reason for including it is to illustrate that a situation corresponding to our model can also occur in an organization that is largely informal and is oriented towards particular objectives which do not constitute the complete activities of the units involved.

As part of the service provided for the employees, most organizations either have a canteen on the premises or some sort of agreement with a nearby restaurant. In a survey undertanken in 1974 the state (which is the largest single employer in Sweden) found that conditions at different workplaces in the public administration varied considerably. It was felt that some effort to provide better-quality meals service was called for (Samarbetsdelegationen, 1974). The proposal, so far not put into practice, was that a central delegation should be set up as an "information pool", and to try to influence the agencies. The agencies were to be responsible for the service they provided, but they were to register and report their performance in terms of certain objectives or attributes, and the central delegation was to review their investment plans, in terms of the same objectives or attributes.

This process, covering more than 400 workplaces with restaurants of their own and numerous workplaces with external contracts, seems to resemble closely the kind of planning situations we have been discussing here. The delegation's final choice of plans would only be a recommendation, but in all other respects its role corresponds to our CU. The delegation would be the "interpreter" of the state employer's wishes (A11), it would recommend a certain resource allocation and plan (A13), and it would evaluate the local alternatives in a way that was not possible for the individual LUs themselves (A14 - A15). Thus we have decentralized knowledge, as described in A5. Other assumptions also hold; for instance there would be recurring decisions (A6) and some impact on local possibilities from the central recommendations (if enacted) (A21). The more exact requirements contained in the C-statements have not been tested.

In relation to the present study, the identification of the attributes to be used in the dialogue is of especial interest. This is discussed in Appendix A, Section A.8. It turned out to be impossible to find minimum standards for these attributes, as the members of the committee responsible for the study would not accept any general norms of this kind. As the committee members would probably have formed the core of the CU in the proposed delegation, this is an interesting reaction. It illustrates my basic thesis that desired values for the attributes in a particular case cannot be formulated in isolation, but only together with available possibilities and existing standards elsewhere. A dialogue is needed where possibilities and preferences are explored together.

Discussion with the committee members also seemed to indicate that they would probably be able to fulfil their mediator role in the proposed organization, using information of this kind - although it did not consist of fulfilment values for the different objectives, but only of observable properties of the available alternatives. See also my discussion in Riksrevisionsverket, 1976, Chapter 7.

In this way, a dialogue corresponding to that suggested in our methods could result. It would not matter significantly that the CU would not have full authority over the LUs - in deciding its recommendations, it would behave as if it had, and it would have considerable influence over what the agencies would be authorized to do in terms of subsidies, etc.

This example, although it has not been put into practice, thus indicates that multiobjective budgeting could be used in other situations that differ in some ways from the complete planning of a formal organization. Similar attempts could be made in formal organizations to budget for specific activities, where no single objective dominates.

14.3 THE IMPORTANCE OF THE INFORMATION STRUCTURE: THE CASE OF THE SWEDISH DEFENCE

My first contact with multiple objective decision problems was at the Swedish Army Staff, where I was involved in the annual budgeting for almost three years. Thus planning in the army became a natural setting for my speculations about ways of improving planning, as well as a mental testing-ground for some of my ideas. This section is based on some of my impressions from that period, combined with material from interviews held later to discuss subsequent developments.

The programme budgeting, which was introduced into the Swedish Defence Organization on an experimental scale already in the late sixties and which is now fully established, stresses local responsibility to an unusual extent. As defence is often considered to be a multiobjective activity, it might at first seem natural to devise a budget dialogue in multiobjective terms. In this section, I will not do so. To my mind, little could be learnt in the field of defence planning from an attempt to design multiobjective budgeting. The explanation for this lies in a lack of correspondence with our basic model, particularly as regards the information that different units can contribute to planning.

Swedish defence-planning theory is based on the idea of alternative threats; preparations for facing these have to be balanced against one another (SOU, 1969). In practical peace-time politics, planning is also affected by civilian objectives such as employment and environment. Short-run training results are often studied, with the help of various tests (cf. Tell, 1976). Objectives thus appear to be diverse and possibly conflicting at various planning levels (A1). In several of these situations, planning could be said (i) to concern the selection of one plan from a set of several, (ii) to be recurring, and (iii) to presuppose that the organization possesses the necessary information (A3, A4, A6). Uncertainty (A7) and behavioural factors (A8) can be disregarded with as much or as little justification as in the situations described in Chapter 13. At least in short-range planning of training, I never came across examples of these factors seriously affecting the choice of plan.

Statement A2 stresses the following time period. In the army, the year being budgeted may be more than one year away, because the budget has to be accepted by the Department of Defence and presented to the Riksdag long before the year starts. This does not change the basic situation, in which the Chief of the Army (assisted by the Army Staff) is the CU and the army units (regiments, schools, etc.), are the LUs (about one hundred of them) (A9 - A12).

We have seen that many of the A-statements are fulfilled by this situation. But some are not. The A-statements were formulated to describe the kind of planning situation in which multiobjective budgeting seemed desirable. Situations that fail to agree with some of the vital A-statements may not be candidates for this rather complicated way of planning.

A very important assumption which raises problems here is A5, which states that the information which is needed for choosing plans cannot be centralized. A5 is further developed in A14, A15, and A19. They indicate that information should be divided between CU and the LUs in a specific way. LU information should concern the means that are available, while the CU has to decide what is desirable from the organizational point of view. In defence planning, several factors are problematic in this context.

Foremost among these is the great length of the time-perspective involved. The annual budget is based on five-year plans, which in turn are derived from plans of up to fifteen years. In planning for any individual year, all that remains to be decided is the exact use of existing personnel and materials. There is not much freedom of choice about what to do, in order to make the results of training (the "products") compatible with long-range plans and activities in other LUs. Decisions about how to do it may affect such things as personnel satisfaction and knowledge, but these factors receive little attention compared to the major defence objectives, and their minimum standard is largely determined by various regulations.

Sudden reductions in the funds available could compel the army to reconsider its training plans, but political decisions of this kind are avoided in Sweden. When reductions have had to be made, there seems to have been a high degree of consensus about the measures to be taken. No analysis of the individual decisions has been attempted, except to find out the exact impact on resource requirements.

A major reason for this seems to be the lack of any ultimate "test" of training results, i.e. of the performance of the LUs. For all kinds of training and likewise for the procurement of material, there are norms for what should be accomplished. As long as these are obeyed, all is well. The norms derive from assumed means-ends relationships, which are the same for both norm-setting and the evaluation of performance. Because of the very hypothetical nature of most defence planning, we find that such well-defined but hypothetical means-ends chains constitute the only knowledge there is on performance "value", as no other "truth" about how activities affect objectives can result from peace-time activities. Consequently, where intuitive evaluations are made, all the decision-makers who are similarly schooled within the organization, come up with very similar views (Tell, 1976).

This reduces the value of involving LU representatives in the planning. They simply do not have much to contribute beyond the models of the world on which everybody is agreed. An activity that could nevertheless benefit from decentralized planning is of course the balancing of lower-level objectives (the exact scheduling of activities, health service and leisure time activities, etc) that takes place during the annual budgeting. The impact of these on military objectives is controlled by the imposition of certain minimum requirements that are fairly rigid. Otherwise, though, the unit commander can decide such things himself, except that an increase in costs will usually not be possible. But even here, exact needs will depend on the weather, the quality of the conscripts, and so on, and it may not be possible to decide things in advance at all. Two years from now, not even the personnel involved will be the same. So the only clear function of local planning remains the same as now: to identify the least costly way of achieving an already defined performance, and to give the local manager a feeling of responsibility and involvement.

The norms for military training as well as for the health service, etc., derive from long-range studies. These are general in nature, and take few local conditions into account. This means that even in the process of planning for a longer term, there is very little call for a planning dialogue. When the training norms are being determined for a new weapon system, training experiments and the feedback of local information are encouraged, but this does not correspond to the recurring exploration of possibilities and preferences that is the keynote of the present study.

I conclude that in this situation, it is probably better to reduce the dimensionality of the planning problem with the help of weights and constraints determined centrally, rather than to keep the full dimensionality of all the indicators used in the means-ends chains. The "hypothetical truth" can be used in choosing weights, transfer prices, etc. and, as there is no reason to question these during the planning dialogue, little motive remains for multidimensionality. A preferences-first strategy of this kind comes rather close to the cost minimization mostly used today. Once preferences have been determined, this approach will of course always offer the advantages of lower costs and fewer alternatives to be explored.

14.4 REAL-LIFE "IMPERFECTIONS"

Of the statements in set A (Section 4.2), two in particular are in the nature of simplifying assumptions, such as are not uncommon in models of this kind, but which could not be expected to be fully met in practice. These are the assumed absence of uncertainty and behavioural factors (A7 and A8). Although these do not seem to me to be realistic, much real-life planning nevertheless appears to be based on implicit assumptions of this sort. Uncertainty is reflected mainly in the choice of plans, where alternatives presenting unacceptable risks are simply not considered. To let the dialogue explicitly concern ranges rather than point estimates of outcomes seems much rarer. Behavioural factors relevant to this kind of planning, apart from the implicit-knowledge concept and some effects of the budgetary system (see the B-statements listed in Section 4.4), are cheating and uncooperative behaviour. These are generally guarded against in informal ways - in most budgeting systems, as such, there is little to show that this sort of "imperfection" exists.

In a multiobjective situation, both assumptions take on added significance. Regarding uncertainty, the multidimensional character of performance and CU judgments means that we can differentiate between several types of uncertainty. As for behavioural factors, multiattribute plans obviously provide new and possibly more fertile opportunities for cheating.

We will examine these two assumptions a little more closely in the present section, although I have not yet made any practical investigations of these aspects.

14.4.1 The handling of uncertainty

Throughout this study, we have followed the assumption (A7) of certainty in all estimates. LUs and CU cooperate in finding the preferred plan, and they do not expect that their knowledge of performance possibilities or of preferences will later prove to have been mistaken. In this section, I will try to find some ways of treating uncertainty (or risk) rather more explicitly.

Let us first examine the risk that results from uncertain LU estimates of performance possibilities. This involves two questions:

(1) Which LU activities are possible?
(2) How will they affect plan attributes?

A simple method here would be to let the LUs announce the uncertainty that is associated with the plans proposed with the help of an extra attribute (or attributes), for instance dispersion estimates. This resambles the approach used in portfolio theory (Markowitz, 1952), where the risk is associated with singleobjective profitability. When there are several objectives it might be better to find uncertainty measures for each one, rather than to seek some overall measure.

This would certainly make planning more cumbersome. The LUs would be required to make more complicated estimates, and CU would have to have preferences over the risk values as well as over other attributes. (If the attitude to risk is specified well enough, perhaps attribute values could be discounted into some sort of certainty equivalents.) But there should not be any theoretical obstacle to introducing uncertainty in this way. Although there would be a need for specific relations between objectives and attributes, the attributes themselves could obviously have any identity.

An alternative would be for the LUs to provide an interval estimate for each attribute value - or a few estimates, as in PERT (see, for instance, MacCrimmon & Ryavec, 1964). In both cases CU would have to consider a new problem in judging the combined effect of LUs' plans (the H-transformation of formula (4-10)), and its judgment here could also introduce uncertainty:

(3) How will the plans of several LUs combined affect organizational objectives?

As several uncertain estimates are thus combined, CU will have to know something about their interaction. Will the combined LU performance show more, or less, uncertainty than that of individual LUs? The additional information thus presents new demands on CU.

CU also has to consider the other type of uncertainty: that its own estimates of preferences may be uncertain. The estimates refer to future time periods, and what is thought now to be good for the organization may not necessarily turn out to be so.

CU may be uncertain about the best balance of organizational objectives and about how LUs' combined plans fulfil organizational objectives. Following Lahdenpää (1974), the objective-balance problem could even be divided into two parts:

(4) How much importance will different stakeholders attach to different objectives?

(5) How powerful will different stakeholders be?

Different power balances could perhaps be used here as "states of nature" in CU's decision analyses. Tell (1976) describes an evaluation model for multiple objectives which highlights the probabilities of different future states. As Tell deals with ex post evaluation of existing commodities, the states are possible future "situations of use", but a similar analysis should be possible in our present case.

For a further analysis of this question, the concept of ex post optimality (Demski, 1967; Magnusson, 1974) could be introduced. Optimality would mean here adaptation not only to ex post information about possibilities, but also to ex post preferences. This concept would probably be very difficult to use in practice, however.

