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MODEL DEVELOPMENT FOR MULTI-FACTOR BASED FINANCIAL PLANNING An Integration of Strategic Concepts

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MODELES D'AIDE A LA DECISION EN PRESENCE D'INCERTITUDE ET DE
CRITERES MULTIPLES POUR LA PLANIFICATION FINANCIERE

RESUME

Dans ce cahier, nous décrivons une méthodologie pour le développement et la recherche expérimentale de systèmes d'aide à la décision pour la planification financière dans des entreprises. Nous avons développé un modèle hiérarchique de planification financière dans lequel l'analyse multicritère, l'évaluation des options et une représentation multi-facteur pour exposition des activités de l'entreprise à des changements dans des facteurs externes et internes sont intégrés. Les problèmes de coordination dans des environnements caractérisés par de l'information incomplète et de l'information asymétrique sont étudiés. Des parts du modèles peuvent être utilisées sur des centres de décision et contrôlées à un niveau central. Des expérimentations sont proposées dans lesquelles le processus de planification et l'utilisation d'information peuvent être étudiés.

Mots-clés : Aide à la Décision, Distribution des Ressources, Planification Financière, Comportement de Décision, Expérimentation.

MODEL DEVELOPMENT FOR MULTI-FACTOR BASED FINANCIAL PLANNING

ABSTRACT

In this paper, a methodology for experimental design and investigation of financial decision support systems for business firms is described. A financial planning model is designed in which multiple objectives, optional decisions and a multiple factor representation for the firms' exposure to unexpected changes in external and internal factors are integrated. The problem of timing and coordination of decisions in environments characterized by incomplete information is emphasized. The resulting model is considered as the basis for a decentralized support system. Investigation in laboratory environments of impacts of alternative man-computer task structures in relation to decision processes may result in improved procedures to be used in decision support.

Keywords : Decision Support, Resource Allocation, Financial Planning, Decision Behavior, Experiments.

1. Introduction

In designing support systems for financial management, it is of interest to understand how financial management decisions in business firms are made. This includes interrelating processes such as (mis-)use of information, judgment, control and decision or choice. The firms' decision system deals with decisions to be taken in external markets (capital market, resources markets), but also considers long term strategy. The decision system itself is organized partly by internal (imperfect) markets, partly by means of procedures. An example which we shall investigate further is the process of resource and capital allocation among several business units in the firm. Support systems for this problem should contain sound theoretical concepts. Financial theory may result in useful concepts (such as risk, value, arbitrage, option) to be employed in support systems, but application of these concepts is guided by situational requirements such as information available, computational complexity, organizational procedures and the negotiation character of many decision situations. These aspects are undervalued in finance theory, which is mainly devoted to decisions in efficient (capital) markets. However, the design of theory through the stadia of testing of these concepts in new situations, experience in practice resulting in observations, and formation of concepts is a process that is of direct practical importance, and may result in interesting concepts as well as in principles for procedures and support systems to be used by financial managers. This paper is mainly directed to the step of integration of concepts in a framework for financial planning.

In this paper, a methodology is described to be used in investigation of financial decision processes and in designing and evaluation of computer-aided procedures for support of these decisions. A model of the firm is designed, on basis of abstract concepts (exposure, risk, options, arbitrage), and this model defines the support system to be used by the firm. This support system is combined with a task structure which allows communication between decision units within the firm which are supported by parts of the model. The approach is to be used in a gaming environment with a simulator software system which is currently in development. In presenting the approach, we concentrate on a simple systems model of a firm which consists of three levels: a strategy

level, a level for demand for resources and allocation of resources to business units as well as efficient supply of resources through markets, and as a third level the utilization of resources for investment projects by the collection of business units. The model formulation which will be presented in section 4 formalizes some actual developments in corporate strategy and is directed to financial and resources policy. It applies also a multi-factor approach for optimal exposure of the firms activities to risk, which is expressed as sensitivities of business results for unexpected variations in systematic factors. The function of the model, which also forms the basis for the simulator system, is to define the context of the paper more clearly and to present a starting point for further model development. An interesting direction of research is the formulation of rule-based models for sub-units which are coordinated by a central level. We therefore should weaken assumptions with respect to complete information as common in hierarchical optimization models, and we shall pay attention to the structure of 'loose coupled' models to be employed by lower decision levels. In constructing such models, it can be shown how, at least theoretically, the financial management system may improve.

Emphasis in developing the approach is on dynamic financial decision situations with strategic interaction among decision levels. Emphasis is also on process (the sequence and type of actions) rather than on outcome. Bottlenecks in financial decision making can be understood more clearly and this may provide a basis for more effective decision support. Also, advice from normative theories can be compared with actual decision behavior and possibly supplemented by decision and coordination rules.

The problem area is financial strategy and capital investment in business firms. In this context, financial management decisions are undertaken at multiple decision centres by decision makers having multiple objectives (often corresponding to claimholders' wishes), various and different information sources to be used in decision support systems, in an environment creating new information (events), new decision problems and new project opportunities, and disciplining management decisions through the capital market. Computational complexity gives rise to decision rules. Decisions are planned and implemented in a set

of procedures which allow delegation and coordination among decision levels. In this structure, financial managers select and transfer information (often in the form of constraints for other decision levels), adapt their and others' decision rules, select and implement plans and so on. In doing so, managers use support systems (forecasting and decision models, data, decision rules, manuals). Thus, object of study is a network of man-computer relations. Of concern is the representation and control of agency-situations, to be considered as instances of (potentially) degenerating learning systems.

The paper is organized as follows. In section 2, the approach is explained. Then, in section 3, we introduce some concepts (multi-factor representation, optional decisions, multiple objectives) to be used in financial models. Section 4 we present a simple model formulation. We conclude with a discussion of experiments to be organized with the approach in section 5.

2. Background and Methodology

2.1 A financial planning experiment

A financial planning game was constructed where a firm was represented at two levels: a (financial) central level and an operational divisional level consisting of two divisions. Each of these three decision units consisted of two players who interacted with a computer program (Lotus spreadsheet on microcomputer) representing their specific decision and planning problem (See Fig 1). Objectives and decision variables of the central and divisional level were different. At the beginning of the game, specific information and data were presented to the three groups, along with a problem description and specific objectives for the group. Information thus was distributed asymmetrically over decision units. New information (for instance sales results) as well as performance resulting from implemented decisions was introduced specific for decision units during the game. Thus the tasks of the the three groups consisted in solving their own planning problem and negotiation and communication with other decision units. Players recorded their actions in written accounts and also the evolution of the game was

observed by independent observers. We will now present some observations on strategic interactions which resulted from the game.

It could be observed that information was communicated by divisions to the central level in a distorted manner in order to create short-term divisional profits. This was especially the case while the central level did not control the results of divisions. Also, this was stimulated by difference in objectives of central level and divisions. There were, at least informal, instruments for the central level to control results of divisions but these instruments were not used satisfactorily. The central level did not create clear norms for divisions, possibly because the importance of doing this was not clear. Thus, the central level had no clear insight in what was happening at the divisional level. This resulted in divisional goals to be seen as more important by divisional units than corporate goals which were left unclear by the central level.

The planning process that evolved was bottom-up (both top down and bottom up was possible in principle). The reason was possibly the information overload of the central level. Plans were accepted easily by the central level.

Divisional players tried to estimate relations for market share development in time on basis of historical results. Plans apparently were created in such a way to be insensitive for unexpected developments in market growth as well as resulting in highest profits.

Alternatives were generated by divisions in a 'satisficing' manner. There was no software available to produce a 'best' plan, but the Lotus system was used to design and adapt plans in a successive manner. In fact a 'best' plan is difficult to define because outcomes of plans are dependent on other units' actions. New information resulted in adaptation of divisional plans. This was also a reason of information overload of the central level.

From this one-shot case study, it becomes clear that the network of decision units in a firm, at least under the conditions as indicated, results in decision processes that easily may lead to inferior results (in terms of market value of the firm or other central objectives).

Therefore there is an interest in designing procedures and support systems that facilitate control by the central level as well as leaving flexibility as well as incentives to lower level decision units. In the remainder of this section we give an outline of a gaming methodology facilitating design and investigation of such support systems.

