System Dynamics as a Tool for Corporate Planning

Erich Zahn
Corporate Modelling and Planning Research Group
Betriebswirtschaftliches Institut
Universität Stuttgart

1. Introduction

Corporate modelling in general and System Dynamics modelling in particular have now a history of more than two decades. Despite this fact impacts on the corporate planning process have not been very satisfactory. The reason is that in many cases system dynamics models (as well as other types of corporate models) had not been constructed, validated and implemented adequately for managerial use. They did not provide the information support which is needed in order to make the necessary decisions in the various phases of a complex planning process that has a lot to do with major changes in markets, products, production processes, technologies, governmental regulations etc. Here, formal decision rules as used in operational planning are impractical in most cases.

In corporate modelling we have observed almost the same pitfalls as we have experienced with management information systems. Failures in both areas do indicate that wherever non-routine decisions have to be made generalized solutions will be very limited. Instead ad hoc usable decision support devices seem to be a much more effective approach. With the help of such a decision support system the appropriate information can be generated and fed directly into the planning process. The kind of demand for information that does exist in most planning situations requires models that are problem-oriented,

sufficiently detailed, and easy to develope and to adjust. Their structure should be understood by the manager and reflect his own way of thinking. Our research indicates that this type of model has to be developed within an intensive dialogue between model builder and model user. If this modelling process is organized and carried out well the result might be an experience-generalized model which is really needed in strategic planning and which therefore is much more likely to be accepted by managers, because it seems to enhance managers 'thinking processes'.

In this paper we will discuss how the potential of system dynamics models in supporting corporate planning could be realized more effectively. Our remarks on model conceptualization, validation and implementation will be based on two model-projects. Both of these are carried out with a system dynamics model that in each case does represent a real world problem in a concrete firm.

2. A System Dynamics Model for Operational Planning

a) The problem to be studied with the model

The first model deals with an operational planning problem; the simultaneous planning of marketing logistics at a German shoe-producer. The model is used in order to gain better insights into the complex "sales-inventory-manufacturing".

In reality this complex is characterized by a rather strong seasonal development of order entries and deliveries on the one side (as illustrated in figures 1a+b) and the need for continuous production in order to realize high capacity utilization rates on the other side.

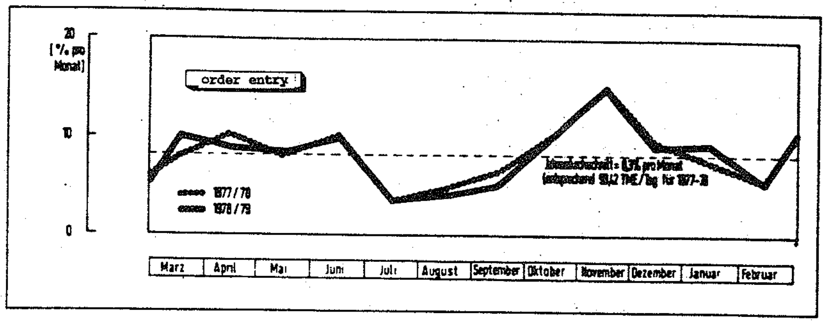

Figure 1a: Observed seasonal dynamics of order flow

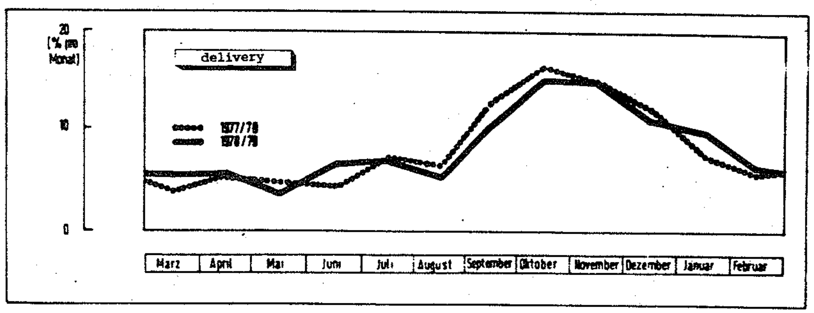

Figure 1b: Observed seasonal dynamics of delivery flow

Orders are differentiated in those for the account and in those that have to be delivered within a short time. Seasonal dynamics of orders of the first category - their entry, backlog and delivery-are represented in Figure 1c.

