Der Rütli Management Simulator - a new concept in system dynamics based management flight simulators

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Abstract

A new management institute, Der Rutli Fuhrungskrafteseminar, was established in Germany this year. Its leadership is committed to the teaching of management based on the principles of System Dynamics. As an element in the promotion of these ideas, a new System Dynamics management simulator has been developed. There are several ways in which this simulator constitutes a new concept in management training and research. In particular, we have addressed the issue of teaching policy design, supplemented by decision making.

The properties of the simulator originate from the characteristics of the underlying software. Consequently they can be applied generally to any system dynamics based management simulator. In particular, the simulator;

(1) the simulator is a multi-group simulator utilizing any personal computer network that supports MS Windows;

(2) The simulator allows the user not only to submit decisions to the server that calculates and returns a new state, but also to formulate and try out, on their local computer, their own strategies over any strategic horizon;

(3) the simulator gives the users access to;

-the underlying simulation model (to an extent determined by the administrator);

-The tool by which the simulation model was built, allowing the users to formulate and test their own dynamic hypotheses.

In this paper, we describe these characteristics of a new generation of simulators for management training, illustrated by Der Rutli Management Simulator, and we discuss the potential implications of taking advantage of these characteristics.

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ModellData AS, the Department of Information Science, University of Bergen, and Stord College of Education, Norway, have developed a number of interactive, computer-based learning environments for system dynamics modeling and simulation. Applications range from a relatively general training simulators for Der Rütli, a German management institute, and the Norwegian Naval Academy, via production and market management simulators for Norwegian enterprises in a variety of domains ranging from the aluminum industry, via fish farming, and on to tanker, helicopter, and airplane simulators for pilot training. These applications have been developed using the associated MS Windows™-based modeling and simulation package Powersim™.

Powersim™ by itself is a general purpose learning environment for the investigation of complex, dynamic systems. In this paper we will focus on the general principles of its application to specific domains and, for now, we reserve the concept "simulator" for that purpose. The system dynamics approach implied a series of requirements that are generally not satisfies by current, computer-based learning environments., often called "management flight simulators" (Morecroft et al. 1992). In this paper we outline some of these requirements and document how we use Powersim™ in the case of Der Rütli Management Simulator to meet these requirements.

The system dynamics approach supports the management of dynamic systems at all these levels by helping us understand the intimate relationship between structure and behavior in such systems. The higher levels of administration on which we operate, the wider is the time horizon, the more complex are the systems in question, and the larger is the need for an approach of this kind.

Although system dynamics based learning environments can be used to learn domain-specific decision procedures, the purpose of developing and using such environments is more general. When managing dynamic systems, the implementation of operating procedures should be thought of as a result of a strategy formulation (Forrester 1980, 1986). A strategy is composed of a well-balanced set of domain-specific policies, such as production, inventory, marketing, sales, personnel, and capital management policies. Moreover, there is the tactical selection and adaptation of policies leading up to operative decision procedures. The challenge we face is to design learning environments that allow us to design and test policies before they are implemented. In this paper, we describe how this challenge has been met in the case of Der Rütli Management Simulator.

Before we focus on the novelties of the concept "computer-based learning environments" supported by Powersim™, we will briefly describe the model underlying this simulator and the seminar which constitutes the context in which the simulator is being utilized.

The model

Sectors

The model consists of four parallel production-supply-lines satisfying orders that originate in a market and is adjusted in accordance with the level of saturation in the backlog- and supply-lines. There is one supplier of raw material, four producers, four groups of retailers, each associated with a producer, serving two market segments, a small special market segment that prefers quality to low price, and a large mass market segment that prefers low price to high quality Exhibit 1.

When used as a management training simulator, the trainees act as one of the four producers. An example of the kind of product sold is mid-sized cars used in the mass market as the consumers' only car and in the special market as the consumers ' second car.