2.2 Interactive Decision Making in Games

An experimental game concept is explored here in which changes in the firm and its environment partly are kept under experimental control (modeled as exogenous input events and processes), partly under control of one or more decision makers participating in the game. A central aspect of a game is the task division between decision makers and computer. In the one extreme, these decision makers are modeled using a rule-based program; in this case a complete simulated decision process can be carried out. In the other extreme, the decision maker is allowed to continuously adapt the man-computer task division, on basis of information presented by the computer. In this case, analyses and decisions partly are delegated to the computer (automation). For example, when a business unit causes no problems, fixed decision rules at the central level are used for coordination; when problems are recognized, ad hoc analysis at the central level is necessary.

Within a specific man-computer task structure, several specific decision processes are of interest, for example (1) negotiations between financial strategy level and capital investment level; (2) anticipation and learning processes as found in some extent in financial agency and signalling theory (See Myers and Majluf [1984]). An important question is how alternative man-computer task structures constrain or facilitate these processes.

The constituting parts of each gaming situation are defined by several dimensions, among them (1) number and objectives of decision makers; (2) decision mechanism; (3) support system per decision level; (4) information differences among decision levels; (5) task division between decision makers and computer. Actual choice of a particular setting in an experiment depends on the experiments' objectives.

In order to explain these experimental objectives, some observations and speculations might be useful. (1) A firm operates through sets of decision rules. Decisions may be operating decisions (capital investments, timing, adjustment of decisions to forecasts) or strategic decisions (choice of constraints, and also 'decisions on decisions': choice and adaptation of rules). Firm decisions and firms' state might at least partially be explained by its decision structure: its set of rules. It is then useful to investigate whether decision support systems may enhance decision making in alternative settings. (2) The well-known agency problem within the firm, and between the firms' shareholders and management, has consequences for alternative modes of (financial) planning. From public and business policy studies it is known that adjusting policies to current forecasts is not always an optimal policy because of (among others) anticipation mechanisms. Rather, inflexible rules will have advantages. Even in static situations rules might be better than static trade-offs (See Myers [1984] in case of capital structure decision, using an anticipation under information asymmetry argument). A case is then under what conditions agency situations become destructive for learning capacity of the system, and how in dynamic environments financial decision support system might aid a financial manager in optimally adapting to new situations. (3) In real-world decision making, managers not only optimize and design, but also make mistakes and detect and recover from failures. Firms not only optimize, but also engage in insurance and stabilization actions, and corrections. These activities require different types of knowledge. A support system should contain facilities to store, use and adapt these different types of knowledge.

In Fig. 1, the abstract firm and its environment (markets, data-generation) is represented as a decision system with communication flows between decision units. All decision units use a support system (models, data, decision rules).

The over-all methodology consists of the following parts: (1) Development of financial models to be used in a support system (See section 4); (2) Development of a simulator representation of the firm and its environment; (3) Development of a process model in which decisions on decision-making are specified; (4) Creation of represen-

tative financial decision situations (examples: negotiation process, risk sharing process, agency situations) within the context of financial policy formation and implementation by the firm; (5) Use of decision support (decision rules, financial models, multi-factor models, data etc) in the gaming situation; (6) Evaluation of composite parts of the approach; (7) Application in practical settings. The next two sections will introduce concepts to be used in the financial models and will present a simple multi-level model formulation.

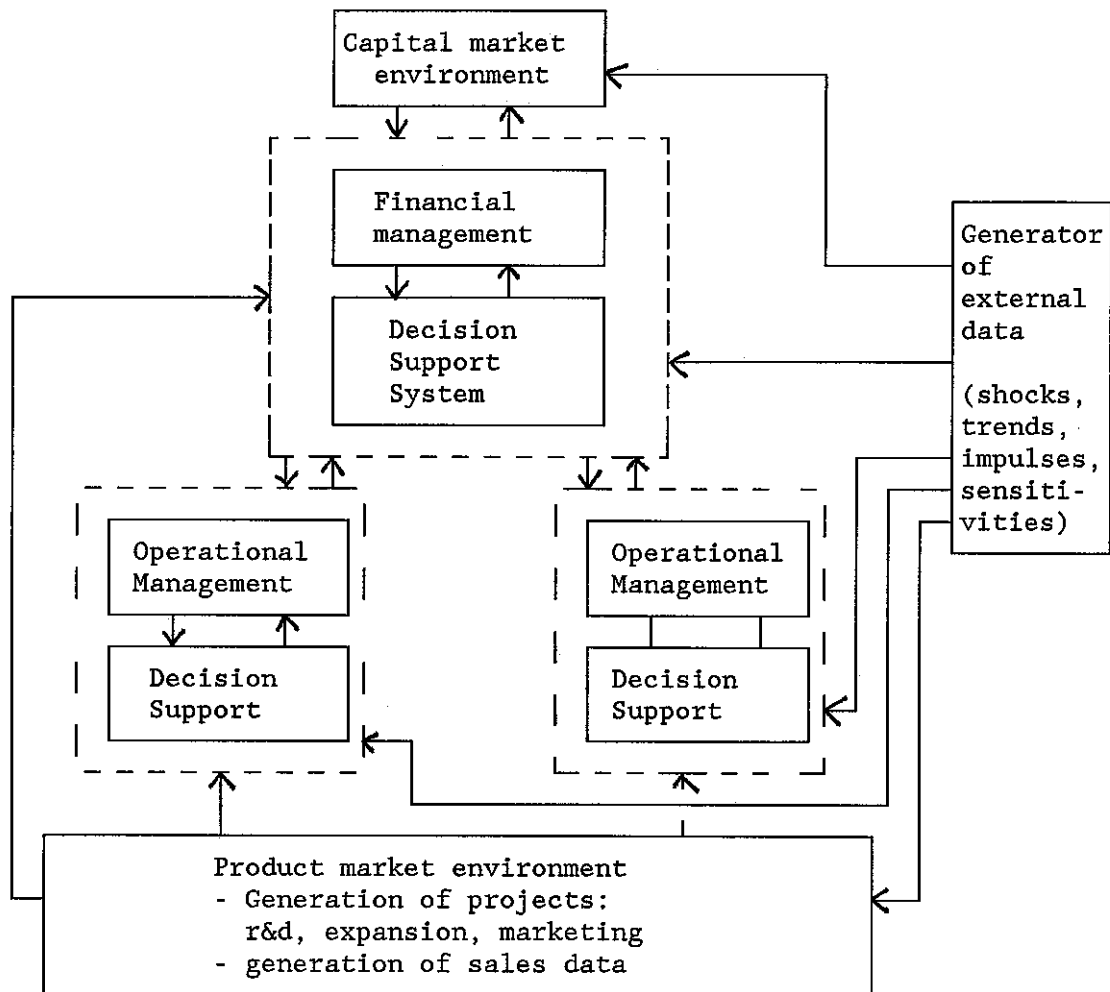


Fig. 1 Financial decision system representation

3. Multiple Objectives, Multi-Factor Representation and Optional Decisions in Financial Planning

3.1 Multiple Objectives in Financial Planning

In this paper we are not dealing with interactive procedures for multiple objective decision making (See a.o. Spronk [1985]). Rather we will show how a multi-factor approach for modelling uncertainty as well as the optional character of plans can be integrated in a multiobjective formulation. We start with assuming that the central level as well as the business levels contribute separately to attaining objectives represented by vector $g[\underline{x}^C, \{\underline{x}_i\}]$ where $\underline{x}^C$ denotes the vector of central decision variables and $\{\underline{x}_i\}$ denotes the set of vectors of decision variables in business i (for example, decisions on projects $l(i)$). Besides these common objectives, businesses i have their own objectives which are not precisely known to the central level. The value of the firm, which should be maximized, then is represented by $V(g)$, including impacts of real as well as financial decisions in plans. We will concentrate to a static formulation where investment decisions create a level stream of cash-flows.

3.2 Modeling Uncertainty Through Factor Sensitivities*)

A multi-factor approach to the modelling of uncertainty in cashflows can be integrated in an interactive financial planning model (For background, see Hallerbach and Spronk [1986], Goedhart, Schaffers and Spronk [1987]). Outcomes of financial plans are generally uncertain, due to unexpected changes in input data (for example, sales, inflation, interest rates, oil price, market developments). Modelling of uncertainties can be accomplished in several ways, in which we shall have to trade-off aspects like completeness, computability, and user-friendliness. Uncertain outcomes of planning alternatives often are modelled as probability distributions defined on the set of possible outcomes. Decision-makers are then required to assess parameters (mean and variance) of these distributions. In addition, decision-makers have to express their preferences (e.g. utility values) with respect to the

*) Parts of this section are adapted and revised from Goedhart, Schaffers and Spronk [1987].

uncertain outcomes. The information thus provided is then used in the formulation of an objective function (e.g. the expected utility of the decision alternatives). However, in situations with changing environments and incomplete information not all aspects of uncertainty can be modelled satisfactorily.

