Management Flight Simulators; a New Approach to the Development of Decision Support Systems

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Abstract: This paper presents an overview of the System Dynamics methods and the existing knowledge and practices for the development Management Flight Simulators. Management Flight Simulators constitute the ultimate cybernetic method for learning and testing strategies prior to implementation. The main issues and trends in the field are identified, and new views to the development of System Dynamics simulation models are suggested. Having gone through a review process of relevant sources, a conceptual framework for the development of System Dynamics Management Flight Simulators is proposed. The proposed framework would be particularly useful for researchers in the field but also for practitioners and developers of decision support systems.

Key-Words: System Dynamics, Management Flight Simulators, Microworlds, Modeling and Simulation, Cybernetics, Decision Support Systems

1 Introduction

All businesses, ranging from conventional organizations, e-commerce enterprises, are faced with complex strategic and operational decisions due to an increasingly dynamic economic environment and accelerating social, economic and technological change. In this context of uncertainty and complexity, it is impossible to make perfect decisions and find optimal solutions for a given problem. Therefore, managers rely on their experience, rules of thumb, formal hierarchies, existing organizational procedures or simply intuition when making decisions. Our rationality in making decisions is very much limited by our processing capabilities. As Sterman (2000) [1] stated people mostly act in the continuum between perfect rationality and mindless, capricious behavior. And our intention to solve a problem may result in unforeseen side effects causing even more problems. Sterman (2001) [2] called this effect “policy resistance”, which is due to human mental model limitations to comprehend the systemic effects.

This is where System Dynamics comes in to put the diverse pieces of the system together. System Dynamics can be used as the modeling method for creating Management Flight Simulations, also called “microworlds” – a concept first defined by Papert in 1980. Microworlds help its users “in practice” to understand the dynamic behavior of complex physical, biological, and social systems and helps managers and policy makers learn and make more effective decisions on policy design and organization. The simulation environment created by microworlds compresses time and space for the decision maker to be able to understand a complex system, see the long-term effects of our decisions, learn faster, and design more successful strategies.

2 System Dynamics and Management Flight Simulators

A Management Flight Simulator can be a board game or a physical model, but for a complex dynamic system there is only one form – a computer simulation game. Simulation games are very effective tools in identifying time delays of the existing systems and their long and short term effects on an organization, by enabling users to increase or decrease the time delay in the game environment and see the changes it would produce over time. “Flight simulators” can compress time, enabling decade-long scenarios run in a matter of seconds on the desktop. In the same way organizational feedback loops (communication paths) can be reproduced in a computer simulation environment, and the effects of their modification or removal evaluated. Thus a system or a set of policies get to be tested without the real consequences and expenses.

Properly constructed computer simulations have the power to challenge our mental models, making us aware of possible unintended outcomes of our actions. They also help us test how various factors can improve organizational efficiency and effectiveness in situations where it is not possible to perform a real-world experiment. As expressed by De Geus (1992, p.3) [3], addressing the management of organizations: “By computer modeling their world, we give managers a ‘toy’ (a representation of their real world as they understand it) with which they can ‘play’, i.e. with which they can experiment without having to fear the consequences”.

2.1 System Dynamics

Management Flight Simulators use Systems Dynamics as a conceptual tool. Thus, the first step of literature review was to find what System Dynamics is and how it has developed over time.

The birth of System Dynamics is marked by Jay W. Forrester’s of the Massachusetts Institute of Technology “Industrial Dynamics” book published in 1961 (Forrester, 1961) [4]. Forrester defined System Dynamics as the study of industrial activity’s infromation-feedback characteristics, which aims to show how the structure of an organization, policy amplifications and action time delays interact, which influences performance of the whole organization. Forrester was the first to show how System Dynamics treats the interactions between various flows such as money, materials, personnel, information, equipment, etc. in an industry, company, or economy. The symbols used by Forrester to depict the stocks or levels and flows or rates of change were taken from the Feedback Control theory. The high complexity of Forrester’s stock-flow diagram, led to the creation of hybrid diagrams, a mixture of both causal and flow diagrams, but closer to the causal diagrams (Richardson, 1991) [5].

Since then the concept of System Dynamics did not undergo many vital changes, except that now it is applied mostly in an Information Technology context and its definition can be narrowed down to: a method for solving problems by computer simulation. Unlike Systems Thinking or Systems Analysis, System Dynamics is based upon quantitative computer simulation models for strategic decision making, and feedback thinking. System Dynamics is used for modeling complex feedback systems characterized by multiple decision feedback loops, delays, and nonlinearities.

