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An interactive heuristic for financial planning in decentralized organizations

Marc H. Goedhart *, Jaap Spronk

Department of Finance, Erasmus University Rotterdam, P.O. Box 1738, 3000 DR Rotterdam, Netherlands

Abstract

Planning and controlling overall performance in decentralized organizations is a complex task for central management because it is confronted with incomplete information on organizational opportunities and possible conflicts of interest with local managers. Many formal procedures for the support of planning processes in decentralized organizations are based on decomposition methods for mathematical programming. Most of these procedures assume organizational decision models with a single overall goal that is supported by all decision makers involved. In this paper, a framework for an interactive heuristic planning procedure is proposed for decentralized organizational decision models with multiple goals that may be conflicting within and between decision levels. This procedure aims at solving the planning problem straightforwardly in a low number of information exchanges between the decision levels, which makes it more acceptable for decision makers in practice.

Keywords: Financial planning; Goal programming; Multiple-criteria decision making

1. Introduction

The majority of today's large business firms have a divisionalized structure in which decision making authority and information is distributed over several management levels (for example Hoskisson et al., 1992). This decentralized structure arises in response to the bounded rationality and opportunistic behaviour of organizational members and offers several advantages over centralized structures (see for example Williamson, 1987, Chapter 11). As centrally administered firms grow larger the danger of information and decision making overload of central management increases. This calls for some delegation of decision tasks to divisional managers who have the knowledge to handle specific and relatively independent problems. Controlling the firm's overall business portfolio and corporate financing are central management's main responsibility. Decentralized structures reduce possibilities of adverse discretionary behaviour of managers whose performance is difficult to measure in centrally controlled organizations. Also the motivation of divisional managers may be enhanced because of the acquired responsibility and authority (see for example Mintzberg, 1979, Chapter 20). On the other hand, a loss of control of central management over the firm's activities arises because of

* Corresponding author.

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lack of information on divisional opportunities, which can lead to a sub-optimal solution to the organizational decision problem from an overall perspective. Furthermore, conflicts of interest can arise when divisional managers not only try to contribute to central goals but also pursue their own, local goals. To mitigate these effects, decentralized planning and coordination procedures are required (cf. Burton and Obel, 1984). For example, consider a company with two or more divisions that undertake activities generating cash flows in foreign currencies. Without any form of coordination by central financial management, each division might decide to hedge its own currency risk. However, the currency risk for the company as a whole might be negligible if divisional cash flows in the same currency are of opposite sign. In that case, divisional hedging would be redundant and suboptimal. To reduce these and other costs of decentralization, it is necessary to use planning and coordination procedures that enable central management to carefully balance divisional activities.

In Section 2, we present a brief review of decentralized organizational decision models and procedures found in the literature. In Section 3 we propose a framework for an interactive heuristic planning and coordination procedure for so-called compromise organizational decision models with multiple goals. The procedure is essentially budget-oriented, allows for multiple goals at all levels and seeks to derive an organizational compromise solution in a straightforward manner, without using shadowprices or detailed information on decision makers' preferences. An illustrative application of the interactive proce-

Holistic/Single goal

$$\begin{aligned} &\text{Max} && c'x = z_1 \\ &\text{s.t.} && \sum_{k=1}^{K} B_k x_k \leqslant b, \\ &&& A_k x_k \leqslant a_k \quad \text{for } k = 1,\ldots,K \end{aligned}$$

e.g.: Dantzig and Wolfe (1961), Ten Kate (1972), Burton and Obel (1984)

Holistic/Multiple goals

$$\begin{aligned} &\text{Max} && Cx = z \\ &\text{s.t.} && \sum_{k=1}^{K} B_k x_k \leqslant b, \\ &&& A_k x_k \leqslant a_k \quad \text{for } k = 1,\ldots,K \end{aligned}$$

e.g.: Rietveld (1980), Goedhart (1994)

Compromise/Single goal

$$\begin{aligned} &\text{Max} && c'x = z_1 \\ &\text{Max} && h'_k x = d_{k1} \quad \text{for } k = 1,\ldots,K \\ &\text{s.t.} && \sum_{k=1}^{K} B_k x_k \leqslant b, \\ &&& A_k x_k \leqslant a_k \quad \text{for } k = 1,\ldots,K \end{aligned}$$

e.g.: Ruefli (1971), Freeland and Baker (1975)

Compromise/Multiple goals

$$\begin{aligned} &\text{Max} && Cx = z \\ &\text{Max} && H_k x_k = d_k \quad \text{for } k = 1,\ldots,K \\ &\text{s.t.} && \sum_{k=1}^{K} B_k x_k \leqslant b, \\ &&& A_k x_k \leqslant a_k \quad \text{for } k = 1,\ldots,K \end{aligned}$$

e.g.: Reimers (1985), Haimes et al. (1990), Goedhart (1994)

where:

z: $(1 \times m)$ vector of central goal variables, $z' \equiv \{z_1,\ldots,z_i,\ldots,z_m\}$.
c: Vector $(1 \times n)$ of goal coefficients for firm's activities.
x: Instrument vector $(1 \times n)$, indicating firm's activity level; the vector is partitioned as $x' \equiv \{x'_1,\ldots,x'_k,\ldots,x'_K\}$.
B_k: Matrix $(p \times n_k)$ of overall technological coefficients for division k.
b: Vector $(1 \times p)$ indicating scarce overall resources.
A_k: Matrix $(r_k \times n_k)$ of divisional technological coefficients for division k.
a_k: Vector $(1 \times r_k)$ for divisional resources and technological restrictions.
C: Matrix $(m \times n)$ of central goal coefficients.
c: Vector $(1 \times n)$ of goal coefficients for firms' activities.
h_k: $(1 \times n_k)$ vector of divisional goal coefficients.
H_k: Matrix $(m_k \times n_k)$ of divisional goal coefficients for division k.