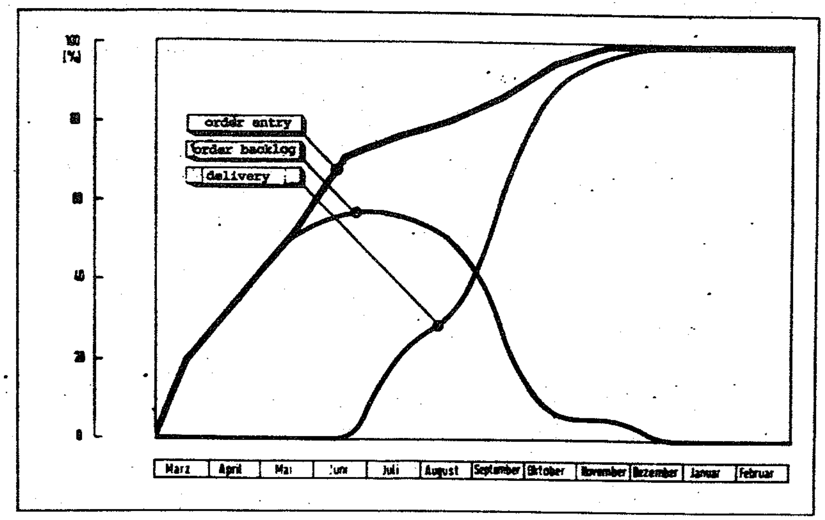

Figure 1c: Observed seasonal dynamics of orders for the account

The stock of finished goods in its yearly avarage lasts for 50 work days (see figure 1d). Resulting inventory costs are about 1.5 Mill. DM per year.

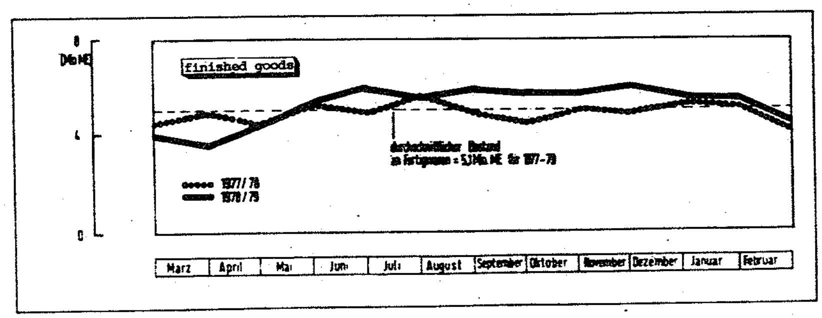

Figure 1d: Observed dynamics of inventory (finished goods)

Sales effectiveness during season significantly depends on low delivery delays. Operational goals of the firm are a stock of finished goods that last for 20 days (seasonal componant excluded), a delivery delay of 24 hours for goods that are ordered for current sales, production in large lot sizes, and a continuous production output.

b) Objectives of the model

The particular objectives of the model are:

- to identify areas within the firm and its markets that seem to be relevant in order to understand the investigated problem;
- to analyse changes in systems behaviour caused by disturbances in the market, and
- to formulate policies for improving the real world systems behaviour in terms of performances.

c) The structure of the model

The model structure includes the production process which is devided into three phases, capacity, material and man power control, as well as all relations of the firm to its labour-, machine-tool-, and material-markets, that are relevant for operational planning. The basic flow diagram is illustrated in figure 2.

d) The behaviour of the model

After validating the model with real world data and experiences from middle level and upper level managers the model was used for several tests, including a constant demand, a sudden jump

