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Learning to Cope with Complexity: Management Teaching Supported by System Dynamics Models

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Abstract

Coping with complexity is at the heart of management. As the environments of organizations have become more turbulent, the question how management can be learned and taught has grown in importance. Given this issue, case-study-based teaching has penetrated business schools all over the world.

The authors propose that

a) Simulation models are, in principle, a necessary and essential component for effective case-study-based teaching on general management, in many domains of operations and strategy;

b) System Dynamics models can and should play a crucial role to improve case-study-based teaching in these areas.

The first proposition is grounded in the Conant/Ashby-Theorem (Conant/Ashby 1981). The second proposition is based on the specific strengths of the System Dynamics methodology, which is particularly suited to the modeling of issues faced in managerial contexts.

In a cooperative venture between The Institute of Management at the University of St. Gallen, Switzerland, and BRB Consulting Ltd., Salisbury, U.K., a case study with a System Dynamics model implemented on the VENSIM software (from Ventana Systems Inc., Harvard, MA) was developed. The case was used in the context of a management course for approximately 250 business school students in their third year of studies. To facilitate the interaction with the model, an interface was designed, based on the SABLE software (from BRB, Salisbury, Wiltshire, U.K.). However, the students had access to the full model, including diagrams and equations. This paper reports on some of the experiences and insights gathered from this application.

1. Introduction

The essence of management is coping with complexity. As the environments of organisations have become more turbulent, the question how management can be learned and taught has grown in importance. Given this issue, case-study-based teaching has penetrated business schools all over the world.

However, this methodology is subject to limitations: In many instances, namely if complex issues of strategy or operations are at stake, it is difficult for teachers and for students to think through and assess the implications of the „solutions“ or courses of actions proposed for the problems under study. We shall consider three pertinent factors:

1.) The *complex interrelationships* of the essential variables, which constitute the issues at hand, tend to have counterintuitive implications (cf. Forrester 1971); intuitive problem-solving tends to be counterproductive (cf. Dörner 1997).

2.) A *lack of contextual knowledge* concerning the case under study or insufficient practical experience of students are obstacles which often preclude solid diagnosis and conclusions.

3.) *Deficits of conceptual knowledge or skills* are an additional barrier in many instances.

Consequently, ill-founded recommendations by M.B.A.-students on how to "solve" the problems posed in case studies are paramount. This has led to profound critiques of the case-study-method as such, which go as far as to question its usefulness altogether.[i]

Our aim in this article is to pursue further the question, how case-study-based teaching can be improved. We shall elaborate on how to support case-study-based teaching more effectively, with a particular emphasis on the use of System Dynamics models for this purpose. A report on a pertinent experiment realised with M.B.A.-level students, the results of which support our argument, will be at the core of our paper.

2. Propositions

We make two propositions:

1.) Simulation models are, in principle, a necessary component for effective case-study-based teaching on general management, in many domains of operations and strategy;

2.) System Dynamics models can and should play a crucial role to improve case-study-based teaching in these areas.

The first proposition is grounded in the Conant/Ashby-Theorem: „Every good regulator of a system must be a model of that system.“ This theorem, formally proposed and proven by Conant and Ashby (1981) has two implications:

a) It changes the status of modelling from optional to compulsory.

b) It implies that the results of any management process are essentially determined by the quality of the model(s) underlying it.

The second proposition is based on the specific strengths of the System Dynamics methodology, which is particularly suited to the modelling of issues faced in managerial contexts: The nature of these issues is one of dynamic complexity. System Dynamics, more than other methodologies, provides a set of principles and concepts, as well as powerful software tools, to model and simulate (many of) these issues efficiently and effectively.

3. System Dynamics Models to Support Learning: A Case Study on Case-Study-Teaching

In a co-operative venture between The Institute of Management at the University of St. Gallen, Switzerland, and BRB Consulting Ltd. Salisbury, Wiltshire, U.K., a case study with a System Dynamics model to support pertinent decision-making was developed. This case study is entitled *Saentis Airlines.*[ii] The subject matter is a corporate crisis of a regional airline. The task for students is to design a turnaround strategy for the firm in question.

3.1 Context

The case study was used in the context of an operations management course for approximately 250 business school students in their third year of studies.[iii] To facilitate the interaction with the model, an easy-to-use interface was designed. However, the students have access to the full model, including diagrams and equations.

3.2 Overview of the Model

The Airline Corporate Planning Model (ACPM) to support the case study is a relatively complex System Dynamics model implemented in VENSIM (cf. footnote 2) and made up of more than 1'300 variables (including subscripts). These were organized along a set of modules that incorporate the different aspects of an airline business from market to services to production, finance, logistics and organization (Figure 1).