Fig. 1. Four categories of organizational decision models.

dure to a financial planning problem in a decentralized firm is presented in Section 4.

2. Organizational decision making: Models and procedures

Some interesting models of organizational decision making and associated planning procedures originate from decomposition methods in mathematical programming designed by Dantzig and Wolfe and by Ten Kate (see for example Burton and Obel, 1984, or Dirickx and Jennergren, 1979, for an overview). These methods split the original programming problem into several, more amenable subproblems and a master problem. The subproblems are separately optimized, conditional on some parameters that are iteratively updated by the master problem. Baumol and Fabian (1964) already noted the similarities with planning and coordination procedures in decentralized organizations. The subproblems can be regarded as the divisional decision problems and the master problem as that of central management. The original problem before decomposition represents the overall organizational decision problem. The Dantzig–Wolfe decomposition method can be interpreted as a form of price coordination and Ten Kate's method as a form of budget coordination.

Here, we make a distinction between decision *models*, which represent the organizational decision problems, and decision *methods*, i.e. the procedures that are used to solve these problems. In classifying the organizational decision models that – implicitly – underlie the wide range of existing procedures based on decomposition methods, we employ two elementary criteria: the degree of cooperation and the number of goals in the organizational decision problem. Based on these two criteria, four general categories of linear organizational decision models are formulated as shown in Fig. 1. In each model, vector b forms the right-hand side for the so-called common restrictions, which apply to more than one division, representing for example shared use of scarce resources or interdivisional deliveries. The division-specific restrictions with right-hand side a_k apply to division k only. Holistic models represent situations in which all divisional decision makers fully support the goals of the central decision maker. These models represent decentralization of information but no decentralization in decision making. In compromise models, however, divisional decision makers primarily pursue their own goals, which may be conflicting with the central goals. Compromise models are more realistic because they represent autonomous decision making with divisional managers taking account of, possibly legitimate, local interests (cf. Freeland and Baker, 1975). Across the four categories 'the solution' to the organizational decision model is defined in a different manner. In the holistic single-goal model, it is defined as the solution $z_1^* = c'x^*$ for which the objective function z_1 reaches its maximum value. In holistic multiple-goal models it is the most preferred solution $z^* = Cx^*$ that maximizes some implicit preference function $P_0(z)$. [1] 'The solution' to compromise single-goal models is defined as the set of values for the goal variables $(z_1^*, d_{11}^*, \dots, d_{K1}^*)$ that are Pareto-efficient with respect to all individual objective functions (cf. Freeland and Baker, 1975). For compromise models with multiple goals, the solution is the set of values for the goal vectors $(z^*, d_1^*, \dots, d_K^*)$ that are Pareto-efficient with respect to the implicit preference functions $P_0(z), P_1(d_1), \dots, P_K(d_K)$ of all individual decision makers. Following Bogetoft et al. (1994), we define these as organizationally efficient compromise solutions. The four categories of organizational models thus have different types of solutions and call for different types of solution methods.

The models in Fig. 1 stand for the hypothetical, overall organizational problem, i.e. the problem that the organization as a whole would like to

[1] Interactive solution methods for multiple goal problems optimize the implicit preference function by collecting information from the decision maker on his preferences in a series of man-model interactions (see Stewart, 1992, for an overview). Alternatively, the solution to a multiple goal problem is sometimes defined as the set of non-dominated values for the goal vector z, which can be found by some vector-maximum algorithm (see Steuer, 1986, for an overview).

solve (cf. Sweeney et al., 1978). In decentralized organizations this problem is solved by a group of decision makers who all have information on only part of the overall organizational problem. Divisional decision makers do not have information on the effects of their decisions on the performance of other divisions and the organization as a whole, as is modelled in the common restrictions. On the other hand, the central decision maker lacks information on the local conditions represented by the division-specific restrictions. This is why special planning and coordination procedures are required to solve decentralized models. Many of these procedures are based on decomposition methods and operate in an iterative manner by exchanging information between the decision levels in a series of planning cycles. In most of these procedures, central management directs divisional decisions towards appropriate activities by means of prices or budgets for scarce resources and transfers, or some combination of prices and budgets (see for example Reimers, 1985, or Burton and Obel, 1984, for an overview). In general, the solution that is derived with a planning and coordination procedure is not as good as the solution to the overall organizational problem and the difference can be seen as the cost of decentralization (cf. Rietveld, 1980).