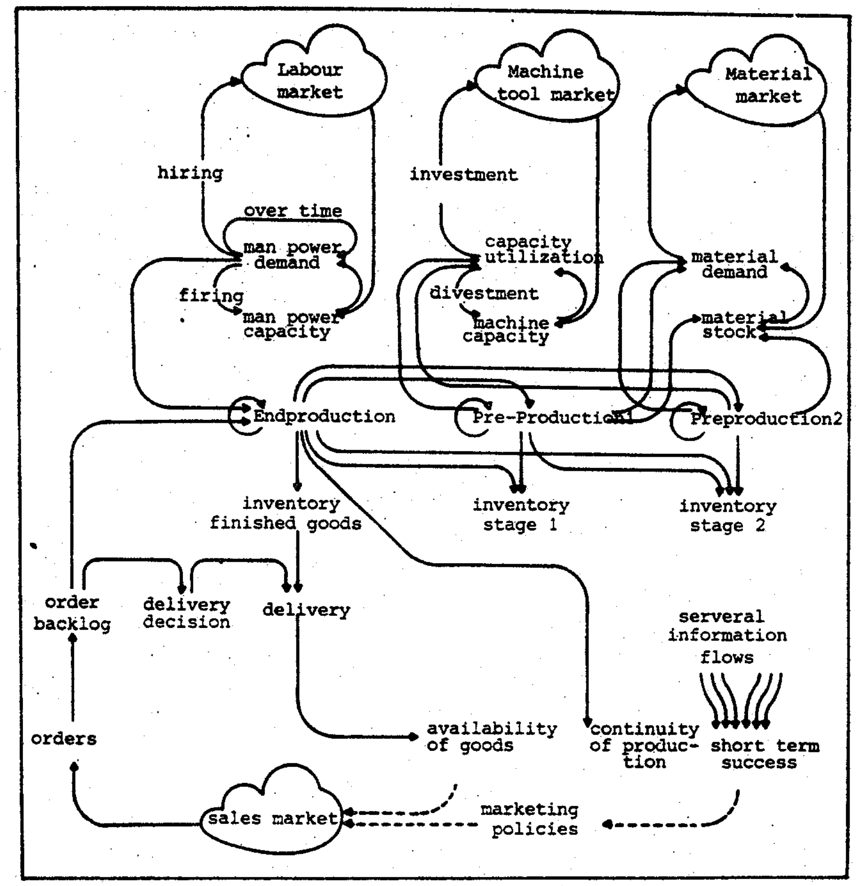

Figure 2: Basic Causal diagram of the model.

in demand, a large order, increasing and decreasing demand, a flop in product innovation, a too optimistic sales forecast, seasonal and shorter fluctuations in the flow of orders.

In figures 3a-f a selected number of test results are illustrated.

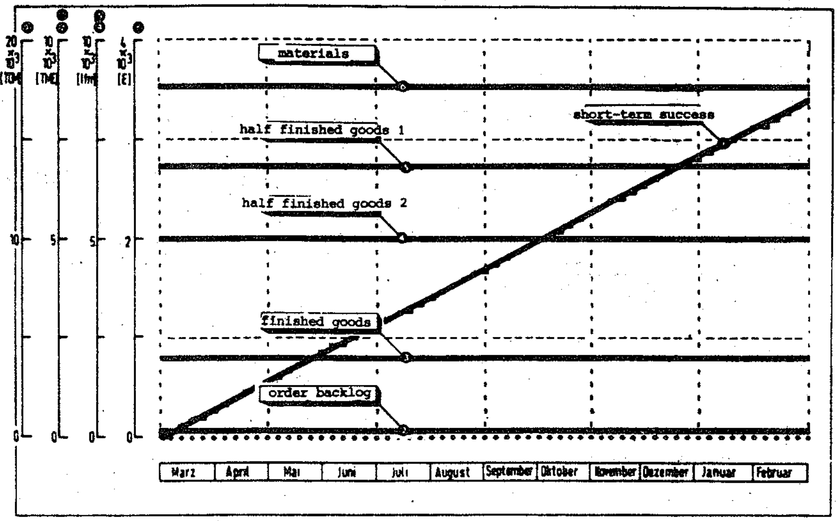

Figure 3a: Dynamics of important level variables with stability conditions.