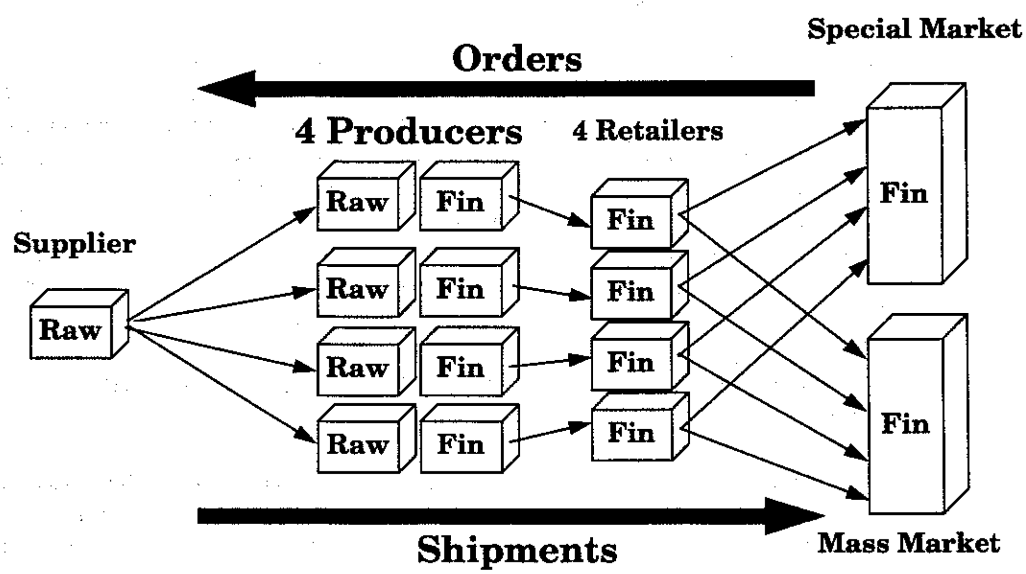

Exhibit 1. Inventories and supply-lines of raw material and finished goods.

The volume produced and shipped downstream is determined by the order flow upstream, restricted by production capacity, and subject to inventory and backlog adjustments. Capacity (capital and work force) is adjusted with a delay to satisfy demand. There is a full financial sector. The effective value of the firm (growth and profit taken into consideration) determines the availability of loans and the unit gain from issuing shares. The liquidity feeds back to impact investments, acquisition, production, marketing, quality upgrade programs, and payments.

The product is characterized by its functionality, life expectancy, image (added value through packaging, advertising etc. that position the product in the market), and price. To increase quality, capital may need to be retrofitted and the work force may require training. This quality upgrade program eventually results in production, marketing, and supply of better products. The goal of this program is determined by the target quality of the product to be produced. There is a delay, determined by the investment in the program. The effect of those investments is marginally decreasing. Therefore, to speed up the program, implies exponentially increasing costs. To adjust more quickly to the goal, capital can be depreciated at a higher rate than normal. There is co-flow of product quality originating from production that eventually causes the installed base in the market to attain the produced quality.

The market responds to its perception of posted, effective prices of the product. It is characterized by a constant elasticity of demand and a constant elasticity of substitution. The effective price is a measure of the market value of the product, relative to its posted price.

The perception of prices and product characteristics takes time. The perceived functionality translates the perceived price into a perceived net value, onto which we may add a value of perceived image. When the perceived life expectancy is taken into consideration, this transforms into a perceived value-rate, i.e. value per time unit, which constitutes the basis for product comparison and substitution.

Subject to discrepancies in the elasticity of demand to functionality, life expectancy (interest rate), and image, the two market segments may respond differently to changes in price and modifications in product quality.

The market can be affected by delivery delays as well as advertising. The sensitivity of the market segments to advertising may vary. Assuming no advertising, the perception of functionality and life expectancy drifts towards the average real characteristics of the products that constitute the installed base and the perceived image erodes. Advertising may change these perceptions and the speed with which they are obtained. The effect of investments in advertising is marginally decreasing. Therefore, to speed up the effect of marketing, implies exponentially increasing costs. Moreover, there is a measure of credibility, depending on the advertised product qualities as compared to their real characteristics. If a product is advertised as better than it actually is, then the credibility of the company falls. In the long run, this reduces the effectiveness of investments in advertising. To restore credibility, a company must advertise the true product characteristics for a relatively long period of time.