In the reality of corporate planning, uncertainties often are modeled implicitly in terms of sensitivities of cashflows for changes in multiple environmental conditions. Decisions are taken which result in acceptable sensitivities of the firms' plan for various environmental factors. For example, forms of operational hedging can be designed in which business activities are balanced with the firms' consumption of inputs. Also, diversification of business activities may result in less business risk. Therefore, the use of multi-factor models is proposed as a way of structuring aspects of uncertain situations. The results of a financial plan (for ease of exposition we take the firm's cash flow as the only relevant output variable) will depend on the one hand on the decisions made by the firm and on the other hand on the various forces and influences from its dynamic environment. We assume that it is very hard to define a probability distribution over the value of the resulting cash flows, but that the firm is able to define its expectations concerning these cash flows (for instance by using business planning models and/or expert opinion) and, in addition, that it is able to assess the sensitivity of these cash flows for unexpected changes in a number of factors which influence these cash flows.

The impact of a decision then can be modelled as an expected level of the cash flows plus a series of sensitivities of cashflows for unexpected changes in a number of factors influencing these cash flows. The firm does not necessarily know how these factors themselves will change in the future. Also, it may only have found some of the factors influencing its cash flows. Nevertheless, on basis of this way of modelling, a firm can estimate the firm's aggregate sensitivity (i.e. the sensitivity of all decisions combined) for the various factors it has found to be important. Furthermore, the firm may experiment with different scenarios with respect to future developments in factor values, to see what the effect on the firm's cash flows might be.

In using this approach, objectives which describe the financial plan's sensitivities for unexpected factor changes have to be added to the multiobjective formulation. Thus, when we have N 'normal' objectives and K factors, a general first-order approximation for the sensitivity objective function is:

$$g_{N+k}(\underline{x}^c, \{\underline{x}\}) = [\delta g_1 / \delta F_k; F_k = E(F_k)]$$

which denotes the sensitivity of objective g_1 (for example, total cashflow) for unexpected changes in factor F_k and is a function of decision variables (E denotes the expectation operator).

Implementation of this approach in a financial planning model is rather complicated. Factors influence firms' cashflows at several levels with different sensitivities. With regard to the risk generating factors that affect the company's cash flows, one can make the following classification :

- systematic (s) risk factors (F^s_j), j denoting the factor index;
- idiosyncratic risk factors, which can be subclassified in company (c) specific factors (F^c_f), unit (v) specific factors (F^v_w) and a random disturbance ϵ (f, w denoting factor indices).

Through application of this classification to the multi-factor model we obtain:

$$\begin{aligned} CF_{1(i)} = & E(CF_{1(i)}) + \sum_j \beta^s_{1(i)j} (F^s_j - E(F^s_j)) \\ & + \sum_f \beta^c_{1(i)f} (F^c_f - E(F^c_f)) + \sum_w \beta^v_{1(i)w} (F^v_w - E(F^v_w)) + \epsilon \end{aligned}$$

($CF_{1(i)}$: cash flow for project $1(i)$ in business i , $\beta^z_{1(i)k}$: sensitivity of cashflow $1(i)$ for factor $k \in \text{set } \{j, f, w\}$ of class $z \in \{s, c, v\}$; ϵ : random disturbance; E denotes the expectations operator).

As sources of the systematic risk represented by F^s_k , Chen, Roll and Ross [1986] suggested unexpected changes in growth of industrial production, in the inflation rate, in the long term real interest rate and in the risk premium in the stock market. These four factors are supposed to influence the returns of all securities. The company- and unit specific factors can be chosen in such a way that they are both

mutually independent and independent of the systematic risk factors, but this does not need to be necessary. A company specific factor could be e.g. the price of natural resources used, a unit specific risk factor could be the autonomous growth of its sales market. The distinction between the three kinds of risk is useful because of the diversification opportunities that arise at the different levels of aggregation of the cash flows.

To the financial market the only important risk is the systematic risk of the company in terms of its cash flows' sensitivities to the systematic factor movements. Thus, only for the sensitivities $\{\beta^s_k\}$ a risk premium on the stock market return is required. For central management, however, the company specific factors may form a substantial source of risk, as it lacks the diversification effects of a large well-chosen portfolio. The unit specific factors in turn are non-systematic for central management, because they tend to neutralize each other over the lower units' results for a sufficiently large number of lower decision units. Analogously, to the management of the lower businesses all three classes of risk generating factors are relevant.

In this way we obtain as objective functions, to be supplemented by other objectives, for the central level:

$$g_1(\mathbf{x}^c, \{\mathbf{x}_i\}) = g_1^c(\mathbf{x}^c) + \sum_i g_1^i(\mathbf{x}_i) = CF^c + \sum_i CF^i$$

$$g_{N+k} = g_{N+k}^c + \sum_i g_{N+k}^i = \beta_k^{cz} + \sum_i \beta_k^{iz} \quad \text{for factors } k$$

where: β_k^{cz} the contribution of the central level to the sensitivity of cashflow CF^c for systematic or firm specific factors z ; β_k^{iz} the contribution of business i to the sensitivity of cashflow CF^i for systematic or firm specific factors z . The firm sensitivities g_{1+k} are contingent on investment levels (modelled as specific resource) in central and business project activities $1, 1(i)$, through sensitivities of these activities to factors, β_{1k}^z and $b_{1(i)k}^z$.

As a supplementary goal variable the expected rate of return over investment, g_2 , is introduced as measured by :

$$g_2 = g_1(\underline{x}^c, \{\underline{x}_i\}) / [\sum_j r_j * p_j]; \quad \begin{array}{l} p_j: \text{price of resource } j; \\ r_j: \text{resource use} \end{array}$$

and the required rate of return deduced from the exposure of the firm's cash flow to the systematic factors, assuming arbitrage:

$$g_3 = r_f + [1/\sum_j r_j * p_j] \sum_k \beta^s_k \lambda_k ,$$

with λ_k representing the required risk premium for one unit of exposure to risk factor F^s_k (in the absence of a capital market g_3 might be assessed heuristically) and r_f the risk-free rate. Thus, the central management not only has to evaluate the exposure to risk factors but also corresponding expected rate of return and required rate of return. This formulation already indicates that the firm consists of a portfolio of businesses which is managed by investigation of (temporary) extra returns. This is in line with strategic management approaches where businesses are allowed to grow as long as returns are greater than required returns and should be divested when growth is substantially lower than required returns (See Hax and Majluf [1984]).

For the business management in unit i additional sensitivity objectives are:

$$g_{N(i)+k} = \sum_l(i) \beta^v_{l(i)k} \quad \begin{array}{l} \text{for factors } k; v: \text{unit-specific} \\ \text{factor sensitivities.} \end{array}$$

We thus specify the business goal variables as a vector of a decision units' cash flow, and its exposure to subsequently : systematic risk factors, firm specific risk factors and unit specific risk factors.

Thus, the firm can design a plan for exposing its activities to different kinds of risks in terms of sensitivities (See section 4 for details).

3.3 Modeling Flexibility Through Options

Flexibility in terms of optional value of decisions as an element of financial plans to be developed can be valued explicitly through analogy with options. At all decision levels of the firm, planning decisions may be interpreted in terms of holding, buying or selling options. Several

decisions on central financial instruments or local investment activities as well as decisions on central resources (for example, the unused amount of resources) can be interpreted and valued as options or option-generating decisions. For example, some of the central or local decisions may involve costly activities such as research and exploration, which may create 'good' investment projects later in time when circumstances are profitable (this involves a timing problem of exercising the option after acquiring the option). Also, the level of central resources can be chosen such that an unused part kept in reserve by the central level facilitates investment in a 'good' project that comes up at the operational decision levels later in time. In addition, projects may have other optional properties (such as the possibility to postpone or to expand or adapt the project) that increase their value and therefore should be valued^{*)}.