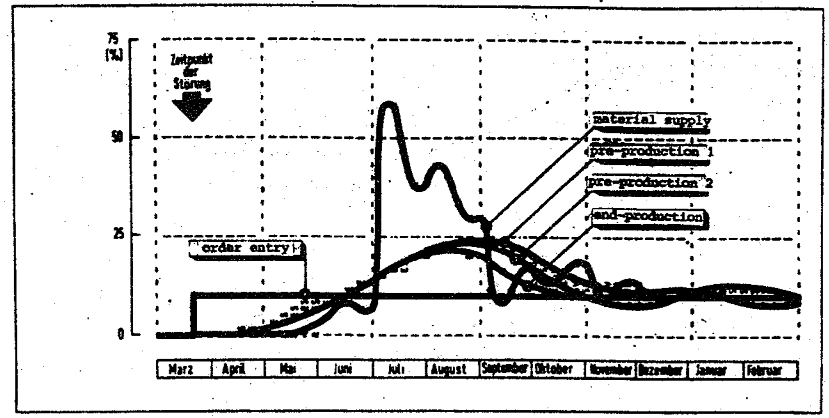

Figure 3b: Response of production rates according to an unexpected demand jump of 10%.

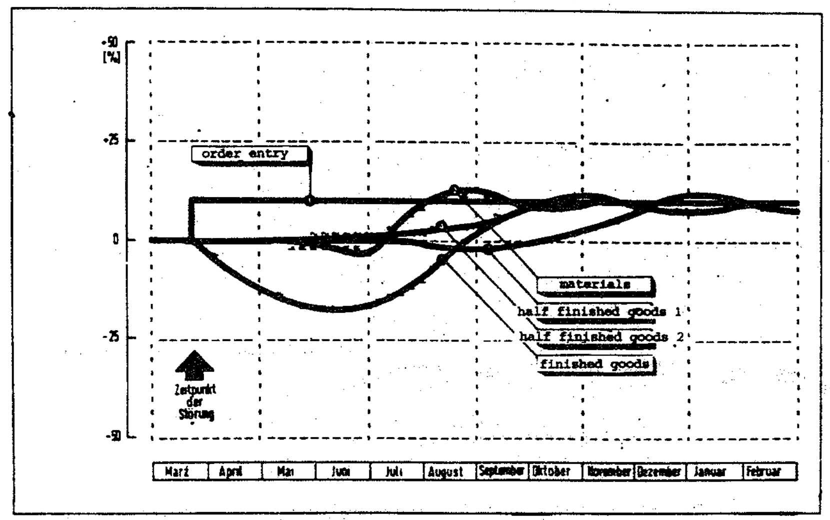

Figure 3c: Response of inventories according to an unexpected demand jump of 10%.

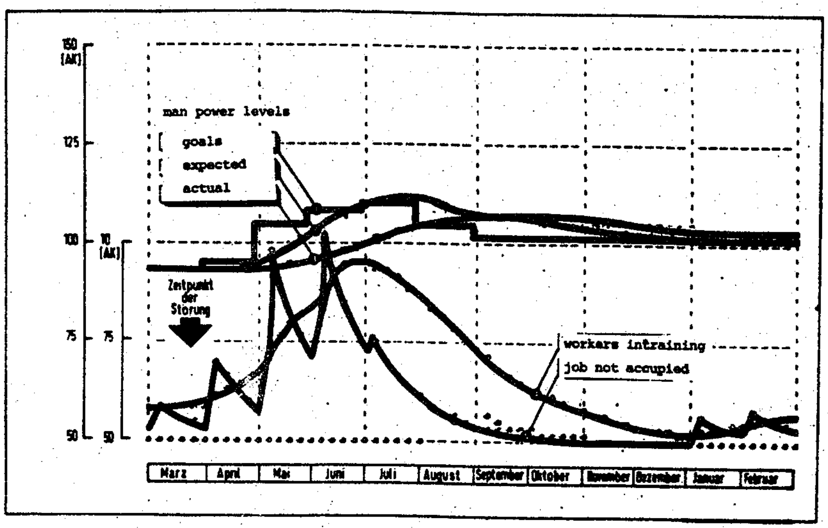

Figure 3d: Changes in manpower capacity according to an unexpected demand jump of 10%.