System Dynamics was first applied for the study of industiral and economics systems. From the begining System Dynamics became an attractive topic and there was a wide variety of System Dynamics areas that recearchers from all over the world began to develop. Some of them are: Urban and Public Policy Dynamics, started by Forrester in his paper “Urban Dynamics” (Forrester, 1969) [6]; Global Modelling, as introduced by Meadows *et al.* (1972) [7]; in 1985 Sterman wrote his first paper on Economic Modelling (Sterman, 1985) [8], which was a base of STRATAGEM-2 game, testing the decision rules rationality; other papers were validating and further formulating the System Dynamics Models, as done by Morecroft (1982) [9] and Richardson (1986) [10]; then System Dynamic methods were applied by various researchers to particular areas of interest: police work (Homer, 1993) [11], and Gardiner *et al.* (1987) [12], supply chain management (Towill, 1996) [13], shipbuilding and marine (Cooper, 1980) [14], medical (Homer, 1987) [15]. Other applications of System Dynamics models inlude energy and environment, software engineering and many other diverse areas from organic farming to the fall of the Soviet Union.

One of the broadest areas where System Dynamics found the widest application is Management of Organisations. Many researchers worked on developing market models using System Dynamics Methods, where Coyle was a pioneer with the paper he wrote in 1977 on “Management System Dynamics” (Coyle, 1977) [16]. Later Morecroft (1984) started the topic of System Dynamics application for Strategic Management and design of high-level corporate strategy.

Morecroft [17] reviewed Herbert Simon’s concept of bounded rationality, and, using Forrester’s Market Growth model, he showed how globally ineffective outcomes may arise out of locally effective decisions. In his later works Morecroft further developed the issue of how System Dynamics models can be accessed on their decision rule rationality. Also, Sterman (1989) [18] did a lot of research on how System Dynamics can support decion making in organisations. One of the experiments he performed involved a simple economic system where subjects had to make many managerial decisions. Findings were that the participants would systematically generate expencive oscilliations, ignoring nonlinearities, feedback loops, time delays and accumulations, resulting in poor decision making.

Those findings leaded researchers towards investigating methods of developing computer based management simulators aimed at improving the decisiong making process and organizational learning. In 1988 Morecroft wrote the “System Dynamics and Microworlds for Policymakers” paper on the System Dynamics model building tools available at the time. Two years later Senge, encouraging management to create microworlds, posed the question: "We learn best from our experience, but we never experience the consequences of our most important decisions. How, then, cam we learn?"(Senge, 1990, p.313) [19].

The first Management Flight Simulator game for organizational learning was designed by Kim (1989) [20], and was presented as a case study. Later Sterman and Morecroft (1992) [21] started developing this field, proposing various methods of organizational learning, tools for simulating various mental and formal models and Management Flight Simulators. And in 2003 Communications of the ACM released a special issue called "A Game Experience in Every Application" dedicated to simulation applications and games.

In the very beginning computer based management simulators had to be built on expensive computer workstations and be run in "batch" mode. Statistical packages or programming languages (e.g. Simula, Dynamo, and Dysmap) were used to program variables. Output was textual, numeric or simple histograms (Saunders, 1998) [22]. Since then a major step forward was made with the introduction of new dynamic graphical software.

2.1 Management Simulators Software

Modern System Dynamics modeling software with its graphical user interface and powerful desktop PCs allow their users to quickly sketch causal loop diagrams, registering stocks and flows, feedback patterns, time delays and nonlinearities. No advanced mathematical knowledge is required in order to construct equations, since most of the software uses "friendly algebra". After the model is constructed, the simulation can be run and the results viewed immediately.

Stella/ithink, developed by High Performance Systems, were the first software with full graphical interface for modeling stock and flow diagrams. Other powerful simulation environments were facilitated with Vensim by Ventana Systems, with many features for analyzing model behavior, Microworld Creator from Microworlds Inc. supporting information displays defined by users and Powersim Constructor from Powersim AS, Norway allowing its users easily build models and transform them into simulators. Further AnyLogic a Java based software with multiple simulation methods from XJ Technologies, St.Petersburg, Russian Federation, interacts with users through a web browser and supports many levels of aggregation. Recent software keeps on constantly improving its capabilities by adding new functions, admitting matrix equations and accepting optimization techniques. Still, the software is just a modeling environment making work of a manager or a policy maker more efficient and allowing anyone to participate in the modeling process, but does not replace the thinking activity behind the model construction and development of a Management Flight Simulator.

