Model Management by Means of Computer-Based Information Systems in Managerial Contexts

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ABSTRACT

Models and computer-based information systems frequently meet resistance and suspicion by management, because they often do not meet the knowledge demands of management in a company. Solving this problem requires approaching modelling and information systems development as a management discipline. This discipline involves the activities of developing, maintaining, effective using, and conserving of models and systems. The paper concludes with a normative view of the relation between management levels and model management activities, and considers the possible use of computer-based information systems for effective model management.

THE PROBLEM

Modern organizations are confronted with increasing managerial complexity resulting from shorter product life cycles, increasing market demands, increasing organizational size, increasing capital intensity, and changing laws that demand a reduction of environmental pollution and market liberalization. This growing complexity has traditionally been met by allowing slack resources (e.g. large work-in-process capital and stocks) and independent tasks or working groups (Galbraith, 1973). More recently, managerial complexity is also coped with by the formulation of specific company strategies aiming at a reduction of the amount and diversity of markets and products to be managed (e.g. focus and niche strategies, see Ansoff, 1987; Porter, 1985) and aiming at outsourcing of company divisions.

The subject of this paper is to explore the strategy of increasing the existing information processing capacities in organizations. This interest is motivated by the growing technical opportunities of computer-based information systems in recent years (lower priced and improved user-interfaces) and developments in human intellectual capacities to make sense out of data, e.g. as a result of improvements in system dynamics (Senge, 1990; Vennix, 1990). The problem with both developments is that they frequently are **means and technologies without a clear link to managerial needs.** When not first seriously considering what managerial requirements both can meet, and where its limits are, history will probably repeat the well known problems with M.I.S. and Operation Research, which both overshoot demands and pretended much more than what could be considered realistic (Ackoff, 1967 and 1979).

The purpose of this paper is to derive **criteria** from insights in business management, by which we can assess the **value of models** and the **contributions of computer-based information systems** for management. To avoid a technology push, I will first describe management types that explain different model needs. Second, I will investigate the possible role of computer-based information systems in management (development, maintenance, use and conservation) of models. Both discussions will converge to a normative view of types of models and computers for different management levels.

MANAGEMENT TYPES AND THE NEED FOR MODELS

Because of their ability to assess problems and find means-ends relations in a systematic way, models can be of much value to management. The actual use of the models is, however, highly dependent on their shape (mathematical or qualitative, complex or simple, formal or informal). Different types of management require different types of models. Strangely enough, no explicit consideration about the relation between management types and the shape of models is known to me. Therefore, I will first describe a typology of management and then explore its consequences for models.

1. Typology of management.

The most well known typology of management consists of a distinction between strategic planning, tactical management, and operational planning and control (Anthony, 1965). Strategic management is concerned with the definition of company goals, policies and general guidelines charting the course of the organization. Tactical management is concerned with the acquisition of resources, the formulation of acquisition tactics, determination of plant locations, and the arrangement and monitoring of budgets. Operational management involves effective and efficient use of existing facilities and resources to carry out activities, and monitoring and control of activities in relation to precisely formulated targets and (budget) constraints.

2. Strategic management and models.

When formulating organizational goals, management aims at prescibing what the company should do and what should be like for staying viable. This idea generating process mostly uses only implicit models about goals and means. Sometimes, like in Delphi-sessions, such a management process is well organized and specifically aims at finding consensus among its participants (Linstone and Turoff, 1975). This can be done by first finding consensus about the main factors at stake (definition of an idiom, vocabulary) and then second, members can start discussing relations between these variables. One step further, people can try to quantify these relationships. At the strategic level, however, models stay quite soft and not much effort is done in making the models very precise. The most important thing at this level is finding a common language which is politically acceptable (De Geus, 1988).

The emerging model must be motivating and directing people in the organization. Because models at this level stay rather imprecise (frequently with very imprecise definitions), they are flexible enough to be used for legitimation or explanation of actions and they are sometimes improved after reflecting on actions (Mintzberg, 1987). Alternatively, many business scientists have acquired knowledge which, when used well, improves the chance for developing effective plans and strategies and making the organization more proactive as well (Ansoff, 1987; Porter, 1985; Buzzell and Gale, 1987).

Besides these more or less scientific tools, also much information from informal media, news papers, literature and intelligence services could be used. It is necessary to have creative minds which connect all these impressions and make sense out of them with relevancy for finding a way the company should go. In this case, management is clearly rational as well as intuitive (Mintzberg, 1976).