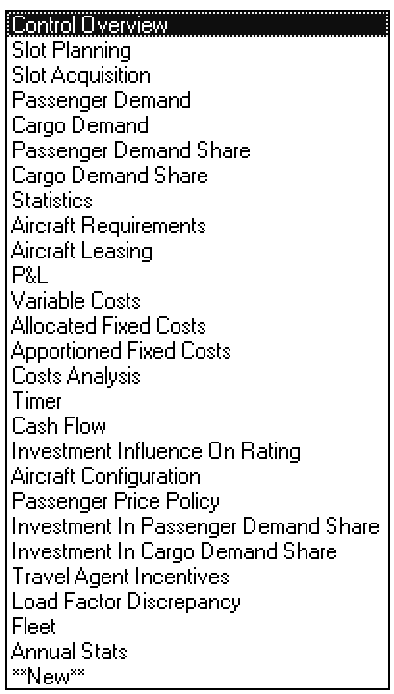

Figure 1: Modules of the Saentis Airlines model

The logic of each module is accessible on diagrams (“maps”). An overview of the Passenger Share module is given in figure 2.[iv]

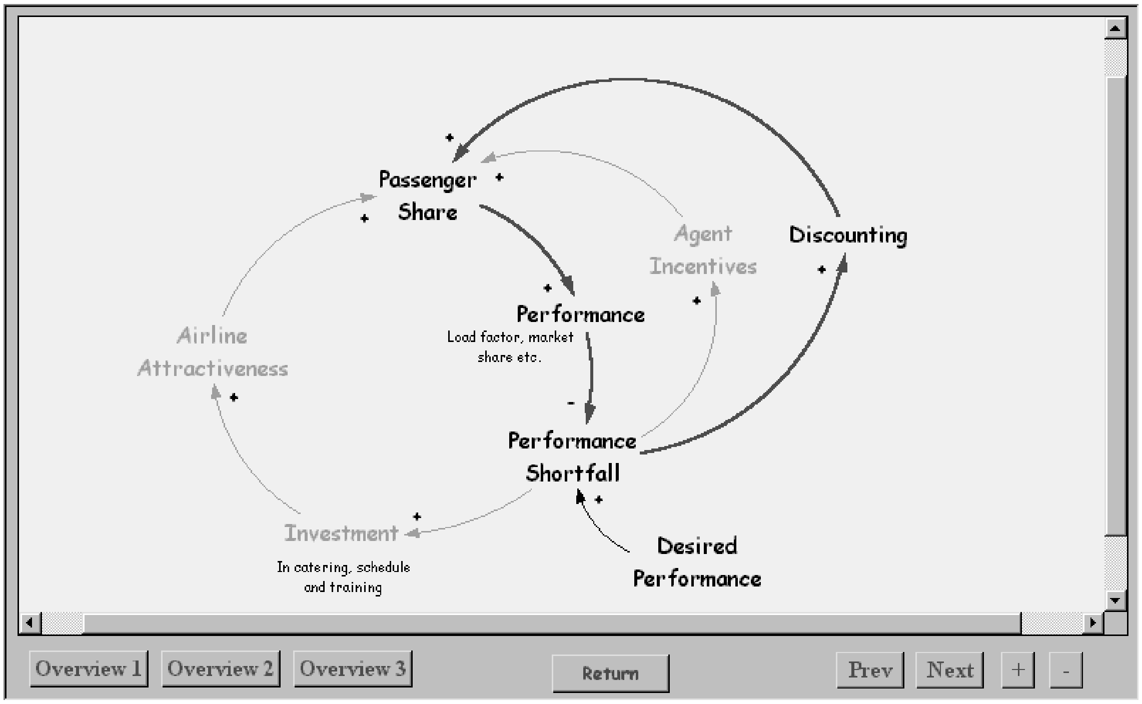

Figure 2: High level map of the Passenger Share module (example)

Given the nature of the airlines business, the comfortable subscripts facility offered by VENSIM was very useful to create the dynamic arrays needed to account for the complexity inherent in an airline, with different routes and different airplanes.

The Airline of the case study has only three airplanes and three routes, with a possibility to change routes or expand the network up to 8 routes. This simple structure, and the corresponding case of a small airline, was chosen in order to confront the students with a small business setting in which different kinds of decisions (market, product, finance) have to be taken together, by the same persons, not by separate departments. However, the ACPM would in principle enable easily to support a much bigger and more complex case.

3.3 User Interface

The user interface designed by means of the SABLE software (cf. footnote 2) was aimed at relieving the students from much of the heavy load of complexity residing in the model.