Most planning procedures found in the literature are based on decomposition methods and assume *holistic single-goal models* in which the overall organizational problem is modelled as a linear program with a single objective function. Divisional decision makers in fact only supply central management with information about possible activities and implement the latter's decisions, so that there is no genuine decentralized decision making. Practical applications of these procedures to resource allocation in decentralized firms were made in the seventies (see Burton and Obel, 1984, or Dirickx and Jennergren, 1979, for extensive overviews). In the area of decentralized financial planning, Maier and Vander Weide, (1976) and Carleton et al., (1974) presented decomposition-based procedures to allocate scarce financial funds over various investment projects in divisionalized firms. Freeland and Baker, (1975) and Ruefli (1971) developed planning procedures for *compromise single-goal models*, which were based on decomposition methods applied to goal programming. Rietveld (1980) describes an interactive planning procedure that is budget-directive for a *holistic multiple goal model*, with an application in regional economic planning. For the same model category, an interactive planning procedure that employs both prices and budgets can be found in Goedhart (1994). Very few planning procedures exist for the most complex category of models: the *compromise multiple goal models*, in which each division k $(k = 1, \dots, K)$ and the central decision maker have several goal variables d_k and z. Sometimes the multiple goal problem is translated in a goal programming format, so that in the end a single objective function per decision level results (see Ruefli, 1971, or Freeland and Baker, 1975). But this approach requires that the decision maker explicitly formulates his preferences a-priori and that these can be appropriately described in a goal programming format. As this may not always be possible in practice, it is more realistic to model decision problems at all levels as genuine multiple-goal problems. This complies better with the notion that managers at all levels are confronted with a complex of goal variables and have only implicit knowledge of their preferences over these variables (Spronk, 1985). Haimes et al. (1990) developed interactive solution methods for non-linear models with multiple levels and multiple goals, which are numerically intensive and require a high number of information exchanges between the decision levels. Therefore, they are not very suitable as blueprints for planning procedures. Reimers (1985) presented a heuristic budget-directive planning procedure based on an interactive multiple-goal solution method, STEM. His procedure differs from the one proposed by us in Section 4 in that it does not explicitly seek to attain a compromise solution that is organizationally efficient.

Based on viewpoints on decentralization from economic and organizational theory, we formulate a list of minimum requirements for decentralized planning procedures. The requirements roughly correspond to those suggested by Schmidt and Leichtfuß (1986), Burton and Obel (1978) and Sweeney et al. (1978) and concern both technical and behavioural properties. A lot of attention has been given in the literature to *technical* properties, such as goal achievement and convergence. Goal achievement concerns whether the derived solution is feasible for the entire organization and how close it is to the overall optimal solution or, in case of multiple goal models, to a non-dominated solution. Convergence properties regard the number of planning cycles that is required to arrive at the derived solution and the feasibility or near-optimality of the intermediate solutions generated in the planning cycles prior to termination (see Burton and Obel, 1978, for details). In our opinion, technical properties play an important but not exclusive part in assessing the quality of decentralized planning procedures. Also *behavioural* properties, such as a procedure's complexity and motivational effects are important because these are crucial for the acceptance of the procedure by its future users. The complexity of the procedure concerns its ease of use, as measured by for example the amount of information required from the decision makers involved and the difficulty of providing that information. Motivational effects refer to what extent a procedure can convince its future users that they are better off by using it.

Some important conclusions follow from economic and organizational theory for the design of useful and practicable procedures for decentralized planning. Theory provides us with the conditions under which decentralized organizations arise and thus implicitly with some caveats for procedural design. This leads to the following *technical* requirements. Because decision and information overload of central management is one of the main reasons for decentralization, planning procedures should not involve too many information exchanges between management levels. In general, price- and budget-directive planning procedures that are based decomposition methods converge to the optimal solution of the overall model in a finite, but possibly high number of planning cycles. In many cases, this number grows too large for practical purposes (cf. Burton and Obel, 1984, p. 13 and Atkins, 1974). Dynamic market conditions favour decentralized decision making but also imply that information is often uncertain and inaccurate. As a consequence, procedures should produce a satisfactory solution in a few planning cycles rather than a 'razor-edge' optimal solution in a large number of planning cycles. Furthermore, a procedure should generate intermediate solutions that are feasible so that the planning process can be truncated prior to optimality when management finds that the current solution is good enough. *Behavioural* requirements state that bounded rationality calls for planning procedures to be easy to comprehend for all decision makers involved, without requiring complex information. This implies that a procedure preferably should not ask decision makers to provide shadowprices for resources or marginal preference trade-offs, as in many decomposition-based procedures. Decision makers should not have to specify their preferences a-priori, as is the case in goal programming approaches. Furthermore, planning procedures should not undo the motivational effects from decentralization that arise from subordinates having decision making power and responsibility. A procedure should allow for some form of genuine decentralized decision making: divisional managers should have the opportunity to take account of local circumstances that are unknown to central management, but may be quite legitimate. Ideally, procedures should also leave little or no room for opportunistic behaviour of divisional managers by creating a good incentive structure (see Groves and Loeb, 1979, or Jennergren, 1980). Here, we abstract from such moral hazard problems.

3. Planning with an interactive heuristic

Following the requirements stated above, a decentralized planning procedure should be based on an underlying compromise multiple goal model. An interactive budget-oriented planning procedure is proposed which operates in an iterative manner. It differs from decomposition-based approaches to decentralized planning in the following respects. The communication between decision levels is structured in terms of sets of alternatives in order to reduce the number of planning cycles required to produce a feasible solution to the overall problem. Multiple local goals are explicitly taken into consideration in the planning procedure, which aims at generating a close-to-efficient compromise solution.

Furthermore, the procedure is designed to handle multiple-goal problems at both decision levels interactively, without the decision-maker having to explicitly define his preference function a-priori. The basic model is of the compromise type with multiple goals, as shown in Fig. 1. In the interactive procedure only straightforward information is exchanged: decision makers do not have to formulate any shadowprices on resource transfers or marginal preference trade-offs. Central managements sets budgets and targets and divisional managers respond with activity proposals. In contrast to the multiple goal compromise planning procedure of Reimers (1985), the procedure explicitly seeks for a compromise solution that is close to Pareto-efficient with respect to central and divisional decision makers, i.e. organizationally efficient. Finally, the procedure contains some heuristic elements in the selection of divisional proposals. It operates in three successive phases: an initialization phase, a planning phase and a coordination phase (see Fig. 2).