The optional value of decisions on activities at the central or business level can be included in one of the central objective functions. In general, this optional value is a function of (among others) the amount of investment in central or business project activities $\underline{x}^C$ and $\{x_1\}$ (the cost of exercising the option), the value of assets generated with $\underline{x}^C$ and $\{x_1(i)\}$, the risk of the activities, and the expiration times of the options. With respect to reservation of central resources s_j , which is treated as an 'activity' by the central level, the first problem is to value this amount and to compare this with its opportunity cost. As with the option-generating activities $\underline{x}^C$ and $\{x_1(i)\}$, we have an optimal timing (and postponing) problem of activities which come up later in time and which are made possible by the reserve s_j , but this problem will not be dealt with here (a general structure is given in 3.3). As explained later in more detail, decision units i specify a value function $O^i(\underline{s}_i)$ which represents the optional value for unit i of a vector $\underline{s}_i$ of additional resources s_j , kept in reserve by the central level for unit i . This function may be approximated by unit given a set of candidate future projects with their resources needs. At the central level, the aggregate value function $O(\underline{s})$ is included in the multiobjective problem and is to be traded off with other goal functions in vector $\underline{g}$.

^{*)} See Mason and Merton [1985] for an overview of valuation methods and further literature on the subject.

The optional value of central slack $\underline{s}$ which is distributed to business units i ($\underline{s}_i$) and the central level itself ($\underline{s}^c$) and decisions on activities is thus introduced as a goal variable:

$$g_4(\underline{s}) = g_4^c(\underline{s}^c) + \sum_i g_4^i(\underline{s}_i)$$

Functions $g_4^c(\underline{s}^c)$ and $g_4^i(\underline{s}_i)$ are deduced from option value functions $O^c(\underline{s}^c)$ and $O_i(\underline{s}_i)$ ($i = 1, \dots, I$), which are assumed to be calculated using option pricing theory.

3.4 General Structure for Real Optional Decisions

Brealey and Myers [1984], and Myers [1984] indicate financial planning as 'management of a portfolio of options'. We will show in a qualitative way how, in principle, the option perspective can be applied in organization of investment decisions. There exists a logical structure between 4 categories of real options for each business activity:

- growth-options (for instance, investment in promising activities); these options can be created for example by R&D investments and will be important at a strategic level;
- options with respect to timing or postponement decisions (for instance, postponement of an investment in development of a new product;
- options with respect to continuation or stopping decisions;
- options with respect to adaptation decisions, for instance change of products in process industry as a consequence of changing economic conditions.

At each decision level, the decision problem can be divided in:

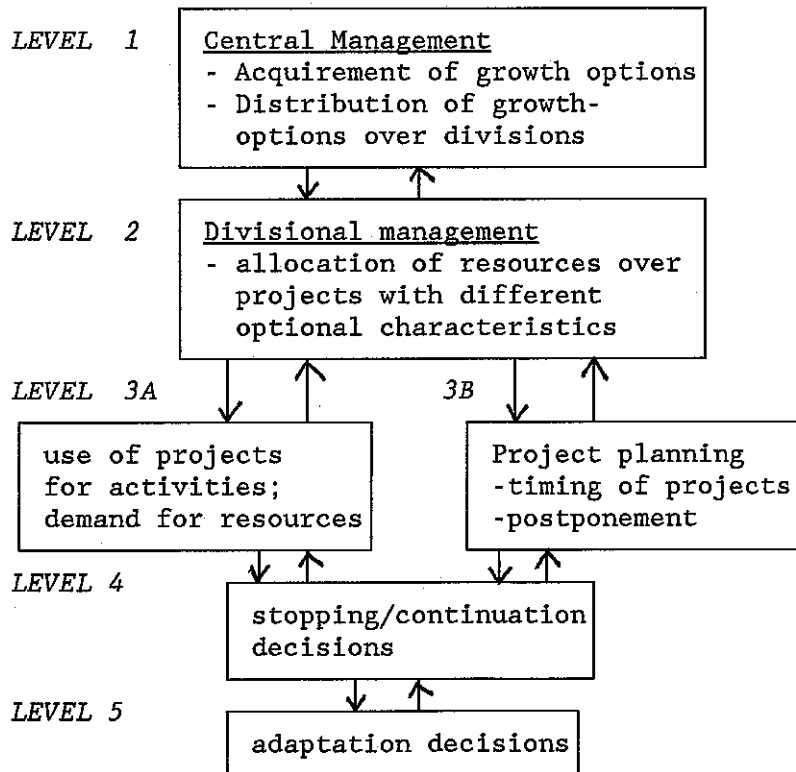
- acquirement of options (investment decisions)
- exercising the options (postponing, production or adaptation decisions).

A business activity thus can be represented as a combination of types of options, to be managed by decisions on options connected with that activity. Thus, the aggregate problem of investment decision making can be decomposed in a series of subproblems at different hierarchical levels. At each level, specific option valuation models can be applied in solving the specific problem, given state information from higher levels and

results from lower levels. The hierarchical structure is indicated in Fig. 2. At level 1, central management allocates strategic resources to divisions on basis of valuation by the divisional level of its optional decisions. The division consists of a number of return generating activities (level 3A) to be executed by projects. These projects use strategic resources. Business activities are using strategic resources as well as projects, thus a problem of optimal project planning exists (level 3B) to be solved by valuation of postponement options. Divisional management solves a trade-off between benefits, generated by project-using activities and costs of project planning. Problems at levels 4 and 5 can be solved given states resulting from higher levels; solutions for these problems are used in solving higher level problems.

The elements of the approach as described give rise to a decomposition of the over-all goal-optimization problem in a set of level problems to be solved by decision units within an information and coordination structure. The levels and the problem formulations are represented in Section 4.

Fig. 2 Hierarchical Structure of optional decisions



4. Multi-Factor Based Financial Planning Model

4.1 Introduction

In this section, we develop a systems model of a firm in terms of its characteristic activities (use of resources, development of resources, coordination of supply and demand of resources) and its environment (resource markets). Prices of resources are sensitive for various systematic factors. The firm is organized in three levels: (1) a strategy level; (2) a resource allocation and supply of resources level; and (3) a business unit level. Upper levels coordinate lower levels by means of coordination parameters. Several possibilities exist here: price coordination (non-feasible method), budget coordination (feasible method). We will use a form of budget coordination, applied to a vector of resources. The firms optimum decisions are the result of coordination of supply and demand of resources. Demands of resources stem from the needs of business units activities. These activities result in returns and cash-flows. Supply of resources at a certain level results in costs and risks. Risks are treated as sensitivities of returns for systematic factors. Costs, returns and risks are traded off at the coordination level.

Systems methodology has been developed primarily for large-scale systems (See: Singh and Titli [1978], Himmelblau [1973], Haimes [1982]). The framework we present, integrates methodologies of systems theory (hierarchical optimization) with the multi-factor approach. The objective is to derive a basic set of models suited for description and control of the firms financial and real operations, and to be used in experiments (See section 2, 4). Of course, the framework can and should handle multiple objectives of the firm, and should allow dynamic optimization, but for expository reasons the firms' objectives are represented by its market value and the formulation is static. However, development of resources by means of planning capacity expansion of projects, and planning of activities by units, is possible in the framework. Also, it will be shown that options can be integrated in the framework. We will indicate also possibilities for design of stochastic optimal control models. The framework formalizes some actual developments in corporate strategy (See for instance Naylor [1984]). These developments involve

design of explicit resource strategies for competing businesses. We show how these approaches easily can be integrated by the desire for optimal exposure of the firms activities to multiple risks.

4.2. Notation

In next section, following notation is used:

i, j, k :	index for respectively units, resources, systematic factors
$\underline{l}^i$:	project (activity) available for i (vector: $\underline{l}^i$)
b_k :	sensitivity of company return for factor k
μ_{ik} :	sensitivity of cashflow of business i for factor k
α_{jk} :	sensitivity of price p_j for factor F_k
ϕ_{jk} :	sensitivity of price π_j for factor F_k
$\underline{\sigma}^1$:	vector $\{\sigma_j^1\}$ of restrictions for the totality of resources
$\underline{\sigma}$:	vector of restrictions for slack
$\underline{\sigma}_i^2$:	vector of resources to produce by unit i
$\underline{h}_i$:	vector of resources available for unit i
$\underline{r}^{1,2}$:	resources supplied by markets or produced internally $\{r_j^{1,2}\}$
$\underline{\pi}$:	vector of prices for resources $\{\pi_j\}$
$\underline{s}$:	vector of slack for resources j $\{s_j\}$
$\underline{CF}$:	vector of business cashflows $\{CF_i\}$
$\underline{d}$:	vector of financial decisions
$K(\underline{r}^1)$:	cost of realizing the totality of resources $\underline{r}^1$
$\underline{x}_i$:	vector of outputs of type 1 for units i $\{x_{1i}\}$
$\underline{y}_i$:	vector of final net outputs $\{y_{1i}\}$
$\underline{p}$:	vector of prices $\{p_j\}$ of outputs
R :	return
O :	optional value
r_f :	risk-free return
k^U :	required return unlevered firm
V, V^U, V^F :	value of the firm, value of the unlevered firm, value of financial decisions
A :	matrix with cross-activity coefficients $\{a_{ij}\}$
C :	matrix with production coefficients $\{c_{ij}\}$
Z :	matrix with resource use coefficients for resources $\{z_{j1}\}$
D :	matrix with resource use coefficients for activities $\{d_{ji}\}$

All subscripts i for vectors and matrices denote application to business units i ; symbols underlined denote vectors. E denotes an expectations operator; $\{ \}$ denotes a set.