On entering the software environment, after an initial welcome screen, the user is faced with the main menu screen (figure 3).

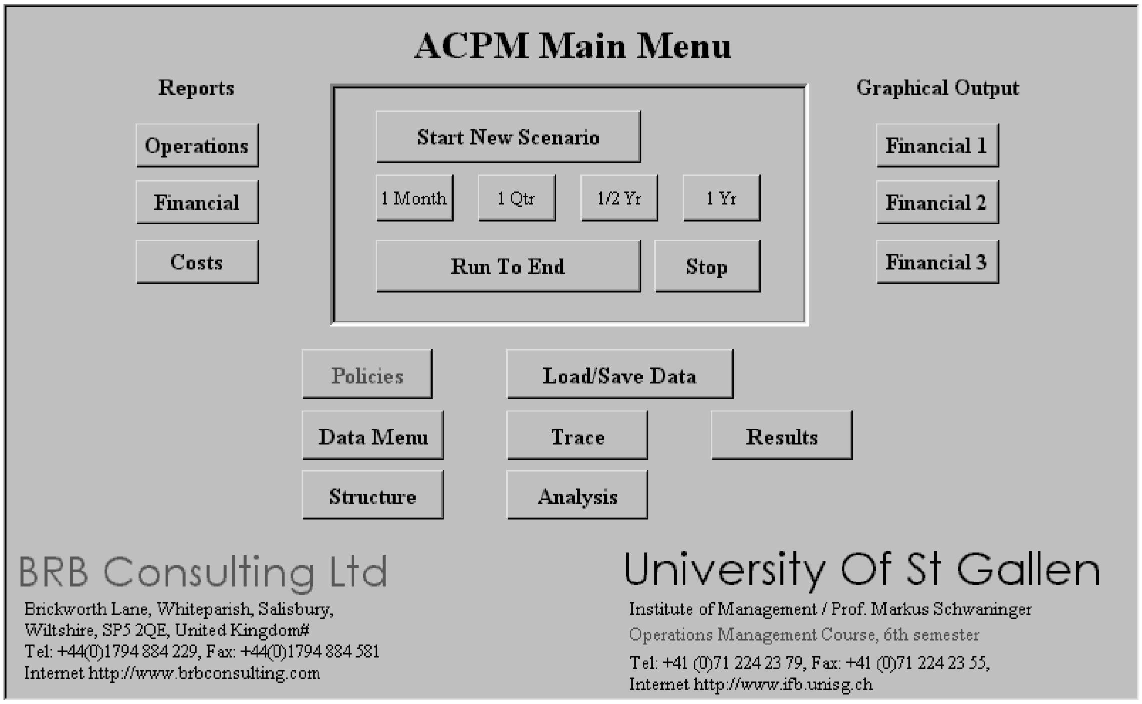

Figure 3: ACPM Main Menu Screen

The model can be run in both, a game mode, or a scenario approach with runs to end. In this application, the latter version was adopted. Individual groups of students designed their turnaround plans. They were enabled to simulate certain moves with their implications. To guide the student through the model, the user interface had to limit the available decision areas, in order to hide most of the overwhelming complexity of the underlying model. In the software used in our classes, a user-friendly screen design focused the students' interventions on the most relevant variables.

The policy options menu in figure 4 shows which decisions can be assessed. These embrace alternative goals (changes in load factor, changes in passenger rating, changes in market share[v]) and a set of different paths for coping with the liquidity problem, the firm is faced with (sell & lease of aircraft, purchase of aircraft, price policy[vi], changes in the operated routes).