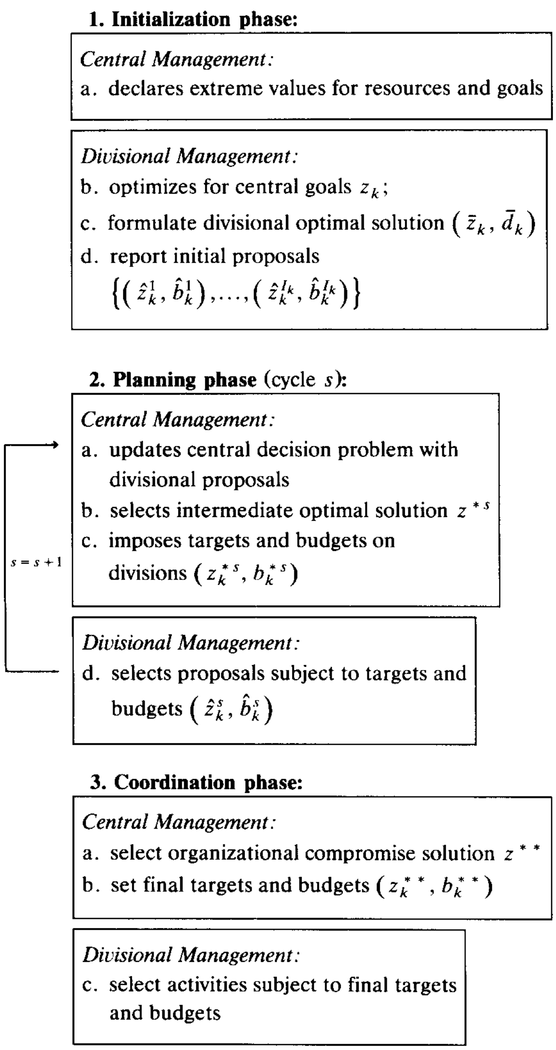

Fig. 2. Interactive planning procedure.

ad 1. *Initialization phase.* This phase helps the procedure to generate good intermediate solutions in the first few planning cycles by giving central management information on a wide range of divisional solutions. In the first cycle ($s = 1$), central management communicates information on the overall availability of resources and minimum requirements on goal contributions to the divisions. Each division subsequently formulates a series of initial proposals. This series contains the optimal solutions for the divisional decision problems for each central goal variable (1) and the solution $(\bar{z}_k, \bar{d}_k) \equiv (\hat{z}_k^{I_k}, \hat{d}_k^{I_k})$ that is most preferred by the division itself (2).

Thus, for each division k the following problems are solved:

$$\begin{aligned} &\text{Max} \quad C_{kj} x_k = z_{kj}, \quad \text{for } j = 1, \ldots, m \\ &\text{s.t.} \quad A_k x_k \le a_k. \end{aligned} \tag{1}$$

$$\begin{aligned} &\text{Max} \quad \left\{ \begin{matrix} C_k x_k = z_k \\ H_k x_k = d_k \end{matrix} \right\} \\ &\text{s.t.} \quad A_k x_k \le a_k. \end{aligned} \tag{2}$$

Problem (2) is solved by means of an interactive solution method for multiple goal models. In our planning procedure we propose Interactive Multiple Goal Programming (IMGP), although other methods such as for example STEM, might be used instead (see Spronk, 1985, and Stewart, 1992, for an overview). By also solving problem (2), the proposals reflect not only divisional opportunities for the realization for central goals but also divisional preferences over the proposals. Thus, a series of initial proposals is obtained, each stating the divisional contribution to central goal variables and associated levels of resources used:

$$\left\{\left(\hat{z}_k^1, \hat{b}_k^1\right), \dots, \left(\hat{z}_k^{I_k}, \hat{b}_k^{I_k}\right)\right\}$$

with

$$\hat{z}_k^i = C_k \hat{x}_k, \qquad \hat{b}_k^i = B_k \hat{x}_k \quad \text{for } i = 1, \dots, I_k.$$

ad 2. *Planning phase.* During the planning phase additional information on divisional opportunities is reported to central management on the basis of centrally administered targets and budgets. By taking strictly convex combinations of the divisional proposals $(\hat{z}_k^i, \hat{b}_k^i)$, central management constructs an inner approximation of the divisional opportunities in terms of resource usage and goal contribution.

This leads to the following central decision problem:

$$\begin{aligned}
\text{Max} \quad & z = \sum_{k=1}^{K} \sum_{i=1}^{I_k} y_k^i \hat{z}_k^i \\
\text{s.t.} \quad & \sum_{k=1}^{K} \sum_{i=1}^{I_k} y_k^i \hat{b}_k^i \le b \\
& \sum_{i=1}^{I_k} y_k^i = 1 \quad \text{for } k = 1, \dots, K, \\
& y_k^i \ge 0 \quad \text{for all } k, i,
\end{aligned}$$

where
I_k: Number of proposals received from division k in the current planning cycle s and all previous cycles ($I_k = m + 1$ in first planning cycle).