System dynamics modelling is very useful for strategic management, because it is a means for organizing ideas in a systematic way (from very soft to very mathematical) and it supports the understanding of unintended impacts of policies (Vennix 1990). One example of this way of reasoning is given by Senge (1990: 99-100) in an assessment of quality circles. Senge states that quality circles were initiated to improve problem solving by means of open communications. Open communications, however, were regarded as threats to traditional union-management relationships, because they were inconsistent with adversarial attitudes of unions to management and were a threat to management's uni-lateral control. This means: the more successful quality circles are, the more resistance they will meet, possibly leading to their failure at a later stage.

System dynamics models for strategic management will mostly be very soft, having no explicit measurements of variables and no estimation of parameters. This type of soft modelling (Checkland, 1981) is precisely what is needed for effective strategic management.

3. Tactical management and modelling.

At this management level, many models are developed and improved on the basis of experience. Business Science Schools are developing ideas especially in this area; e.g. econometric models for planning fund needs (e.g. Du Pont analysis described by Weston and Brigham, 1979; M. Aiso, 1973 for an econometric approach to financial forecasting). Many quantitative variables are involved here. Just to mention a few: interest rates, inflation, growth expectations of production and markets, need for capital and people, fiscal policy with respect to interests, dividends, taxes assets etc. On basis of these variables, one could develop a model with which predictions can be made about fund needs and determine the best type of funding (loans, stocks). These models can be used many times with some adjustments on parameters involved (interest rates etc.).

For budgeting many models can easily be developed by means of a spreadsheet. Moreover, one needs a systems for evaluating budgets and supporting cost accounting, which contain a model with process variables to be measured, goals variables and analysis tools for comparing performance against agreed-on norms (c.f. Lawler and Rhode, 1976; Hofstede, 1981).

The determination of plant locations, contains decisions that can be supported by models as well. Important variables are: human resources available in the neighbourhood, availability of transportation and other infra-structures, availability of mineral resources, fiscal policy. political stability and support from (local) government.

New products must be developed, produced and marketed. These activities require large sums of money, with sometimes an uncertain contribution to a company's profits. In this situation, market information is mostly outdated before the product comes on the market. Therefore, a more long-term view is required, in which characteristics of the aimed market(s) are systematically linked. This would probably lead to a more or less qualitative view, containing ideas about cause-effect relationships.

At this level of management, system dynamics models can be helpful for assessment for decisions. One example of this kind is given by Senge (1990: 316-320). A computer company had a very effective sales group, realizing each year a 20 % growth in sales. Therefore, each year more salesmen were appointed. Each year. the growth in sales personnel was realized by hiring experienced people from other companies. At a certain moment, there were not enough experienced people to get from competitors. The policy of personnel growth, therefore, did not work any more. The company had to start training programmes for junior salesmen, led by seniors. The last group was not motivated for this teaching job, because they received the main income from the contracts they realized. The company had to chose between a different payment system for seniors or to decide to restrict growth ambitions. Just hiring more junior salesmen would only lead to more management problems for the sales division and could harm the reputation of the company.

Whereas at the strategic management level especially soft models were proposed, at this management level more formal and quantitative models are applicable as well. I call these model medium soft/hard.

4. Operational management.

This management level is concerned with the effective and efficient use of existing facilities and resources within given budget constraints. The essence of models at this level is to precise the definitions of performance indicators, measurement instruments (for providing feedback information) and ideas about effective actions to adjust behaviour. The model functions as a rigid set of rules and is

very far from the dynamics described earlier. Functional organizations with stable environments do not suffer much from the rigidity of control systems. However, when more dynamics in organizational environments exists, the organization can lose contact with its environment as a result of the inflexibility of the steering models applied at operational planning and control. Feedback should be applied to the principles of management (theory) which are used at this level and are imposed by tactical management. System dynamics brings in important insights which should be added. It is not so that the implementation of these dynamics is only computer-based. Systems around the control system are essential for providing people with the necessary feedback. These "infra-structural" systems can consist of open interactions among people to find better ways of learning, a management style that supports learning and that is not based on uni-lateral control, a culture that aims at mutual support and responsibility for the common goals of the group and a political atmosphere in which class struggles are made subordinate to company performance should be created (cf. Argyris and Schon, 1978).

In an insurance company, management was based on the principle of hierarchy. This meant that reports were sent upward in the organizational hierarchy and inspected by management. Sometimes actions were undertaken to motivate people and to adjust organizational behaviour. This way of management did not fit with the view of the new president of the company. He suggested that the company should become more flexible and more people should be concerned with management issues. Therefore, a project called "MIS" was set up with the aim of measuring performance of people and divisions. The information from this system has become available for division presidents and CEOs. This meant that division presidents had access to data about their colleagues as well, which motivated division presidents to be knowledgeable about data from their own division. In meetings of CEOs with division presidents, performance problems were discussed on basis of the data. The open discussions were not only a control on what is happening, but also led to supporting each other in finding solutions. In this way mental models received many new useful ideas never thought about in the specific division.