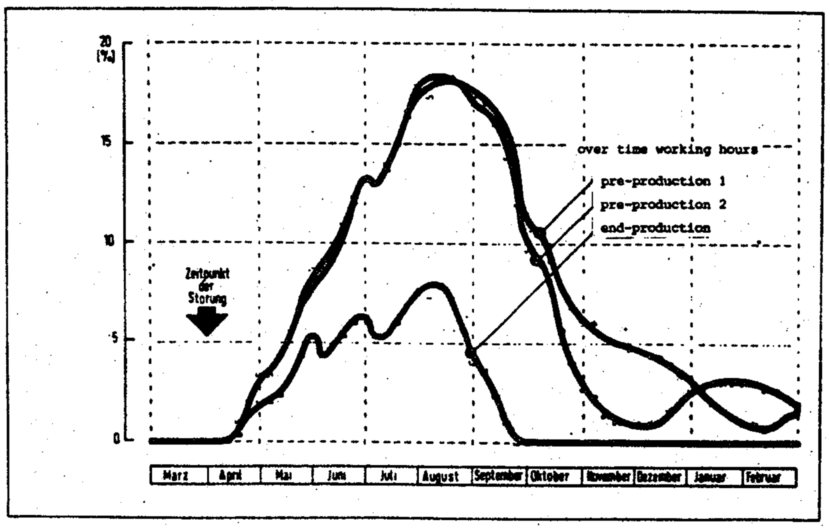

Figure 3e: Changes in additional work hours according to an unexpected demand jump of 10%.

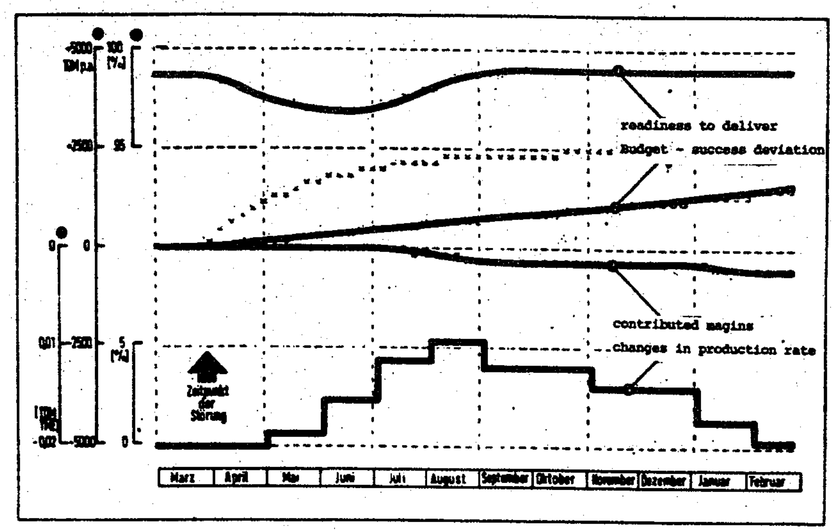

Figure 3f: Development of short-term goals according to an unexpected demand jump of 10%.

As a result of an unexpected demand jump of 10% total costs will increase by 33.900,-- DM, where 15.600,-- DM are due to more overtime working hours and 18.300,-- DM are due to an increase of current assets.

Summarizing these test results two recommendations could be given to the firm for improving the performances of its subsystem "sales-inventory-manufacturing":

First, simulated market conditions show that reserves in all three inventory stages seem high enough in order to allow an average decrease of stocks by 15 to 20%. The situation of reserves looks more comfortable at inventories for raw materials and partly finished goods than for finished goods.

Second, a shortening of the reaction time from now 20 to 15 days would lead to a significant improvement of the time-variant behaviour. For operational planning such an action would mean that observed gaps in inventories have to be eliminated faster. Similarly a speeding up of the planning rhythm or a faster implementation of plans would result in a better dynamic behaviour too. All policies for applying the recommendations have been discussed with the management in detail; it turned out that they are feasible.

