Results of First Steps in Applications of System Dynamics Principles at University of Economics in Prague, Czech Republic

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Abstract

The authors will attempt to overview domestic experience of using the system dynamics models in various fields, mainly with respect to practical use of simulations for management decision-making support.

This paper will present management flight simulators created at University of Economics in Prague. Theoretic background of these simulators comes from the methodology of system dynamics and systems thinking. These simulators are considered to be tools that would help to understand dynamic relations in an organization as a whole.

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Keywords:

Economy, Post-communist Country, System Dynamics, Model, Computer Simulation, Interface, Market Structures, Firm

1. Turbulency of Post-communist Economic Environment

In the current turbulent economic situation in post-communist countries, of which the Czech Republic' is one there are innovations, adjustments and changes, in which managers must make their decisions. The complexity of decision-making problems grows, time urgency gets into foreground, the number of unstable and disturbing effects in the competitive environment rises and risk of wrong decision-making threatens more than ever before (Mildeová 2003).

The decision-makers need efficient support in solving these problematic situations. Therefore we have focused mainly on questions like how to use computers for helpful simulations of entrepreneurial reality and how to contribute to “building of knowledge” of future and current managers.

We tried to find an environment which enables the user to analyze situations, find and experimentally test new solutions and immediately evaluate the effectiveness of different decisions. An environment which allows us to work up through specific problems in systems with occurrence of dynamics complexity[1]. And of course an environment which would bring the systems thinking to managers in an enjoyable form (Mildeová 2004).

Our search led us to management flight simulators based on the methodology of system dynamics and systems thinking. They have showed us that human mental models play a crucial role in decision-making procedures. To solve the problems, we have to change them and outperform their shotcomings (Sterman 1991, Sterman 2000), especially certain influence of conventionality and the current thinking paradigm – tendencies to linearization and to omit feedbacks and delays (described in words of Herbert Simon as “bounded rationality”).

We use system dynamics as a practically oriented discipline, which can help in solving problem situations, where the human mental models are insufficient - it is obvious that we can not consider any solution to be the right one unless we stick with the systemic procedures respecting our limitations and important characteristics of the complex social systems (Mildeová 2003), (Vojtko 2002).

2. Our Experience in Management Flight Simulators Development

A widely used, fixed particular definition of a simulator probably does not exist and it is becoming more specific parallel to their development. We indeed recognize a simulator as a useful tool (defined on Fig. 1) for reflecting real systems behavior for educational purposes and for estimations of a future development (Mildeová 2004).

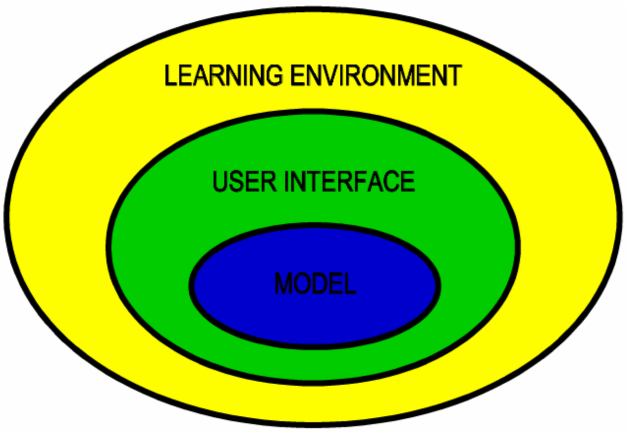


Figure 1 – Our definition of Management Flight Simulator

[1] As was mentioned by Peter Senge (Senge 1990).

The model is a core structure (stock-and-flow diagram) with all equations defined.

The interface represents a layer between user and model (usually inputs, outputs, help indicies, etc.). It should help even an inexperinced user to control the model.

The learning environment is everything else that is needed for successful learning (story, assumptions, case studies, printed materials, techniques of using of the simulator – teamwork, coaching, etc.).

