TWO-LEVEL FINANCIAL PLANNING WITH CONFLICTING GOALS

AN INTERACTIVE PROCEDURAL APPROACH

A brief survey

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Abstract

In this paper we consider financial planning as a process within and between two hierarchically distinct decision levels. The information regarding the future is assumed to be asymmetrically distributed over the different decision units.
We propose an interactive procedural approach to this type of planning problems, in which a certain degree of flexibility is granted to decision-makers at both hierarchical levels. The proposed approach differs from other approaches to the same problem (e.g. goal programming, decomposition techniques) in that the communication between different decision levels is structured in terms of sets of decision alternatives, which can be adopted in a systematic interactive way.

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1. Introduction

In this paper we consider financial planning as a process within and between two hierarchically distinct decision levels. The upper decision level consists of one internally consistent decision unit called the principal or coordinator. The lower decision level consists of a number of mutually separate decision units (subordinates), each of which is internally consistent. The principal decides on the distribution of resources over the lower level decision units. These decisions are a.o. based on the information provided by the lower level units.
Each decision unit has to deal with a complex of goal variables. The principal deals with several 'central' goal variables, the subordinates have to deal both with their contribution to the central goal variables and with additional goal variables which are included in order to take account of 'local circumstances' (possibly including the subordinate's own interests, thus giving rise to agency problems). Since financial planning is, per definition, dealing with an uncertain future, and since not all outcomes can be foreseen (even not in probabilistic terms) it is necessary to build a certain degree of flexibility within the planning process. Moreover, the information regarding the uncertain future is assumed to be asymmetrically distributed over the different decision units. That implies that not all flexibility in the planning process has to be concentrated at the principal decision unit, but has to be distributed over both the central and the subordinate decision units.
In this paper, we propose an interactive procedural approach to the above circumlined problem. The approach is interactive in two ways. One, each decision unit selects by means of an interactive programming approach a set of satisfactory plans. Second, a description of this set is communicated to the decision units at the other hierarchical decision level. At this level, a (new) set of plans, taking into account the de-

sires and/or requirements of the other decision level, is determined. And so on, until the upper hierarchical level inforces its conditions on the lower level. Both interactive procedures are structured in a systematic way, guaranteeing stepwise improvement of the resulting sets of alternative plans until a satisfactory set of plans (including sufficient flexibility for each decision unit) is reached.
The proposed approach is different from other approaches to the stated problem (e.g., goal programming, decomposition techniques) in that the communication between different decision levels is structured in terms of <u>sets</u> of decision alternatives, which can be adapted in a systematic interactive way.

In the next section we describe the decision problems with which both top and lower management are confronted in some more detail. Then, in section 3, two tools for co-ordination are distinguished and briefly discussed. In section 4 these two tools are used within our interactive approach. In the concluding section, an experimental design is proposed by means of which a number of hypotheses with respect to the functioning of this approach can be investigated for different organizational circumstances.

2. <u>Top and local management's decision problems</u>

The central decision unit defines a series of 'central' goal variables g_m, $m = 1,\dots,M$. In principle, each of the lower level decision units contributes to each of the central goal variables; g_m^u measuring the u'th units contribution to the m'th central goal variable ($u = 1,\dots,U$ and $m= 1,\dots,M$). The central decision level can influence the values of its central goal variables both directly and indirectly. Directly, because it controls a number of central instruments x_i, $i = 1,\dots,I$. Examples of these instruments are the size of dividends and the amount borrowed during a certain period. The central decision unit influences the values of the central goal variables also indirectly, because it controls the distribution of a series of central resources (r_j, $j = 1,\dots,J$) over the different lower level decision units. If we define $g_m^u = g_m^u\ (x_i,\dots,x_I)$ as the central decision unit's direct influence on the m'th central goal variable, the latter can be defined as

$$g_m = g_m^c + \sum_{u=1}^{U} g_m^u \qquad \text{for } m = 1,\dots,M. \qquad (1)$$