Central management solves this multiple goal problem for the centrally most preferred solution $z^{*s} = Cx^{*s}$ with IMGP (see Section 4 for details). The intermediate solution z^{*s} is an underestimation of the truly attainable solution because it is selected from an inner approximation of the overall model. If central management is not yet satisfied with intermediate solution z^{*s}, targets for goal contributions and budgets for resources, (z_k^{*s}, b_k^{*s}), are derived as directions for each of the divisions:

$$\left\{\left(z_1^{*s}, b_1^{*s}\right), \dots, \left(z_K^{*s}, b_K^{*s}\right)\right\}$$

with

$$z_k^{*s} = C_k x_k^{*s}, \qquad b_1^{*s} = B_k x_k^{*s}.$$

The targets and budgets are imposed on the divisions and represent the most preferred divisional plan from the viewpoint of central management, given the currently available information. In the planning phase, the divisions gather information on their opportunities in the neighbourhood of the central targets and budgets. In the same way as in the initialization phase, each division makes a series of proposals. But now the proposals are selected subject to the targets and budgets, within some pre-specified tolerance range of $\delta\%$ so that the following restrictions are added to models (1)–(2) above:

$$C_k x_k \ge (1 - \delta) z_k^*,$$

$$B_k x_k \le (1 + \delta) b_k^*.$$

In each planning cycle s, such a series of proposals is reported to the central level, so that more and more column vectors $(\hat{z}_k^i, \hat{b}_k^i)$ are added to the central program above, thereby gradually improving central management's approximation of the feasible set.

ad 3. *Coordination phase.* When at some stage in the planning process, central management is satisfied with the current intermediate solution z^*, the procedure enters the coordination phase. This solution z^* does not yet explicitly take account of the quality of the solution for the divisions. But from the initial proposal $(\bar{z}_k, \bar{b}_k)$ to problem (2) in the initialization phase, central management knows what budget and target allocation corresponds to the divisional optimum solution for each of the divisions. Central management now chooses a final organizational compromise solution from the following problem:

$$\begin{aligned}
\text{Max} \quad & z = \sum_{k=1}^{K} \sum_{i=1}^{I_k} y_k^i \hat{z}_k^i \\
\text{Min} \quad & e_k \quad \text{for } k = 1, \dots, K
\end{aligned} \tag{3}$$

$$\text{s.t.} \quad \sum_{k=1}^{K} \sum_{i=1}^{I_k} y_k^i \hat{b}_k^i \le b,$$

$$e_k \ge \left| \frac{\sum_{i=1}^{I_k} y_k^i \hat{z}_{kj}^i - \bar{z}_{kj}}{\bar{z}_{kj}} \right|$$

$$\text{for } j = 1, \dots, m \text{ and for } k = 1, \dots, K,$$

$$e_k \ge \left| \frac{\sum_{i=1}^{I_k} y_k^i \hat{b}_{kj}^i - \bar{b}_{kj}}{\bar{b}_{kj}} \right|$$

$$\text{for } j = 1, \dots, p \text{ and for } k = 1, \dots, K,$$

$$\sum_{i=1}^{I_k} y_k^i = 1 \quad \text{for } k = 1, \dots, K,$$

$$y_k^i \ge 0 \quad \text{for all } k, i.$$

Thus, a compromise solution z^{**} is selected with associated final targets and budgets (z_k^{**}, b_k^{**}), which also takes account of the solutions that are preferred by the divisions. The new goal variables e_k are minimax distance measures [2] that reflect the extent to which each division k can realize its most preferred proposal $(\bar{z}_k, \bar{b}_k)$ when confronted with the final targets and budgets (z_k^{**}, b_k^{**}). In this kind of implicit hierarchical bargaining, central management determines the appropriate balance between divisional goal realization and central goal realization (cf. Schneeweiß, 1995). Central management has gathered information on what is achievable in terms of its own goals in the planning phase and determines an organizational compromise solution in the coordination phase, while taking account of divisional preferences. Alternatively, an explicit bargaining process among all central and divisional managers could be executed to collectively select a compromise solution (for example Schneeweiß, 1992, Chapter 5; see Franz et al., 1992, for an overview of multiple goal group decision making). The final targets and budgets are imposed upon the divisions in the implementation stage, during which each division selects its most preferred solution subject to the final targets and budgets.

Because the divisional opportunity sets are underestimated in problem (3) relative to the true overall decision problem in Fig. 1, the resulting compromise solution z^{**} is not always exactly organizationally efficient. How close z^{**} is to an organizationally efficient solution, depends on the quality of the central approximation of the divisional opportunity sets (see Section 4).

4. An illustration in financial planning

Below we demonstrate the application of the interactive planning procedure to a financial planning problem in a divisionalized firm with two management levels. Central management is responsible for the overall business portfolio and financing policy and divisional management decides on more operational issues. At both levels multiple goals are pursued: central management wants to maximize the firm's market value to its shareholders and to optimize its risk profile. Under conditions of perfect financial markets only shareholder value is a relevant company goal, but market imperfections can lead to the additional goal of controlling the firm's risk profile (cf. Shapiro and Titman, 1986). The risk profile is an indication of the chances of financial distress and is described in this example in terms of the average debt level and the sensitivities [3] of shareholder value to changes in two risk factors: market demand and the currency rate. The central decision problem is to find the combination of investment and financing decisions over a 5-year planning period that leads to the best result in terms of shareholder value and risk profile. As explained in the introduction to this paper, the existence of these multiple goals in the firm implies that divisional contributions to central goals have to be carefully balanced. Furthermore, divisional dependencies that arise from the common use of scarce resources call for central coordina-

[2] In the proposed procedure other measures to reflect 'divisional desirability' of a solution could be used instead, such as for example some average distance measure.