A decomposition of the uncertainty associated with alternative plans in the way proposed here will rarely conform to any exact rules. Nevertheless, an awareness that uncertainty may result from each of the five planning questions introduced in the last few pages, could prove useful in a less formal consideration of plans. And certainly such factors should not be ignored in practical implementations.

14.4.2 Behavioural factors: cheating and personal goals

In our basic model behavioural factors (A8) were disregarded, mainly because their impact and influence varies in different practical situations, and my intention here has been to consider a rather abstract and "general" case. We can look briefly at one of the most important behavioural factors: the effect of personal self-interest on the part of the budgeteers. This could result in problems:

> [If the superior] gives his subordinate a great deal of autonomy and does not make an effort at observation, the subordinate will maximize his own rather than the superior's objective function. If the superior makes the costly effort at observation and

> deprives the subordinate of autonomy, he is likely to give wrong orders because of his technological ignorance. A possible solution is a reward structure which brings the objectives of the two parties closer together (e.g. output sharing). ... it is meaningful to seek an optimum combination of observation effort, delegation authority (grant of autonomy), and reward structure. (Hurwicz, 1973, p. 25)

For an overview of these problems and some references, see Hurwicz (1973, pp. 23-27). The properties of several formal planning models have been investigated. For less formal procedures such as those of the present study it is much less possible to say anything definite about the consequences of "disloyal" behaviour. Optimistic estimates of performance possibilities would of course lead to more resources, but the probable under-attainment of plans that would result, would not seem very attractive to the LUs. Rather, the LUs might be more interested in forcing a generous allocation by overestimates of resource requirements, but then they would run the risk of a reduced scale of activities. Here we are entering the realm of game theory, because very soon all the LUs - and CU! - would be involved in bargaining.

My own guess is that the introduction of more precise descriptions of plans and preferences would greatly increase the risks of making "false promises". Deviations from plans that do occur will be much more obvious, and this could result in various forms of penalties. An LU might be allowed less influence over the next period's budget, for instance, because it had lost some of its credibility.

It would probably be advantageous to combine the methods proposed here with various ways of involving people more actively in the planning process, for instance by introducing a <u>management-by-objectives</u> scheme (MBO). One of the proponents of this concept has suggested that various areas for which profit cannot provide a yardstick - personnel, research, law departments and so on - should be evaluated as programmes. (See Odiorne, 1965.) These programmes must be discussed before budgets are decided, to avoid the pitfalls mentioned above. A single performance indicator is necessary for each programme. In most cases, such an indicator also is said to be possible, if the responsible people are made more conscious about agreed objectives. There is a risk that estimates may be excessively conservative, because of the penalties imposed if plans are not fulfilled. This can be avoided by allowing some percentage of non-attainment.

MBO is sometimes seen as an alternative to programme budgeting, but it is difficult - apart from the more personal character of the discussions between superiors and subordinates about achievement, problems, and plans - to see the big contrast between them that is claimed by such writers as Ree (1974). If MBO can provide the basis for more active involvement on the part of the participants in budgeting, it should certainly be tried as a complement to the methods we recommend for multiobjective situations.

14.5 RELATION TO PRESENT BUDGETING PRACTICES

Among the aspects of the models discussed in this study that need to be investigated further is their "fit" with present-day budgetary planning practices. This relates especially to one of the B-statements (B5), which speaks of "compatibility" between the old and the new systems.

In order to find out about this, the present proposals can be compared with the budgetary-planning dialogues charted by Bergstrand (1973 and 1974). Bergstrand uses diagrams to show how proposed and completed budgets "move" in the organization. How would our methods fit into such patterns?

The budget process corresponding to method II is shown in Figure 14:1. This method has been chosen here because it is the one that uses the most iterations - others omit some of the steps. In the figure, contact is made between the budgeteers and the budget officer to perform Step 3, while two iterations are shown for the first resource allocation and one for the second which both involve the central management.

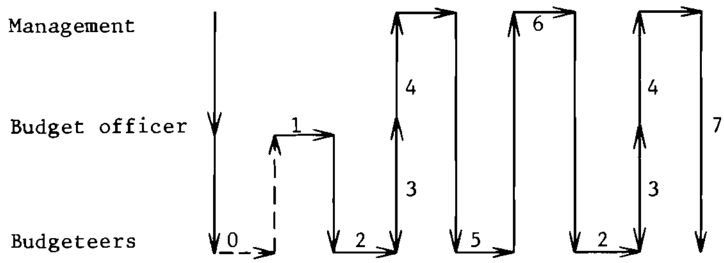

Figure 14:1. A budget process corresponding to procedure II (Section 9.3). Numbers are step numbers in the procedure: (0) determining an ideal point, (1) deciding an initial resource allocation, (2) deciding LU plans, (3) changing these for organizational efficiency, (4) reporting to CU, (5) revising plans in accordance with CU preferences, (6) changing resource allocation, and (7) announcing the final budget.

To describe budgetary planning in greater detail, Bergstrand proposed a chronological list of activities during planning. Its main activities are:

(0) introductory administrative activities
(1) clarifying goals
(2) clarifying basic assumptions
(3) developing preliminary budget sections
(4) participation in budget dialogue
(5) developing a budgetary forecast
(6) consolidating sections into a corporate budget
(7) suggesting changes in preliminary budget sections
(8) reworking the corporate budget
(9) concluding administrative activities.
(Bergstrand, 1974, p. 13)

Some of these remain unchanged if the budget is given a multiobjective character. Some, such as "clarifying goals", receive a different emphasis (cf. Section 2.1 on current practices). There are also some activities which must be added, such as a prior identification of objectives and attributes to be used in the dialogue.

Bergstrand uses his scheme to identify the strength of the tendencies in particular cases towards "build-up", "break-down", or other types of budgeting, by identifying the responsibilities for different tasks. A multiobjective dialogue would need a fairly strong degree of central control, if local plans are to be organizationally efficient and effective. This would probably give CU - or to use Bergstrand's terms, management and the budget officer - a more demanding role. (Bergstrand's budgeteers can be identified with our LUs).

Bergstrand also identifies subactivities within each of his nine steps, each connected with a particular actor. If we try this for Figure 15:1, but exclude some trivial steps such as "receiving" budgets, we will get the following (numbers withinparentheses refer to Bergstrand, 1974, pp. 13-15):

Management: Identifies objectives (111), takes part in budget dialogue (141) by providing preferences (113). Considers and confirms total plans (161, 191).

Budget officer: Initiates the process (201). Gives initial resource allocation and "interprets" management objectives (221/2, 231/2), evaluates combined effects of partial plans (261). Takes part in budget dialogue (241 and perhaps 262/3). Determines and announces changes in resource allocation (271, 371, and also 171 as this change is more administrative in its nature than those considered by Bergstrand).

Budgeteers: Find the range of feasible attribute values (part of 411), and develop LU budgets (431). Take part in dialogue (441) and revise plans (481). Detailed budgeting (432) may wait until a late stage in the process.

(The first figure in the activity numbers used by Bergstrand identifies the actor, the middle figure corresponds to the numbers of his nine basic activities, and the last one to the different subactivities.)

If we compare these tasks with most of the case studies from Swedish industry and public administration, reported by Bergstrand, we find that the budget officer's role is more important in our procedure than Bergstrand found it to be in his real-life cases. This is because:

- The budgeteers are not able to judge their plans themselves, as a total perspective is necessary
- The nature of management's preferences require a judgment of the total impact of plans, before the plans can be evaluated
- Management cannot divide a need for replanning between budgeteers (nor will the budget officer always be able to help here)

Bergstrand found one firm whose budgetary planning process revealed a similar complexity (Astra). It should be noted, however, that more complex budgetary planning also yields solutions to some problems that would otherwise require separate forms of planning.

Bergstrand did not discuss the contents of the budgets, e.g. the type of accounts used. A number of Swedish firms have attempted to refashion their budgeting along the lines of Madsen's variability accounting (Madsen, 1970). Their experiences were reported by Polesie (1976). Although Madsen's "formål" is a type of objective, used to systematize costs and revenues, there is no immediate relation between the use of such budgeting and the approach of the present study. Polesie speaks of a direct causal relation between resource-input and his cost objectives ("formål", or "ändamål"), where each cost is incurred for one objective only. In addition to this there may be a final relationship between resources and, for instance, the sales of individual units, but there is no attempt to link costs to several such organizational objectives (see Polesie, 1976, p. 76; also pp. 58-66).

Nevertheless, I think that this kind of budgeting may provide a better starting-point for multiobjective budgetary planning than traditional budgeting systems. The type of accounts proposed by Madsen and Polesie would probably be able to provide more of the information needed in the reformed budget dialogue. This points to a tentative general conclusion: although the contents of actual budgets have not been considered in this study, they may affect the chances of a successful implementation of some of the procedures discussed here.

14.6 CONCLUSIONS AND DIRECTIONS FOR FUTURE WORK

In Chapter 13, one potential application of multiobjective budgetary planning was discussed in depth. In Chapter 14, this discussion has been complemented by a discussion of selected aspects of the models proposed in this study, as they relate to practical situations. The results of this brief analysis have to remain indicative rather than conclusive, but they provide some new insights not only into the feasibility and desirability of the approach used here, but also into some of its limitations which could inspire further work in this area.

Some <u>conclusions</u> from the present chapter are:

- <u>Some sort of multiobjective budgeting may be feasible and desirable even in untypical situations</u>, for instance for some types of activities within an organization, or (the case described in Section 14.2.2) for coordination between basically independent units.

- <u>In particular, technical interdependence between LUs may cause problems</u> and to these no solution has so far been suggested, although basic ideas from the approaches used in this study may still prove useful (cf. Section 14.2.1).

- Thus, whereas the <u>feasibility</u> of multiobjective budgeting may depend on the organization's "technical" structure, its desirability depends on, among other things, the <u>informational structure</u>. The LUs must have some knowledge to contribute to the process, if they are to be involved in the planning dialogue (cf. Section 14.3).

- Deviations from the models used here in the form of uncertainty or cheating, etc. (cf. Section 14.4), should be considered before implementing any model. Such <u>"imperfections" may assume a more complex form</u> in a multidimensional context, <u>but</u> on the other hand they may also be easier to identify and deal with because of the fuller descriptions of plans used here.

- Implementations will mostly involve additions to some existing system. Their desirability will depend on the characteristics of the earlier system. A look at typical systems of this kind seems to indicate an expanded role for the budget officer (cf. Section 14.5).

Some of these conclusions also suggest directions for further work. In particular, I am convinced that this very obvious dependence on the nature of the practical situations indicates empirical work as a necessary step. A suitable point of departure could be that certain developments in present-day firms and agencies seem to point in directions similar to an application of our procedures. Thus, social accounting and auditing (see for instance Dilley, 1974; Carlweitz, 1975; Social Audit, 1976; and Social Measurement, 1972) would be a natural starting-point for "social budgeting". At least, this should be the case, provided that social-accounting ambitions really extend beyond mere "window dressing" and the defence of already decided plans. The same could probably be said of human-resource accounting (Brummet, 1968).

Relations to another technique dealing with similar problems, namely cost-benefit analysis, are more complicated. The characteristic feature of this approach is of course the evaluation of social effects in monetary terms. This is something I have tried to avoid, except when there is a consensus about the evaluations, or when it involves a purely temporary step through objective pricing. But before making his unidimensional evaluation, a cost-benefit analyst must identify the relevant facts in much the same way as our planners. One difference is that a cost-benefit analysis is generally a once-for-all venture, while the methods proposed here deal with recurrent planning and have to be used several times in order to justify their initial costs.

These earlier experiences have something to contribute to any attempts to develop multiobjective budgetary planning.

In particular they should be able to help in identifying the attributes for planning (cf. Appendix A), and in creating an awareness in the organization of the need to consider multiple criteria. Though a certain minimum organization size seems necessary, some initial experiments could perhaps take place in a modest-sized organization. Or perhaps they could be geared to a single function or some aspect of activities in a larger organization, as suggested in our first conclusion above. Examples could be marketing, or personnel recruitment.

For instance, where performance indicators or "key numbers" are now used for evaluating activities, implicit expectations probably already exist during planning about the values aimed at for these indicators. It would then be quite natural to try to make these expectations explicit. As we have seen in Section 14.2.1, this is already being done in some quite complicated cases, although the exact nature of the targets could be clearer.