In relation to the other management types these models are very quantitative, formal and precise, and are called hard models. However, technical they may look like, they do not make human and social processes entirely obsolete.

COMPUTER-BASED INFORMATION SYSTEMS AND MODEL MANAGEMENT

In the previous section, the idea of different modelling needs related to different management types has become obvious. Now, I shall study the role of computer-based information systems in these **modelling** processes. The modelling process is aiming at supporting management. This can only be realized when well-managed, leading to high satisfaction of the model user. Analogous to information systems management, one can describe four functions in model management: **development, maintenance, use and conservation.** The development process is well described in the literature on information systems development and modelling. When finished, the system is said to be installed or implemented. This means that it should be ready for use, which implies that it should be conserved and available. Additionally, it must be maintained, meaning that it should be improved when required. When costs for maintenance are too high in relation to the user's satisfaction, the system or model should be dismissed and the model management process can start again with developing a new model. In the next section, I will explore these roles for model management in relation with computer systems in more detail.

1. Development.

Especially in the area of strategic management, the development of a model is important, because the process of model development is recognized as an important learning result. When the knowledge is acquired, the model is thrown away, because strategic management processes are mostly non-

repetitive, aiming at finding structure in fuzzy problems and agreeing on the way the problem(s) should be perceived. Computer systems can be supporting this management level in three ways:
1. Use of *existing external systems (data and models) by which comparisons with other companies are possible.*
One example of this kind is PIMS (Buzzell and Gale, 1985), a database containing data about competitive positions, market characteristics, and capital and product structure. On basis of a large database with market choices and business results of over 3,000 companies and strategic business units, an econometric model has been developed with which data of a specific company subscribing to PIMS, is compared with others and analyzed (anonymously). The aim of PIMS is to find the critical success factors which are applicable to the company in its specific market and situation.
2. *Frame works for structured thinking* at the strategic level.
An interesting example of the support of structured thinking is developed in Ansplan, a software package by which management thinking is organized by prompting the right questions and issues in a systematic way (Ansoff, 1986). One part of Ansplan consists of the Strategic Position Analysis, which is split up in an analysis of market attractiveness and an analysis of competitiveness. In the attractiveness analysis predictions of demand and profits are made on basis of three methods:

- extrapolation of historical developments.
- developing expectations under "stable" market development. This means that changes that will impact on success and that certainly are going to happen are also considered.
- developing expectations under "turbulent" conditions. Here the chance element is taken in consideration and optimistic (opportunities) and pessimistic (threads) scenarios are developed.

The other part of Ansplan supports assessing strengths and weaknesses of existing human resources, company competencies and other company assets. A comparison between market developments and organizational strengths and weaknesses leads to the description of an organizational strategy.
3. Tools for organizing thought: *System dynamics modelling.*
Whereas PIMS is very useful for comparing the organization with others, Ansplan has the capability to develop one's own ideas in a systematic way. Nevertheless, both use many presumptions that are not always regarded as relevant. Especially, when cause and effects, or means-ends relationships, are considered, PIMS is restricted to the economic variables only, whereas Ansplan does not explicitly support thinking in terms of means and ends. The importance of system dynamics is that it does not requires heavy presumptions for management, except the idea that management is based on a theory of actions that involves thinking about feedback processes, functions and dysfunctions of possible policy alternatives. When companies meet disastrous environments, e.g. the oil crisis in 1972, new ways of thinking must be developed that can cope with situations never encountered before (cf. De Geus, 1988). Our knowledge and experiences, then can act as conditions making things even worse. In this kind of situation brainstorming and Delphi-research are important processes in the board room.

Computers can support these processes with providing flexible tools for the organization of thought only in terms of logic and not of assumptions. One of these tools is STELLA, which enables the flexible development of system dynamics models (cf. Vennix, 1990: 52-54 and 223).

In development processes, ways of reasoning are invented for structuring perceptions. This is typically one of the major activities of strategic management. Models and model development tools must, therefore, contain a minimum of presumptions, or must have gained a superior high reputation, which also could act as a legitimation for action (e.g. Ansplan and PIMS). Also in the case of reused models the relation between management and models is very loose, leaving management with much tasks in thinking and deciding themselves.