[3] A sensitivity S^j is defined as $S^j \equiv \Delta V / \Delta F^j$. It states how much the shareholder value V changes for a unit change in a specific risk factor F^j – such as for example the currency rate – and it may be positive, negative or zero.

tion. This is modelled in the financial 'sources–uses' equations (8) below.

$$\text{Max} \quad V = \sum_{k=1}^{2} \text{PV}_k + \sum_{t=1}^{5} \left\{ D_t \frac{r_d T}{(1+r_d)^t} + C_t \frac{r_c(1-T) - r_d}{(1+r_d)^t} \right\} \tag{4}$$

$$\text{Min} \quad \bar{S}^1 = |S^1| \tag{5}$$

$$\text{Min} \quad \bar{S}^2 = |S^2| \tag{6}$$

$$\text{Min} \quad \bar{D} = \frac{1}{5} \sum_{t=1}^{5} D_t \tag{7}$$

$$\text{s.t.} \quad \sum_{k=1}^{2} \text{CF}_k^t + D_t - (1+r_d) D_{t-1} - C_t + (1+r_c) C_{t-1} = 0, \tag{8}$$

$$C_t \geq r_d D_t \quad \text{for } t = 1,\dots,5, \tag{9}$$

$$S^j = \sum_{k=1}^{2} S_k^j \quad \text{for } j = 1,\dots,2, \tag{10}$$

where:

- V: Firm's shareholder value.
- PV_k: Present value contributed by division k.
- D_t: Amount of debt financing in period t.
- r_d: Cost of debt financing.
- C_t: Investment in liquid assets in period t.
- r_c: Rate of return on liquid assets, $r_c < r_d$.
- T: Corporate tax rate.
- $\bar{S}^j$: Unsigned value of the firm's overall sensitivity for changes in risk factor j.
- $\bar{D}$: Firm's average debt level.
- S_k^j: Sensitivity of division k's present value for changes in risk factor j.
- CF_k^t: Cash flow generated by division k in year t.

According to the concept of adjusted present value, the shareholder value of the firm equals the present value of its real assets plus the value of its debt financing, which is positive because of tax savings, plus the value of its liquid assets, which is negative (see for example Brealey and Myers, 1991, Chapter 19). This is stated in the first goal variable V, in (4). The unsigned value of both factor sensitivities S^1, S^2 is to be minimized because exposure to positive as well as negative changes in the risk factors is considered to be relevant and is modelled in Eqs. (5)–(6) and (10). The average debt level $\bar{D}$ over the next five years, which serves as a proxy for the firm's insolvency risk, is to be minimized (7). Furthermore, the firm's liquid assets should at least cover the interest payable on debt financing in each year (9). In solving this model, central management essentially faces two problems. First, it does not know which combinations of (PV_k, S_k^1, S_k^2, $\text{CF}_k^1,\dots,\text{CF}_k^5$) are feasible for each division because of a lack of information on local, division-specific restrictions. This means that central management can not decide on the assignment of divisional targets and budgets that lead to the centrally most preferred solution. Another difficulty is that central management does not know which of these combinations are preferred by divisional management and that it therefore can not decide on a suitable organizational compromise solution.

Divisional management has two goals. It tries to maximize the net present value PV_k of its investments and thereby directly contributes to the first central goal. But it also pursues a purely divisional goal, namely to maximize the employment level within the division EMP_k. This can give rise to some conflict with the central goals. The divisional decision models for $k = 1,\dots,2$ are as follows:

$$\text{Max} \quad \text{PV}_k = \sum_{i=1}^{N_k} x_{ki} \text{PV}_{ki} \tag{11}$$

$$\text{Max} \quad \text{EMP}_k = \sum_{i=1}^{N_k} x_{ki} \text{EMP}_{ki} \tag{12}$$

$$\text{s.t.} \quad \text{CF}_k^t = \sum_{i=1}^{N_k} x_{ki} \text{CF}_{ki}^t \quad \text{for } t = 1,\dots,5, \tag{13}$$

$$S_k^j = \sum_{i=1}^{N_k} x_{ki} S_{ki}^j \quad \text{for } i = 1,\dots,2, \tag{14}$$

$$\sum_{i=1}^{N_k} A_{ki} x_{ki} \leq a_k, \tag{15}$$

where:

- x_{ki}: Decision variable for investment in project i in division k: $0 \leq x_{ki} \leq 1$.

Table 1
Initial proposals for division 1

Proposal	$\hat{PV}_{1i}$	$\hat{S}^1_{1i}$	$\hat{S}^2_{1i}$	$\hat{CF}^1_{1i}$	$\hat{CF}^2_{1i}$	$\hat{CF}^3_{1i}$	$\hat{CF}^4_{1i}$	$\hat{CF}^5_{1i}$	$\hat{e}_{1i}$
$i=1$	261.6	−96.2	16.8	−157.1	142.9	−78.8	69.7	71.4	0.87
$i=2$	294.4	−72.9	17.9	−169.7	125.9	−296.2	141.8	239.7	0.99
$i=3$	30.4	25.3	7.8	−21.0	3.7	−186.8	80.0	174.1	0.34
$i=4$	214.8	−35.8	0.1	−158.3	116.7	−309.8	244.5	89.1	0.75
$i=5$	177.4	−59.2	30.6	−48.1	−12.8	55.9	38.4	223.3	0.70
$i=6$	291.2	66.9	16.9	−172.2	113.2	−289.8	133.4	258.8	1.00

PV_{ki}: Present value of investment project i in division k.
EMP_{ki}: Incremental employment for investment project i in division k.
CF^t_{ki}: Cash flow generated by investment project i in division k in year t.
S^i_{ki}: Sensitivity of the value of project k for changes in risk factor j.
A_{ki}: Subvector $(r_k \times 1)$ of matrix A_k, containing technological coefficients for investment project x_{ki} in division k.
a_k: Vector $(1 \times r_k)$ for divisional resources and technological restrictions.

The equations in (15) represent local restrictions on the choice of investment projects x_{ki} that are specific to each division ($i = 1,\dots,N_k$).