3 Development of a Management Flight Simulator

The research of the literature performed for the purpose of this paper shows that at present there are no generic frameworks available for the development of a Management Flight Simulator. Different researchers suggested various guidelines on the development of management flight simulators. The various suggestions and guidelines have been reviewed and incorporated in the following framework as shown in Fig. 1. The various stages of framework are explained as follows.

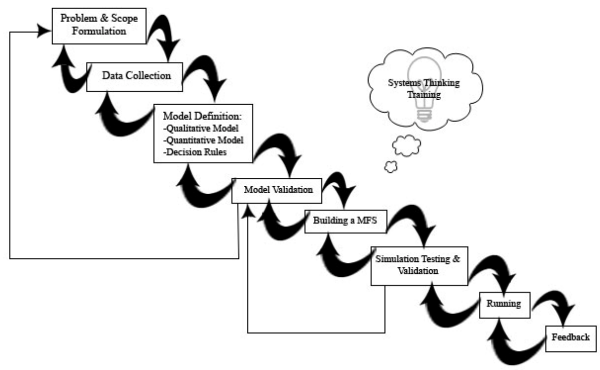

Fig. 1: Proposed Framework for the Development of a Management Flight Simulator

3.1 Formulating the Problem and Scope

The first step is formulation of the problem to be solved and definition of the scope or boundaries of the microworld. Here the questions that the simulation will aim to resolve will be identified. The scope will define how closely the simulator will represent the "real world". This requires careful investigation, to identify what should be a part of the simulation and what can be safely left without oversimplifying the simulation model as Morecroft, (1999) [23] suggested.

Formulating the Problem and Scope consists of clarifying the purpose of the modeling effort. The first steps towards an explicit formal model should be undertaken to a degree enabling the first attempts for extracting mathematical relationships, corresponding to the described phenomena. The iterative character of the process would enable us to return and correct or improve accordingly. A suitable way of accomplishing this is to create a Reference Behaviour Pattern (RBP), which is a plot over time of one or more variables that summarizes the dynamic phenomenon we are interested in understanding and improving.

A RBP is not a hypothesis in an objectivistic sense whereby the hypothesis should carry clear implications for testing the stated relationship, that is, variables must be measurable or potentially measurable. It is rather a description of a pattern or a determination of universal elements and an apprehension of relationships. It is not a matter of acceptance or rejection according to a predetermined set of criteria because the criteria for the pattern's utility and validity to us are in most of the cases decided on an ex post basis. It documents how a process has been performing in the real system or, when no history exists, how it is expected to perform.

For example, an RBP relating Product Quality and Market Share is expected to follow an S-shaped curve. It is the fundamental, meta-level, generalized relationships that are important here. Quality is here taken to mean a combination of all characteristics and aspects including usage-context and production processes, e.g., engineering tolerances, etc. of the product. What the curve says is that until a certain level of quality is achieved, the product or service will not meet the needs of the potential market. Thereafter, increases in quality rapidly expand the possible market. Finally, large increases in quality are necessary to satisfy the remaining more demanding customers. Curves of interacting price and value would simultaneously be at work at the various quality levels.

3.2 Data Collection

The main purpose of creating a Management Flight Simulator is to enhance the learning process of the person who is to use it. The first step of learning is identifying, documenting and representing the existing knowledge. That is knowledge of the structure of the system under study, patterns of interaction of its components and the decision rules guiding them. The data should be collected through interviews and exchanging information and mental models using quantitative and qualitative System Dynamics methods. All of the main stakeholders and knowledge experts should be involved at this stage. The proper knowledge retrieval and ultimately the construction of this relational framework of the system components is the biggest challenge in the process of development of an effective Management Flight Simulator.

Next, building a Management Flight Simulator would require both qualitative and quantitative (formal) modelling.

3.3 Model Definition

With the general Reference Behavior Patterns drawn and the data collected we are now in a position to:

- Formulate a pattern of interaction of variables
- Decide the objectives of our model
- Choose the pertinent variables
- Define the boundaries of the system significant to us

Then for each of the significant variables to include, we will have a rather clear indication on:

- What is the direction of the effect
- What non-linearities should be recognized, affecting the decision functions.

The model in turn will reveal the magnitude of the effect.

Finally, when we are to judge the validity of our model, we will direct our attention to the values of its parameters (constant coefficients). Then the model's dynamics (unfolding with simulation) will identify the few sensitive parameters by model tests. It is in this sense that it is less important to know their past values because our purpose is to control their future value in a system redesign.

In a later stage, when confidence in the model's utility and validity requires a comparison of the model's results with real world observations, then assessing what constitutes passing a relevant statistical test of the sensitive variable's parameter values. That is the point we will decide what more data we need and selectively and economically then collect it. We have now a clear model objective that determines the value of new information and hence enables a meaningful cost and benefit analysis.