The central resources can be used to support the central activities x_i or, alternatively, be distributed to the lower level decision units. Thus

$$r_j = \sum_{i=1}^{I} \rho_{ij}\, x_i + \sum_{u=1}^{U} r_j^u \,, \tag{2}$$

where ρ_{ij} denotes central activity i's pro unit use of resource j and r_j^u represents the amount of resource j distributed to unit u. Obviously, ρ_{ij} may be negative in the case that central activity i adds to the amount of type j resources (for example, borrowing increases the amount of funds available). In addition, it is possible to define for each central resource j, an activity variable measuring the unused amount of this resource. This type of variables can be actively manipulated in order to guarantee the required flexibility in the plans to be developed. Of course, the central decision unit is not completely free in choosing the values of the instrumental variables. We assume the choice of instrumental variables restricted to the feasible set X. Thus $x \in X$, with x the vector of instrumental variables.

Central management is assumed to be able to choose between different combinations of goal variables. However, it is assumed not to have a mathematically well-defined preference function which is 'ready for an optimization algorithm'. Likewise, no precise knowledge is assumed with respect to the relation between the g_m^u, the lower levels' contribution to the central goal variables, and the r_j^u, the central resources distributed to these lower levels. Without the latter two assumptions, the problem would boil down to a more or less conventional optimization problem. With these assumptions included, it becomes a multicriteria problem mingled with an information problem. Next, to give a better insight into the nature of this problem, the lower level decision units' situation is sketched.

In addition to the central goal variables, each lower level decision unit has to deal with other goal variables in order to take account of 'local circumstances', possibly including the subordinate's own interest.[1)] The u'th unit's contribution to the m'th central goal variable was denoted by g_m^u. The local goal variables of decision unit u are denoted by $g_{m(u)}$, with $m(u) = 1,\dots,M(u)$. So in total, decision unit u has to deal with $M + M(u)$ goal variables. Each of these goal variables is a function of the I(u) local instrumental variables :

$$g_m^u = g_m^u (x_{1(u)} \dots x_{i(u)} \dots x_{I(u)}), \text{ for } m = 1,\dots,M; \text{ and}$$
$$g_{m(u)} = g_{m(u)} (x_{1(u)} \dots x_{i(u)} \dots x_{I(u)}), \text{ for } m(u) = 1,\dots,M(u). \tag{3}$$

The choice of the local instrumental variables is restricted by local constraints, i.e. $x_u \in X_u$ with x_u the vector of unit u's instrumental variables and X_u the convex feasible set described by local constraints. In addition, the choice is restricted by the amounts of resources r_j^u, $j = 1,\dots,J$; available to unit u. This leads to the constraints

$$r_j^u \geq \sum_{i(u)=1}^{I(u)} \rho_{i(u)j}\, x_{i(u)}, \; j = 1,\dots,J; \tag{4}$$

where $\rho_{i(u)j}$ represents decision unit's u pro unit of activity i(u)'s use of resource j. Obviously, one or more of the $\rho_{i(u)j}$ may be negative in the case that local activity i(u) adds to the type j resources.
Like central management, local management is assumed to be able to choose between different combinations of goal variables. Likewise, local management is assumed not to have a mathematically well-defined preference function. With these assumptions, the problem of local management becomes a multiple criteria problem, too. This problem differs from the multiple criteria problem of top management, since given the goal variables (3), local management can determine the goal values associated with a given instrument vector x_u. If in addition, X_u and the amounts of resources r_j^u, $j = 1,\dots,J$ are known, local management can calculate, at least in principle, the best values for each of the goal variables (3) separately. Top management's problem is more difficult, since its goal variables depend among others on the results of the lower level units, which in their turn depend not only on the resouces distributed to them by top management but also on local circumstances, including both local goal variables and local resources.

3. Two tools for co-ordination

Basically, top management has two tools for co-ordination, one of which is the use of incentive functions. Such an incentive scheme may both include rewards for a lower level decision unit's contribution to the cen-

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1) See e.g. Christensen and Obel, 1981, and Christensen, 1982.