In our classes, we have been in particular trying to solve how to use pre-built system dynamics based management flight simulators of a company, where we have two types of possible applications.

The first one works in a very short time, say 1.5 hours, and is a decision support system for students' exploration of possible futures of an investigated company's story. We call this approach "black box simulator use". Our hypothesis was that we can use the management flight simulator with a complex underlying model only via user interface in the way shown on Fig. 2.

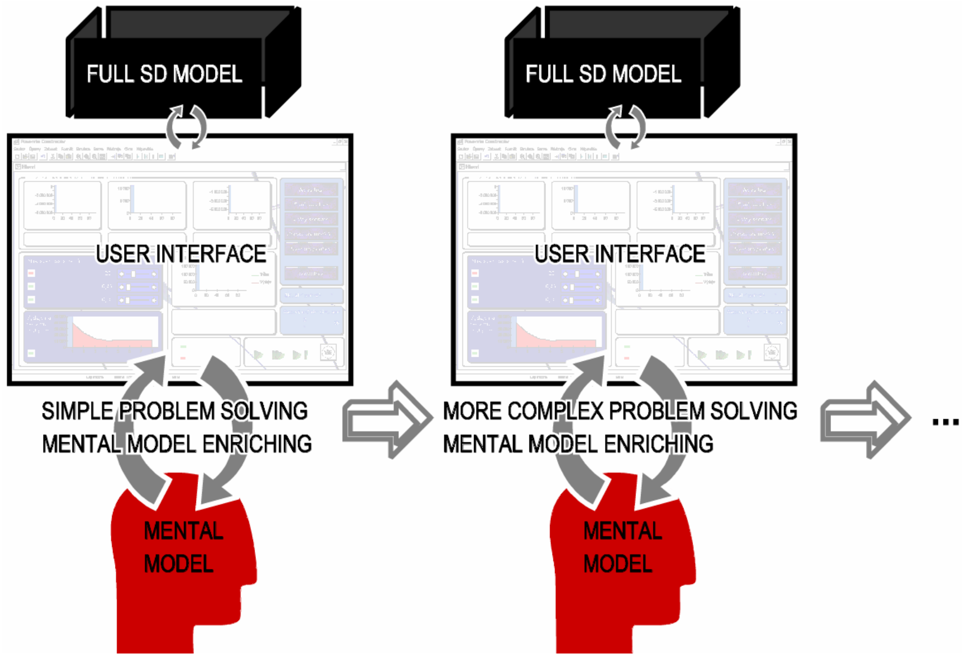


Figure 2 – The black box approach

The second requires a longer time-spare, say half of a semester, when students can build their own models of a given problem, use it for strategy or policies testing and compare it with the pre-built one. We call this approach "transparent box simulator use".

This approach is very familiar for everyone with system dynamics experience. We use it for learning purposes in this sequence:

1. Immerse the students into a problem given, for example, by some case studies.

2. Let them try to solve the problem using standard tools they have learned during their studies (e.g. MS Excel and static economic calculations) and present conclusions (mental models).

3. Build the system dynamics models in teams. Each team build their own model. They can be a little different so the lecturer works as a coach to lead the whole process to comparable results.

4. Revise the mental models, previous decisions and expected company's future behavior.

Two commercial products from Proverbs Inc. have been used for the creation of management flight simulators at University of Economics in Prague – DealSale and StartCom models. The DealSale model was used for the transparent box approach and the StartCom model for the black box approach.

Obviously, the quality of the model is decisive for the whole management flight simulator (let us repeat, that the model does not take all the real system’s aspects into account, it works only with those which have a remarkable impact on the system behavior).

During the process of models’ transformation into simulators we benefit from the fact that business flight simulators make it possible to learn how the system (the aggregate) behaves, based only on changes of its part. The user gets a comprehensive view of a structure of simulated system and is also able to experiment with different approaches (strategies) and bets their reflection on model behavior in time.