4.3. Problem formulation

We present a rather simple formulation, based on adjusted present value maximization. Thus, value function $V(g)$ in Section 3 is operationalized in a specific way. We will abstract from g and concentrate to objectives such as firm cash flow ($g_1: \sum_i CF_i$), optional slack value ($g_4: \sum_i O_i$), and sensitivities of business returns for systematic factors ($g_{N+k}: b_k$). In this formulation, operational cash flows $CF_i(y_i; p)$ from i -th business activities are assumed to consist of products of output levels y_i and prices p (revenues minus allocated cost). The value of the firm V is composed of the unlevered value V^U and value of financial side-effects V^F . $V^U(y, p, k^U, K)$ is a function of product output levels y , output prices p , investment $K(r_1)$ in the totality of external acquired resources including slack supplied by resource markets r_1 which is a product function $\pi^T * r_1$ of resource prices π and resource quantities r_1 ; and opportunity cost of capital k^U , representing business risk. Available resources r can be supplied by resource markets (r^1) with prices π or by own activities (r^2); $r = r^1 + r^2$. The present value of central (financial) decisions $V^F(d)$ is a function of financial decisions d . In addition, V consists of optional value of slack $O(g)$ which is a function of slack vector g and which presumably can be derived by specifying a return generating process of businesses i and deriving the riskless hedge. Also, $O(g) = \sum_i O_i(g_i)$.

The function V^U , representing unlevered net present value of cashflows generated with vector of resources r_1 , in its static form can be written as:

$$V^U = -K(r^1) + (1/k^U) \sum_i [p^T * y_i]$$

The cashflows are discounted by k^U which is, following a arbitrage equilibrium approach, a function of sensitivities b_k of company return R for systematic factors F_k , risk-free return r_f and prices Ω_k for these sensitivities which are obtained from the capital market or alternatively can be estimated by the firm:

$$k^U = r_f + \sum_k b_k \Omega_k$$

Company expected return $E(R)$ and function b_k can be written as follows:

$$E(R) = [\sum_i (p^T * y_i)] / K(\underline{x}^1, \underline{\pi}) = H(\underline{y}, \underline{x}^1, \underline{p}, \underline{\pi});$$

$$b_k = \delta H / \delta F_k = b_k[\underline{y}, \underline{x}^1, \{\delta p_j / \delta F_k\}, \{\delta \pi_j / \delta F_k\}]$$

Functions b_k can be expressed in sensitivities of p_j 's and π_j 's for F_k 's which should be available as data, as well as vectors $\underline{y}$ and $\underline{x}^1$. In the decomposition approach explained below, sensitivities b_k are to be obtained from sensitivities of business cashflows μ_{ik} for systematic factors F_k . Sensitivities μ_{ik} then can be obtained from $\{\delta p_j / \delta F_k\}$, $\{\delta \pi_j / \delta F_k\}$, $\underline{y}_i$, $\underline{x}^1$:

$$\mu_{ik} = \delta CF_i(\underline{y}_i, \underline{p}) / \delta F_k = \mu_{ik}[\underline{y}_i, \{\delta p_j / \delta F_k\}] \quad ; \text{ and:}$$

$$b_k = \delta H(\underline{CF}) / \delta F_k = b_k[K(\underline{x}^1, \underline{\pi}), R(\underline{CF}), \{\delta CF_i / \delta F_k\}, \delta K / \delta F_k]$$

where $\delta K / \delta F_k$ is a function of $\underline{x}^1$ and $\{\delta \pi_j / \delta F_k\}$.

In defining its policy, the firm may set constraint levels β_k for b_k , or alternatively may set weight levels also denoted by β_k in a process of multi-objective optimization. In the first case, optimization at the central level results in Lagrange multipliers λ_k , which are to be interpreted as:

$$\lambda_k = \delta V / \delta \beta_k$$

These λ_k can be compared with Ω_k . In the second case, optimization results in b_k . Then, prices Ω_k for sensitivities can be compared with weights β_k .

Decisions to be taken in order to optimize the firms' objective function are slack $\underline{g}$ kept in reserve, resources to employed $\underline{x}$, outputs to be produced $\underline{x}$. Our formulation implies that project decisions are already implied in decisions on $\underline{x}$, but the problem formulation easily can be adapted to take these more specific decisions into account (See Goedhart, Schaffers and Spronk [1987]). Constraints (for example, sources-uses constraints, production possibilities) are denoted by:

$$G(\underline{d}, K(\underline{\pi}, \underline{x}^1), \underline{y}, \underline{p}, \underline{x}) = 0 \quad ; \quad \underline{x} \in X$$

Thus, the firm has as its over-all objectives:

- (1) maximize net present value of cashflows generated:

$$\text{MAX } [V^U(\underline{y}, \underline{p}, K, k^U) + V^F(\underline{d})]$$
- (2) maximize the optional value of resource slack: $\text{MAX } \sum_i O_i(\underline{s}_i)$
- (3) minimize sensitivities of returns for systematic factors: $\text{MIN } [\underline{b}]$

Organization of the decision process in which this is accomplished follows from a decomposition structure. Business units i maintains an output level $\underline{x}_i$ (a vector consisting of elements $\{x_{1i}\}$ over all i) in order to support cross-activities ($A\underline{x}$), production of resources ($C\underline{r}^2$) and final output ($\underline{y}$ with elements $\{y_{1i}\}$), such that

$$\underline{x} = A\underline{x} + C\underline{r}^2 + \underline{y}$$

Resources available ($\underline{r} = \underline{r}^1 + \underline{r}^2$) will be divided among resources necessary for $\underline{x}$ ($D\underline{x}$), resources necessary for $\underline{r}^1$ ($Z\underline{r}^1$) and slack $\underline{s}$:

$$\underline{r} \geq D\underline{x} + Z\underline{r}^1 + \underline{s}$$

Here, $Z\underline{r}^1$ is a vector with only one non-zero element at position 1, denoting the investment $K(\underline{r}^1)$ necessary for resource level $\underline{r}^1$.

Decomposition Structure

The Lagrangian to be maximized for the problem is:

$$\begin{aligned} L(\underline{x}, \underline{y}, \underline{r}^1, \underline{r}^2, \underline{\lambda}, \underline{\theta}, \underline{s}; \underline{p}, \underline{\pi}) = & V(\underline{y}, \underline{p}, \underline{\pi}, \underline{d}) - \sum_k \lambda_k (b_k(\underline{y}, \underline{r}^1) - \beta_k) \\ & + \sum_i O_i(\underline{s}_i) + \underline{r}^T (\underline{x} - A\underline{x} - C\underline{r}^2 - \underline{y}) + \underline{\theta}^T (\underline{r} - D\underline{x} - Z\underline{r}^1 - \underline{s}) + \underline{\Phi} G(\underline{r}, \underline{y}, \underline{d}, \underline{p}, \underline{\pi}) \end{aligned}$$

This formulation lends itself to decomposition as is shown in next sections (See Fig. 3). The decomposition is based on budgets for resources. Thus, the firm follows an explicit resource strategy. The decomposition proceeds by coordination parameters:

- The strategy level (1) uses $\underline{g}^1$, a vector of restrictions for external resources $\underline{r}^1$ and $\underline{g}$, a vector of restrictions for slack $\underline{s}$. It receives as results from the second level: optimal $\underline{y}(\underline{g}^1, \underline{g})$ and $K(\underline{g}^1)$, and furthermore the corresponding Lagrange multipliers.
- The resource allocation level (2) uses $\underline{g}_i^2$ as vectors for restrictions

for resources to produce by units i , and h_i as a vector for resources available for units i . It receives as optimal decisions from units i : $x_i(g_i^2, h_i)$, $y_i(g_i^2, h_i)$ and corresponding lagrange multipliers.