An attempt could then be made to use one of the four approaches described in Part Two above to structure the resulting multidimensional planning dialogue. The distribution of knowledge between CU and the LUs in different organizations should make one or the other of these the most attractive one in any particular case. To be able to recognize practical situations to which one or the other of the methods would be appropriate, would in itself be an interesting addition to our knowledge, as the "organization profiles" contained in the sets of C-statements in Chapter 12 are the results of theoretical studies only.

Some such attempts at multidimensional budgeting could lead to practical revisions of the methods, or they could themselves provide new information. They could also be used for evaluation with the B-criteria listed in Section 4.4.

Further <u>theoretical work</u> could also prove valuable, although by comparison it seems less promising. The dilemma here is that the reasons for the relative failure of existing planning methods to handle the kind of situation envisaged in our model, lie in its informational assumptions, and in particular the implicit preferences of the CU. To continue theory-building without additional information about the knowledge of possibilities and preferences possessed by organizations in the real world, does not seem realistic.

This also makes me doubt the usefulness of simulation studies at this stage, as (i) the procedures in their strict form are interesting only as representatives of alternative approaches, and (ii) simulations would require "realistic" assumptions concerning so many variables, their relations, and knowledge about these, that the resulting recommendations would be highly disputable. Somewhat better results could be hoped for from experiments such as business games, where real decision-makers could take part. Even here, designing a situation activating the right type of behaviour would obviously be a problem.

Simulation and experimentation could become very interesting, however, once some more practical experience has been collected, and plans to use them could very well influence the design of any subsequent empirical studies.

As a later step, attempts could be made to deal with the major difficulty discussed in Section 14.2.1, the interdependence between LUs. Such externalities are a classic problem in planning theories, but they can be expected to be even more important in multiobjective organizations. Just as the aim of this study has been to find practical guidelines rather than to achieve formal elegance, I believe problems caused by externalities should be given high priority in future work - even if recommendations for such situations can be expected to remain tentative and heuristic rather than final or based on "complete" theories.

To summarize: I recommend that further work should be empirical; that carefully selected planning situations should be sought, preferably where multiple attributes are already being used in an informal way; and that such studies should be expanded gradually to include other factors not considered in the models presented here. A valuable intermediate product of such research would be examples of situations where one or other of the approaches discussed in this study, or combinations of several, had turned out to be useful. Practical inspiration from the ideas contained in this study should be given priority over algorithmic developments, although there is also a need for this latter type of studies.

PART FOUR
SUMMARY, APPENDICES, REFERENCES, INDEX

15. SUMMARY

15.1 THE BASIC PROBLEM

This is a study of budgetary planning in decentralized organizations with multiple objectives. Budgetary planning is the part of budgeting which deals with the preparation of a budget, i.e. the choice and design of the activities for a future time period. Budgeting involves different levels of organization and is a recurring activity which obeys certain rules, the design of which is the main interest of the study.

The term multiple objectives implies here that there are several criteria which have to be kept separate during planning, as no permanent "superobjective" is known, such as a weighted sum of the objectives. The choice of a "best" balance between objectives is made by the organization head or its central unit, relying on this unit's implicit knowledge of organizational preferences. Various assumptions are made about how this knowledge can be used. Characteristic is that the implicit preferences cannot be communicated in full, but can be revealed in part if they are "activated" in confrontation with plan proposals.

There are two basic strategies for achieving this. One, preferences-first, is to use special techniques, for instance hypothetical choices, to explore preferences as a preparation for budgeting. Preferences are then represented in some way which makes traditional planning techniques available. Another, an interactive exploration of possibilities and preferences, means that the central unit reacts to actual proposals. The organization learns about its possibilities and its preferences during a planning dialogue.

The latter strategy is used in this study, because of its more explicit handling of multiple objectives. Producing units know their own production possibilities; they also know how their choice of activities affects their contributions to various objectives. This knowledge is also implicit, in the sense that only individual plans can be presented to the organizational head. This means that the opportunities for using this decentralized information have to be taken into account in deciding how the dialogue should be organized.

Attempts are made here to find alternative approaches to the problem of procedural design: How should the dialogue be organized, and what communications should take place? Special attention is devoted to the prerequisites of the dialogue: What do different dialogue designs require of the organization?

15.2 METHOD

The major part of the study is concerned with the development of a unifying theoretical structure, which embraces the relevant parts of a variety of theories. The essence of this analysis is contained in three sets of statements concerning potential applications, which correspond to a number of alternative organization models.

The first set, denoted set A, is our basic model. It identifies the situation briefly described above, in terms of assumptions about organizational characteristics: structure, division of information and authority, to what extent information can be communicated, etc. This description is fairly general and should fit a large number of business firms, agencies, and public utilities.

The design of a planning procedure which can be used to handle the planning situation has to be guided by a number of considerations: quality of solution, ease of use, etc. These are defined through a <u>B set</u> of statements. As these also become the criteria for an evaluation of actual procedural applications, these <u>desiderata</u> can be considered part of the problem formulation. Set A describes the situation for which planning methods are to be developed, set B determines which planning methods should be regarded as good.

On the basis of existing theories and the A and B statements, four alternative planning methods are developed (see below, Section 15.4). The third set of statements, <u>set C</u>, adds to set A those statements which are introduced for <u>individual methods</u>. To some extent these statements are identical for different methods: set C can be considered as the union of four subsets, each corresponding to one planning method. The application of one method requires the fulfilment of the A-statements <u>and</u> the C-statements in the relevant subset. The planning procedures are formulated with the help of a literature study and a theoretical analysis of the problem.

The development of planning procedures can thus be seen as the formulation of alternative <u>organization models</u>. The basic model (set A) identifies the problem, while four more specified models (set C) show the situations where each of four alternative methods could be used.

These models deal with the characteristics of organizations. Naturally, however, the methods are also in the nature of <u>procedures</u>: rules for a sequence of steps. To help in the formulation of these procedures, set A is complemented by a formulation in mathematical terms. The investigation of different theories which are to be used in the planning procedures also starts from this formulation. Nevertheless, this presentation of the methods in algorithmic form should be regarded as purely illustrative. It is the <u>general approaches</u> to the planning problem that would be most useful in any subsequent practical work.

This was illustrated in some empirical studies. In an interview study, the planning situation in a public utility was compared with our organization models. Not unexpectedly, it was not possible to achieve a perfect fit with any of the procedural models, but indications were fairly strong as to which approach was the most promising for the particular organization.

In studies of some other organizations, certain special aspects of the models were considered. In this context the feasibility and desirability of multiobjective budgetary planning were discussed.

15.3 STRUCTURE OF THE REPORT

The basic model is developed in Part One (Chapters 1 - 4), where also the characteristics of organizational preferences and current budgetary practice are discussed. This broad exposition of the problem situation is summarized in the sets A (Section 4.2) and B (Section 4.4) that were discussed in Section 15.2 above.

The theoretical analysis is performed in Part Two (Chapters 5-12). Here Chapters 7, 8, and 10 provide summaries of various theories from the literature of multiobjective decision-making, decentralized planning, and mathematical programming. These theories provide a basis for the formulation of four procedures which are presented in Chapters 9 and 11 and compared in Chapter 12. In this context we use the C-statements that were discussed in Section 15.2.

Part Two thus specifies the situation described in Part One in four alternative approaches. Some attempts to study applications of these approaches are made in <u>Part Three</u> (Chapters 13 - 14), where some practical situations are considered.

The design of the study is also illustrated in Figure 0:1.

15.4 RESULTS

The four approaches or procedures identified in Part Two can be summarized thus:

Method I (single local-unit (LU) objectives and adaptive constraints) is based on a method by Geoffrion and Hogan (1972). The central unit (CU) provides each LU with a tentative resource allocation, a single objective, and constraints for all other objectives. This enables each LU to propose a plan, together with information on available trade-off possibilities. As CU discovers what can be accomplished, changes in the resource allocation and the constraints are used to direct LU replanning, until an acceptable plan is found. In its formalized version, the informational requirements of this method are considerable.

Method II (MRT approximations and ideal points) is based on concepts from methods for multiobjective decision-making. CU provides each LU with a tentative resource allocation and an unfeasible target, based on "ideal points" identified in advance by the LUs. The LUs rely on the targets and comparisons of technical trade-off opportunities to find the preferred plans. As CU receives these, changes in resource allocation and constraints on individual plan attributes (related to specific objectives) are used to direct LU replanning. In this case CU needs only a limited ability to communicate preferences. The LUs have to be able to identify technical trade-offs.

Method III (CU targets based on believed LU possibilities) is derived from a method by Weitzman (1970). It differs from the other methods mainly in that CU now explicitly formulates expectations about LU possiblities. These are used to find targets for each LU; these targets are announced together with targets for the use of resources. The LUs try to get as close to these targets as possible in the plans they propose; at the same time they supply some information about their actual possibilities. As CU receives these, it first updates its expectations about LU possibilities, and then issues new targets based on the revised expectations.

Method IV (preference-based CU prices) is a variant of the price-adjustment method due to Lange, Lerner, and others. It is combined here with some quantitative information in the form of resource allocations. CU provides each LU with a tentative resource allocation and with prices for each objective. This enables each LU to propose a plan. As CU receives these, the resource allocation and the prices are adjusted in light of the plans. To be able to provide prices, CU needs to know more about its own preferences than in most other methods. LUs have to be able to use received prices.

A comparison of the sets of assumptions required by the different methods reveals no clear dominance, although the demands posed by method I are probably the most difficult to meet. Where this is possible, a procedure with known mathematical properties could perhaps be found. But if the main interest is the general type of approach, such considerations are probably not of overwhelming importance.

The remaining three methods correspond to different mixes of CU and LU abilities. The choice between them will have to be based on the characteristics of the use situations. To illustrate this, I report in Chapter 13 on an interview study at the National Swedish Telecommunications Administration (Televerket). In this case it proved rather difficult for the CU to use the approximation-building approach of method III; at the same time the LUs did not find the idea attractive of maximizing for given objective prices, as in method IV. The more heuristic method II seemed more promising.

In practical situations we may also expect certain deviations from the exact situation assumed in the study. Certain cases of this kind were discussed in Chapter 14, where we concentrated on the way such deviations would affect the desirability and feasibility of different approaches. This also gives us some indication of the type of studies needed as a preparation for practical implementations.

The theoretical structure of the chosen approach, and the basic organization model used, should provide a basis on which future work could be built. This should be mainly empirical in nature. Certain directions for it are suggested here.

15.5 USE OF THIS REPORT

Although a major conclusion of this study is that further empirical research is much needed, several of its results could be useful already now in several contexts.

In designing practical budget systems, I would suggest the following.

- The basic model's conception of budgetary planning as a coordinated exploration of possibilities and preferences should be considered. What parts of budgeting are concerned with the possibilities and/or preferences? What knowledge is available?
- The B set of criteria for evaluating alternative planning methods should be considered and, if possible, adapted to the particular situation at hand, e.g. by indicating the importance of the various criteria.
- The choice of attributes for describing plans always has to be adapted to the particular situation. In this context, however, our discussion of the relations between attribute and objectives could prove useful (see Appendix A).
- The four approaches (methods) can be used, entirely or in part, at least to structure practical planning.
- Even when none of the four approaches is used in its original form, an attempt to identify organizational characteristics using the A-statements and C-statements as a checklist should give an indication of the abilities that exist in a given situation and that could be used in the planning system.

Further research could take as its point of departure any of a number of aspects contained in the study, such as (also see Section 14.6):

- The fundamental philosophy of the design of planning as something based on studies of LU and CU abilities and the desired balance between a number of choice criteria (Sections 3.1 and 4.4).
- The basic model with its interpretation of budgetary planning as a coordinated exploration of possibilities and preferences (Chapter 4).
- The discussion of attribute choice, and relation of attributes to objectives (Section 3.3 and Appendix A).
- The basic interactive, search-learn procedure (Section 5.6)
- The four alterantive approaches or methods (Chapters 9 and 11)

15.6 CONCLUSIONS

The list of practical uses for the report in Section 15.5 agrees almost exactly with the list of suggested directions for further empirical research. This is hardly surprising: both should be seen as closely related parts of the same development. It only serves to emphasize the identity of the contributions I hope to have made in this study. They are:

- A philosophy of the way in which the design of planning is related to abilities and desires, and in particular to the ability of CU and LUs to communicate their knowledge
- A basic model of a multiobjective, decentralized planning situation
- Different approaches for handling such situations
- An initial attempt to use all or some of these ideas in a few practical situations

APPENDIX A. MULTIOBJECTIVE JUDGMENT AND THE CHOICE OF ATTRIBUTES[1]

A.1 IMPLICIT KNOWLEDGE

In Section 1.1, a multiobjective situation was described as one where several objectives were experienced by the decision-maker, and where the latter knows no way of reconciling them into a superordinate single objective. On the other hand, the model presented in Chapter 3 still requires an ability to show consistent preferences between different plans, i.e. between alternative vectors of objective-fulfilment values.