In addition, we are taking advantage of the fact that it is possible to simulate not only the real “hard” systems (which are extensively used for pilot training for instance), but also the “soft” ones (including human behavior).

The structure of our business flight simulators consists of three parts. It is the mentioned system dynamics model that constitutes the manager simulator core, user interface and simulation environment, represented by case studies and different scenarios (as seen on Fig. 1).

In addition to the simulation model, students were given a "story", i.e. case study that defines both external and internal firm surroundings and the basic rules.

By this way, the simulation enables user to trace the impact of particular decision on the whole firm’s behavior.

Design of the user interface - as the element of user and simulator interaction - can be very divers. Its creator has to respect the way of using the simulator. For teaching purposes, it is important to have a clear and understandable interface, on the other hand, more advanced users will appreciate more information displayed on the screen and access to the model structure (Mildeová 2004).

Surely, there will be a difference between the interface made for specialists and for the needs of teaching (for university students). They search different entries, and swiftness to be acquainted with the interface is certainly higher for the specialists. Similar issue arises when the task is to determine the computer simulator control mode and to choose the number of model parameters to be influenced by means of the user-interface during the simulation. On that account, a number of diverse user-interfaces can be designed for one management flight simulator.

Another interesting feature is the work with scenarios. Scenario is a fictitious situation that fits a particular model and which the user tries to solve as best as possible. Several different scenario versions can be composed for one particular model. So, our primary thoughts were aimed to create as versatile as interface as possible, which is also capable of simple parameter modification or restriction for the use of multiple scenarios (or editing of these scenarios within the computer simulator). Versatility condition was crucial. Perspectives of computer simulator supported learning progress can be seen – we claim – within the scope of scenarios solved during tuition.

For our simulators development we have been using Powersim Constructor software. This software fully utilises visual interactive environments for simulator creation, full coverage of system dynamics based modeling needs connectivity to other applications or data. We tried and used data exchange with such widely spread office applications as MS Excel so the user can work with the data afterwards.

Due to final graphical interface in Powersim, software end-users need not possess the knowledge of model making. As a default, graphical control elements, graphs, circle-type and bar indices are available, which serve for controlling the simulation conditions, i.e. model initial parameters and decisions.

Our target users were university students and the simulators were then designed for single users on one machine only.

From the viewpoint of time consumption the graphical interface creation was not a simple business. Graphical adjustments of the interface elements and testing occupied most of the time. The available version of Powersim 2.5d (which is the only version in Czech language) is a powerful tool for modeling but hard work with graphical objects is needed within the user-interface set up: e.g. difficult group changes and complicated picture insertion. Further drawbacks are the lack of built scenarios support and the complication of graphical item visualization dependent on the chosen variables values. Powersim Studio 2001 and 2003 comprise particular mode of presentation designed for user interface working and improve the work with the graphical items of the interface but many features are not yet supported .

However, we consider Powersim and the work with it to be very useful. Everyone who has at least mediocre knowledge of computers grasps the program quickly and can create his/her own models. Superior user-interface creation demands, however, lengthy work with the program.

By creation of the user interface, there was one particulary interesting feature of Powersim used: – the ability to interconnect two or more models. In this case, the user interface contains only information about the proper link between models.

The model remains hidden for the end-user due to this solution, and he/she only operates with the user-interface. Moreover, the original model stays untouched as a favourable consequence of the solution. Whichever the original model modification may be, it necessitates high-quality documentation creation and thus the model conservation is questionable. Many user-interfaces can be designed for one model and these ones are, therefore, comparable, since we obtain in principle comparable results due to the same manager computer simulator core.

As far as the technical aspect of the matter is concerned, model variables connection is realized through "chains". Scenarios selection is made through a constant containing the scenario number. This scenario number determines initial values concerning the decision of which scenario variables are fixed and which ones the user can alter during the simulation process. Auxiliary variables designed for information display are not contained in the model itself so the model is much more comprehensive.