- The resources supply level (2) receives g^1 and returns optimal $r^1(g^1)$, $K(g^1)$ along with lagrange multipliers for resource levels.

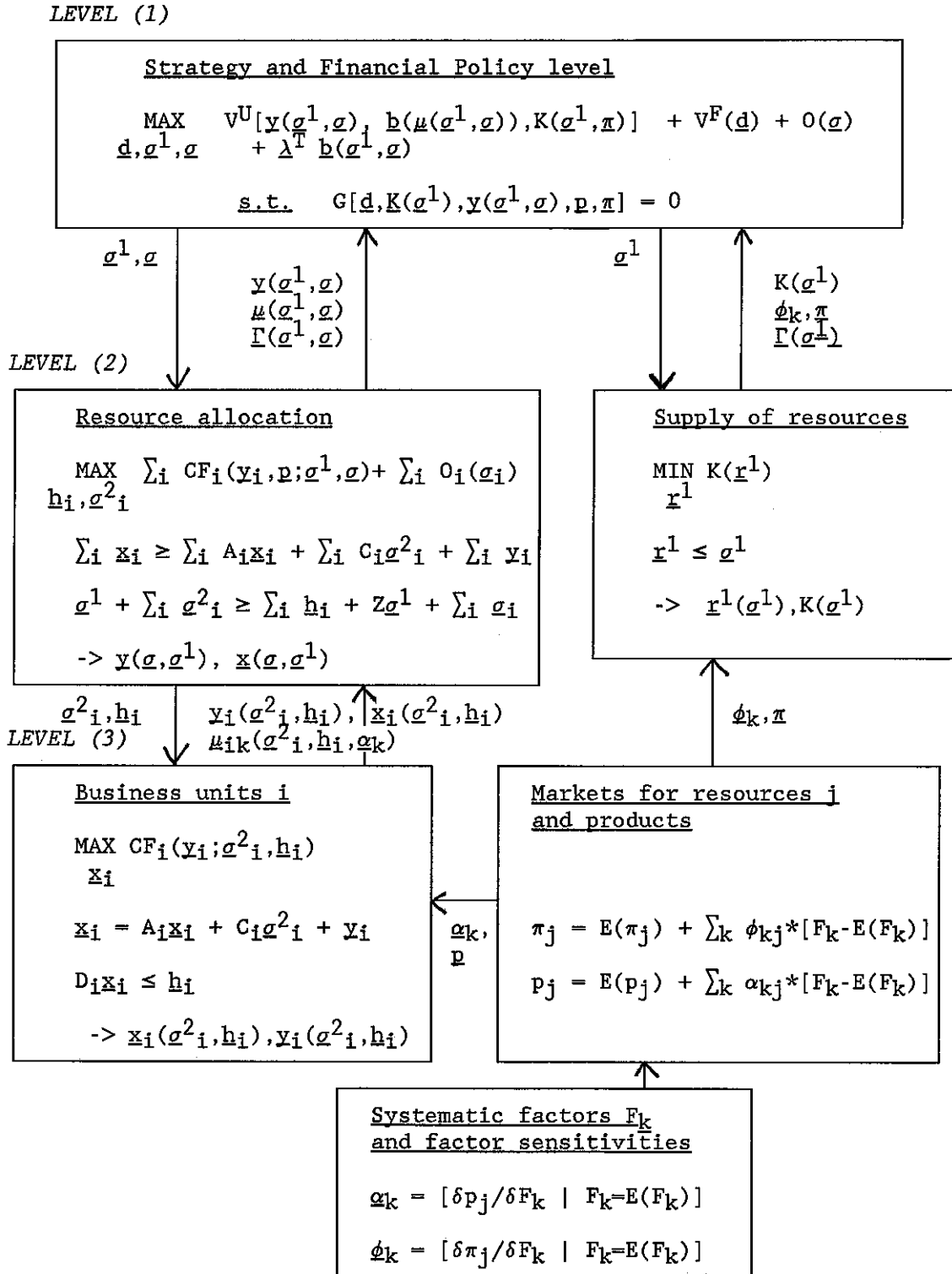
First level: Strategy and Financial Policy. The first level provides a long-term view in development of product and factor markets, diversification of activities, development of resources. Its objective is to maximize firm value and to secure continuity. It matches demand and supply of resources. Therefore, this level designs a resource strategy, along with financial policy (dividend decision, financial structure, etc). A vector of external resources capacities g^1 is sent to the demand and supply at the second level in order to maximize over-all value of the firm. The value of the firm is decomposed in an unlevered part V^U , to be optimized by the resource allocation to business units 1, and a financial part $V^F(d)$, d denoting strategic financial decisions, to be included at the first level.

Systematic factors F_k will influence returns of units i as well as markets for resources j . An objective at this level therefore is to design an optimal exposure strategy. The objectives of the firm are represented by its overall return and the sensitivity of return for systematic factors. This level could also set prices for systematic factor sensitivities or may derive them from market data.

The first level receives information from the resource allocation at level 2 in the form of cashflows, sensitivities of cashflows to factors, and shadow prices $\Gamma(g, g^1)$ associated with constraints at this level. From the supply sector at level 2 it receives information in the form of costs of realizing a demand for resources g^1 , $K(g^1)$, along with shadow prices of associated constraints.

Second level: Demand of resources. The resources allocation among units is based on maximization of cashflows plus optional value of slack, given the resources capacities g^1 and constraints for slack g . Therefore, the resource allocation level coordinates units at the third level. This happens through using constraints for resource allocations

Fig. 3 Decomposition structure



g_i^2 to units i , as well as production requirements for resources h_i as coordination parameters. The units i respond with cashflows, sensitivities of cashflows for factors, and shadow prices associated with the constraints at that level. This level also designs resources projects for supply of resource capacity g^1 (therefore, this level again may be decomposed in a sector of demands and a sector of cost minimization).

Second level: Supply of resources; resources development. Information that is sent to the first level includes cost $K(g^1)$ and sensitivities associated with prices π of g^1 . Resources are defined by a set of characteristics: types of resources, sensitivities ϕ_{jk} of prices of resources to systematic factors F_k . To facilitate the analysis, it is assumed that resources projects are defined by its price and its set of sensitivities to factors.

Third level: Unit i operational decision making. Unit i decisions on projects from the set $\{l(i)\}$ are represented by decisions on outputs x_i and are constrained by resources available h_i and resources required g_i^2 . A project (activity) is characterized by its use of resources d_{ij} . This level sends information concerning cashflows, sensitivities of cashflows to factors, and shadow prices to the second level.

Coordination of Submodels. For coordination of submodels, existing techniques may be used such as price coordination and budget coordination. When the problem satisfies specific requirements, a dual coordinator may be used. It is also possible to design heuristic coordination procedures (Rosenblatt and Freeland [1980]). As explained in the main part of the paper, dynamic and stochastic aspects of the problem require development of coordination procedures where man-computer interaction and learning elements are explicit part of the procedure. We will now investigate whether dynamic optimization theory might provide a basis for development for such procedures.

First of all we should emphasize the essential dynamic and stochastic character of a number of variables and parameters in our formulation. In future time periods, new information with respect to stochastic input variables, factors, projects $l(i)$ (their sensitivities, cashflows, investment requirements) will become available. Current decisions then