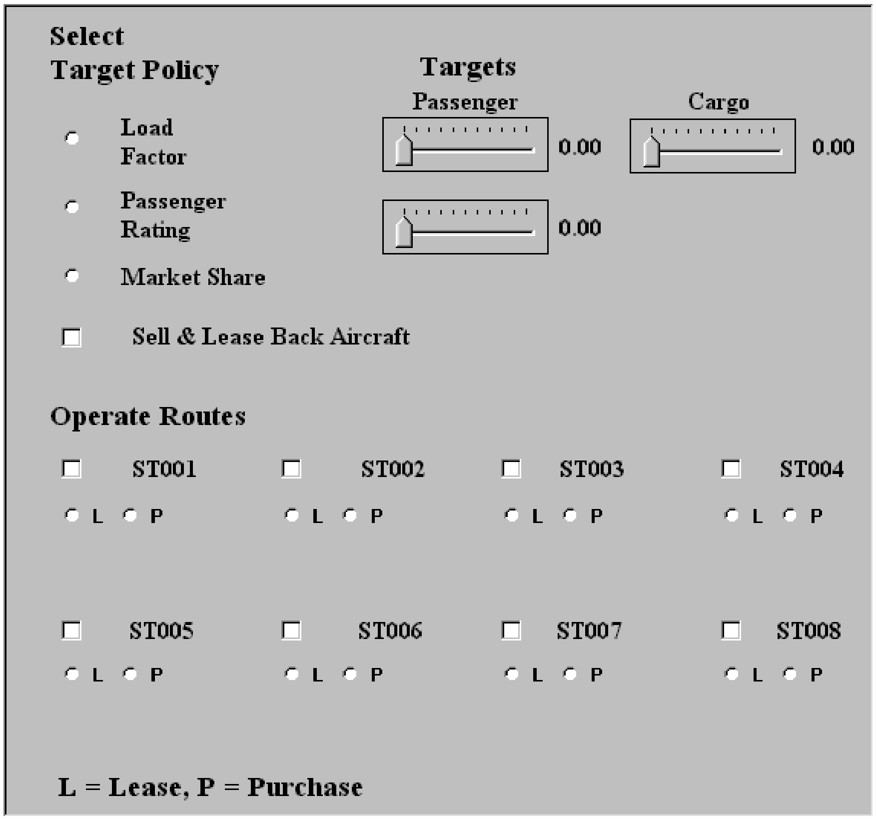

Figure 4: Policy options menu

The *Graphical Output* section enables selecting and displaying the output of any variable selected. Through the *Select Runs* facility, also different runs can be compared comfortably (cf. figure 5). By means of the *Subscripts* button, detailed structures of results, e. g. segmented by routes, can be examined.

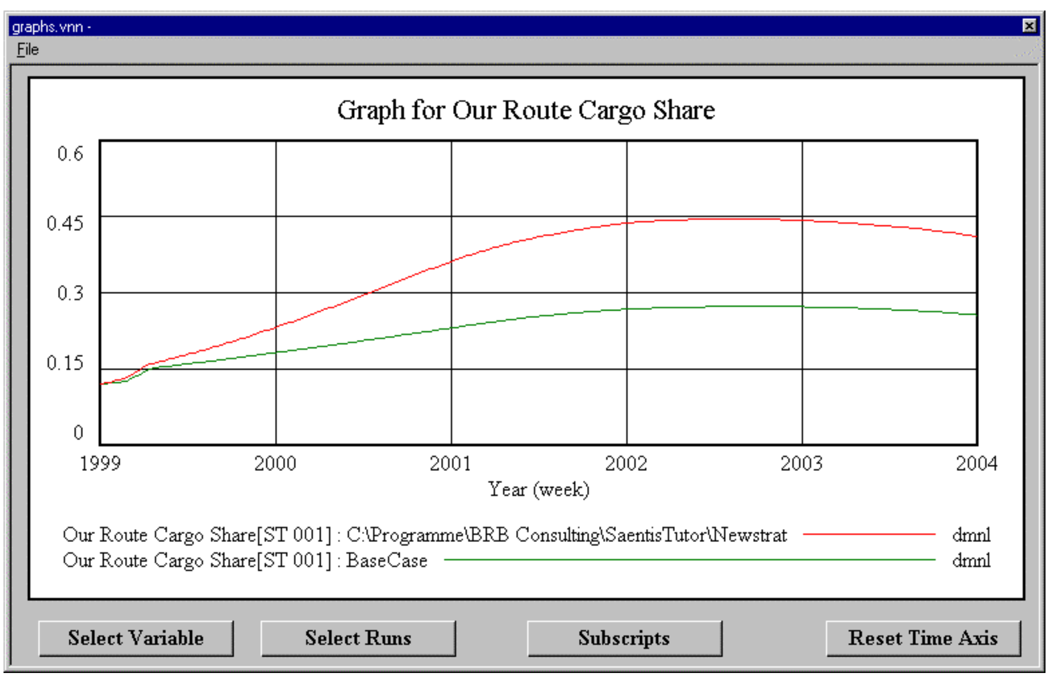

Figure 5: Graphical output (example)

The causes of results can also be traced graphically. In the model, and example, causal structure has been included with “Reported Profit” as it’s focal point (cf. figure 6). The student selects an output result by clicking on the desired button, and the results will be displayed in the graph.