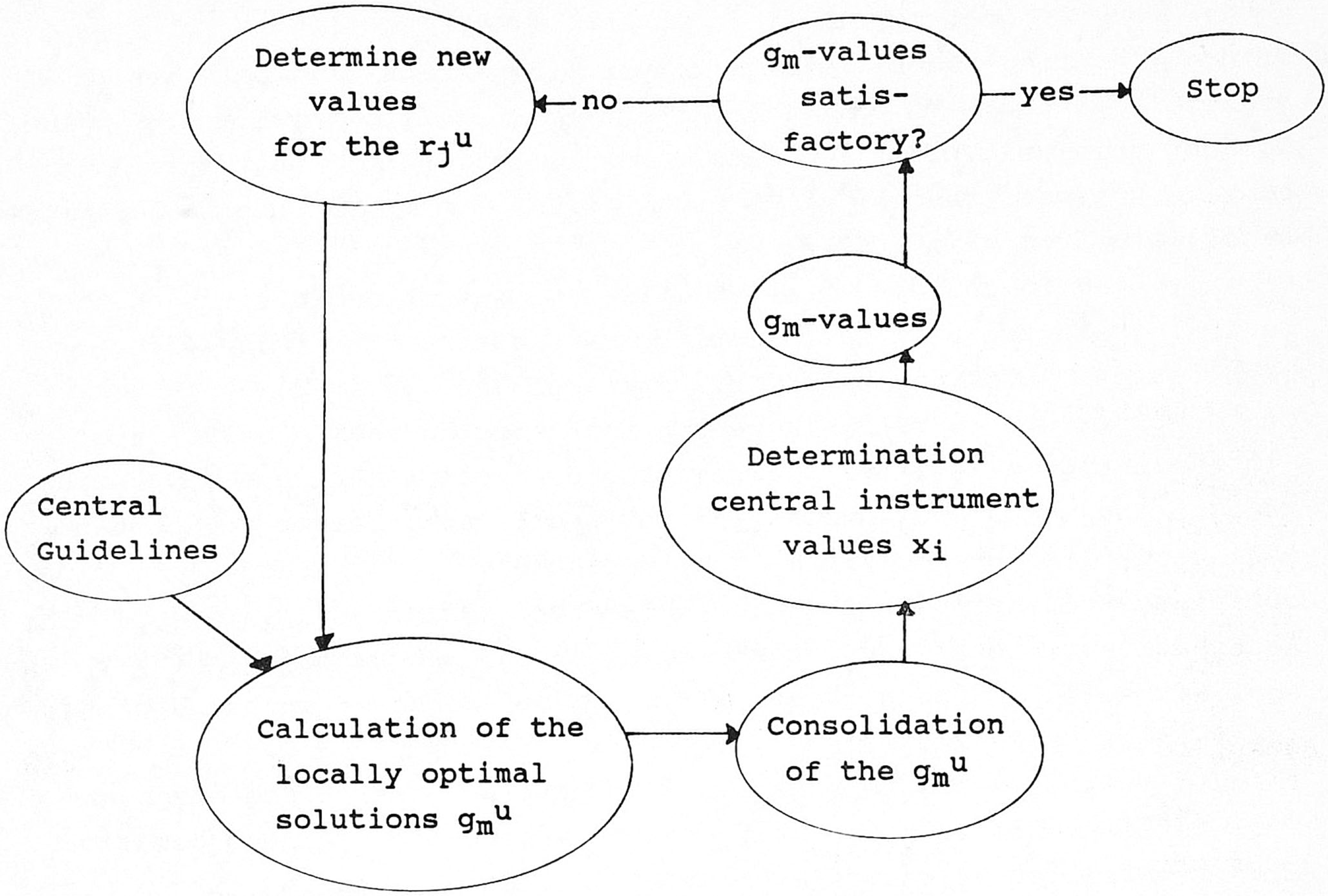
tral goal variables and for efficient use of resources (savings) and it may include punishments for excess use of resources. Thus, the incentive scheme for decision unit u can be written as