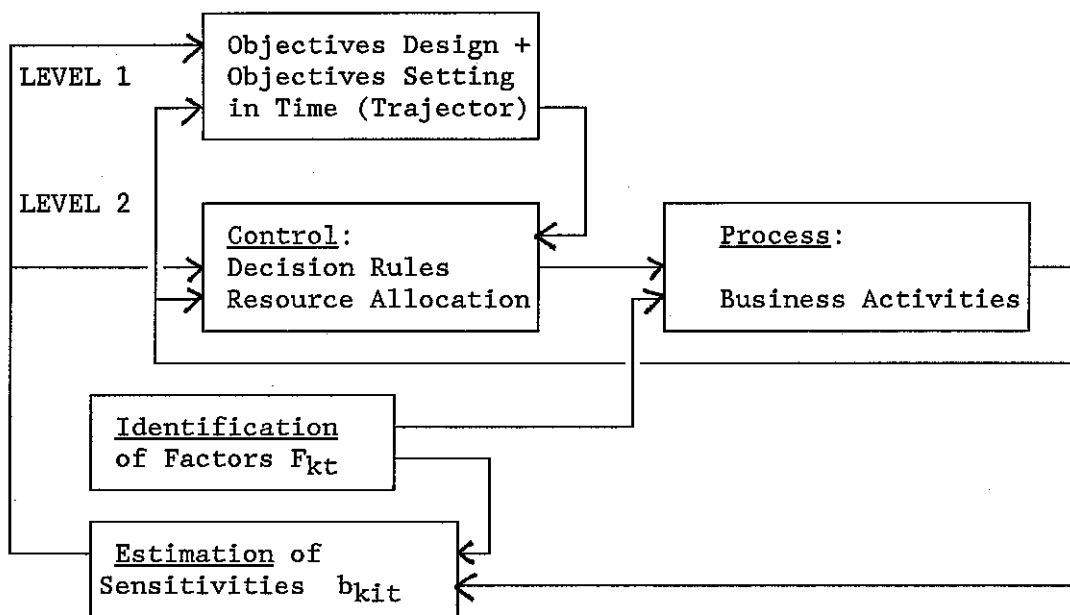
are not independent of future optimal decisions to take. State variables (and input variables) not always can be measured with certainty due to measurement error. Parameters may vary in time and may be stochastic. Therefore, parameters and states should be re-estimated properly. For instance, it will be necessary to adjust factor sensitivity vectors α_k and ϕ_k . This might be seen as a filter problem. The problem is made much more complex when also state variables (or non-controllable input variables) cannot be measured properly. We then can apply Kalman-filter theory. However, especially when we have non-linearities, multiplicative uncertainties (products of state variables and/or control variables and stochastic parameters), the computational problem becomes formidable (Kendrick [1981]).

When the problem is deterministic with quadratic objective function and linear state equations, the optimal policy is a linear (in state variables) decision rule. This holds also when uncontrollable inputs are introduced. When measurement error is introduced, the problem is one of estimating states (by Kalman-filter theory) and optimal control. When objective functions are quadratic (in state variables and control variables), for instance in terms of firm value, dividend decision, financial structure etc at times t over a horizon T , when we have multiplicative uncertainties and when states are measured with measurement errors, algorithms can be designed for passive and active learning (Kendrick [1981]): 'passive learning' denotes re-estimation of parameters and states while 'active learning' also takes into account the existence of future measurements and thus takes into account the information value of decisions.

In our problem it is in principle necessary to (re-)estimate parameters (sensitivities of returns to systematic factors) and to optimize the policy of the firm simultaneously. Factor values can be considered as uncontrollable input variables, of which the impacts (unexpected factor movements) should be controlled (optimal exposure policy). An updating process can be defined to generate new expected factor values, resulting in expected returns. State variables are market and book value of the firm, cash level, asset level etc. When we ignore measurement-error in state variables, the impact of alternative control principles might be estimated as is illustrated in Fig. 4. At the first level, a

deterministic control algorithm might be used to compute a long term strategy trajectory, to be revised each time period. Decision variables are resources constraints and weights for sensitivity levels. At the second level, each time period decision rules are used to adapt to objectives, resulting from the first level. This results in resource allocations to business units. Time lags between decision and results can be included. Along such lines, effectiveness of the decision structure in attaining 'good' and stable results might be assessed.

Fig. 4 Learning Model



Due to problems of incomplete information and asymmetrical distribution of information over decision levels, and furthermore incentive problems, the approach as sketched has restricted value. It is necessary to design coordination structures that deal with this circumstances.

In Section 5 we will outline an approach in which submodels, introduced in this section, can be coupled in a less restrictive way. As indicated in section 2, a support system includes not only mathematical models to be executed in an automated way, but also man-computer procedures aiding the decision-maker in choosing the task as considered important at specific points in time. Furthermore, rules can be used to

contain knowledge with respect to activation of specific submodels, thus broadening the support system to a computer-assisted rule-based system.

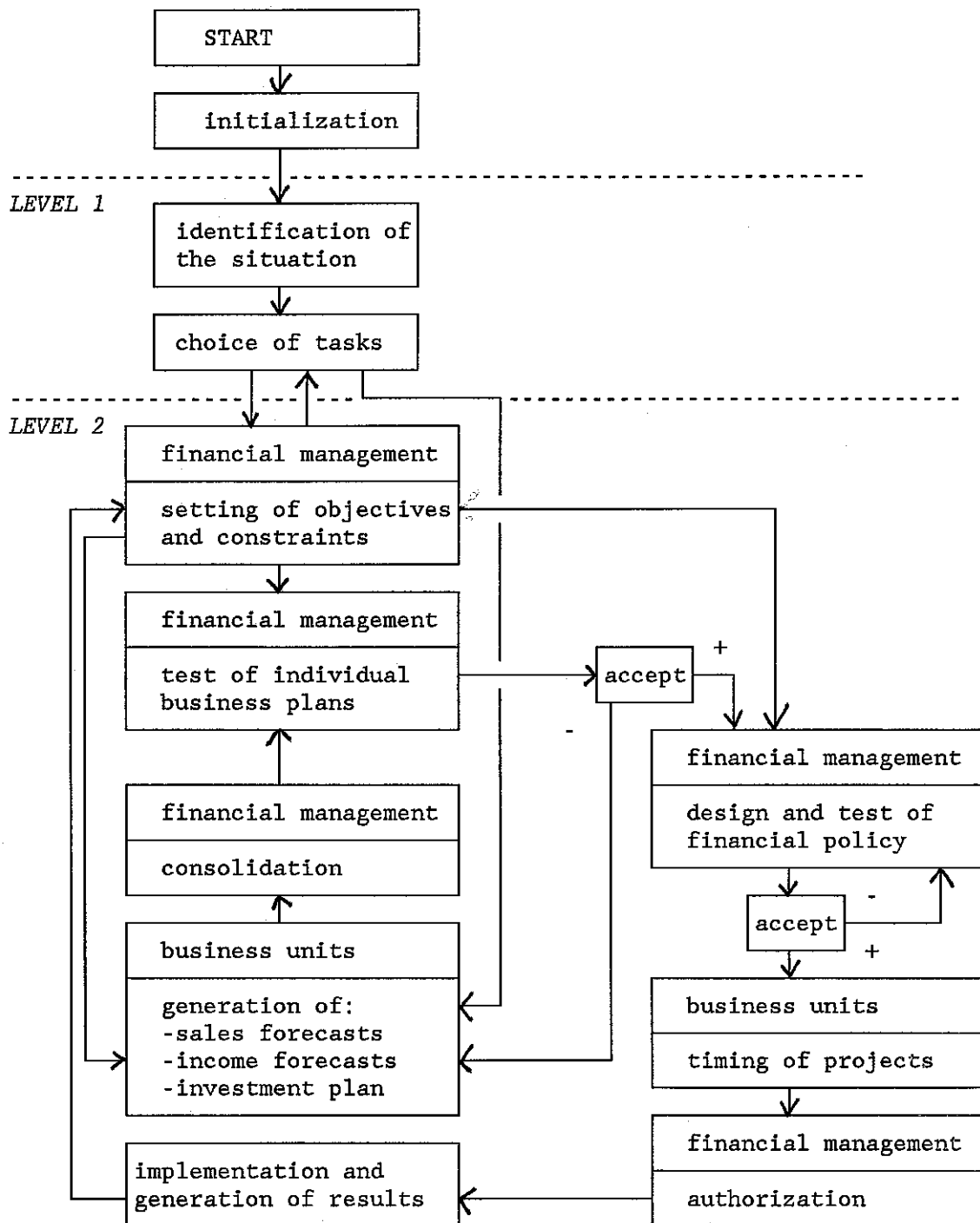
5. Experimental Investigation of Financial Planning Behavior

5.1 Structure of a financial planning simulator

Currently, we are developing software on basis of principles explained earlier. As a first step, we have developed a planning simulator in Pascal on microcomputer^{*)}. A structure is chosen consisting of two levels (Fig. 5). A task structure (section 5.2) deals with choice of tasks at and inside these levels. At level 1, decisions on decision-making are organized. Results of decisions along with the past and current states are interpreted and classified in terms of types of decision situations. Then, using models and rules, or human judgment (this depends on the experimental situation), a choice is made from a number of central tasks. These may be strategic tasks (revision of norms, objectives and decision rules to be used by other decision levels), analytical tasks (observation and diagnosis of bottlenecks) or operational (budget decisions, capital investments, timing, policy decisions). At level 2, execution of (a sequence of) tasks is performed in a set of stages where planning, design of alternatives, implementation and control are among the most important ones. The financial strategy and capital investment process as structured as a level 2 process in the simulator is modeled in a set of procedures. Dependent on the experimental situation, different transitions between and sequences of activities are possible (See section 4). One possibility is as follows. The planning process starts with initialization. Then, the business units prepare investment and income plans. These plans are judged at the financial management level. Financial policies are designed and evaluated against business units' desires. As a result, business re-planning may become necessary, thus initiating further iterations. The implementation stage starts with timing of projects by the businesses. After authorization or rejection, further project

*) Our recent work, which is in line with the concepts presented in this section, is on rule-based financial planning models. See Van den Bergh, Goedhart, Schaffers [1988].