In directing the divisions towards appropriate investments, central management can impose budgets for annual cash flows and targets for contributions to central goals, which restrict the divisional model in (11)–(15) above:

$$PV_K \ge PV_k^*, \tag{16}$$

$$S_k^j \le S_k^{j*} \quad \text{for } j = 1,\dots,2, \tag{17}$$

$$CF_k^t \ge CF_k^{t*} \quad \text{for } t = 1,\dots,5. \tag{18}$$

Central management has to set these targets and budgets in such a way that a compromise solution for the firm's investment and financing problem results that provides satisfactory values for shareholder value and the risk profile and at the same time gives divisions sufficient opportunity to realize their own goals. How this can be achieved with the interactive planning procedure is discussed in the remainder of the section.

The *initialization phase* starts with central management imposing some absolute minimum requirements on the divisions that have to be complied with in any case. Subject to these bounds on the sensitivities for factor risk allowed, minimal present value and cash flow requirements, the divisions formulate a set of initial proposals. The set contains the solutions

$$\left\{\hat{PV}_{ki},\ \hat{S}^1_{ki},\ \hat{S}^2_{ki},\ \hat{CF}^1_{ki},\dots,\hat{CF}^5_{ki},\ \hat{e}_{ki}\right\}$$

(for $i = 1,\dots,5$) that result when independently optimizing the contributions to central goals, i.e. the present value PV_k and both factor sensitivities S_k^1, S_k^2. The sensitivities are maximized as well as minimized because at the outset it is not clear whether a division should have positive or negative sensitivities. In this example, divisional managers also assign a solution quality index $\hat{e}^i_k$ to each proposal, reflecting its proximity to the divisionally most preferred plan, for which $\hat{e}_k^{I_k} = 1$ ($I_k = m + 1$): [4]

$$\hat{e}^i_k = \frac{P_k(\hat{z}^i_k, \hat{d}^i_k)}{P_k(\bar{z}_k, \bar{d}_k)} \quad \text{for } i = 1,\dots,I_k.$$

Table 2
Potency matrix in planning cycle 2

	V	$\bar{S}^1$	$\bar{S}^2$	$\bar{D}$
Ideal values	398.6	0	0	58.5
Required values	198.5	−164.7	40.8	106.7

[4] This particular implementation of the framework for the interactive procedure requires that the – implicitly known – divisional preference functions $P_k(\cdot)$ are linear. In case of less stringent assumptions on these preference functions, the more general approach as depicted in Section 3 can always be employed.

Table 3
Targets and budgets in cycle 2

Division	PV_k^*	S_k^{1*}	S_k^{2*}	CF_k^{1*}	CF_k^{2*}	CF_k^{3*}	CF_k^{4*}	CF_k^{5*}
$k=1$	254.9	−93.3	17.9	−148.4	130.5	−68	61.1	83.5
$k=2$	20.9	49.2	2.8	−17.4	2.7	−1.9	−26.5	54.3

In this way, the proposals reflect not only divisional opportunities for the realization of central goals but also divisional preferences over the proposals. Furthermore, a division solves its own multiple goal problem for the most preferred solution from its own point of view, i.e. including its employment goal by means of IMGP. [5] This implies that each division reports six proposals to central management. For division 1 these are presented in Table 1, where proposal $i=6$ is the division's most preferred solution with an employment level of $EMP_1 = 112$.

In the *planning phase*, central management updates its information by adding the proposals made by each division k to the central decision model from (4)–(10):

$$PV_k = \sum_{i=1}^{I_k} y_{ki} PV_{ki},$$

$$S_k^j = \sum_{i=1}^{I_k} y_{ki} \hat{S}_{ki}^j,$$

$$CF_k^t = \sum_{i=1}^{I_k} y_{ki} \hat{CF}_{ki}^t,$$

with

$$\sum_{i=1}^{I_k} y_{ki} = 1.$$

The updated model is solved by means of IMGP for the most preferred solution, given the currently available information (I_k is the total number of proposals received from division k). In IMGP, a multiple goal decision problem is summarized in a potency matrix as in Table 2. This

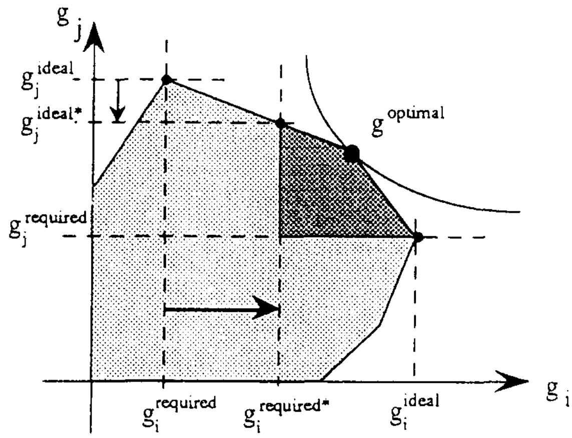

Fig. 3. Increasing the required goal value.

matrix shows for each goal variable the so-called ideal value and the required value. The ideal value is the best attainable value for some goal variable when it is optimized subject to the required values for all other goal variables. For each goal variable, the required values are interactively raised by the decision maker until they are equal to the ideal values for all goal variables or until the solution is good enough [6] (see Spronk, 1985, for more details).

The intermediate solution selected by central management in the second planning cycle is {286, − 44.1, 20.76, 90.7}.
This solution is not yet satisfactory for central management because of the substantial sensitivity for changes in market demand and therefore the

[5] In the example, all most preferred solutions and proposals were determined by assuming some preference functions $P_1(\cdot)$, $P_2(\cdot)$ and $P_0(\cdot)$ for divisional and central management.

[6] Essentially, a potency matrix is a summary of the feasible region in criterion space, restricted by the required goal values. In IMGP the required values are updated in such a way that the optimal solution lies in the restricted feasible set. Fig. 3 shows the effect of increasing the required goal value from $g_i^{required}$ to $g_i^{required*}$.