2. Maintenance.
At the strategic management level, models are used once for finding a way of thinking about the problem at stake. The discovered method for thinking is institutionalized in data-gathering and analysis

departments or functions (cf. De Groot, Waalewijn, De Wolf, 1989). At the tactical management level, complex problems having sometimes a repeating character, are handled, and it is worthwhile considering to keep a model and do research on it to improve it as well. Two types of maintainable knowledge are applicable here: quantitative types (based on statistics, mathematics and econometrics) and qualitative types (based on knowledge based systems).

Quantitative models.
PIMS is again a good example for a quantitative model here. Knowledge from economics is formalized in an econometric model and parameters are estimated on basis of the data received from the 3,000 applicant companies. The Strategic Planning Institute now maintains the model and provides individual companies with information about their position in relation to other companies via the model (anonymous of course, and with the payment of an annual fee).
Some companies develop their own models for management. One case I met in a Dutch University where the financial management office developed a model to distribute money among the several faculties in a quantitative and precise way. In The Netherlands, it is generally so that the government pays most funds for universities. The sum of money is applied as a lump sum, so that the university board can apply its own policy to distribute it. The model was used as an instrument to make discussions less political and speculative and make budget allocations more precise and predictable. The result was that the model maker was asked each year to add more variables and parameters, so that the model is so complex now that only a few insiders can validate the results and be serious participants in the discussion.

Qualitative models.
Qualitative models can have a very soft shape. At the moment knowledge engineers are studying the application of computers for maintaining qualitative knowledge. Some major improvements in the field of the application of knowledge based systems for managing manufacturing are mentioned by Kerr (1991). One of the basic features of the systems Kerr studied was that the principles in which a production process should be performed, can be formalized in so-called production rules. This means that one can define precisely which substances should be added to the process in what quantities and proportions. This has large implication for the planning of procurement, stocks and supplies. Moreover, the implications of market strategies can be passed on in terms of needed capacities. Essentially, the models developed are maintained not only because they are programmed, but also because engineers and managers have access to them, can verify their validity and improve them when necessary.

Models at the tactical management level have a rather complex, formal and quantitative shape. However, they are not used without a critical view and only when applicable. Own experiences and new insights must be added to the model, and therefore (like a good computer based information system) it must be open for maintenance activities.

3. Use.
At the operational management level, processes are monitored by comparing processes and activities with norms. The norms are chosen on the basis of a theory of action, which management thinks will give them most success. Therefore, the norms and the ideas behind them are a frame of reference by which actions and data are interpreted and management actions are motivated. This frame of reference is of course constrained by the general policy and objectives defined at the strategic and tactical management levels in the organization. Again one could distinguish quantitative and qualitative models.

Quantitative models.
Operational managers are frequently given some targets and short term goals. These are mostly defined

in a precise quantitative form, e.g. the production of 1,000 computer mother board next week. Performance control is simply the comparison of this norm with actual performance at certain point in time. Nevertheless, there is more at stake. Knowing that a performance standard is not achieved is only the start for finding out means how this problem can be solved and how management hypotheses should be changed. It is sometimes very difficult to find the roots of the problem, because information can be hidden for management, and there is no open learning orientation (Argyris and Schon, 1978). Besides the organizational changes required for effective learning, also system dynamics modelling tools can be useful for analyzing the situation and for finding the roots for the problems discovered. For instance, system dynamics models are useful for extrapolating the consequences of not meeting deadlines and from these insights and consequences, alternative actions can be found. The organizational techno-structure can be useful in supporting the development of models and ideas for solutions (Mintzberg, 1979). They are also the guards of models and knowledge for the problems which are not used on a daily basis.

Qualitative models.
For analyzing the roots of problems and actions to be taken, the use of knowledge-based systems is growing in importance. As stated before production rules can be formalized and become part of an expert system. Coupled with a monitoring system, analysis of problem causes is possible and actions can be triggered. In monitoring of chemical processes, this can be part of the process control system. In manufacturing it can be added to existing production planning and resource planning systems like MRPII (Kerr, 1991). This means that computers are used as instruments for the interpretation of data. For developing such models and systems, a clear view must be available of the production process and about factors influencing its performance. Also feedback loops must be defined. Systems Dynamics then is an integral part of systems development and the way processes are actually controlled.

Especially at the operational management level, hard models are introduced to be used not too critical. Even not applying them could damage the consistency of management. This does not mean that managers have no decision discretion any more. Applying one model does not mean that only one solution is possible. Use of the systems applicable here (be it MIS, DSS, MRPII or what else) is highly compulsory at this level.