The model typically generates business cycles and provides the producers with limited control over the market, partly due to significant delays and partly due to the intermediate layer of retailers, represented by the model, that adjust backlog, inventories, and prices simultaneously in competition with each other.

Management; policies to be designed

There are altogether 6 policies to be designed -- characterized by 26 parameters. The policies focus on relative volume, quality, and rate of change of various processes. Associated with the panels applied to set these parameters is information of immediate relevance to the policy (Exhibit 2).

For the product, target attributes are set by the producers. So is the time spent on upgrading capital and work force to produce that quality. The trainees obtain an immediate estimate of the associated current cost per year and can adjust the policy accordingly. The time to depreciate capital can also be set by the producers, e.g. to substitute low-quality capital with new capital expediently.

The volume of production is determined implicitly by the producers through their inventory policies. The producer determines the target inventory coverage of raw and finished goods.

The market is influenced by the producer, indirectly through pricing and directly through advertising. To demonstrate the difference between operative and strategic pricing, we offer two ways to set the price (Exhibit 2). The price can be set unconditionally (upper panel). Current costs (unit raw material and production costs) are indicated as a platform for decisions. So is the is the average competitors price. However, these circumstances may change over a period of time and it is far more convenient and effective for the trainee to develop a general price policy.

The price policy available is determined as a weighed average between a profit-oriented policy and a competition-oriented policy (lower panel). On the one hand, the desired and the minimal profit fractions are set. On the other hand, the price, relative to the weighed average of competing prices is set. Then there is a possibility to negotiate between the two policies by assigning a relative weight to the competitive policy.

As for advertising, target levels for the perceived functionality, life expectancy, and image, and the time taken to establish this perception is set. Again, the consequent current costs are indicated immediately to allow for policy adjustments.

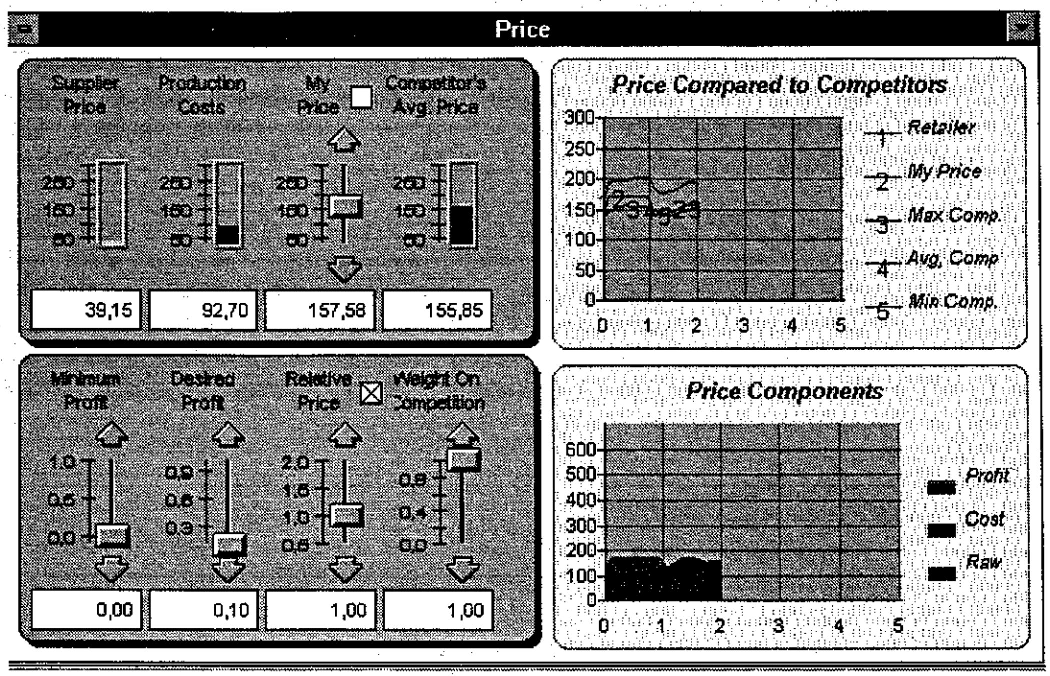

Exhibit 2: Operative and strategic pricing. Note the information supplied to support the identification of a policy.