3. A System Dynamics Model of Coal Dynamics

a) The problem and objective of the study

The second model deals with a strategic planning problem; the decision to mine or to import coal, and to allocate coal to different sectors of consumption: steal production, conversion to electric power, and heating. The model-project which is a consulting work for a large West German coal company is still in a pilot phase. It is intentea to use the model as an early-warning instrument. In todays energy business conditions do change fast and often very sudden. Therefore management needs something that can help to forewarn of changing conditions such as jumps in prices for crude oil and gas, supply cuts, import stops, modifications in EEC-contracts, problems concerning the acceptance of nuclear energy, technological substitutions etc. Informations about such kind of environmental changes are crucial for formulating effective business strategies: To give management decision support in this respect is the main objective of the model-project.

b) The structure of the model and preliminary results

According to a broadly stated request by our customer the model tries to represent all aspects of todays and tomorrows coal business which seem to be relevant for strategic planning. The basic structure of the model, illustrated in figure 4, shows the main elements: a mining sector, a buying sector, three sectors of coal consumption, connected by an imaginary variable coal inventory and an allocation mechanism. The latter is determined by demand structures in the various consumption sectors on the one side and by long-term contracts as well as short-term reactions on the other side.

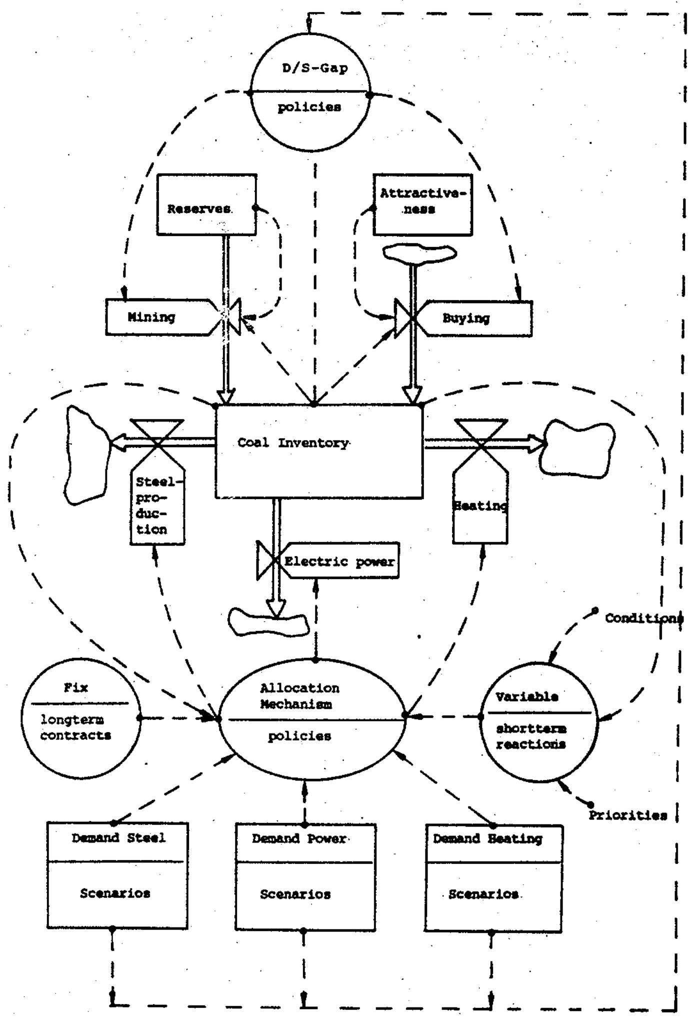

Figure 4: Basic structure of the coal model.

Consumption sectors are modelled seperately as modules for isolated operations. Besides transformation processes, demand structures, and marketing relations they also do represent special governmental regulations and EEC-contracts. Interfaces are constructed in a way that allows easily a connection of the different modules.

The model-project is at the end of a pilot phase, now. It's result is a relative simple model which gives the following performances:

- it captures the essential structure of the real world system as seen by the management,
- it generates time-variant trajectories which fit roughly to historical time series, and
- it enables preliminary analysis of policies.

A second phase of the model-project is planned. Here a system of models with much more detail will be developed, as outlined in figure 5.

4. Some thoughts about applying system dynamics models

In the two model-projects mentioned above we made experiences similar to those mentioned in the technical paper of James Lyneis and in earlier publications by Edward Roberts (1973) and Henry Weil. These experiences could be summarized as follows: *First*, start with a relatively simple model which captures the basic structure of the system studied!