Fig 5 Structure of capital investment process simulator



proposals follow. Another possibility, in analogy of parallel processing, is to actively choose and evaluate at level 1 the sequence of tasks to be executed at level 2.

This task structure follows from the general conception of the strategic and operational management process, modeled as hierarchical coordination of supply and demand of funds, as explained in section 4. The demand side embeds the use of resources in business units; the supply side models the efficient generation of basic resources and price movements on markets. The multi-factor approach for representation of returns in terms of expected returns and a set of sensitivities for systematic factors can be integrated in a very natural way in this conception. Also, the optional character of decisions (for instance, on slack, or types of projects) shows a promising potential for integration (See also Goedhart, Schaffers and Spronk [1987]).

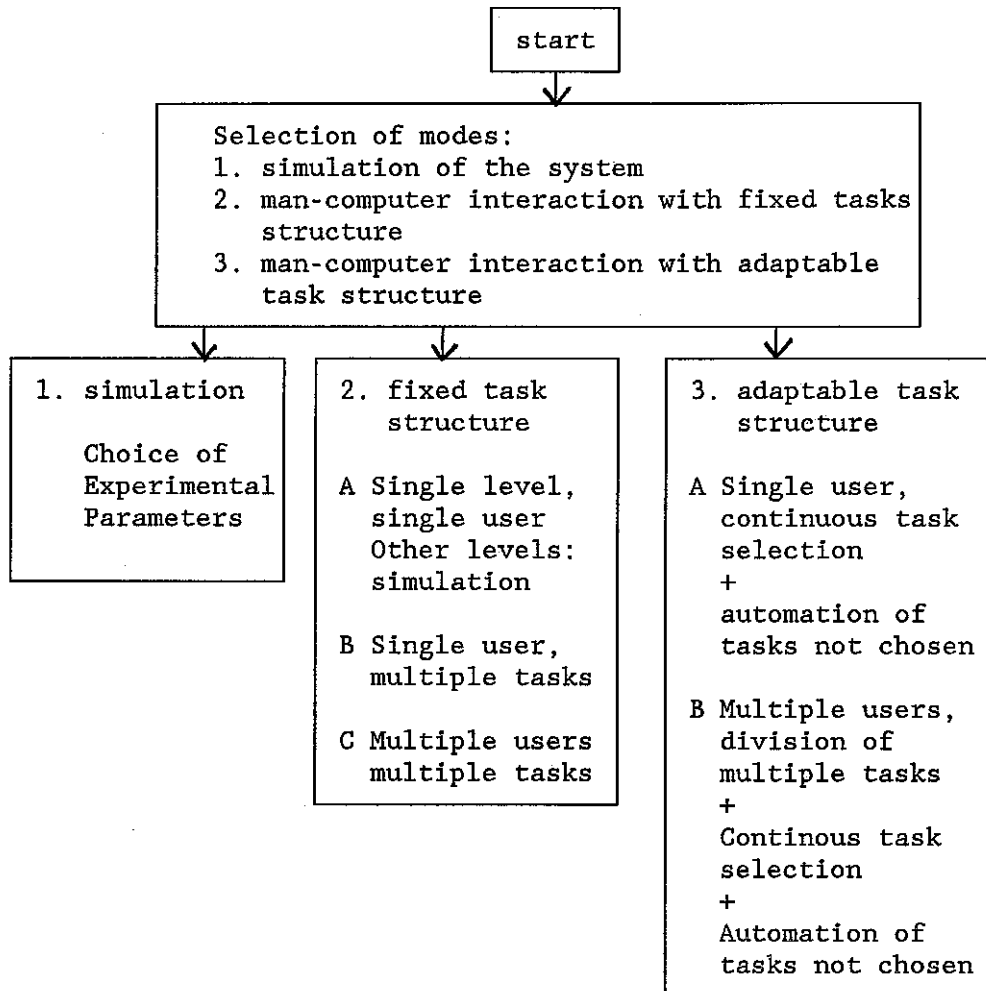
5.2. Experimental Task Structure Settings

In Fig. 6, an overview of experimental task structure settings is given. These settings are meant to coordinate tasks among decision units. Three basic options are shown. In the simulation option, there is no human user. The behavior of the system with respect to several factors can be investigated. These factors are, among others, mechanisms for generation and selection of alternatives, environmental shocks or disturbances, production rules which guide information-dependent actions, resource allocation mechanisms, incentive and reward systems, constraints on available projects, time, resources, financial constraints. An important problem in this approach is the mathematical modelling of learning processes associated with failure or success in decision making.

In the fixed task structure option, 3 subcases are distinguished. These cases guide the range of tasks which is allotted to the decision maker(s). For instance, in case A one decision maker is placed at one level, while the other decision centres are simulated (automated). In Case B, there is only one decision maker who may select among decision tasks at all decision centres. In Case C, there is a fixed task division among more than one decision makers who are allocated to the several decision centres.

In the adaptable task structure, two subcases are distinguished. In case A, there is a continuous task selection by one single decision maker, while all other tasks are executed automatically. But also parts of the task at hand can be automated by using decision rules as specified by the decision maker. In case B, this can be done by more than one decision maker.

Fig. 6 Classification of experimental task structure settings



An important element of the simulator as proposed here is that it is possible to generate different decision situations. Not only it is a testing environment for theoretical frameworks (for instance the multi-factor approach), it is also possible to use it in generating several kinds of agency-situations. While it is very difficult to attain valid conclusions from experiments in which the objective is to test a theory, or to link decision behavior to decision setting, it is very well possible to

isolate characteristics of decision situations resulting consistently in specific decision performance.

5.3 Experiments in Gaming Situations

Currently we are defining experiments which will be carried out with the gaming system as described*) (See also section 2.1). We will give a general indication of the possibilities.

First, it is attempted to represent agency-situations in our framework. This provides a means to investigate the various hypotheses from agency theory and to compare mechanisms that mitigate agency problems. There are many possibilities, but we want to emphasize the contract formation process (negotiations) and anticipation games (such as included in the information asymmetry model of Myers and Majluf [1984]). With respect to contract formation games it is useful to investigate, among others, the role of procedures and decision support on decision performance. One can try to develop an acceptable 'robust' mechanism that presents the players with sequences of choices that structure a contract. This relates to the theory of games under incomplete information and metagame theory. In terms of game theory, one might think of 'self-policing systems'. With respect to anticipation games, it can be said that the Myers-Majluf [1984] model is a theoretical result under strongly simplifying conditions, and that behavioral processes might very well alter the results of such games. The anticipation also is an instant of a general (degenerative) learning process. The decision maker is presented with a sequence of states leading to a worse situation when deciding with a short-term view. Here also the role of decision support might be of interest.

Second, it is useful to compare alternative theoretical frameworks (such as the multi-factor model, possibly supplemented with option models) in this gaming situation. These methods enclose alternative theories about information handling of decision makers, interpretability of data and computational results etc., and have procedural consequences (gathering data, decision types etc).

1) Some of the work is performed in the context of rule-based financial planning models. See Van den Bergh, Goedhart and Schaffers [1988].

It would also be fruitful to investigate the many links between mathematical control theory and factor models more systematically. In the context of decision support, the factor model should be adapted continuously. New data will make re-estimation of models necessary. Thus, the control and decision problem is a combination of model identification (where filter methods possibly can be used) and optimization using the estimated model. Also, not only minimization of sensitivities of criteria with respect to factors is necessary, in a dynamic environment emphasis should be given to stabilization of these sensitivities according to changes in environments. Instruments and procedures should be designed that aid the decision maker in this stabilization and anticipation tasks.

6. Conclusions

It is possible to design financial planning models based on a multi-factor approach and on analysis of contingent claims. The disturbing influence of informational agency problems emphasizes the need for rule-based support systems, in which submodels are coupled through rules or man-computer interaction. The outline of such a system is given. Laboratory experiments can be useful to provide us more insight in effectiveness of such interconnected support systems.

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