Financially, the producer must determine the fraction of profit to be paid as dividends and must identify the borrowing fraction of any financing. Alternatively it must be determined what fraction to finance by issuing shares.

A typical scenario to be evaluated would be this: Suppose you plan to cut prices relative to the competitors, in order to increase demand and production volume. The assignment would be, in view of the expected reaction from retailers and producing competitors, to identify effective policies for inventory, quality, marketing, and finances that work in harmony with that price cut. Typically, a price cut will increase demand and, unless inventory coverage is cut, a significant oscillation that amplifies along the order- and supply-lines will result. Moreover, the liquidity will deteriorate, partly due to reduced income and partly due to increased investments as well as acquisition and operating costs. An aggressive marketing policy will aggravate the situation even if it grossly exaggerates product quality, because credibility is lost only gradually as the installed base increases. Quality modifications complicate the picture.

Clearly, such a price-move requires careful planning. Inventories should be built up in advance under sound financial circumstances, and the volume and timing of marketing initiatives should be well-adapted.

The seminar

Der Rütli Management Simulator is relatively complex. The model contains about 2.500 elements, in part distributed along 4 dimensions. For this purpose, the Powersim™ array capabilities are being extensively utilized. The model can easily be adopted to a larger number of products, supply-lines (producers and retailer-groups), product characteristics, and market segments (refer to the description of the model below). There are 137 parameters and graph functions available for the adaptation of the simulator to various contexts. In view of this complexity, the key to success is a five days seminar associated with the simulator. The seminar takes this form:

The two first two days, there is an introduction to system dynamics utilizing a series of replica of the submodels of the simulator. These models are open for inspection and we encourage the participants to familiarize themselves with these sub-structures and their resulting behavior. The panels used to run these replica, correspond to those of the simulator. In addition, there are panels for setting and manipulating the exogenous conditions under which the replica are being run -- conditions otherwise provided by the simulator itself. These submodels are;

1. Retailer and supplier
2. Producer
3. Order-line and deliveries
4. Supply-line and quality diffusion
5. The management of the quality in capital and work force
6. The price mechanisms
7. The market's perception of effective price
8. Marketing
9. Financing

Each submodel session includes an introduction to the practical and methodological issues addressed by the model, assignments to be solved using the models, free experimentation, and a summary of the lessons learned utilizing system dynamics to understand the underlying model structure and design matching strategies.

Having completed these sessions, the participants engage in a session on Der Rütli Management Simulator itself, run in a single user mode, i.e. against their own computer. This is to familiarize the trainees with the complete interface and the complexity involved when told to combine effectively a number of different policies.

The following two days, the simulator is run in a network whereby the participants can compete against each other (exhibit 3). We can set up four teams of competitors or simulate specific controlled strategies on an idle computer. The participants can enter a session at any point of time allowing us, for instance, to study the building of barriers against entry.

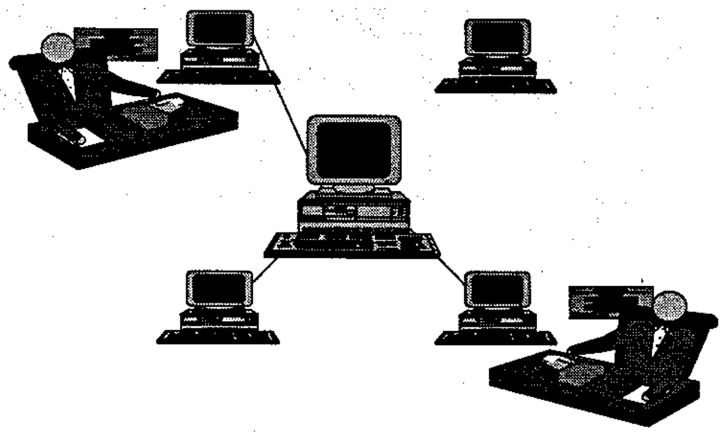

Exhibit 3: Two human competitors, a controlled strategy run on an idle computer, and one computer ready to allow a fourth competitor to enter.

The simulator

Transparency and modifiability; representing the integration of structure and behavior.