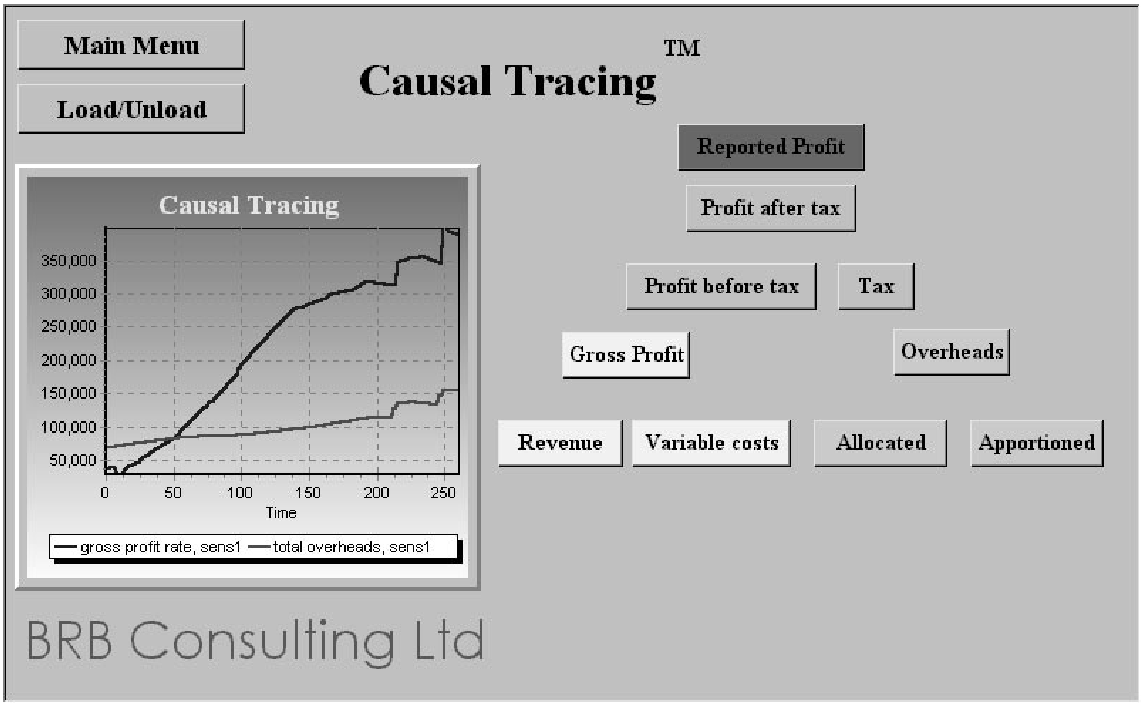

Figure 6: Causal tracing of results

The *Structure* button gives access to the detailed diagrams of the model (figure 7).