Process of operations when designing the interface was as follows:

1. Simple conceptual design of the simulator interface.

2. Analysis of the manager flight simulator scenarios parameters.

3. Detailed graphical interface design.

4. Interface testing.

5. Debugging and incorporation of test phase reminders.

Ad 1. Mainly for testing purposes a simplified version of the interface was designed. Different user views were made and tested. Then we chose the appropriate one according to user opinions and their cognitive load.

Ad 2. Scenario parameters were then chosen and tested. Improper choice can shift the understanding of the simulation out of the desirable course, and the user focuses on unsubstantial parts of the problem, thus corrupting the holistic view of the system.

Ad 3. One working window system for the graphical interface was designed. Graphical items are arranged to sections according to displayed blocks of information in this window. There is an information section (it displays important simulation outputs in graphs and numbers), a control-button section (display into further windows, e.g. initial and more detailed parameters, scenarios, help), and a simulation run control section.

Ad 4. Within this phase, the end-user interface was tested. Bugs were looked for and recommendations for interface changes were proposed.

Ad 5. User-interface corrections according to the testers' reminders were incorporated.

3. Case 1: Management Flight Simulators in Small Business Companies

Microsoft Excel (and spreadsheets in general) is a widely used tool for the data analysis and decision support in the Czech private and public sphere. Notwithstanding, it is an insufficient tool where dynamic complexity appears for standard decision which can lead - using it inappropriately - to serious errors.

We practically verified Microsoft Excel and Powersim connectivity within the StartCom system dynamics simulator. Microsoft Excel was used to input and edit initial data and to support non-numerical data processing. Powersim provided dynamic features computation.

The Simulator StartCom is a dynamic simulation model (belonging to the category of models including soft variables – e.g. customers' satisfaction ratio) which strives to model the course of the first years of entrepreneurship (mainly financial and operational factors including market behavior).

According to the user preferences, it is possible to modify the model with different scenarios and interfaces to fit the concrete subtype of small business focused on providing services. The main quality of the model is represented by its clarity and its focus on the most important parts of such business activity.

The story behind the MFS is very simple. The user is in the position of a small entrepreneur owning a hair studio who wants to survive the first two years of company's existence.

We want the students to find and learn how to balance key relationships, for example between resources, capacity and consumer behavior.

The StartCom has four scenarios intended for the black box approach. They are different in accessible inputs and depth of the problem involvement. The fouth scenario gives access to all inputs.

The results were unclear. The users were able to find some successful strategies in a given short time but their confidence was not very high. Some of them gained anticipated reasonable insight but others did not.

Our conclusion is that the black box approach is viable but that much attention must be paid to the learning environment. We think that interesting progress can be made with creativity and imaginative involvement.