The learning-environment must effectively support strategic investigation, formulation, and evaluation. This implies that the model, embedded in the learning-environment, must be available for inspection and modification whenever required. Consequently, the learning-environment must offer a smooth transition from tools used to model and set up simulations in general to the kind of "management flight simulators" currently marketed, where the model is often hidden and where there is minimal support for anaylysis.

Users investigate the underlying simulation model of the learning environment by inspecting the structural assumptions embodied in that model and by utilizing a test mode to reveal their behavioral consequences. Using PowerSim™, we can open the model for inspection. We do so by iconizing views of the model to be opened by the user, the result of which is potrayed in Exhibit 4.

These model views can represent the model in the form of a stock-and-flow diagram (Davidsen 1994, Exhibit 2a) where the user is allowed to inspect the underlying equations. Also, the model can be represented in the form of a feedback loop diagram (Davidsen 1994, Exhibit 2b-c) and in the form of texts. Moreover, there are icons that can be opened to specify input or define plicies using slid-bars (Exhibit 2) or opened to study the resulting mo-el behavior.

To facilitate investigation, we integrate into the structural representation of the simulation model, whether in the form of stock-and-flow diagrams or feed-back-loop diagrams, ("live" graphs and/or numbers representing the model behavior. This is illustrated in exhibit 5, where we dynamically map the behavior of the supply-line onto a stock-and-flow diagram.

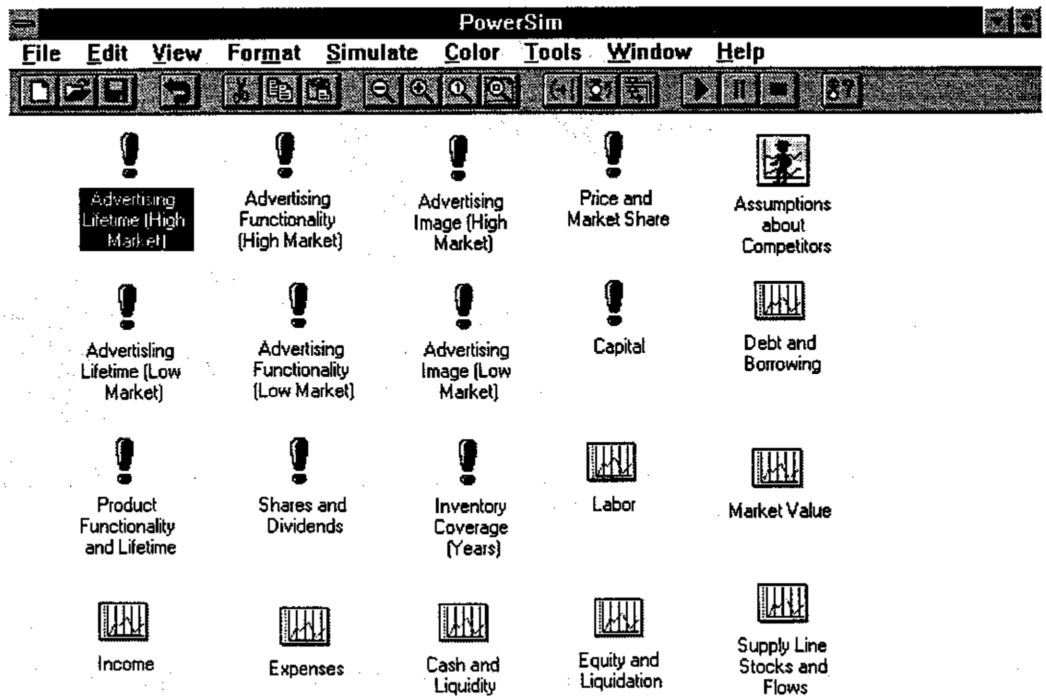

Exhibit 4: Der Rütli Management Simulator.

We can also embed such miniature graphs directly in texts (Davidsen 1994). Thus, using the graphical editing tools of PowerSim™, we let the structural documentation in the learning environment "come alive" during simulation. In that way, behavior is linked closely to the underlying structure and becomes self-explanatory.

Strategic formulations typically require strutural re-formulations of the model. To facilitate that, we can open windows on the underlying model that focus on policies to be designed by participants as parts of a new strategy (Davidsen 1994, Exhibit 6).