The element of conflict between these assumptions is resolved by the introduction of the concept of implicit knowledge, used in similar contexts also by Geoffrion and Hogan (1972) and Jennergren (1971, p. 12). In practical planning situations, CU knowledge of organizational preferences could seldom be expected to be "complete" or "explicit", in the sense that CU can assign utility values to all possible plans. The implicit knowledge means that CU behaves as if it possessed a ranking order over all possible organizational plans, but that it is able to communicate only part of that knowledge.

This assumption of CU ability is in line with the long philosophical history of such decision-making. How can CU evaluate and choose between things it has never experienced, perhaps even suggesting their transformation into something else? Such basic questions about human thought and learning can be traced back to Plato, and it has even been argued

[1] This appendix can be regarded as a fuller version of Section 3.3 in the main text.

(Weimer, 1973) that little knowledge has been added to the field since. CU's implicit knowledge would be an example of "knowing" more than can be explicitly put into words. Such knowledge is often mentioned as an explanation for people's ability to use grammar or to recognize faces, even when they are unable to describe the rules they are using. Polanyi (1966) calls this, perhaps more vividly, tacit knowledge. For contrasting views on the validity of this concept, see Weimer (1973, the note on p. 31) and Argyris and Schön (1974, pp. 201-203).

Implicit recognition of faces may mean, for instance, that we cannot describe the individual traits but still recognize the face of a person. If we try to see the parts of an entity, we lose our awareness of the whole, of its Gestalt properties. We may not even be able to identify which traits or attributes we use in recognizing the face. Argyris and Schön (1974, Chapter 1) discuss several alternative meanings of knowledge - that we know only what we can state, for instance.

By introducing the concept of implicit knowledge in this study, we accept the idea that knowledge may exist which its possessor cannot easily communicate. But we also assume that it is possible for him to reveal parts of this knowledge. He does this in different ways. According to the A-statement introduced in Section 4.2, CU can choose between any two organizational plans. This is a minimum requirement, in the sense that additional assumptions will be introduced in Part Two for individual methods, in the form of C-statements.[1]

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[1] LU knowledge of possibilities is also assumed to be implicit: LUs are unlikely to be able to enumerate all possible plans, but they are assumed to behave as if they had a full list of these of which they could only communicate a part. The basic A-statement is that an LU can propose one nondominated (efficient) plan for each resource allocation.

A.2 ATTRIBUTES

In addition to an assumed ability to choose between alternatives, thereby revealing part of its implicit preferences, it is also assumed in the A-statements that CU can recognize which attributes it needs as input for this choice. In the light of some of the theories mentioned in Section A.1, this is rather controversial, but the statement seems necessary in the context of any planning system.

By an <u>attribute</u>, I mean here any one-dimensional description of something, in this case of proposed plans. Basically such a description constitutes a measurement, although the scale used for this may sometimes only be nominal. The identification of the attributes to be used in a budget dialogue constitutes an important preliminary stage in multidimensional budgeting. If we suppose that CU's implicit preferences can be represented by a preference function, which assigns a utility value to each plan-description, then the attributes will be the arguments of that function. Sometimes, additional attributes will be needed so that CU can check on the fulfilment of various external constraints imposed by law, custom, etc. The attributes used in any particular organization will probably be unique to that planning situation.

A.3 THE RELATION BETWEEN OBJECTIVES AND ATTRIBUTES

In Section 1.1 objective-fulfilment values are said to result from some sort of aggregation of attribute values. In the model, this aggregation is performed by CU, and the attributes that enter its imagined preference function will therefore reflect organizational objectives quite closely. For some objectives such as profits or sales, attributes of LU plans can probably be found that correspond directly to the organizational objectives. For other objectives, such as a balanced product line or an acceptable impact on the natural environment, several plan attributes could be needed as indicators. Obviously it has to be possible for the LU to observe the attributes, as it has to communicate attribute values for the plans it proposes to CU. This limits CU's choice of attributes.

The attributes can be relevant to one or more LUs, and they may relate to one or more objectives. As an illustration, consider Table A:1.

Table A:1. A matrix of LU attribute vectors

Attribute type \ LU number	1	2	3	4	5
A	X		X	X	X
B	X	X	X		X
C	X		X	X	X
D		X			
.					
.					
.					

X = relevant attributes

The vector of attributes reported by an LU is shown here as a column in the matrix, possibly containing one or more zeros for irrelevant attributes. CU's judgment of the way in which all LUs together will affect a particular objective can be based on different combinations of matrix elements.

- An element can be a direct indication of the fulfilment of some objective. For example, if LU number 2 in Table A:1 is a research department and attribute D some measure of technological skill, this could in itself measure research quality, an objective not affected by other LUs.
- The same attributes, applying to several LUs, may have to be combined. If attribute A in the table is sales (in dollars), and if this is an objective of the firm, a sales objective for the organization requires that these LU attributes are combined. In this simple case, attributes could be added together; sometimes the relevant transformation can be more complicated.

- Several attributes from several LUs may have to be combined. For such objectives as self-financing or employee satisfaction, CU may prefer to use more than one information element from each LU, or different attributes from different LUs (cf. attribute types B and C in Table A:1). There are two possiblities here: either that each LU reports only one element pertaining to an organizational objectives, but the attributes will be different depending on the activities involved, or that some LUs report several attributes per LU.

It is important to realize that the attributes will serve as objectives for the planning within an LU, so that our discussion actually concerns the different relations between these objectives and the objectives of the organization.

If measures of objective-fulfilment are available, and assuming that CU preferences conform to a preference function, a CU preference function could be written with objective-fulfilment values as arguments. The attributes of LU plans that are to be used in the dialogue should be the arguments of a decomposed version of the same function.

This gives us a hierarchy of increasingly disaggregated attributes, starting from the objectives themselves. The choice of attributes can be regarded as the choice of one level in the hierarchy, or a set of attributes selected from different levels. The rule that attributes should be observable to the LU obviously does not identify any single "description level" in this hierarchy as the best (cf. Ramström, 1967, p. 39).

A.4 CU PREFERENCES AND SEQUENTIAL JUDGMENT

The CU receives information in the form of plan descriptions from all LUs using the agreed attributes. The latter are chosen so that they provide information about the fulfilment of organizational objective that would result from the described plans. CU's evaluation of the attributes can thus be seen as a two-stage process:

- Judging objective-fulfilment from a set of LU plans on a basis of their attribute values, i.e. combining LU plans into total organization plans
- Choosing between alternative total plans on a basis of their objective-fulfilment values

The distinction between the two steps is mainly one of explicitness. In the first step, the descriptions (in attribute terms) of LU plans are translated into a single description of organizational performance (in objective-fulfilment terms). The definition of objectives in Section 1.1 makes this the highest level to which the CU is prepared to aggregate plan information. In the progress from this aggregation level to the final and necessarily unidimensional choice of one particular plan, intuitive judgment and the use of implicitly known preferences come into play.

By its relative explicitness, the first step will often be rather value-free. It is a judgment about how combined LU activities will affect various organizational objectives. When the attributes are LU sales or profit contributions, it should be a relatively simple matter to combine them into organizational-objective values. Sometimes the combined impact of LU attributes will be less easy to identify; an example could be the impact on total employment, where employment changes in the LUs have to be combined, and the possibility of personnel transfers between LUs allowed for.

The second step, on the other hand, directly concerns "values" (Churchman, 1961), where consensus between different judges cannot be expected. By assuming a CU which has preferences, we bypass the problem of group judgments. How realistic this assumption is seems hard to tell. The introduction of intergroup bargaining in order to identify group preferences seems difficult, and studies such as Wildavsky (1964) suggest that budgeting tactics may cause difficulties of a political character. On the other hand Dalkey and Rourke (1971), working with a Delphi-like method, claim that collective value judgments can be made. See also Berthel (1973).

These two steps are used in the formalized model in Section 4.3. In practice, the borderline between the two steps may be difficult to identify, and their relative importance may vary. The intention here is to indicate that elements of relatively value-free and explicit judgment could be expected to precede the more intuitive final step, in a sequential process. For each step in this process, the decision-maker will have a limited capacity to deal simultaneously with more than about seven attributes, or objective values (cf. Section A.6, below).

It is the entire sequence that would need to be modelled in a preferences-first approach, in a way which makes clear the impact that changes in individual LU attributes have on a "superobjective" or total preference index. We must turn to the psychological literature for information about the characteristics that the preferences involved in human decision-making can be expected to have. For a review of this subject, see Slovic and Lichtenstein (1971). Such findings could also help us in selecting reasonable additional assumptions about people's ability to reveal part of their implicit knowledge. Information about this could also be found in the discussion of multicriteria decision-making methods.

A.5 FORMS OF PREFERENCE FUNCTIONS

In studies of decision-making attempts are often made to find some preference function which can be used to predict the decisions. Here, additive weighting of attributes (i.e. a linear function) often performs surprisingly well, considering how the decision-makers themselves often claim to use very complex rules. See Yntema and Torgerson (1969), and Slovic and Lichtenstein:

> The linear model accounts for all but a small fraction of predictable variance in judgments across a remarkably diverse spectrum of tasks.

> However, ... recent studies ... have exposed a different view of the problem, one that accepts the limited predictive benefits of nonlinear models but, simultaneously, asserts the definite, indeed widespread, existence of nonlinear judgment processes, and emphasizes their substantive meaning.
> (Slovic & Lichtenstein, 1971, p. 681)

In other words, modelling decision-making nonlinearly is of limited use (also see Tell, 1976), but this does not mean that the judgment processes must actually consist of linear weighting. Einhorn (1970) shows some types of nonlinear decision-making which are quite simple and correspond to everyday choice rules:

- Conjunctive: minimum requirements on all attributes
- Disjunctive: only the attribute with maximum value counts
- Lexicographic: most important attribute studied first, then going on to attributes of lower rank, one at a time, as long as alternatives are not discriminated sufficiently

Montgomery and Svenson (1975) suggest that such rules can often be used sequentially, either as a succession of different types of rules, or by applying the same rule repeatedly with increasing requirements (cf. Simon's, 1955, notion of adaptive aspiration levels). For sequential models of business decision-making, see Clarkson (1962) and Howard and Morgenroth (1968). Another form of sequential decision-making is presented in Soelberg (1972). Soelberg found that part of such a dynamic decision process consists of justifying a preliminary decision, through a search for additional information and the applying of additional tests. Similar ideas have been elaborated in Zeleny (1976).

I suggested in Section A.4 that CU's evaluation of LU plans could be regarded as a sequential process. Where the first step, judging objective fulfilments, is completely explicit - for instance summing the LUs' profit contributions - and the number of objectives is small enough, it may be possible for the decision-maker to combine objective-fulfilment values into an overall preference judgment "directly". But where the first step is more complicated, it seems natural to regard the processing of attribute values into a unidimensional judgment as a sequence of steps. This also makes probable more complex dependencies of the final judgment on individual attributes.

Some information about the preferences we can expect in organizations can also be derived from the methods recommended in the business administration literature. In his survey, MacCrimmon (1973, p. 40) suggests a combination of rules adapted to the problem on hand. Similar rules, mainly heuristic, are proposed by Pinkel (1969). The recommendation in Johnsen (1968, 1973) has strong affinities with the conjunctive rule, or satisficing. The same is true of many checklist approaches, such as Gundhus (1971) or Andrén (1973, pp. 61-80). Easton's (1973) discussion of several types of choice rules provides no firm recommendation. The same is true of Green and Wind (1973, Chapter 2). These authors also survey the multidimensional decision rules.