Table 4
Potency matrix in coordination phase

	V	$\bar{S}^1$	$\bar{S}^2$	$\bar{D}$	e_1	e_2
Ideal values	417.2	0	0	58.0	0.94	1.00
Required values	196.2	−159.4	42.5	114.9	0.66	0.49

procedure continues. From the intermediate solution follow the goal and sensitivity targets [7] and cash flow budgets for both divisions (see Table 3). Subject to these targets and budgets plus or minus a deviation δ of 10%, each division formulates a new set of proposals and reports these to central management.

In the third cycle, central management again updates its inner approximation of divisional opportunities with the new proposals and, just as in the previous cycle, selects an intermediate solution with IMGP:
$\{260, -14.9, 17.8, 96\}$
(see Table 6, second row). This solution is considered satisfactory by central management so that the planning phase ends.

$$\text{Max } e_k = \sum_{i=1}^{I_k} y_k^i \hat{e}_k^i \quad \text{for } k = 1, \ldots, K. \tag{19}$$

In the *coordination phase* central management tries to determine a suitable organizational compromise solution that takes account of divisional preferences without giving in too much on the quality of the central goal values. Now, the divisional solution quality indexes e_1 and e_2 from Eq. (19) are included as goal variables in the central decision problem stated earlier in Eq. (3). Starting from the potency matrix in Table 4, the final compromise solution is chosen with associated final targets and budgets for divisional present value, factor sensitivities and cash flows. These are all summarized in Table 5; the value of (e_1, e_2) in this solution is (0.70, 0.73).

[7] Because the unsigned value for each sensitivity is minimized, it is not clear in advance whether the divisional targets should be $S_k^i \geq S_k^{i*}$ or $S_k^i \leq S_k^{i*}$. In each cycle this depends on the sign of $\bar{S}^j$: in cycle 2 the targets are therefore formulated as $S_k^1 \geq S_k^{1*}$ and $S_k^2 \leq S_k^{2*}$.

Table 6
Successive intermediate solutions

Cycle	P_0	V	$\bar{S}^1$	$\bar{S}^2$	$\bar{D}$	e_1	e_2
2	*142*	286	−44.1	20.76	90.7	0.58	0.86
3	*160*	260	−14.9	17.8	96.0	0.58	0.72
Final	*148*	266	−25.1	18.3	97.3	0.70	0.73

Table 6 contains all intermediate solutions during the planning cycles, including the values of the -implicit-central preference function P_0 and (e_1, e_2). It shows how the planning phase serves to secure a satisfactory central solution and that in the coordination phase the central manager gives in somewhat to the realization of divisional goals.

Of course, it is interesting to measure how close the final compromise solution comes to a solution that is Pareto-optimal with respect to all decision makers. Following Bogetoft et al. (1994), we measured this in the following way:

$$\begin{aligned} &\text{Max} \quad g \\ &\text{s.t.} \quad P_0(x) \geq g P_0^{**}, \\ &\qquad P_k(x) \geq g P_k^{**} \quad \text{for } k = 1,2, \\ &\qquad x \in F, \quad g > 0, \end{aligned}$$

where:
$P_0(\cdot)$, $P_k(\cdot)$: Central, divisional preference function; P_0^{**}, P_k^{**} are the values corresponding to the final compromise solution z^{**} from Table 6.

Table 5
Final compromise solution

Unit	PV_i/NV	S^1	S^2	$\bar{D}$	EMP	CF_1	CF_2	CF_3	CF_4	CF_5
Division 1	26.7	39.0	3.3	–	113	−18.9	1.3	−0.5	−24.8	54.1
Division 2	227.4	−64.1	15.0	–	69	−143.2	112.4	−69.8	80.1	0.7
Overall	265.5	−25.1	18.3	97.3	182	−162.1	113.7	−70.3	55.3	54.8

x: Vector of all instrument variables in overall decision model.

F: Feasible set in overall decision model.

For this particular example, the maximum for g is 1.02, which means that the compromise solution arrived at could be improved by 2% for each preference function if all information would be centrally available. Because of the fact that each division reports a set of proposals in each planning cycle that cover a wide range of possible outcomes, the approximation of divisional opportunities is in this example quite reasonable, after only three cycles.

5. Evaluation

This paper presents a framework for an interactive procedure to solve decentralized decision problems with multiple goals and multiple decision makers for a compromise solution that aims to be close to Pareto-optimal. It uses straightforward concepts in transmitting relevant information on divisional opportunities in a compact way to central management. Solving the individual decision problems at the various management levels does not require complex information from the decision makers because of the interactive multiple goal programming method used. Also the formulation of divisional proposals that are contingent on resource budgets and performance targets as set by central management to direct divisional activities is straightforward and corresponds to management practice in large organizations (cf. Goedhart, 1994). Furthermore, the procedure generates an organizational compromise solution within a few planning cycles because relevant information on divisional opportunities is transmitted in a set of proposals per division. Because the divisional proposals and central budgets/targets are heuristically generated, it is difficult to formally assess the interactive procedure's technical properties such as for example the Pareto-optimality of the resulting compromise solution. Of course, no proof follows from a single example such as the one above, in which the compromise solution is indeed close to Pareto-optimal. The quality of the compromise solution strongly depends on the quality of the approximation of divisional opportunities that is generated by the procedure at the central decision level. From numerical experience with the procedure it seems that this approximation of divisional opportunities is quite reasonable within very few iterations (Goedhart and Spronk, 1994). Nevertheless, more research is required on this and other technical issues. Interesting extensions within the proposed framework can be made by also using shadowprices on goal targets and resource budgets, as shown in Goedhart, 1994.

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