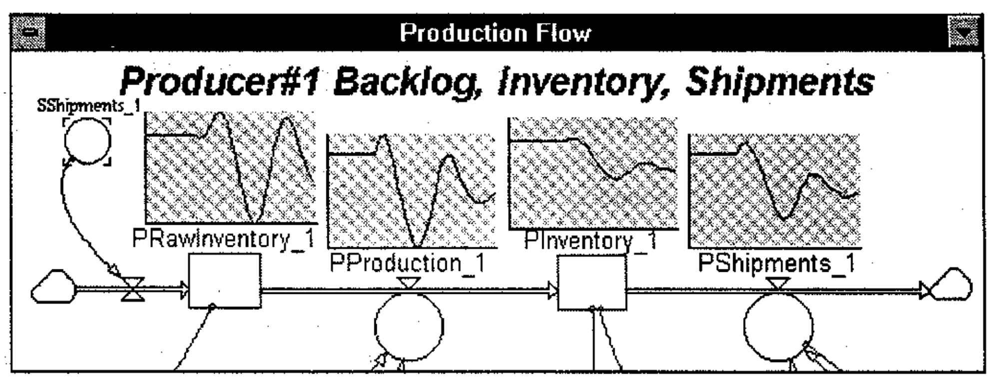

Exhibit 5: A structure/behavior graph.

Most importantly, Powersim™ is all the time available during the sessions. So are the replica of sub-models used in the introductory sessions. Thus the trainees have available to them the tool applied to create the simulator, and may experiment with turn-key models as well as with their own, self-made models.

Facilitating the interaction between operative and strategic modes of management.

Although presented as strategic, most simulation-based learning environments do not support the design and evaluation of policies and strategies. For an environment to do so, three requirements must be satisfied. The learner must be allowed to (1) investigate the underlying assumptions, (2) formulate alternative policies, and (3) evaluate these policies before deciding to continue. Moreover, this must be done repeatedly so that the experience gained from evaluating of a strategy, can form the basis for re-investigations, and the formulation and evaluation of alternative strategies. Current "management flight simulators" have not opened for an option whereby hypothetical strategies can be made subject to simulation-based evaluations, whereupon the simulator reverts to current time. Using PowerSim™, we have built in this capability in the Rütli Management Simulator. Thus we facilitate double loop learning (Senge et. al. 1991) implemented in the form presented in Exhibit 6.

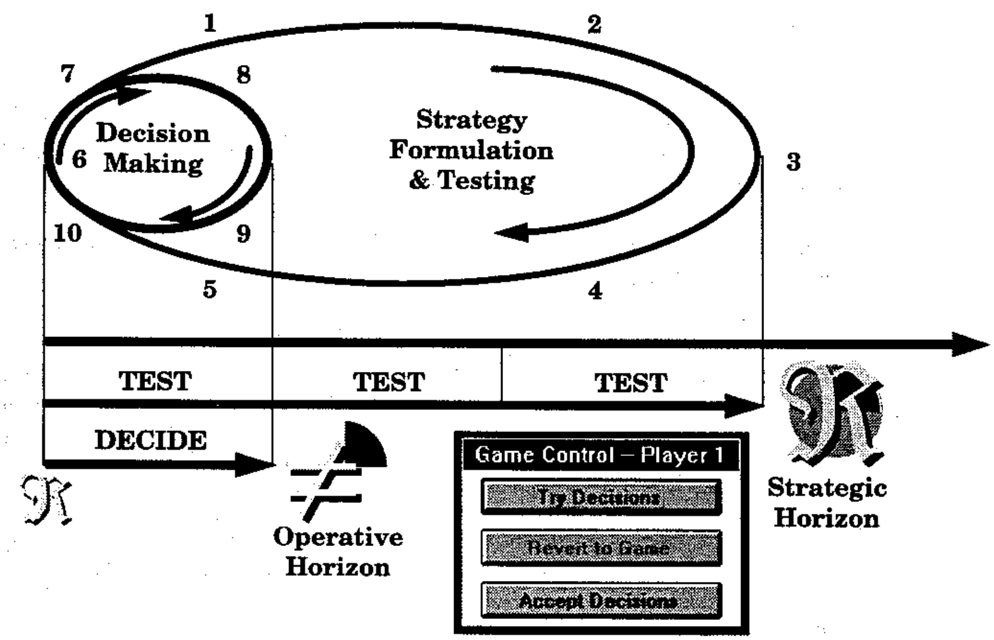

Exhibit 6: The two modes of strategic policy design and operative decision making.