4. Conservation.
Organizations always are in a tension between renewal and reusing of solutions. From one perspective (efficiency), it is not smart to regard all problems as unique and, thus, having to reinvent solutions. Therefore, it might be useful to conserve knowledge generated from experience and earlier research in models, knowledge bases and data bases. Conservation can be realized by giving specific organizational units this job. In strictly functional organizations this task is (implicitly) allocated to the technostructure (saving knowledge about technology of production in the shape of soft or hard models) and the support staff (saving administrative data about specific cases, aggregate or individual) (Mintzberg, 1979). Besides, much of this knowledge can be saved on computer systems in model bases and knowledge-bases (saving production rules, recipes etc.; cf. Kerr, 1991). When these models and knowledge bases are not used frequently (especially in case of tactical management), knowledge about them starts to erode, leading to underutilization of existing knowlegde. In this case, internal consultants in the technostructure, the support staff of the organization, or specialists within a functional unit or working group, could act as model librarians and consultants. The model consultant also should make models available for organizational groups that have not been involved in the development of the model, or have never encountered the related problems before.

The conservation of models can be very effective and efficient at the operational management level because the same models are used on a very frequent basis in recurring decisions. At the tactical management levels, model conservation is useful, because of the costs of developing them anew. As

stated before, the model should then be open for amendments and improvements. At the strategic management level, model conservation is frequently outsourced and done by highly respected institutes that also take charge of improving the models on basis of new scientific insights.

However interesting the subject of model conservation may be, some warning is necessary because it could easily lead to a conservative mind not adapting to new and future problems. Therefore, a system dynamic approach to knowledge conservation is absolutely essential for keeping a critical view on the impact of historical solutions for the future.

SYNTHESIS

It was suggested that strategic management uses primarily the model development activity, with specific computer support. At the tactical level critical reuse of models is proposed, demanding model maintenance activities and models that are open for maintenance. At the operational level compulsory use of models is proposed. The conservation activity is mainly outsourced at the strategic application field, conserved by specialists in the technostructure and support staff of the organization at the tactical application field, embedded in computer application that are frequently used at the operational management level. These propositions are summarized in next table.

Manage ment level:	Model management activity			
	Development	Maintenance	Use	Conservation
Strategic	Soft modelling. Computer support by Stella, Ansplan, PIMS	1.	5.	Outsourced conservation by highly respected institutes.
Tactical	2.	Medium soft/hard models. Computer support with DSS (model bases), Master planning.	3.	Moderate conservation, e.g. by specialists in technostructure and support staff.
Operational	6.	4.	Hard models. Computer support: DSS, MIS, MRP, Knowledge-based systems.	Much conservation, e.g. by DSS and knowledge based systems.

Table I: Normative relations between management level, model management, model type and computer use involved.

The table describes a **normative view** on model types and computer use for different management levels. Diverging from these norms (the empty cells 1 through 6) will likely lead to the same problems O.R. and MIS have met in the past, because of a discrepancy between their features and management demands. I will shortly describe the contents of these open cells.

Cell 1. Medium soft/hard models used for strategic management can likely lead to resistance of use, because strategic management will then feel too restricted by presumptions they do not agree or which they find irrelevant.

Cell 2. Using too soft models for tactical management, will not give them enough constraints (e.g. organizational goals and directives). They will feel uneasy with the fuzziness of the models and feel

unconfident for using them during decision making.
Cell 3. Using hard models for tactical management will lead to problems, because tactical management will feel that the model is too formal and overprecise.
Cell 4. Applying medium soft/hard models to operational management will lead to failure because the model does not give the support for making the precise decisions needed at this management level.
Cell 5. Hard models for strategic management are overshooting, discussing issues in a too precise and formal way and therefore lead to severe resistance and disqualifications of the supplier or consultant proposing it.
Cell 6. Soft models for operational management will lead to serious disqualifications of the consultant or supplier again.
Cells 5 and 6 are very obviously wrong. Cells 1 through 4 are more difficult to assess, because some models and systems can be interesting for more then one management level. Besides, it needs a very precise understanding of the way management is thinks and works.

CONCLUSIONS

In this paper I have described a link between modelling, computer-based information systems and managerial needs for both technologies. The resulting insights lead to some propositions that could explain historical problems in this area and give ideas for avoiding them in the future. Nevertheless, for this proposed model counts the same as for all other models: it should not only be used and conserved, but also be maintained and if necessary be replaced by better ones. For instance, one could study in more detail the organizational environmental conditions (culture, management style, market environment) involved with effective model and computer use in a management context. What should be aimed at is not the optimization of the means (models and computers), but the optimization of the interface between the means and the organizational goals.

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