$$\gamma^u = \gamma^u \; (g_m{}^u, \; \Delta \, r_j{}^u; \; m = 1,\ldots,M; \; j = 1,\ldots,J) \qquad (5)$$

with $\Delta \, r_j{}^u$ being the difference between the amount of type j resources available to decision unit u and the amount of type j resources actually used by this unit. Ideally, each decision unit should have similar incentive schemes (thus $\gamma^u = \gamma^{u'}$ for $u \neq u'$), but sometimes valid reasons to deviate from this rule do exist.
Clearly, the incentive scheme γ^u will have its price in terms of the central goal variables. For simplicity we assume that this price has been taken account of in the definition of the $g_m{}^c$ in (1).
On the other hand, γ^u will have its influence on the formulation of the u'th unit's goal variables. For instance, local management may decide to replace the m goal variables $g_m{}^u$ (the local contribution to the central goal variables) by the single goal variable γ^u. Of course, γ^u is to be optimized together with the M(u) local goal variables $g_{m(u)}$.
Alternatively, local management may define γ^u as one of the M(u) local goal variables. In both cases, γ^u should be expressed in terms of the local instruments $x_{i(u)}$.
In this paper, we assume that the incentive schemes γ^u are given and fixed. In doing so, we concentrate on the second tool for coordination, the distribution of central resources, and ignore a number of interesting questions concerning the incentive scheme. For instance, we assumed that central management had no mathematically well-defined preference function. How then, should the incentive schemes be defined? Furthermore, the interrelationship between the two tools of co-ordination, incentive schemes and distribution of resources, should be studied.

The problem of distributing resources over the different subunits is illustrated in Figure 1. We assume that the distribution process is initiated by giving some central guidelines to the local decision units (cf. Ruizendaal and Spronk, 1982). These guidelines include a description of the central goal variables (at least those which can be influenced by the subunits), the incentive scheme and possibly also a rough indication of the amounts of resources available. Among others on basis of this information, the subunits develop a plan, which is communicated to top management in terms of the $g_m{}^u$, the contribution to the central goal

Figure 1 The distribution of resources



variables, in terms of the amounts of resources required to achieve these $g_m{}^u$, possibly supplemented with some of the instrument values (e.g. important capital investment projects). Centrally, the required amounts of resources $r_j{}^u$ and the resulting goal values $g_m{}^u$ are consolidated. Given these consolidated values, top managment can determine the values of the central instruments x_i, resulting in the best, i.e. given the $g_m{}^u$ and given the available resources, central goal values g_m. If these values are considered to be satisfactory, the resource distribution process is terminated by confirming that the required amounts of resources will indeed be distributed to the subunits. If not, top management has the possibility to revise the proposed $r_j{}^u$-values after which the subunits can recalculate the $g_m{}^u$-values, and so on until the g_m-values are considered to be satisfactory.
In essence, the distribution of resources process helps top management to solve an information problem. If it had sufficient information, top management could simultaneously determine the $r_j{}^u$ and the x_i values which would yield the 'optimal' combination of g_m-values. However, espe-

cially the relationship between the resources $r_j{}^u$ distributed to the units, and the contribution $g_m{}^u$ of these units to the central goal variables are largely unknown. Of course, each plan which is communicated from the subunits to the central authority gives some information on this relationship.[2)] If the 'loop' in the described distribution process could be repeated many times, the amount of information would eventually be sufficient to find a close to optimal solution. However, it is clear that the amount of iterations (loops) should be very limited in practice. One of the ideas in the procedure described in the next section is to structure the communication process between top management and subunits in terms of <u>sets</u> of plans, thus increasing the amount of information even if the number of iterations is very small.