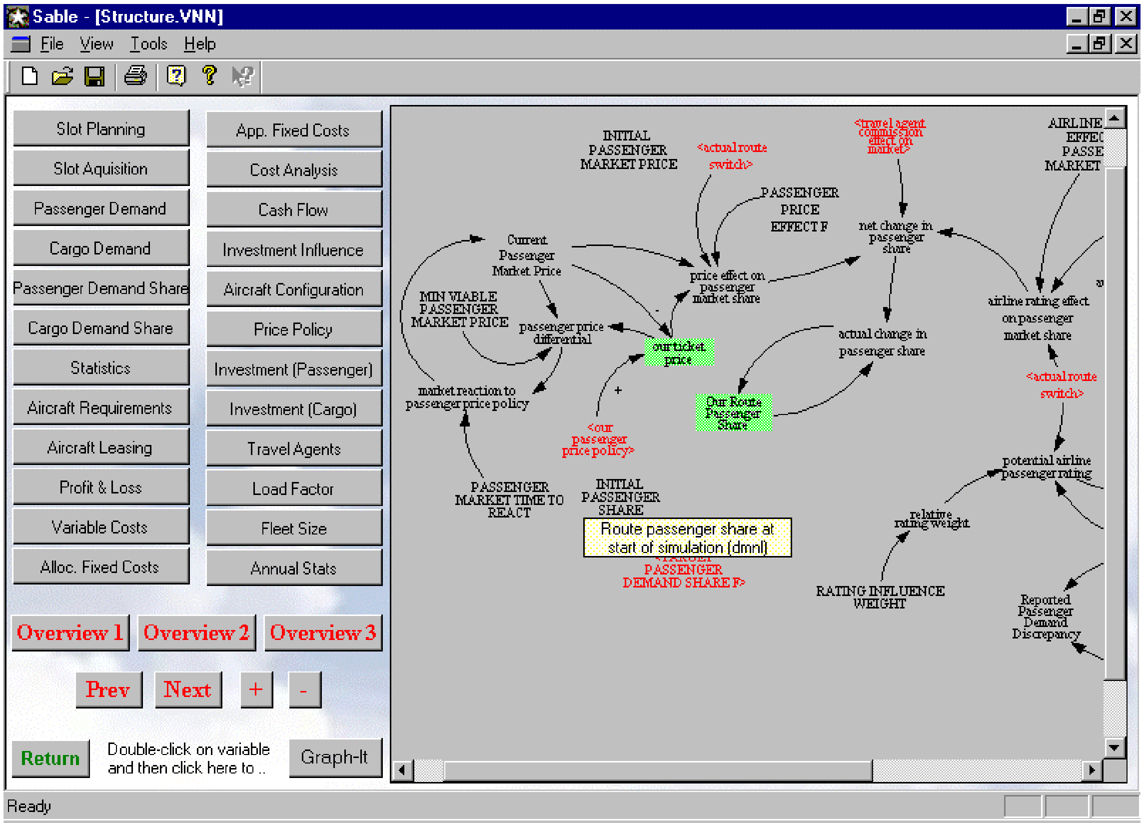

Fig. 7: One of the more detailed views onto the model

Finally, the *Analysis* facility offers a number of powerful analytical features:

- all parameters and variables of the model can by viewed in the form of graphs, tables or equations
- statistical measures of any variable or parameter of the model are accessible instantly
- a navigation systems enables the user to trace forward and backward links between variables in a hypertext mode; the structures called up are visualised immediately (figure 8).

These features go back to the capabilities of the VENSIM software. However the additional strength of SABLE is that virtually any change in the Interface can be realized very fast and flexibly. This feature is very powerful in the customisation of interface features such as graphical output, analysis, reporting etc.

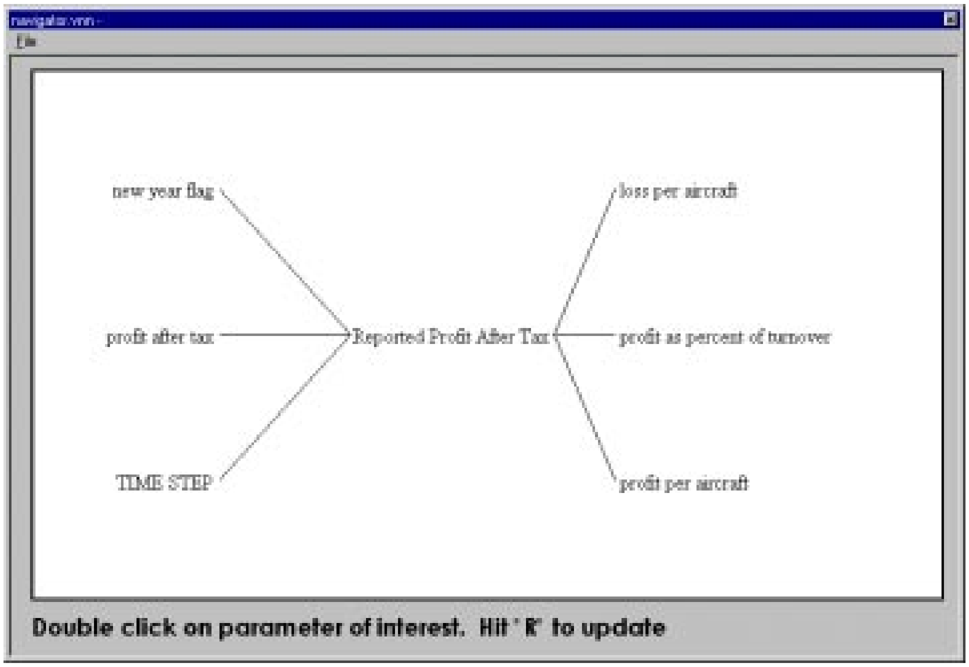

Figure 8: Navigator through structure of model (example)

4. The Experience Gained

In this section we shall briefly report on the experience and insights gathered from this application. The model was run in spring 1999 for the first time. The results of this run were not gathered as systematically as we would have wished to. The 250 students were distributed in 8 groups and accompanied by 8 faculty members. In each one of these groups one team had to present their solution for the case.