Taking the cybernetic stand the question to be answered is: "How can the organization's policies give rise to a particular behavior pattern?" Obviously that frames the boundaries around the organization and focuses our effort to where one should look for means of improving performance. It does not deny the existence of external forces.

However, the relevant standpoint for the company management to adopt from a Systems Thinking perspective is: “What can we do to resolve the current complex problem situation”.

The RBP serves as a device for operationalizing our effort to achieve a sharp behavioural focus. The Stocks and Flows stage that follows plays the role of incorporating the structure needed to exhibit such behaviour in our model.

The task of a Management Flight Simulator is to represent the system so that its behaviour can be simulated, predicted, and changed. And that representation is manifested in the system model. It can be defined in three steps: its physical model, the formal model and the decision rules underlying the model.

3.3.1 Qualitative Model – Identifying Stocks and Flows

At this stage the objective is to build a high level aggregate view of the system problem area – a qualitative simulation model. In order to achieve this, we need to construct a causal loop diagram. The structure of the model should accurately reflect the physical side of the system: the stocks like number of roads, road capacity, people, money, information and their flows. Stocks and flows can be identified through interviews, surveys, financial documentation and many other methods involving identification of key stakeholders with different perspectives on the system. Computer software can be used to draw the model. The product of this stage is a graphical causal loop diagram.

At this stage we are concerned with determining the nature of the activity at work in producing the particular inflows and outflows to stocks. Causal loops means looking for feedback relationships that regulate the flow activities in the model. The primary target here is to achieve an operational specification of how each flow works in the real system. The question is not "what are all the things that influence this flow?" but "what is the nature of the activity generating the flow?".

Out of the literature of systems methodology and Management Cybernetics the basic flow processes with typical generic behavior patterns are amazingly few. Normally the activities would be of a self-reinforcing positive feedback compounding nature, or the opposite, i.e., a draining process (negative feedback).

Here we are seeking to make linkages between the existing model elements. In searching for loops we must distinguish between what is desired and what is possible to achieve. We must make sure to include constraints which may act to limit performance in the real system. Further, we must ask if the converter or flow regulator depends upon one (or more) other variable (s) construct outside and make that connection. We are mainly interested in deciding how to formulate a particular decision function (finding policy as defined previously).

The choice of factors must be made from the viewpoint of what affects the characteristics of information feedback systems. The decisive test in choosing factors with direct influence is to observe model performance with and without the factor. In this way the model itself can help determine what it should contain. Care must be taken to recognize feedback or repercussion of the decision on the factor entering into the decision and the timing of such feedback. That is where we try to detect positive and negative feedback loops operating between flow and stock. Positive feedback creates exponential growth and can ultimately lead to oscillations causing the collapse of the system. An example here would be advertising. If the advertising budget is set as appropriation of sales, then sales increases advertising as well. In this case the degenerative cumulative cycle will continue until maybe the depletion of the customer pool will put an end to commercial activity. Thus, in many cases a negative feedback loop should be at work and repercussion on the factors entering decisions should be investigated, because the effect might not be unidirectional.

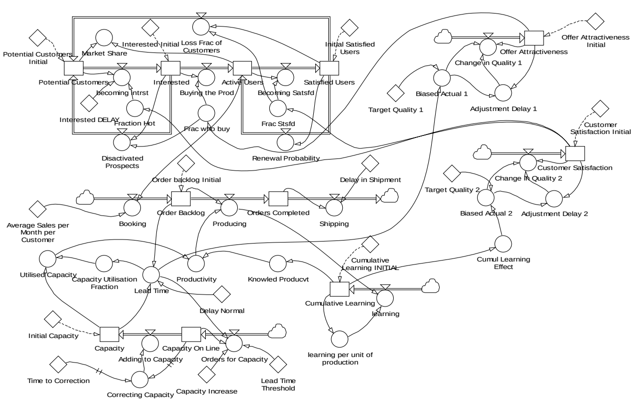

Fig. 2: Example of Stock and Flow System Dynamics Diagrammatic Model

Fig. 2 shows an example of system dynamics model using stocks and flows. The model illustrates many of the concepts of system dynamics such as levels, rates-of-flow and causal loops, discussed in the preceding sections. Rectangles represent levels such as Potential Customers, Order Backlog, Capacity and Customer Satisfaction. Rates-of-flow are represented by valve gauges which cause the levels to change such as the producing rate causes the Completed Orders Level to increase or decrease. Circles represent auxiliary variables and arcs represent relationships that cause the rates of flow to change. For example Productivity depends on auxiliary variables such as Capacity Utilization and Learning. Non-linear relationships are also incorporated in the model.