4. An interactive co-ordination procedure

As explained in the preceding section, the procedure proposed in this paper starts with the development, by each lower level decision unit, of a set of plans. In developing these plans, lower level takes account both of the guidelines forwarded by central management and of its own interpretation of local circumstances. It is the task of lower management to find a balance between the local requirements and those formulated centrally. Obviously, this balance will depend on the amounts of resources provided by the center. Therefore, we propose to construct, for each subunit, plans for different combinations of resources. In doing so, we propose lower management to use IMGP (Interactive Multiple Goal Programming, cf. Spronk, 1981, 1985).
This procedure fits well to the described problem, since it generates sets of solutions (plans) each set satisfying a combination of constraints formulated by the decision-maker. In fact, IMGP starts with a set of solutions satisfying a combination of conditions which is easily fulfilled. Then, successively, the decision-maker reduces the set of alternatives by increasing the conditions, thus obtaining a smaller set of increasingly better solutions. The decision-maker continues until a set of satisfactory solutions is found.
To develop a set of plans which is communicated to top management, lower management starts with the assumption that the resources are very limited. Given this limitation, the IMPG-procedure is used to derive a set

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2) Also the information from the top level to the subunits contains information. Especially when there is no precise incentive scheme, the subunits can partly learn from the resources distributed to them what topmanagement wants them to achieve.

of conditionally (i.e. given the limitations) satisfactory plans. In doing so, managament can take account of local circumstances (both instruments and goals) while searching for a satisfactory contribution to the central goal values. The set of plans which results from this first exercise is labeled 'plan one' of the decision unit concerned and is described in terms of the maximally required amounts of resources and the minimal contribution to the central goal values which can be attained given these resource levels. Given plan one, local management has to determine a second set of plans ('plan two'). This is done by increasing one or more of the goal values which could be reached in plan one. Of course, this can only be done if the limitations on the resources are somewhat relaxed. In the procedure proposed here, it is local management who has to decide which of its goal values and which of the resources are to be increased. However, once plan two has been determined, it is also decribed in terms of the maximally required amounts of resources and the minimal contribution to the central goal values which can be attained given these resource levels. In exactly the same way, plans three, four and so on can be determined , having the property that plan k is referred to plan (k-1), at least by local management.
Central management receives from each of the lower level decision units a series of plans. In fact, central management can view the plans provided by unit u as a hierarchically ordered set of projects $x_{u1},\dots,x_{uk_u}$; k_u being the number of plans formulated by the u'th unit. To be more precise, central management has to decide whether it adopts project x_{u1} or not and, if so, whether it adopts x_{u2} and so on. For each project x_{uk}, lower level management has calculated the minimum contribution to each of the central goal variables. Thus we can reformulate formula (1) for the m'th central goal variable as

$$g_m = g_m^c + \sum_{u=1}^{U} \sum_{k=1}^{k_u} g_m^{uk} \cdot x_{uk} \quad \text{for } m = 1,\dots,M, \qquad (6)$$

with g_m^{uk} the contribution to the m'th central goal variable in case project k of decision unit u is adopted. For each project x_{uk}, u = 1,...,U and k = 1,...,u_k; $0 \le x_{uk} \le 1$ must hold. It is not unreasonable to define x_{uk} as a continuous variable, thus avoiding the burden of zero-one problems[3]).
However, for each decision unit u, the project x_{uk} (k = 2,...,u_k) may only become positive if all preceding projects are equal to one. If the use of zero-one procedures is to be avoided, this condition can be fullfilled e.g. by restricted entry methods.