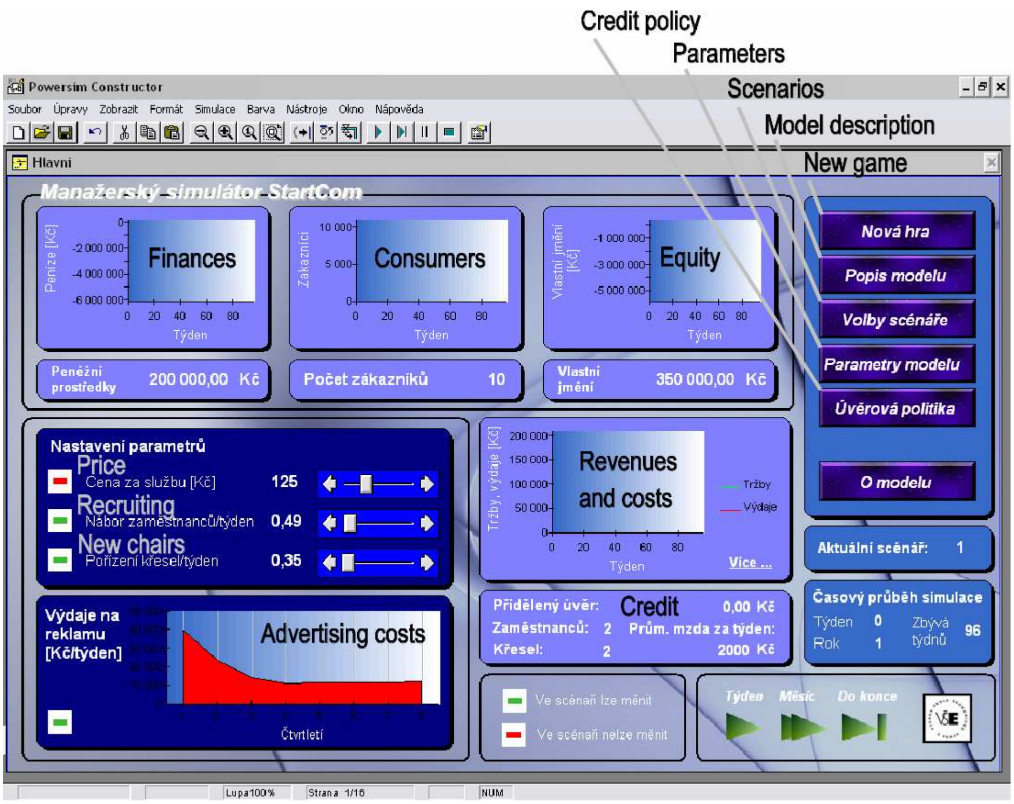


Figure 3 – StartCom simulator user interface

4. Case 2: DealSale and BSC

In this case we wanted to help the students understand the Balanced Scorecard. We used the DealSale model from Proverbs, Inc. (Vojtko 2003) and extended it towards BSC implementation. The DealSale model is a dynamic simulation model of a wholesale company with a dealer-selling network.

The structure of the model points out the key areas of decision-making while keeping a global view of the management strategy process. By this, the main goal of the simulation is achieved: the development and practical use of managerial thinking while retaining the very important global management view.

The simulator primarily shows well-arranged diagram BSC and a record of all important indicators of company health, according to the four key perspectives (finance, customers, internal processes and growth). The next level contains windows with settings of all crucial factors, according to the perspective. Therefore it's possible to do various simulations and investigate influence and sensitivity of several parameters on BSC indicators.

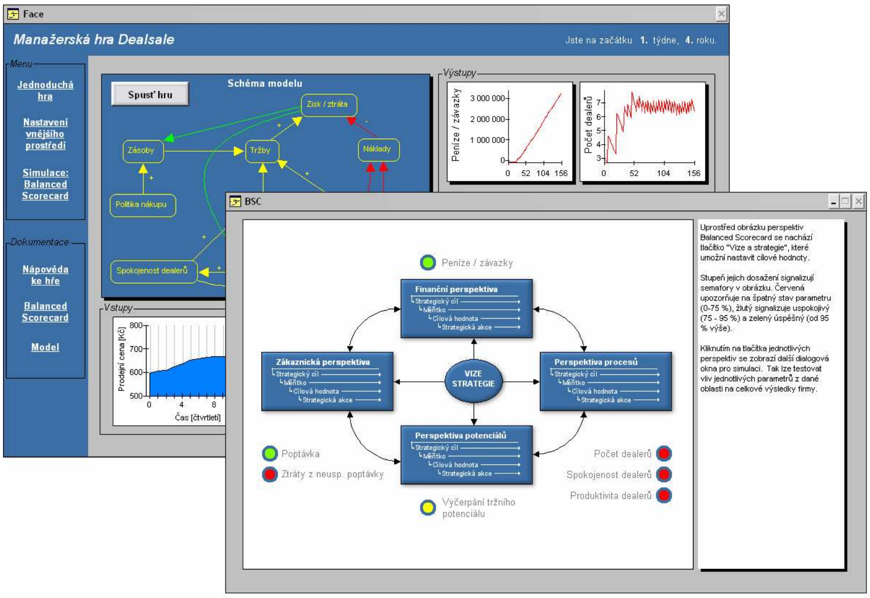


Figure 4 – DealSale BSC perspectives and interface

One of the main advantages of this simulator is the use of Balanced Scorecard as a mediator between the strategy choice and its implementation.