Most of these recommendations include several models that do not correspond to the simple additive models that were claimed above to yield adequate predictions. In view of this, and the believed existence of nonlinear decision processes mentioned by Slovic and Lichtenstein (quoted above), and the possibility of a sequential process, it seems probable that linear as well as nonlinear decision behaviour should be expected in our problem situation. This question was discussed in greater detail in Chapter 6.

Given the fallibility of human decision-makers, it seems possible to conclude that in many cases prediction or simulation of judgment could use additive models. The intention of the present study, however, is to <u>assist</u> human decision-making. In view of this, it seems to me that the need for nonlinear preferences cannot be ruled out.

A.6 PRACTICAL GUIDELINES FOR CHOOSING ATTRIBUTES

In Section A.2, it was suggested that the identity of attributes will vary between different organizations and different planning situations. In spite of this it seems possible to make some general comments on how they are chosen.

There are several considerations that CU should take into account in making this choice, mostly deriving from the fact that a budget format should have a life expectancy of several years and should be acceptable to all who use it. I would suggest in particular the following:

- Attributes should relate to current and known future information needs. This means that forecasts should ideally be made about future use of the budget. Who will use the budget and for what purpose? Which planning assumptions will prove to be important? According to the "hierarchical" way of looking at things discussed in Section A.3 every attribute can be considered a permanent combination of lower-level information. This combination (aggregation) should reflect a similar permanence in the real world.
- Attributes should be strictly limited in their number. Psychologists have found that human decision-makers are able to make simultaneous use of only a small number of attributes. Miller (1956) suggests seven as a maximum. With the help of some sort of sequential judgment, a somewhat larger number could probably be used.
- Attributes should be measurable. To avoid ambiguity, the requirement for observable attributes should be strengthened to constitute a demand for attributes with an operationally defined meaning. For the same reason, they should also be defined in time and space.
- In choosing attributes, past experience of their information contents should be expressly taken into account. For instance, one attribute can be used as representative of several which are known to correlate.

- The set of attributes should give some information on the fulfilment of all objectives. This may contradict other guidelines above, but some imperfect measures of nonmonetary societal effects that are relevant to the firm's objectives should probably be included instead of further "good" measures of conditions that are already described by other attributes.

Additional considerations in choosing this type of compact description of activities can be found in Mossberg (1977). Riksrevisionsverket (1976) also mentions such factors as acceptance by those using the attributes. The choice obviously has an important role in explaining organizational objectives to the LUs.

The choice will also help to determine what information will be readily available to the organization if it should want to inform external parties of its activities. The choice can also be the basis for so-called social accounting, as was mentioned in Section 1.3. The desirability of describing even nonmonetary external effects in this way is underlined by several contributors to the anthology of Dopuch and Revsine (1973, pp. 8, 21, 46-47).

A.7 WHAT DO ATTRIBUTES DESCRIBE?

Attributes should describe any aspects of LU activities that CU feels is relevant in evaluating the LU. In Chapter 3, the term performance is introduced to denote such a description. The attributes included in this description can relate to products. Examples are such attributes as sales, profits, and customer attitudes. Other attributes are directly related to the activities themselves, for example employee turnover, or to a combination of the activities and such environmental factors as pollution. Since our problem concerns the planning of activities when the environment is given externally, we can illustrate the situation as in Figure A:2.

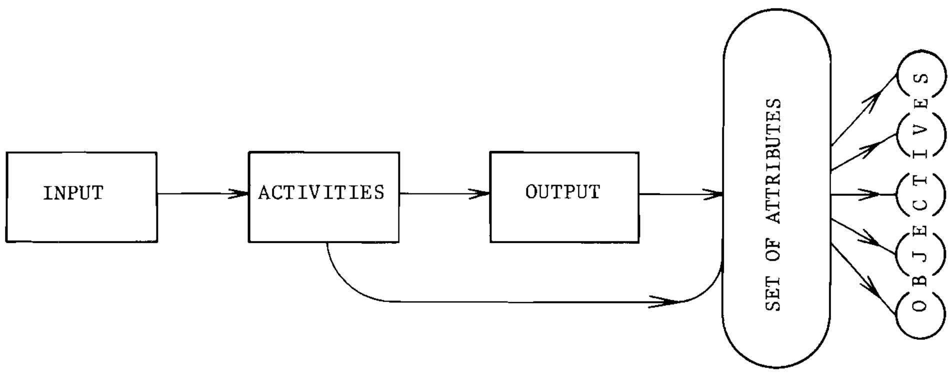

Figure A:1. The relation between activities and attributes. Adapted from Riksrevisionsverket (1976, p. 25)

It can be argued[1] that the identification of attributes to be used in reporting performance could start from the activities or from the objectives. In the former case, characteristic properties are found which give the decision-maker an adequate knowledge about performance. The latter case, on the other hand, corresponds to what is often called means-ends analysis and would rely on a hierarchy of objectives and attributes. While either method may be preferred in individual situations, a combination seems most appropriate as a general recommendation.

Means-ends thinking has been severely criticized as unrealistic and bearing no resemblance to practical realities, at least in many more complex control situations (Normann & Rhenman, 1974; Lindblom, 1951; Braybrooke & Lindblom, 1963, Chapter 4; Wildavsky, 1964; Hoos, 1973). Sometimes the critics recommend analysing the activities instead of the objectives (Werin, 1973, p. 18), which seems rather similar to the first of the alternatives mentioned in the last paragraph. It is sometimes argued, for instance, that an agency should be left to itself to develop knowledge

[1] Part of the following discussion was developed in cooperation with the Swedish National Audit Bureau and reported in Riksrevisionsverket (1976).

about what it does and what it should do, with no external demands for analytical descriptions of its production or fulfilment of its objectives. What should be described and analysed is its ability to learn, to adapt to new situations, etc. (Normann & Rhenman, 1974, p. 51).

To me, this does not really contradict the means-ends viewpoint: if these abilities are the objectives of the organization, it is a natural recommendation that they, rather than output, should be described. In the terms of Figure A:1, the description that is indicated by the direct line from activities to attributes becomes the important one. In most cases, both descriptions would probably be useful, as objectives of both kinds could be expected. It should be possible to try to state objectives without the harmful effects argued by the authors cited above.

A.8 AN EXAMPLE OF ATTRIBUTE CHOICE

To see how attributes could be chosen, using means-ends thinking and starting from both objectives and activities, we can look again at the lunch example described in Chapter 14. This concerned a proposed national delegation whose task was to collect experience of employee lunch arrangements in governmental agencies, and to influence the agencies in the interests of the state employer. The agencies were to retain prime responsibility for providing lunches, but any changes in lunch arrangements were to be subject to review by the delegation.

This meant that the agencies would have to describe both proposed and actual lunch arrangements, i.e. the "activitites" in this case. The attributes used should enable the delegation to assess fulfilment of its objectives, and to make recommendations.

The method used (see also Samarbetsdelegationen, 1974) was means-ends analysis. A number of interest groups was the starting-point, and objectives and attributes of the service were deduced from the attitudes these would have to the lunch service. As an example, an agency might benefit from more nutritional lunches because of improved efficiency in the early afternoon, and because the better conditions attracted better employees. On the other hand, this would probably be a more costly type of service than alternative arrangements. With objectives grouped according to their risk of conflict, the number of objectives was reduced to six as shown in Figure A:2.

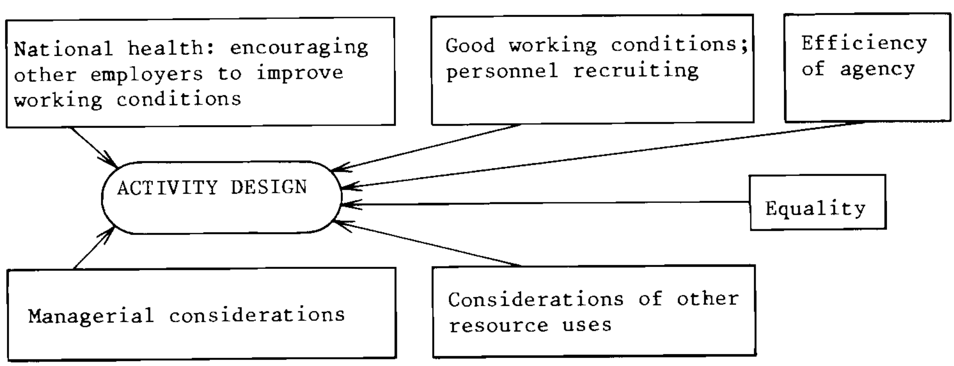

Figure A:2. Objectives for personnel lunches

Among these objectives, equality acts mainly as a constraint. The "resource-use" objectives in the lower part of the figure are in conflict with the upper ones. (If managerial skill is considered as a resource, the two could be combined into one.)

In this case, a great deal of knowledge about the activities that would be possible existed. This meant that it would have been very impractical in this case to try to derive desirable properties or attributes from the objectives, as is done in most "classical" means-ends studies. Instead, an attempt was made to study the impact that conspicuous attributes of the service would have on the six objectives, to find the relations between them. This is an example of the attribute identification discussed in Sections A.3 and A.7, but this time it is already linked with the objectives.

Ten attributes of the meals were chosen and related to the objectives. The results are shown in Table A:2 below. Equality has been deleted, as it refers to the variations allowed between local cases rather than to individual solutions. Rate of use is added, as a high rate of use is obviously a prerequisite for the other objectives to be affected.

Table A:2. Personnel lunches: relations between attributes and objectives

Attributes	Objectives					
	National health	Working conditions etc.	Efficiency	Resource use	Managerial considerations	Rate of use
Location						
- on premises?		x				x
- transportation time			x			x
- attractiveness		x				x
Food						
- judged attractiveness		x				x
- actual nutritional value	x		x			
- price for employee						x
Employer's costs						
- investment				x		
- operating costs (subsidies)				x		
Administration						
- centralization					x	
- detailed directives					x	

It would be possible to find several other relations in Table A:2, but the chosen ones appear to be the most important as regards the effect on the objectives. The table neglects two types of relations, namely:

(1) Between different objectives - they will certainly be correlated in several cases

(2) Between different attributes - in particular, the cost and the administrative factors will be related to the design of the other attributes

The report cited above was the result of discussions in a temporary advisory committe with less authority than the proposed delegation would have. The list of attributes in Table A:2 was considered an acceptable description of lunch service, which could be used in choosing between alternative designs for an individual workplace. For instance there could be: various sizes of restaurant on the premises, run under various forms of contract; or contracts with external restaurants open to the general public; or contact with other firms. Most of the attributes would be measureable; some of them demand forecasts based on experience of similar solutions elsewhere which would be available to the delegation.

A.9 SUMMARY

In the model introduced in Chapter 3, which is the keystone of this study, CU judges LU plan proposals on a basis of plan descriptions in terms of attribute values. In its simplest form, this judgment concerns the choice of the preferred set of LU plans from among several alternatives. To understand more about the nature of this judgment, we need to consider the choice of the attributes and the nature of the preferences. I have collected in this appendix some evidence and some practical experiences with this in mind.

The assumed situation is an example of implicit preferences, whereby a person is able to judge multidimensional (i.e. multiattribute) information in a consistent way. That he is able to do this indicates the existence of preferences, although he may not be able to communicate them or make them explicit in any simple way. It was also suggested that CU's combination of LU plan attributes could be seen as a sequential process, where an assessment of the effects of these plans on the several objectives of the organization was the initial and more explicit step, while the combination of these objective-fulfilment values into a single preferential judgment represented a second and more intuitive step.

There is fairly strong evidence from psychological studies that preferences often conform to quite simple mathematical functions, in particular linear ones. The sequential nature of CU judgment, and the fact that the intention of the study is to assist rather than predict or simulate behaviour, seems to justify the assumption that other forms of preferences are also possible in the model situation. This is of major importance in the choice of general approach made in Chapter 6.

The choice of attributes obviously has to reflect the identity of the objectives, as the attributes are the means of judging objective fulfilment. There will often be one plan attribute per LU that shows its impact on an organizational objective. Sometimes the relationship may be more complex.

It did not seem possible to provide more than heuristic guidelines for the choice of attributes, in view of the variety of situations in real life. It was also suggested that it could often be useful to describe activities as well as products (output), and to analyse objectives as well as the more tangible aspects of performance. In this richer version, means-ends analysis would be a rewarding tool, even where objectives such as "ability to adapt" were involved. A real-life example of choosing attributes with the help of means-ends analysis was described.