Given this decentral arrangement, the evidence gathered has not been complete (cf. figure 9). We got the final presentations of 5 teams, not their computer runs. Of the 8 teams only one had not made use of the model. Three other teams had – to our knowledge[vii] - used the model but not handed in their presentations for unknown reasons.[viii]

Model used \ Results corroborated	Yes	No	Data Missing
Yes	4	0	3
No	0	1	0

Figure 9: Overview of results

Of the five teams which handed in their final documentation, 4 dealt effectively with the cash problem imminent on the company and the respective trade-off between liquidity and profit. All of those teams had used the ACPM. The group with the most elaborate plan differentiated explicitly between three time horizons, short medium and long term. In this group as well as in the other three which had used the model, the planned measures were underpinned with a dynamic calculus of their quantitative implications, as far as the model allowed for it. Even though these students had no specific training in System Dynamics, they made (more or less) extensive use of the model to test their propositions.

The team which had not used the model presented an analysis and recommendations, both in qualitative terms (and with the most elaborate graphic presentation of all five teams). Although that group displayed a plan which contained similar goals and measures as those of other groups, these students had not examined the financial implications of their recommendations. This group handed in the longest, but the most superficial of all presentations.

We are aware that the "hard" evidence reported here is still sparse and not rich enough to draw substantive conclusions about the concrete mode of how simulation models have to be used. However, the binary variable *use versus non-use of the model* turned out to be a powerful discriminator between relatively high and relatively low quality results of the case solutions presented by the students.

The comments fed back to us by the faculty of the course varied in strength and detail. The overall impression we got is that the model was positively accepted. Based on the comments received, we have improved the user interface. Our intention is gathering more and better data from users in future applications, in order to learn more about the strengths and weaknesses of the model and the interface, and get deeper insights into the behavior of model users.

5. Conclusions and Outlook

Critics of the case study method have maintained that it is virtually impossible for students (and their teachers) to elaborate well-founded "solutions" or recommendations to complex case studies on management. The experience gathered in the application documented in this paper indicates that the limitations of case-study-based teaching can be pushed further significantly, if the case studies are supported by System Dynamics models. In this first round of application, we have been limited in our gathering of data concerning the behavior of the users and the results achieved. However, the distinction between use and non-use of the simulation model in solving the case under study has been a strong discriminator between high and low quality solutions presented by the students.

As an outlook, we would like to address the potential progress through using such models, especially in overcoming the limiting factors named at the outset:

1.) Complexity of the case study:

Cases of general management, namely strategy, but also of operations management, tend to be highly complex. Computer simulation models in general have the potential of condensing the outcome of the interaction of multiple variables into specified outputs of time series, showing the behaviour of the system at hand over time. However, in the context of case studies in general management, System Dynamics models have an edge over models based on other modelling and simulation languages. This is due to a) the general-purpose nature and the continuous (as opposed to discrete-events) modelling and simulation characteristic, which enables the modelling of complex systems with relatively few variables, and exploring midto- long-term scenarios, b) the transparency of the models, enhanced by the feedback diagrams which are a necessary component of the models, and c) the emphasis on interpreting patterns of behaviour of simulation outputs rather than point-precise predictions.

2.) Lack of contextual knowledge or practical experience:

The knowledge about the relevant context held by actors in the organisation itself is, in principle, very much richer than the comparable knowledge of a problem-solver dealing with a case study which merely describes that organisation sequentially. A lack of knowledge of the situation at hand on behalf of the students could theoretically be overcome by immersing them into the organisation itself by means of a period of practical training. This option however is usually out of reach. A much less expensive and more feasible alternative is to include context-specific knowledge into the computer model which supports the case study. The Saentis Airline model for example is imbued by a very rich body of insights about the functioning of an airline and the relationships with its market environment in particular and stakeholders at large. This way, a large portion of the data-gathering and linking of facts can be delegated to those who build the model. As far as the question of how to overcome the barrier of insufficient experience on behalf of students is concerned, model-based support can at least give a partial answer. Similar to a flight simulator, a good simulation model gets very close to practical training (cf. Jackson/Sterman 1998), although it cannot substitute for it completely.

3.) Deficits of conceptual knowledge:

A shortcoming of conceptual knowledge on behalf of students is not a specific characteristic related to case-study-based teaching. However, this is one of the most fatal deficits threatening them as managers, and endangering organisations at large. While case studies devoid of model support can in no way contribute to soothe that ill, System Dynamics based case studies, if properly taught, have a huge potential to make progress in teaching conceptual skills. The attribute “properly” refers to three aspects, in particular: First, the students must be encouraged to trace the logic of the model underlying the case. This is possible, if the model is open to the players. Second, they must be motivated, or even obliged, to anticipate the outcomes of each simulation run, to compare it with the results generated by the model. This helps enormously to understand the situation at hand, (always as represented by the model). Third, a clear and insightful debriefing by the teacher, at the end of the exercise, can deliver very important lessons.