Verification (Study)

We intended this simulator to also be a benchmarking tool for the transparent box approach. Students made their own models of a given case study which were then compared to this simulator's behavior and results.

Participants in the verification were students at our university. During the DealSale simulator testing, students were divided into the groups with four members and their task was to suggest, on the basis of engaged case study, acceptable and vital settings of strategic parameters (values of own corporate goals, pricing and advertisement strategy, personnel strategy, etc.) The first version of the proposal was based on their personal analysis with the aid of MS Excel. Only one team of the five teams found a successful strategy, which withstood further testing in simulator throughout the stimulated time of period three years.

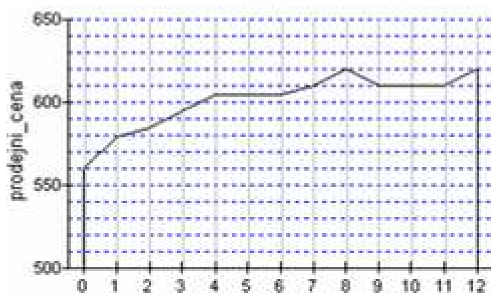
Hereafter, students were working well with Powersim software and they were forming their personal system dynamics models of given a problem. They had the opportunity to try out various possible model structures according to their mental models. Lastly their original strategies (and mental models) were modified, in order to identity what best reached the defined objectives together with minimal unintended consequences.

Outcomes from MS Excel modeling and dynamic simulations were very different.

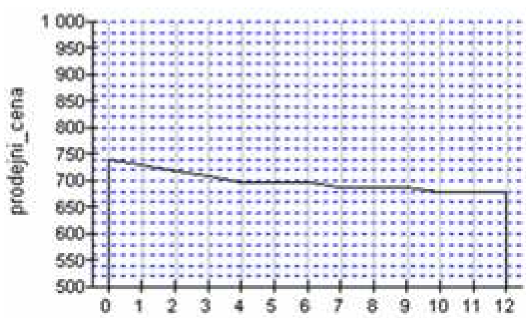
It has to be said that the student's decision making in the original strategies without using the simulation was largely defined by their implicit image of the company that was the subject of the problem solving exercise. During the simulations, we (and students themselves) found mainly these mistaken strategic decisions: insufficient stock reserves, underestimations of cash requirements, unclear understanding of relationships between company's parts, etc. The students appreciated the depth of gained knowledge and understanding of company's behavior compared to traditional approach (with the use of a spreadsheet).

The statement that the main advantage of system dynamics models is ability, which allows the computer model to achieve and manage greater complexity than mental models of man, is sometimes impugned. Nevertheless it is undeniable and our verification confirmed that system dynamics based models and simulators can be useful in fast understandings of possibilities of how the real system could behave. Alternatively, they may help in verifying what could perhaps happen if something in the model need to change.

A choice of examples, running strategically through the advantageous behavior variables is addressed in the next pictures:



a) reference mode of price level based on mental model and Excel analysis



b) after simulations

Figure 5 – Strategic price settings before and after simulations, same goals

In the follow-up problem-solving scenarios, using the simulation and system dynamics modeling the students felt that their perception of reality and their mental models did not fit very well to the simulations' results. By using interative simulations they were able to learn from their mistakes and improve their current mental models.

Students appreciated that the simulation improved their perspective as to the quantity of possible solutions. We believe that overcoming this mental barriers overcoming is for students the biggest asset. With the simulations students also better processed various dynamic characteristics including feedbacks and delays.