APPENDIX B. GOAL PROGRAMMING AND RELATED APPROACHES

This appendix supplements Section 7.4 by providing a discussion of proposed planning methods based on goal programming, and relating them to the problem formulation of this study. As explained in Section 7.4 and below, goal programming could be relevant if the type of problem described in Part One is to be subjected to a first approach. This appendix also includes a discussion of another method which is of related interest, that of Rasmusen (1974).

B.1 GOAL PROGRAMMING

The goal programming (GP) technique in its original, non-divisionalized formulation, was first described by Charnes and Cooper (1961, pp. 215 ff.). Its subsequent history is traced in Lee (1972). A typical problem formulation is:

$$
\begin{aligned}
\text{Min} \quad & \underline{c}'\underline{d} \\
\text{s.t.} \quad & \underline{A}\underline{x} + \underline{R}\underline{d} = \underline{b} \\
& \underline{x},\underline{d} \geq 0
\end{aligned}
$$

where $\underline{x}$ is a vector of activity levels (sometimes called subgoal levels)
$\underline{b}$ is a vector of desired levels for the various goals
$\underline{A}$ is a matrix relating activities to goals
$\underline{d}$ is a vector of non-negative elements, showing the amount of positive or negative deviations from the desired goal levels
$\underline{R}$ is a matrix of appropriate form
$\underline{c}$ is a vector of weights for the deviations in d
(See Lee, 1972, p. 28)

GP thus deals with the problem of minimizing the deviations from some desired goal levels, through a choice of activity levels, i.e. a plan of activities. It handles multiple objectives in two ways. First, by assigning <u>weights</u> to different elements in $\underline{d}$, it is possible to allow for prior knowledge of utility trade-offs between objectives. By giving different weights to positive and negative deviations, it is possible to approximate a piecewise linear preference function (cf. Ijiri, 1965, Chapter 2). This involves explicit knowledge of preferences and the only clear advantage over traditional linear programming is the possibility of using separate weights for performance over and under the target level.

Perhaps because of this, Lee (1972) stresses the <u>second</u> way of handling multiple objectives in a GP formulation. By assigning "<u>preemptive priority factors</u>" (Ijiri, 1965), a solution is achieved where top-priority goals are attended to first, and lower-priority goals are left until the first-mentioned have been fulfilled as well as possible. Here a "goal" is a specified target level for a variable. All goals are ranked by the decision-maker before he solves the problem. If more than one have the same rank, it should be possible to assign traditional weights to these, and they will be handled together. The choice rule implied here seems to correspond to the "elimination by aspect" rule proposed by Tversky (1972).

Lee (1972) argues that this way of handling a multiple objective situation makes realistic demands on the decision-maker, who only has to rank and find target levels for his objectives. These need not be commensurate, so long as they have different priorities. Several increasingly demanding goal levels can be used for one objective, indicating the achievement of each progressively lower-priority rank. But there is no chance here of learning about one's own preferences as alternatives are found - in our terms, this is a preferences-first approach. Such an approach would be natural in the undivisionalized, original case, where possibilities are known (the constraints in the formulation above), but in the decentralized planning case, the objections to this approach discussed in Chapter 6 are still valid.

Lee (1972) finds GP's "satisficing" character attractive, and he also shows how pair-wise comparisons can be used to rank goals (pp. 353 - 359). The ranking technique was adapted for man-computer interaction by Price (1976) but still without reference to the feasible set. Few suggestions exist concerning the choice of target levels. When small sacrifices in connection with one objective can produce big effects on others, the one-goal-at-a-time strategy hardly seems acceptable. Preferences-first can be blamed for both these weaknesses.

An interactive variant of GP has in fact been suggested by Monarchi, Weber, and Duckstein (1976), but the properties of this approach do not seem quite clear.

B.2 DECENTRALIZED PLANNING USING GP

An aspiration-level analogy of GP was suggested by Charnes and Stedry (1964). They deal with an LU manager who is assigned several targets - a situation which will arise from the use of one of our budgetary planning models. In Ijiri's planning model, the GP problem is interpreted as follows:

> ... planning is considered as a process of decomposing given management goals into a set of subgoals (or means) which are more operational and controllable by management or their subordinates than goals.
> (Ijiri, 1965, p. 5)

The best-known application of GP for this type of planning is probably Ruefli (1971a, b, c). Central goals are decomposed into a first CU proposal of LU goals. Each LU uses a GP formulation, where deviations from the received goals are given weights of LU's own choice. Shadow prices associated with the current goals are reported to CU, who uses them to revise the LU goals.

The central goal revision aims at minimizing the sum of all LUs' minimization objectives. As local weights for deviations in the various goals may vary between LUs, the implications of this are not very clear (Ruefli, 1971a, pp. B-514 ff.). Ruefli does not seem to use the preemptive priority factors referred to above. Even apart from this, the different LUs' objective functions would not seem to be commensurate, or necessarily of the same importance to the CU.

If CU wanted the LUs to plan more in accordance with central preferences, LU weights would have to be decided by CU. Even then, summing local weighted deviations would not take into account whether they cancel or reinforce each other. Ruefli (1971a, pp. B515-516) concludes that his method's decentralized optimization is not equivalent to centralized optimization. Among other things, different patterns of organization result in different plans (cf. Ruefli, 1971c). Ruefli also mentions a basic uncertainty as to what is really being optimized.

An interpretation and an answer to this is suggested in the later, and rather similar, model of Freeland and Baker (1975), where the improvements seem largely computational. They suggest that the LU objective function (minimum weighted sum of goal deviations) should be understood as a measure of LU dissatisfaction. In this way, the LUs tell the CU how unreasonable the present goals are when they give their current objective value. They also explain how much less dissatisfied they would be if the goals were changed (p. 684). The CU decisions aim at minimum total dissatisfaction in the organization. The consequences of this are not much clearer than in Ruefli's discussion. But it is claimed to be more in line with modern views on participation in management etc. than traditional planning:

> ... most decentralized coordination schemes can be interpreted as merely schemes by which the subordinate decision makers can be manipulated to attain the same decision at which the superordinate would have arrived, had he known all the constraints ... Under these circumstances, the coordination methods certainly do not enhance the motivational aspects of decentralized decision making. The superordinate's task is really to create an environment in which the subordinte believes he is participating in the decision making process.
> (Freeland & Baker, 1975, p. 676)

Let us summarize some characteristics of these methods:

- The LUs choose activity levels for their various products or projects. They know their own preferences in terms of weights and certain targets, and also their performance possibilities. They try to minimize the weighted sum of deviations from certain other targets or goal levels which are provided by CU. As a result of the minimization, they are able to communicate achieved objective value, and shadow prices for the goals that were provided by CU.
- CU chooses the goal levels for the LUs. It knows the target values for organizational objectives and how they relate to LU variables. On receiving the values of LU objective functions and shadow prices, CU revises the goal levels so that the sum of LU objective functions is minimized.
- The final solution is a compromise: neither CU nor the LUs have priority in deciding the organization's future. On the other hand, it is hard to predict what influences they will have, and the influence will also be affected by the way the organization is divided into units.

Compared to the basic model in Part One, the aim of the process is different. Even where CU wants to satisfy LU preferences to some extent, the implied overall objective of the GP formulations does not necessarily follow. Another difference is the preferences-first character of the GP formulation, where both CU and LU have to establish goal levels and weights in advance.

There are, however, some interesting similarities between GP planning and the approaches discussed in Part Two.

In GP planning LU targets derive from a decomposition of organizational targets. The same is true in our Weitzman-based method III. But in method III, the central targets are based on CU approximations of LU possibilities, whereas in GP they provide the starting-point, and only during planning does CU learn anything about LU possiblitities. In the GP formulation target decomposition seems much more like a case of a bargaining between LUs, as they influence the decomposition by their "dissatisfaction". A process in the Weitzman spirit, on the other hand, concentrates more on teaching CU the true possibilities.

The way CU preferences are defined over a unidimensional objective for each LU resembles our method I, based on Geoffrion-Hogan, where the same problem of CU's acceptance of these objectives occurs. In method I we tried to import a stronger influence to CU by introducing adaptive constraints. Naturally additional targets could have similar effects in the GP formulation.

I conclude from this that an attempt to formulate an interactive, decentralized GP planning method would have several traits in common with the four methods presented in this study. It would have to break away from the preferences-first, noncooperative situation of the existing decentralized GP methods in order to suit the model described in Part One. An interactive GP would probably become rather similar to the decentralized ideal-point methods discussed in Section 8.4. For these reasons, I have not attempted the formulation of any GP-based method in this study.

On the other hand, if CU can accept a GP formulation as representative of its preferences, without going through any interaction, a method such as Freeland-Baker's could be used as the later part of a preferences-first strategy.

B.3 SEVERAL "COUPLED" LP MODELS

Rasmusen (1974) motivates his approach by pointing out certain behavioural deficiencies in planning of the Dantzig-Wolfe or Kornai-Lipták types. He favours Kornai's and Weitzman's use of production targets to guide local planning, but with <u>conflicting</u> CU and LU objectives (which is what Rasmusen assumes) this is not enough:

> Rather than making use of one decomposable model, this system employs two independent sets of planning models, one referring to the central planning process and another referring to the decentralized planning processes.
> (Rasmusen, 1974, p. 157)

CU proposes several activity levels for each LU, using a linear programming (LP) formulation. This model is a fairly crude one, formulated in terms of activity units, productivity in these units (output per unit) and their cost. The LP solution provides activity levels and a resource allocation.

LUs use their own LP formulations which are more detailed and more correct. The CU proposals provide additional constraints on the local possiblities. The LU has its own objective function, probably different from CU's. If any feasible plans remain, the LUs propose one and inform CU of current activity costs and productivity.

CU incorporates these in his model, and finds a new central proposal, if changes are considered worthwhile. By using the two LP formulations in this way, LU and CU gradually come to agree on the technological aspects (productivity and costs), while each is allowed to use its own (linear) preferences, and a degree of disaggregation in the model suited to its own situation. Pau (1976) investigated the formal properties of this model, discussing it from a game-theoretical standpoint and using a control-theory model.

The multiple objectives of Rasmusen's model consist exclusively of the goal conflict between LUs and CU. For each unit, preferences are explicit and can be represented as a linear function. This is contrary to our basic assumptions; ours is a cooperative multiobjective organization.

It could prove possible to incorporate more of our model's traits in the Rasmusen model, however. Some necessary changes would be:

Use of implicit and probably nonlinear CU preferences: If some central decision-model other than LP were used, this would probably be possible. For instance, the interactive methods considered in Section 7.2 could be used, as a formal model of possibilities exists. This would require the CU model to be formulated in objective terms.

A stronger CU role: This is in fact already potentially present. The LUs have to fulfil CU constraints, which means that the only restriction on the CU's ability to impose its will is the difficulty of stating tight constraints.

The Rasmusen model could be used to formulate one more procedure for our problem situation. The characteristic of this approach which has not been used earlier is CU's gradual learning about how activities affect costs and productivity. In a multiobjective context, productivity could easily be changed into a multidimensional concept. In method III CU also learns about possiblities, but in trade-off terms, and this would probably be preferable. Except in the case of technical production, general trade-off opportunities should be easier to discuss than the average impact of some kind of activity units.

Other characteristics of a Rasmusen-based procedure would resemble individual traits of methods I - IV. To accept LU preferences but provide rather tight constraints to influence choice is the same approach as in method I. The use of a central approximation, as has already been said, is a device also used by Weitzman and in method III.

Because it would add little that was new to our set of approaches, I will not illustrate any procedure based on the Rasmusen method. Its main focus on a noncooperative organization is different from that of this study. As was mentioned above, it might be possible to develop it in the direction of implicit preferences, but the resulting combination of multiple communicating LP models and interactive methods to solve them seems too cumbersome to implement, and of questionable value as a basis for practical conclusions.

B.4 SUMMARY

Planning methods using goal programming (GP) and a combination of several linear programming (LP) formulations were studied and found to have several things in common. Foremost among these is the desire to model a type of organization rather different from the one assumed in this study. This is characterized by LUs which exhibit preferences of their own that are potentially in conflict with those of CU. In such situations, the final choice of a plan becomes a compromise between the central and local units. The GP methods results in what can be described as "minimum summed dissatisfaction of the LUs". The "coupled LP-models" approach, on the other hand, provides a solution which satisfies CU's aspirations, and maximizes LU preferences subject to the constraints resulting from this.