Such a model helps modelling experts to learn about the systems, and decision makers to become familiar with system dynamics thinking and modelling. In both projects we developed what

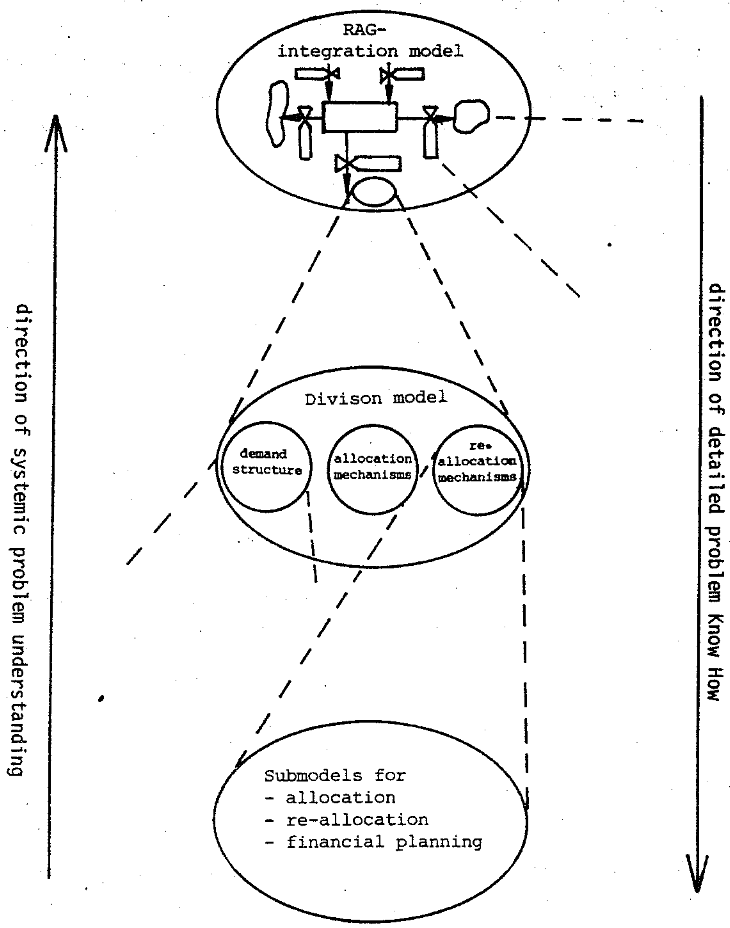

Figure 5: Planned model system.

we call a demonstration model. It helped us to better communicate and structure ideas about the problem. Especially in the second project where we had to cooperate with a project team of staff people and line managers from different divisions and various backgrounds, this approach was very fruitful. It helped us to interpret the various, often fuzzy opinions about the system or its parts and to integrate them into a holistic picture, all participants could agree upon. Here it turned out to be very important that each member of the project team finds his view of the problem reflected sufficiently well. Otherwise he would probably reject the study and participate not any longer. Form a more technical point of view this procedure looks too time consuming and not successful at all. It is sometimes frustrating, indeed. For example, our first coal model didn't look very much like a system dynamics model. But step by step we could form it into one, and at the end of the pilot phase the project members were ready to agree upon the structure, the generated behaviour, and further steps for developing a detailed model system.

Second, try to develope a model that corresponds in detail to the problems of the major parts of the organization (divisions, strategic units, etc.)!

This seems to be a neccessary condition for a model that really may support managers' minds and thus helps to do the strategic planning work.

To follow this demand a modular approach of modelling should be used. It has several advantages. First of all it may help to make model building more effectively and efficiently.

The reason is that modelling experts and specific decision makers could work together more intensively. A lot of useless discussion normaly observed in larger project teams might be avoided. A modular approach delivers managers responsible for a division or a strategic unit a submodel which could be used seperately or in connection with other modules. Sometimes competition between division managers is hard and therefore they will not feel very comfortable to make their problems transparent for opponents. If this is the case good data may only be collected if the division manager could be convinced that he can run the model exclusively with his own data.

Third, according to the last thesis it will be neccassary for model acceptance that inputs and outputs of the model do correspond to available company data.

Last not least success of model applications will significantly depend on appropriate management involvement in all phases of the model building process from model conceptualization to model implementation. Managers participating in model-projects should come from those hierarchical levels and functional areas where they are responsible for making and executing decisions that are supposed to be supported by the model.