Thanks to the simulations, students differentiated long-term from short-term consequences and their critical systems thinking skills were improved. Therefore, this was also a significant change in educational style and teaching tools according to (Richmond 1993).

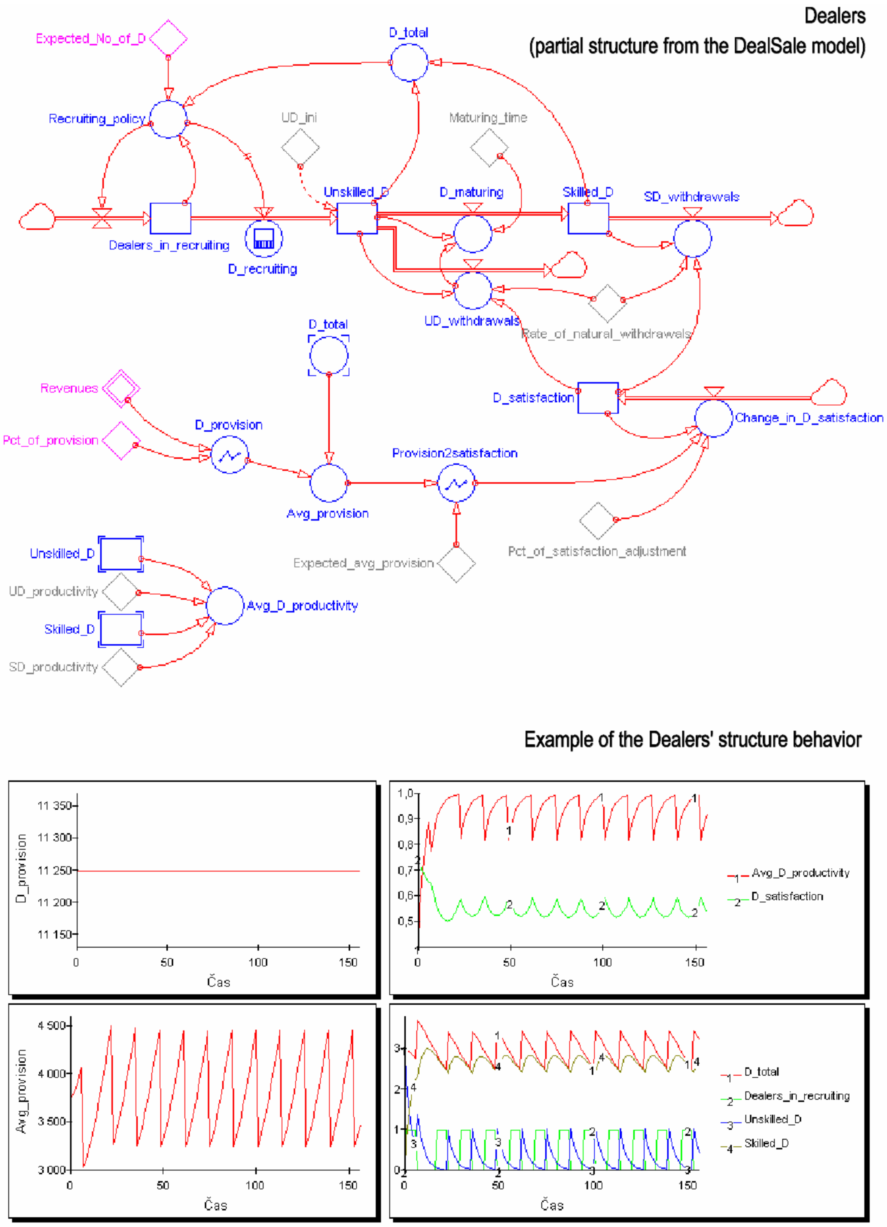


Figure 6 – Example of partial structure and behavior from DealSale model

5. Behavioral Models of Various Market Types

One of the areas where the competence of system dynamics models was largely presented, is without question the issue of market structures. We would like to mention mainly works of Jay W. Forrester (Forrester 1961) and John Sterman (Sterman 2000).