Targets and constraints have already been used in some of the procedures discussed in earlier chapters. The models considered in this appendix could certainly be used to formulate further methods, but as the general situation is rather far removed from that of our problem, this will not be done here. Because of its assumptions, our organization model is a cooperative one, in contrast to those discussed above.

APPENDIX C. METHODS FOR CONVEYING PREFERENCES

The following discussion of alternative ways of indicating partially known preferences is given here because it seemed useful to keep it as an entity, but it would have interrupted the argument of the main text if included as a chapter. The general problem here is: How can a person indicate such preferences in an operationally meaningful way? The alternatives considered here are prices, "incomplete" prices, targets, and constraints.

C.1 PRICES AS TRADE-OFF INFORMATION

Prices serve to indicate the "value" of different commodities. During planning, interest is focussed chiefly on price <u>relations</u>. Prices have to be accompanied by instructions to maximize or minimize total value, or perhaps sometimes to achieve a particular value.

Ability to state a price relation between commodities clearly presupposes a "value function" over these commodities. The basis for this may be a <u>production</u> relationship, i.e. the cost or effort of producing one unit of commodity A instead of one of commodity B. This gives us a price relation corresponding to the marginal-rate-of-transformation (MRT) concept of classical micro-economics. In Figure C:1, EE shows the efficient (Pareto-optimal) production possibilities for a firm producing goods A and B. At a point (production plan) f^*, MRT is equal to the slope of the tangent TT and a "production-based" price relation is given by its normal vector $\underline{p}$. All points on TT are defined by $\underline{p}'\underline{f} = \underline{p}'\underline{f}^*$.

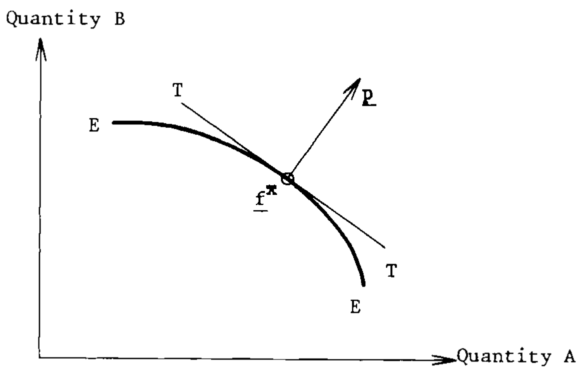

Figure C:1. A point on a production-possibility curve determines a price vector

But prices of A and B can also be based on the utility or value of the commodities in use, i.e. a consumption relationship. This is shown in Figure C:2. The marginal rate of substitution (MRS) at a point u on indifference curve PP determines the price vector. The "market test" often makes the latter type of prices more objective.

In both cases, if there are several inputs determining the p-p-curve, or several uses for the commodities determining the indifference curve, there has to be some way of combining these to arrive at a single p-p-curve or indifference curve. This is often provided by input prices, or the relative importance of different uses. If there is uncertainty about these, knowledge of the "true" EE or PP will be imperfect.

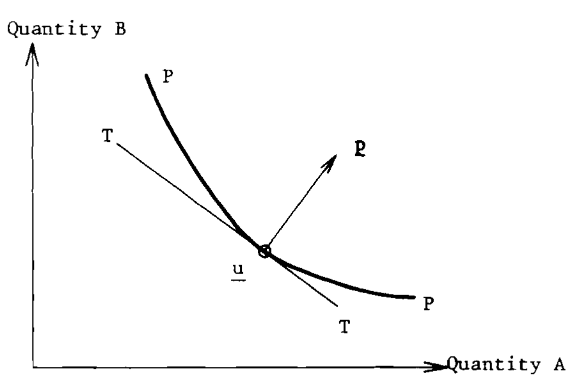

Figure C:2. A point on an indifference curve determines a price vector

For instance, if both A and B use labour and machinery as input factors, and we do not know how much more labour we can acquire if we reduce the amount of machinery, there will be families of PP curves for each of these input factors, showing possible production combinations for different amounts of one factor, assuming a fixed level for the other.

In the same way, if A and B are both used for satisfying hunger and for providing pleasure in eating, and the consumer cannot state the relative importance to him of these two properties, there will be two families of indifference curves, one for each property.

We can summarize it in this way: prices are trade-off information and equivalent to MRS or MRT estimates in their information contents. However, we usually regard prices as more general, as we expect them to take into account all input factors or all the criteria for judging the priced commodities. If these cannot be compared, several parallel trade-off relations may exist.

C.2 INCOMPLETE PRICES

A reason for the universal use of prices is that they make possible profit-maximizing behaviour which, under ideal conditions, will generate market equilibrium with all its well-known advantages. During this process, prices function as a common-value yardstick, where the two price vectors shown in Figures C:1 and C:2 are equalized. But if Figure C:1 is interpreted as "labour production possibilities", with a different curve existing for "machinery production possibilities", or if Figure C:2 showed "indifference in satisfying hunger", with a different curve existing for "providing pleasure", the recommendation would not be at all obvious. This is what happens in a multi-objective context.

When it is possible to compare a few of the inputs for a pair of commodities, but not all of them, these could be used to find "incomplete" price relations.

To continue our example, both A and B may use a common raw material in addition to labour and machinery. If the <u>producer</u> buys labour and materials in the market, he can probably compare these, i.e. transform them both into monetary cost. To evaluate scarce machine hours is more difficult, as their value depends on production plans. Yet there <u>is</u> a relation between A and B given by their demand for machinery. In this situation, it would be possible to find a system of incomplete prices, using the relations between A and B that are given by their production cost exclusive of machinery. This would then have to be combined with their requirements for machine hours, to be reported for instance as "the price of A is Skr 2 and 10 minutes of machine time, while B is Skr 1 and 8 minutes". As prices are "incomplete", a multidimensional description is needed. This corresponds to the aggregating of attributes discussed in Appendix A.

For the <u>consumer</u>, A and B may provide "objective" utility in the form of calories, vitamins, etc., apart from the "subjective" utility of satisfying hunger and providing pleasure in eating. We can for the moment assume that other products on the market provide a touchstone for evaluating the "objective" properties of A and B and also the simple, hunger-satisfying property. Still, we would have to report such a market evaluation together with the intangible benefits of pleasure in eating, perhaps estimated on some sort of attitude scale.

Whenever we speak of nonmonetary objectives or consequences, we mean that existing prices are incomplete. For instance, internal-transfer pricing is usually incomplete, as the prices are only meant to reflect internal aspects of the services. This is probably also the reason why prices are so often supplemented by other information in controlling business activity, or reporting on it. Even where a price system allegedly takes into account all the priorities of the managers of a firm, it is not unusual for the managers to want to exercise control in terms not only of prices and a rule of cost minimization, but of some quantity targets as well.[1]

Incomplete prices thus provide trade-off information between priced commodities for those attributes that are "covered" by the value function that has been used in deciding the prices. They do not involve a recommendation to "equalize" anything, as there are other aspects to take into account. This is exactly parallel to the occasional need to adjust market prices in a cost-benefit analysis, in the light of nonmarket considerations. The value lies in *diminishing* the dimensionality of the description of relative values. This reduces the decision problems of the *price-receiver*: fewer alternatives are potentially optimal.

C.3 ESTIMATING PRICES

In a multiobjective context, incomplete prices may be one way of conveying what is known about relative values, productional or preferential. Another is to use more sophisticated means for making people state relations between products or objectives.

Geoffrion, Dyer, and Feinberg (1972) demonstrated two alternatives for making a decision-maker state preferences by discussing trade-offs between criteria. Both were tried by the authors and can be used interchangeably. They correspond to a "direct" estimate of MRS, and a stating of prices, respectively.

The first method is called the indifference method. The decision-maker finds the amount of change in one criterion that would exactly compensate a decrease by one unit in another criterion. Continued questioning for pairs

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[1] In planning, Malinvaud (1967) suggests that such additional information can save iterations. Likewise, Kornai (1973) argues for some redundancy of information in practical planning.

of criteria identify the entire tangent hyperplane. This type of indifference questions has been much used in studies of utility functions.

The other approach makes use of the fact that what we have is one isopreference surface out of indefinitely many. The normal to the tangent hyperplane is the gradient of utility: the direction of steepest ascent. In estimating this, we can use the concept of "ideal-proportion change" introduced by Geoffrion et al. What would be the ideal proportions of change for two objectives, if both could be improved? By continued questioning more criteria can be included. These proportions then define a price system, something not explicitly discussed by Geoffrion et al. (1972) but hinted at in Feinberg (1972).

Both techniques could be used to trace production possibilities as well. The indifference approach has its obvious parallel in traditional questions of the type: How much reduction of production is needed to make possible an increase of one unit in B? When budgeting alternative resource levels for an agency, the question could be asked: If you were able to produce 10 units more, how would these be allocated between attributes A and B if the total cost for the 10 units is to be minimized? This would be an example of the second approach.

C.4 INFORMATION EQUIVALENT TO PRICES

Even when no estimate can be provided of the relation between objectives, neither prices nor "incomplete" prices, there are certain other ways in which CU can state his desires. The first possibility is to provide targets. This has been discussed by Kornai, Weitzman, and others (cf. Chapter 10). In most cases, optimistic targets tend to be used, because too low a target invites inefficient behaviour. A target that is definitely (and consciously) too high represents an "ideal point", the distance to which the planners seek to minimize. (In Chapters 8 and 9, "ideal point" means the specific point which derives from single-objective maximizations in the LUs.) Targets should be assigned individually to each LU, as there will probably be some knowledge available in CU about specific LU possibilities, e.g. from the preceding period's results.

Sometimes upper and lower constraints for attribute values may be available, which conceptually narrow down the range of solutions which an LU may believe to be optimal.

As an example, suppose that the area A in Figure C:3 is the range of CU's expectations concerning the unknown locus of an LU's performance possibility curve. Before starting the planning, CU believes that the subset B includes all parts of the performance possibilities in A that may become desirable from the organization's point of view. The methods we have discussed for conveying this information about preferences to the LUs are:

- Providing the target P, because if it is known that this defines the lower boundaries of the criteria, only points north-east of it will be of interest. This assumes that the LU seeks efficient plans by itself and may invite waste, as inefficiency is difficult to observe.
- Providing the target Q, because this will make the LU minimize the distance to this "ideal" and find a point in the "interesting range".
- Providing the target R, because all points of interest are what Weitzman (1970, p. 56) call R-efficient (Pareto optimal and for no criterion better than R), and so this tells the LU among which points it should seek the best one.
- Providing maximum or minimum levels for some criteria, corresponding to those of points R and P. If such are given for all criteria, this is equivalent to a target.
- Providing the maximal and minimal price relations between criteria corresponding to the end-points of the expected "interesting range" (also cf. Yu, 1973).

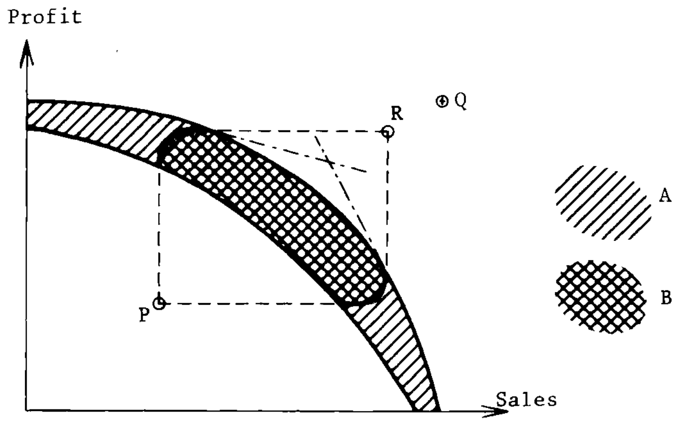

Figure C:3. Different methods of communicating what part of a feasible set to study

If there had been more than two criteria, incomplete prices could be used to state price or price relations that "cover" some of these, as discussed in Section C.2.

C.5 SUMMARY

The term incomplete prices was introduced to describe prices that do not show the total effort of producing a commodity, or alternatively the total utility of its use, but only some aspects of it. Such prices are quite common, especially as transfer prices. They can be used to communicate value judgments, but as a rule not to find the optimum equilibrium position, in the way that is possible with "complete" prices. Rather, their function is to reduce the dimensionality of a decision problem as far as possible.