There are, in other words, two modes in which the simulator can be run interchangeably: (1) an operative mode in which final decisions are being made and submitted to a model that responds with a state projection over the assigned operative horizon (e.g. one year); (2) a stategic mode in which stategies may be developed and submitted along with user-defined assumptions about the environment (e.g. competitors) to a model that responds with a state projection over the assigned strategic horizon (e.g. five years).

Computer-based learning environments should support off-the-shelf computer networks. The PowerSim™ software has been designed to do so. Consequently, the simulator may be run in a single-user mode, i.e. against a local computer, or in a computer network against other participants.

The procedure for running a management simulator designed in PowerSim™, is summerized in Exhibit 1, and is the same whether participants run solely against a local computer or in a network of computers. In the latter case, identical simulations models are stored on each of the local computers participating as well as on the server. The phases in the two modes of the simulator are as follows:

1. *Make assumptions about the environment*
One of the major challenges in the design of computer-based learning environments intended for strategic purposes, is the fact that, during strategy formulations, there is no competing environment available to provide input to the model. The participants are operating into the future, and must each make their own assumptions about the environment in which they are operating. In the Rütli Management Simulator, assumptions are made concerning the price, functionality, lifetime, and image of the products supplied by competitors in a market, and their corresponding delivery delays. A specific panel is designed for the participants to make these assumptions

A technique has beed developed that allows the simulator to choose between "real input" from a computer model or other actors, via the server, while in operative mode, and user-defined assumptions while in test-mode.

2 - 3. *Formulate and submit a strategy to the computer*
Secondly, the participants must formulate their policies. That is, in Der Rütli Management Simulator, set the 26 parameters that make up the price-, inventory-, quality-, personnel-, capital-, advertising-, and finance-policies.

Having done so, the participants press *"Try Decisions"* in a control panel to submit their assumptions and strategies to their local computer.

4. *Let local computer compute the behavioral consequences*
That local computer is now ready to project the model across the strategic horizon. The simulation can be made to pause at a certain frequency, under specific conditions or at the will of the participant so as to allow for the modification of assumptions or strategy.

5. *Evaluate effects of strategy*
Using a number of simulation reports, the participants can then evaluate the effects of their assumptions about the environment and their corresponding strategies.

6. *Revert to current time*
If desired, they can modify their assumptions and/or their policies, run another test, and through a systematic analysis of the results, decide upon a combination of policies. Or the participants may decide to go ahead and implement their strategy. In any case must their local model be brought back to current state at current time. To do so, the participants press *"Revert"* in a control panel.

7. *Formulate and submit an operative decision to the computer*
Having found a policy to be applied and reverted the model, the participants are ready to enter the operative mode. In accordance with their strategy, they then formulate the corresponding operative decisions that apply to the current operative time horizon.

This time they press "Make Decisions" in a control panel to submit their operative decisions to their local computer.
9. *Let computer compute the behavioral consequences*

In case the participants runs solely against their local computer, that computer simulates the consequences of all decisions across the operative decision horizon. In case a network is set up, the decisions are being transmitted to the server which awaits decisions from all participants and projects the model based upon these inputs. In that case, all decisions are being forewarded to all local computers to form the basis for updating the state of the simulation models stored locally.

10. *Evaluate effects of decisions*
Using the available simulation reports, the participants can now evaluate the effects of their collective actions and, when desired, reenter the strategic mode.

Networks of co-models

In most cases, we analyze systems into subsystems and synthesize models from submodels representing these subsystems. Using PowerSim™, we define these models in the form of co-models to be integrated in any super-model. Co-models are being interrelated using "chains" that indicate the transfer of variable values from one model to variables in any of its co-models in the course of the simulation.