In our present research we want to focus on an area tightly connected with the real-life business problems – general characteristics common for various dynamic market structures determining the customers' behavior – and consecutive processing of general system dynamics from the behavioral market model from a company´s viewpoint.

The general system dynamics behavioral market model from a company´s viewpoint should be used for finding policies that can solve problematic behavior and help us to explain the reason why the markets behave in such ways. Also, it should enrich the current basis of models that can be used as components for the modeling of larger wholes (typically in connection with a company model).

We plan to progress n the following way:

- description of common characteristics of various market structures determining the customers' behavior from the system dynamics point of view (this is about to be undertaken),
- creation of a general system dynamics behavioral market model from the company´s viewpoint, optionally – creation of various models, respecting the basic characteristics of different market types (FMCGs, durables, services),
- setting the purpose and scale,
- dynamic hypotheses definition,
- simulation model definition,
- model testing and evaluation,
- explanation of the model´s dynamic behavior, usual policies consequences evaluation, solution of consecutive problems,
- user interface design (building of interactive learning environment), incl. reference help and usage scenarios,
- weaknesses and strengths of system dynamics approach (comparison with other approaches – economic theory, etc.),

The output of this project – behavioral market model from the company´s viewpoint should serve as a reference model for real-life market structures modeling and comprehension of their behavior. It would be also instrumental as a framework for an easier thematic simulation model creation in both academic and practical sphere, for real market behavior analysis and finding successful policies and decisions successful in the long term.

The clear advantages are mainly improvements in decision making in the long run and a significantly shorter learning process. The impact on the Czech society could be demonstrated on higher competitiveness of Czech companies in the upcoming EU environment, higher resource allocation efficiency, consequences of various market structures, etc.

6. Experience in Business-oriented Use of System Dynamics Models in Czech Republic

Simulators based on system dynamics models can serve as an intermediate stage between the theoretical part of education and experience gained by practice.

We found simulators a long time ago to be a safe environment in which it's possible to think creatively about complex problems and their solving (Mildeová 2004).

Simulation models could also help managers of post-communist countries to understand and outline possible future consequences of their decisions in highly chaotic environments. It's much better to make a mistake in decision in the virtual world of our computer, than risk the mistakes in the real world and endanger the running of a whole company.

On the level of a complex social system like a company, system dynamics models or simulators should lead most of all to an increase in performance, but they can also play a very positive role in sustainable development of companies – as such models are known (Mildeová 2003).

In the Czech Republic, the system dynamics models and methods are currently quite unappreciated, which is principally due to the lack of sound experience and knowledge. Nevertheless we can link up to some successful projects, for example in the Ministry of Defence – for which was personnel model "Libuše", in terms of Phare project were verified possibilities of using French system dynamics model of sustainable development in Czech conditions (Mildeová 1999), Models were created for some significant Czech firms covering areas of financial management, strategy testing, risk management, development of distribution chains, project management, implementation of Balanced Scorecard method, etc. (in companies Hartmann-Rico, Precheza, Czech Telecom, local branch of T-Mobile and others) (Mildeová and Vojtko 2004), (Vojtko 2003).

7. Conclusions

Society depends upon people using ICT efficiently and creatively for knowledge building and this requirement is practically supported by system dynamics based management flight simulators. This approach is not yet usual nor in conventional education nor in Czech common managerial practice and authors see contribution which exceeds single software creation.

Even though this paper has in its title „.... first steps ..." we hope that we are not completely at the beginning and practical experience, which we have began to gather, can help in searching for the real possibilities and identification of benefits of the system dynamics simulators, their influence on an improvement of decision making and learning in corporations and public institutions that need to cope with dynamic complexity of the real world problems. It is also needed for the future development and use of the system dynamics models in areas where it is reasonable and needed.

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