In sum, all of these deliberations underpin our propositions: Simulation models are, in principle, a necessary component for effective case-study-based teaching on general management, in many domains of operations and strategy. Furthermore, System Dynamics models can and should play a crucial role in improving case-study-based teaching in these areas.

Finally, we must emphasise that these propositions are linked to one assumption to be made explicit: The potential improvements delineated can only be achieved provided the models used to support the case studies fulfil the prerequisite of strong validity. The challenges of providing high user-friendliness of modelling and simulation software, and the availability of computing power have been coped with effectively. The issue of model validity has been addressed extensively in the literature (cf. Forrester/Senge 1980, Barlas 1989 and 1996, Eberlein/Peterson 1994). Also, advances in software development have made powerful support for the validation of models available (cf. Barlas/Topaloglu/Yilankaya 1997, Ventana Systems 1988-1997). We are convinced that the greatest challenge ahead lies in increasing the confidence in the models by making comprehensive validation a necessary and integral component of the model building process (cf. Schwaninger 1997).

References

Barlas, Y. (1996). Formal Aspects of Model Validity and Validation in System Dynamics. In: System Dynamics Review, Vol. 12, No. 3 (Fall), pp. 183-210.

Barlas, Y./Carpenter, S. (1990). Philosophical Roots of Model Validation: Two Paradigms. In: System Dynamics Review, Vol. 6, No. 2 (Summer), pp. 148-166.

Barlas, Y./Topaloglu, H./Yilankaya, S. (1997). System Dynamics Models Behaviour Validation Environment (BTS), Istanbul, Turkey: Bogaziçi University.

Conant, R.C./Ashby, W.R. (1981). Every Good Regulator of a System Must be a Model of that System. In: Conant, R., ed.: Mechanisms of Intelligence. Ashby's Writings on Cybernetics, Seaside, CA: Intersystems Publications, pp. 205-214.

Dörner, D. (1997). The Logic of Failure : Recognizing and Avoiding Error in Complex Situations, Reading, Mass.: Addison-Wesley.

Eberlein, R.L./Peterson, D.W. (1994). Understanding Models with Vensim. In: Morecroft, J.D.W./Sterman, J.D., ed.: Modelling for Learning Organisations, Portland, OR: Productivity Press, pp. 339-348.

Forrester, J.W. (1971). Counterintuitive Behaviour of Social Systems. In: Technology Review, Vol. 73, January 1971, No. 3, pp. 52-68.

Forrester J.W./Senge, P.M. (1980). Tests for Building Confidence in System Dynamics Models. In: Legasto Jr., A.A./Forrester, J.W./Lyneis, J.M., ed.: System Dynamics, Amsterdam: North-Holland, pp. 209-228.

Jackson, T./Sterman, J.D.: A Flight in the Corporate Simulator. In: Financial Times, December 3, 1998, p. 23.

Schwaninger, M. (1997). Integrative Systems Methodology: Heuristic for Requisite Variety. In: International Transactions in Operational Research, Vol. 4, No. 4, pp. 109-123.

Ventana Systems (1988-1999). Vensim 4.0. Standard Professional DSS Software, Harvard, MA: Ventana Systems, Inc.

Endnotes:

[i] Such a critique was formulated by the eminent management thinker Henry Mintzberg, in an intervention he made at the European Forum for Management Development, Deans' and Directors' Meeting, Helsinki, January 15-16, 2000.

[ii] The Saentis Airlines case study was elaborated at the University of St. Gallen by Urs Strukov-Baer, research assistant, under the supervision of Prof. Markus Schwaninger. This case study is available from the European Case Clearing House, Cranfield University, Wharley End, Bedford MK43 0JR, England. The case study is supported by a computer model developed by Lee Jones in co-operation with Schwaninger and Strukov-Baer. The software used was VENSIM (from Ventana Systems Inc., Harvard, MA, U.S.A.) for the model and SABLE (from BRB Consulting Ltd., Salisbury, U.K.) for the user interface.

[iii] Summer term 1999.

[iv] The screenshots in figures 2, 3, 6 and 7 already include some improvements made for the second use of the model in the summer term of 2000.

[v] Load Factors are defined as the percentage utilisation of available passenger and cargo capacities, Passenger Rating as the desired percentage improvement in passenger rating of airline, Market Share as the desired market share proportion as a function of time per route.

[vi] Price policy is defined as the ticket price multiplier of the average price chosen by carriers on a route as a response of the airline to percentage shortfalls in the chosen target (market share or passenger rating or load factor).
[vii] We were able to check this in a list of all the downloads of the model that had taken place between the start of the term and the group presentations.
[viii] The authors were not in a condition to make the delivery of the results of the model use obligatory.