Similarly, the central resource constraints (2) can be rewritten as

$$r_j = \sum_{i=1}^{I} \rho_{ij} \; x_i + \sum_{u=1}^{U} \sum_{k=1}^{k_u} r_j^{uk} \cdot x_{uk}, \qquad (7)$$

where r_j^{uk} stands for the additional use of central resource j in case plan k of decision unit u is adopted. Relations (6) and (7), together with the constraints formulated earlier, define central management's problem as a linear programming problem with multiple goal variables. As with the local problems, we propose IMGP as a tool to solve the central blem. The main advantage of doing so is that central management can find a series of minimally required values for the central goal variables which are fulfilled by a set of 'masterplans'. Although the master plans will be adopted, it is clear that there is a subset of the local plans which will be adopted in all masterplans satisfying the minimum requirements with respect to the central goal values. This subset of projects is adopted by central management. If central management judges the associated central goal values unsatisfactory and/or if there is an undesirable pattern of local plans adopted, it can decide to give the local decision units another chance to formulate plans, in addition to those already accepted. In this case, local management has to make a new series of plans, knowing that some of its plans have already been adopted and taking account of the 'signals' central management has given by adopting some of the local plans while rejecting others. Other plans than before will result because local management has got a better insight into the availability of resources (a.o. in view of the plans of other local decision units) and because its balance between central and local goal variables will probably be changed.
The whole procedure is repeated until central management is satisfied with the resulting set of solutions. Of course, it has to make a final choice from the remaining set of local plans to determine which will be adopted and which not. Obviously, it has the freedom to leave some flexibility by postponing the decision on one or more of the plans, while attaining the minimum goal value requirements by means of the projects already adopted.

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3) This statement rests on the assumption that additional resources will result in diminishing marginal contributions to the central goal variables. If so, projects with a high rank number, will be less attractive to central management than those with lower rank numbers. This gives an incentive to lower management to 'linearize', through the definition of its plans, the relationship between the resources and the contribution to the central goal variables.

5. Conclusions

At face value, the proposed procedure possesses a number of attractive properties. It gives both central and local management the possibility to deal with a multiplicity of goals, while each decision unit is flexible enough to take account of its own specific circumstances. On the other hand, all plans of all decision units and the central instruments compete for the same resources, which reduces the risk that the possibility to take account of specific local circumstances is misused as a cover for inefficient use of resources. However, to be certain and more precise about the sketched properties, more research is needed. Among others, we intend to design a series of laboratory experiments to get a better insight into the functioning of this approach (cf. also Winkofsky et al., 1981, and Fox and Baker, 1985).
An attempt will be made to investigate some of the aforementioned agency problems (see Christensen and Obel, 1981, Christensen, 1982) and asymmetrical distributed information. Experimental conditions in laboratory experiments may include : the initial amount of information asymmetry; the initial incentive scheme, representation of decision levels by man-computer interaction or by decision rules, environmental conditions such as decision time, constraints on the objectives - settin process and dynamical properties of the decision system (e.g., adaption of incentives and objectives setting). This design implies also the comparison of man-computer interaction procedures and automated decision rules. Learning characteristics of such decision systems show an interesting potential for future research.

References

Christensen, J., and B. Obel, 1981, Incentive Issues in Multilevel Organisations using Iterative Planning, Int. Journal of Policy Analysis and Information Systems, Vol. 5/4, pp. 287-304.

Christensen, J., 1982, Communication in Agencies, Bell Journal of Economics, pp. 661-674.

Fox, G.E. and N.R. Baker, 1985, Project Selection Decision Making Linked to a Dynamic Environment, Management Science, Vol 31/10, pp. 1272-1285.

Ruizendaal, G.J. and J. Spronk, 1982, Projectprofielen, in A.C.C. Herst et al. (eds), Financiering en Belegging, Stand van zaken anno 1982, Erasmus University, Rotterdam, pp. 255-266.

Spronk, J., 1981, Interactive Multiple Goal Programming : Applications to Financial Planning, Martinus Nijhoff, Boston.

Spronk, J., 1985, Financial Planning with Conflicting Objectives, in G. Fandel and J. Spronk (eds), Multiple Criteria Decision Methods and Applications, Springer, Berlin, pp. 269-288.

Winkofsky, E.P., N.R. Baker and D.J. Sweeney, 1981, A Decision Process Model of R & D Resource Allocation in Hierarchical Organisations. Managment Science, Vol. 27/3, pp. 268-283.