We specify the synchronized simulation of all co-models in a main model -- just another co-model. For each co-model, we may define individual start and stop times as well as an integration interval synchronized with the one of the main model. In our design of learning environments, we make extensive use of co-models, beyond the plane analysis of systems and synthesis of models. Here are some examples:

We usually define the control panels and all reports in one or more co-models -- the most essential of which are often contained as part of the main model. Other co-models may be used to emphasize various aspects of the relationship between structure and behavior (Davidsen 1994). Note that we can define views that encompass a variety of controls and reports. Thus we can supply information, relevant to the formulation of a policy, in the form of numerical or graphical reports related to the control panel for that policy. In figure 2, for example, we indicated how information about current costs, historic competitors` prices, and historic price components are being used as a background for price setting.

We can also use co-models to initiate and phase out main models. a Navy project may consist of a 5 years construction and acquisition phase that partly overlaps with a 25 years operation phase, which ageing overlaps with a 5 year phase-out. The first five years period may be represented by one or several co-models that supply the main model with a fleet, initial supplies, infrastructure, trained personnel etc. of a certain quality that, in part, determines the operative characteristics of the fleet, represented by the main model. The final 5 years period is portrayed in a second co-model that gradually takes over and phases out all of the components listed above.

Moreover, co-models with longer integration intervals can be used to sample variable values from any model, and can typically be used to support or represent information systems with its biases and delays, e.g. a financial sector or a user interface. A model can also supply any of its co-models with empirical information -- one of which may compare this information with the sampled behavior of the simulation model.

Carefully defined and individually run co-models constitute an important educational resource. As in the case of Der Rütli Management Simulator, they can effectively supplement an introduction to the model as a whole.

In the case of applying computer networks, co-models are also being used to create an interface between the administrator of such a multi-user leariming envionments and the server model so that she can set up the environment with a well-initialized model and investigate the policies of all participants and their dynamic consequences. Other co-models are developed to form an interface between each of the participants and their local models. These interfaces filter out information that the participants should not share involuntarily, e.g. financial information.

Some features of PowerSim™ that facilitates an integrated design of models and learning environments.

The PowerSim™ software utilizes MS Windows™ facilities extensively. Consequently, we can easily custom design and organize our system dynamics models and learning environments using a variety of graphical tools supported by MS Windows™. A precise and consistent use of colors contributes significantly in that respect. For educational purposes, we can hide parts of the model by assigning the backgroud color to the symbols we want our students to identify on their own. Alternatively, we can use a "show what" menu item to hide any class of symbols in the model (levels, rates etc.) and in the learning environment (graphs, slide-bars etc.) (Davidsen 1994).

In some cases, we may want to prevent anyone from inspecting certain model- or interface-components or to modify such components. In that case, we can use a passworkd to lock the model and the associated environment in simulation mode so that no editing can take place. The same password can be used to gain access to the model, to disclose hidden components, and to modify the result.

PowerSim™ allows us to define models or model components as arrays. To do so is relatively straight-forward. Arrays are indicated by model components equipped with double border lines. Range variables with sub-ranges can be defined and utilized as index variables. A well-formulated grammar and a library of special functions help modelers define complex operations on arrays. An extensive series of consistency checks warn against and prohibit dimensional inconsistencies.

The library of special functions, consists of a set of sub-libraries and are open for user-supplied additions written in the form of dynamics link libraries (DLLs). Each simulation generates a new generation of results. These results can be saved automatically, enumerated, plotted and compared. Moreover the MS Windows™ technologies dynamic data exchange (DDE) and object linking and embedding (OLE) significantly enhances the possibilities to include easily retrievable references to externally stored and processed reference material (say, historic material) including interactive video footage and the activation of Powersim™ from other programs so as to e.g. create dynamic reports based upon simulations running in the background.

References

Davidsen, P.I.:" Perspectives on teaching System Dynamics. Coupling structure and behavior, annotating simulations, and supporting Just In Time Open Learning (JITOL).", Proceedings from the 1994 System Dynamics Conference, Stirling, 1994.

Forrester, J.W.: "System Dynamics - Future Opportunities", in Legasto, pp. 7 - 22, 1980.