There is an entire range of means for conveying imperfectly known possibilities or preferences, such as ranges for price relations, bounds for attribute values, or targets. As they may sometimes be more difficult to understand and/or use, depending on the context, the choice of the one best suited to designing any particular planning system will be a matter of great importance. Examples of the use of some of them can be found in the methods introduced in Chapters 9 and 11.

APPENDIX D. SOME METHODOLOGICAL COMMENTS ON PART THREE

D.1 THE APPROACH USED IN THIS STUDY

As discussed in more detail in Section 3.1, the statements in sets A and C constitute the characteristics of the basic problem presented in Part One, and the alternative methods discussed in Part Two, respectively. In Part Three, starting from these statements, a number of practical situations were examined. If all the A-statements were "confirmed" for a certain organization, this would mean that the organization's planning situation represented a "true" specimen of our problem; if all the C-statements necessary to a particular method were also "confirmed", this would prove that it was possible to use the method in this particular case.

These were the points of departure for Chapters 13 and 14, together with an *a priori* conviction that some real-life cases do exist, corresponding to the model situation. The only way to test this was to investigate a few cases, not expecting to "prove" anything, but hoping to gain greater understanding of the problem and the solutions suggested. In selecting practical situations, I was restricted mainly to cases of which I had some previous knowledge. This meant that when I translated the statements into concrete questions, I could use my familiarity with the activities of the organizations and with the subject matter of their decisions, so that my questions were relevant to the particular practical context.

In Televerket, for instance, I could use concrete figures and could specifically name the objectives, instead of having to speak in theoretical and general terms only. I consider this to have been a great advantage, although it could probably be argued that the subjects were led to discuss only those limited parts of their activities of which I had prior knowledge. Typical questions are listed in Section D.3 below.

The details of my empirical contacts were as follows:

In the case of Televerket I had previously had cause, and the opportunity, to discuss planning problems with a large number of the employees of the organization during management courses. Later, after formulating the statement sets, I conducted the interviews which provided most of the material for Chapter 13. These took place in November 1975 to March 1976. My interviewees were the financial managers of three Tele-Areas, and two analysts from central management's planning department. The interviews in the Tele-Areas were preceded and followed by interviews at central management. A total of six interviews with as many persons produced about 10 hours of taped material, which was then analysed together with other material collected. A draft version of Chapter 13 was approved by my main contact at Televerket.

At Uddeholms AB my contacts (Section 14.2.1) consisted of access to some internal memoranda, a meeting with the financial manager, and a two-hour taped interview with a person responsible for accounting developments. These contacts took place in November, 1976. The last-mentioned also agreed to the publication of our discussion with him after seeing a draft version.

The lunch case (Section 14.2.2 and Appendix A, Section A.8) concerns the report of a committee, which could have been expected to become the core group of the CU of a proposed new organization. The existing committee has much less influence than the suggested body would have had. I wrote parts of the report during the spring of 1974. As my ideas on multiobjective budgeting were in the process of taking shape at that time, I was able to investigate the feasibility of many statements in this setting, and to note the type of information actually possessed by the delegates.

As regards the defence case (Section 14.3), I had worked in the defence organization at a time (1969 - 1971) when many of the ideas later to be included in the basic model were being formed. In 1974/1975, I returned to the Army and Air Force Staffs to carry out a few interviews, which I tried to relate to my ideas about the basic situation as they then were.

While working on the study, I also had valuable contacts with the Swedish National Audit Bureau. I also discussed similar problems with two further agencies.

In connection with empirical studies of this type, it should be noted that attempts to characterize a specific situation in terms of the A-statements and C-statements above, will often only produce a verdict about the degree of resemblance to the models, rather than an absolute verdict about the applicability of a method. Such seemingly unproductive results are actually very valuable. At the present stage, the methods should be seen, rather, as alternative approaches. By investigating the statements at Televerket, I learnt more about the general problem. And, studying the resulting chapter above, the reader may come to a better understanding of the procedural requirements. Any improvement in Televerket's budgetary planning will have to be a later development, outside this study.

D.2 SOME NOTES ON CASE STUDIES

Case studies were discussed from a methodological point of view by Valdelin (1974). He requires a case study to deal with some organizational process in progress. This was not the case with my Televerket studies, which concentrated on certain characteristics of the organization and its decision-makers. In spite of this, I regard this study as a legitimate case study, as it describes a real-life situation in some detail.

I also had a better theoretical foundation for my investigation than Valdelin considers to be characteristic of most case studies. As explained above, this case was certainly concerned in some sense with the validation of methods, or at least with a judgment of their applicability in an isolated case.

I did not expect to prove or disprove the methods with this single case, but I hoped to provide some ideas for further studies. Using Valdelin's term, this shows the influence of a "constructive" motivation for this research, which had been even more prominent in the earlier defence and lunch studies. In these, the constructive aims of the studies had been to support theoretical work. Valdelin (1974, p. 48) claims that research areas with highly developed theories can rely entirely on theoretical work for their constructive studies. In my study, I have relied on a theoretical basis to a comparatively great extent, although I would not say that there is actually any very well-developed theoretical body available. Rather, there are several bodies of theory dealing with different aspects of the problem, as can be seen from the chapter headings in Part Two.

This mixture of constructing and validating makes a strict validation of the propositions, of any meaningful sort, impossible. As the set-A statements claim to describe a problem situation, it should be possible in some cases to confirm them. I think this was done in the Televerket case. But in the case of the C-statements, a failure to prove all the statements for any of the procedures is mainly a signal for continued work, often involving further approximations.

Valdelin also stresses the importance of data-generating and data-processing in case studies. In my cases, this side of things was rather informal. Interview guides (cf. D.3 below) were used but not strictly adhered to. Often several questions were used before I felt that sufficient information had been given on specific points. Since a comparison between several cases was not relevant here, it did not seem to me that this was any problem.

D.3 EXAMPLE OF INTERVIEW GUIDE

The interview guide reproduced here (in translation) was used in the Tele-Areas. Other interview guides were used in the central management, and in the other organizations visited (see Section D.1). Some questions are general in scope, but for those dealing with a particular A-statement or C-statement, the relevant number is given in parenthesis.

D.3.1 LU performance possibilities

- Are the 33 service criteria which are listed in the central service norms relevant also to Tele-Area planning?
- How are service criteria related to activities? Is it usually one particular activity which affects a service criterion, or is there an "interplay" between alternative ways of affecting criteria? (A19)
- How well-known are the consequences of different activity designs? (A19)
- How well-known are the consequences of different profitability requirements? (A21)
- Would it be possible to state trade-offs between different types of service, thus indicating alternative service possibilities? (C24)
- Could a requirement such as "one week shorter delivery-time" be evaluated for its effect on profitability? Other similar requirements? (C24, C25)
- Would a proportional improvement or deterioration in all service criteria have any meaning that could be understood by Tele-Area planners? (C26)

D.3.2 Central service directives

- How do you think the central management should influence or control the service design?
- What knowledge in addition to the values in earlier years do you think the central management has, as regards the service alternatives available to different Tele-Areas? (C8)
- How would you feel about central planning or operational guidelines, whereby various objectives or criteria were assigned weights determined centrally? (C23)

In this context, other ways of indicating preferences were also discussed.

D.3.3 The role of LU preferences

- Should central management act to "equalize" the general level and the emphasis in the service provided, between different LUs? (A11)
- Are there local differences in taste or needs that motivate different service?
- How great are the differences between LUs in the marginal cost of providing a particular service?
- Does the central administration accept today that a Tele-Area chooses its service emphasis itself, provided the profit requirements are fulfilled? (For instance: which of the "ideal" values for service criteria should be violated.)
- Could the Tele-Area or its manager choose between alternative service profiles, such as 70 % share of requested repairs within 8 hours, and 7 weeks delivery time, or as an alternative 60 % repairs share and 6 weeks delivery time?

D.3.4 Today's planning dialogue

- How do you argue about these problems today?
- Does central management control which criteria are used in motivating budgets, etc.? (A31)
- How would you prefer this to be done?
- Televerket's current high profit level should reduce the need to stress the profitability objective. How do you expect this to affect planning?

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INDEX

This index is intended as an aid in "reading across", for instance in finding terms or studying particular problems. It is not an exhaustive listing of every mention of these terms. In particular, no reference is made to the various summaries and reminders, only to those parts of the text where a certain theme is developed. Underlined pages in the list refer to definitions.

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Part I - Analysis	51:-
Part II - Case Descriptions	51:-
BRODIN, B., JÖNSSON, S., NYSTRÖM, H. & SANDKULL, B., Four Papers on Product Development. Stockholm 1976. (In collaboration with Marknadstekniskt Centrum.)	17:-
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Report No. 1: Description of the Participants	25:50
Report No. 2: The Participants and the Work of the Study Group	17:85
Report No. 3: Six Months After the Study Group	15:30
Report No. 4: Analysis and Discussion	15:30
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STOLT, B., Information Exchange Between Citizens and Public Authorities: The descriptive, stipulative and normative framework for information exchange between citizens and public authorities and a classification system for the political resources of the individual. Stockholm 1976.[2]	25:50
TELL, B., A Comparative Study of Some Multiple-Criteria Methods. Stockholm 1976.[1]	39:95
<u>1975</u>	
ASPLUND, G., Strategy Formulation - An intervention study of a complex group decision process. Stockholm 1975.[1]	50:-
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BERG, H. & DOCHERTY, P., Trade Union Strategies in a Changing Environment. Stockholm 1975. EFI/PA-rådet.	18:70
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DOCHERTY, P., MAGNUSSON, Å., STJERNBERG, T. & STYMNE, B., The Business Insurance Department - changes towards increased participation. Stockholm 1975. EFI/PA-rådet.	38:25
FJAESTAD, B. & HOLMLÖV, P.G., Swedish Newsmen's Views on the Role of the Press - Paper presented at the 30th annual conference of the American association for public opinion research, June 1975. Stockholm 1975.[1)2)]	17:85

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STJERNBERG, T., Facilitating and Obstructing Factors in a Change Process in Skandia. Stockholm 1975. EFI/PA-rådet.	20:40
STYMNE, B., The Motor Project - An example of strategy formulation in a large-sale company. Stockholm 1975. EFI/PA-rådet.	28:90
ÅHRÉN, P., Economic Evaluation Methods in Community Planning. Stockholm 1975.	34:-

1974	
AHLMARK, D., Product-Investment-Financing - A contribution towards a theory of the firm as a product-centered financial system. Tables incl. Stockholm 1974.[2]	60:-
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BACK, R., DALBORG, H. & OTTERBECK, L., Industrial Location Patterns - A multidimensional analysis of relationships between firms and regions. Stockholm 1974.[1] [2]	40:-
BERG, C., The Participation System. A clinical study of a growing company. Stockholm 1974.	40:-
BERGMAN, L. & BERGSTRÖM, C., Energy Policy and Energy Use. Stockholm 1974.[2]	17:85
BERGSTRAND, J., Budgetery planning - A summary of two previous books. Stockholm 1974. (In collaboration with Sveriges Mekanförbund)[1]	10:-
BERGSTRAND, J., Budgetary Planning II - The formulation of budgetary relationships. Stockholm 1974. (In collaboration with Sveriges Mekanförbund.)	30:-

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LIST OF REPORTS PUBLISHED SINCE 1970 (cont.)

	Sw.Crs. (circa)
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DALBORG, H., Research and Development - Organization and location. Stockholm 1974.[1]	30:60
HEDLUND, G. & OTTERBECK, L., The Multinational Corporation, the Nation State and the Trade Unions. Stockholm 1974. (Published by P A Norstedt & Söner.)	44:20
HÄGG, C., Periodic Payment Variations - A study in time series analyses of the firm. Stockholm 1974.	34:-
LIND, R., The Effect on Tax Revenues of Changes in Collective Traffic Fares- A quantification of the effects on the tax revenues of the state, the county councils and the primary municipalities of changes in the fares for local traffic in greater Stockholm. Stockholm 1974.[2]	25:50
MAGNUSSON, Å., Budgetary Control - Analysis of budget deviations. Stockholm 1974. (In collaboration with Sveriges Mekanförbund.)	45:-
PAULANDER, H., Distributed Lags. Stockholm 1974.[1] [2]	17:85
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