Diamond shapes indicate variable types which contain fixed values such as Initial Customers and Target Quality that are used in calculations of auxiliary variables or flows. Diamonds can also be used as leverage points for policy formation, such as Capacity Levels. Arcs denote links that can be categorized as information links, delayed links, and initialization links that give information to auxiliary and level variables.

Clouds represent undefined sources or outlets for a flow to, or from a Level. Clouds denote that we are at one of the model's outer limits.

3.3.2 Quantitative Model – Model Formulation

The formal model's objective is to define how user's actions are processed and what outcomes are produced. Formulation of the model has not undergone any considerable changes over the years. The concrete formulation of a model is carried out using of differential equations, displaying causal relations of the system. And a computer simulation is used to solve the simultaneous differential equations formed by the individual equations (Rego, 1999) [24]. That is the role performed by one of the components of a Management Flight Simulator – a dynamic computational engine. It simulates the elapsing time and defines variables and variables relationships, which can change over time of simulation or at a specified point (Saunders, 1998) [22].

In specifying the mathematical relationships, we are providing the computer with a precise description of how the system operates. The equations tell how to generate the system conditions for a new point in time, given the conditions known from the previous point in time. As the computer program automatically calculates the system's equations for levels, rates or auxiliary, supplementary and initial values, our concern is how to pass the logical checks, which most of them are incorporated in the software as correcting signals, so that we can create a computer model for simulation. Then, the choice of the solution interval time-DT (delta time or time increment) becomes the second concern. By definition this interval must be short enough, so that we are willing to accept constant rates of flow over the interval, as a satisfactory approximation to continuously varying rates in the actual system. This means that decisions made at the beginning of the time interval will not be affected by any changes during the interval. The entire computation sequence can then be repeated to obtain a new state of the system at a time that is one DT later than the previous state. The model traces the course of the system as the environment (levels) leads to decisions and action (rates) that in turn affect the environment. Thus, interactions within the system will unfold according to our description or logic set down in the equations of the model. In almost every case this logic, which will generate the system of equations, can be very easily constructed using addition, subtraction, multiplication and division. When, the need arises to use higher level algebraic operations, the program offers a wealth of tools ranging from trigonometric to financial and statistical operations, capable of capturing a great variety of relationships and patterns.

3.3.3 Identifying Decision Rules

While it is relatively easy to define the models components and quantify the model, representing the decision rules of the actors is a much more difficult task (Sterman, 1987) [25]. Here questionnaires, interviews, observations, surveys and other methods can be used.

3.4 Model Validation

The next step after the simulation model is built and quantified is to validate it. The objective of validation is to identify and eliminate errors, and to insure that the model operates as the system it represents, and whether it will answer the questions and cover the scope identified in the first step. This stage involves mainly conceptual validation. And again, the biggest challenge is for the decision models built into a management flight simulator to adequately reflect a rational decision making process. If the model proves to be invalid, then the steps before it have to be repeated, starting from the problem definition and scope.

Model validation, which is associated with verification and calibration, would formally come after a System Dynamics model is created and before simulation experiments are commenced. In reality though model verification, calibration, and validation is a prolonged process spread throughout the system dynamics model development process. It is important to distinguish between statistical forecasting models, which can be thought of as "black box" models and system dynamics models, which are explanatory, transparent causal descriptive models. A statistical forecasting model, which is based on historical information, is considered to be valid if it provides accurately enough short term forecasts. Such models can not really claim any causality but a correlation between variables, so validity is mainly measured on the short-term predictive power of statistical forecasting models. How these models are then evaluated represents no ambiguity and is more of straight forward process using various statistical measures. On the other hand system dynamics models are causal descriptive models and validity represents an entirely different question. System dynamics models require two different aspects of validation, behavior or output validity and structure validity, which is the justification of whether the structure of the model is a good representation of reality. That is whether the causal relationships of the model reasonably or approximately correspond to the real relationships. So a system dynamics model should be assessed on both structural validity and on its capability to reproduce dynamical behavior patterns that exist in the real system. In other words a system dynamics model should be able to produce the right behaviors for the right reasons. Such an implication makes the system dynamics modeling process a very complex task.

3.5 Building the Management Flight Simulator

Here the objective is to build a human-computer interaction component of a Management Flight Simulator. An example of a typical human computer interface of system dynamics flight management simulator is provided in Fig. 3 below. The exhibited simulator refers to a manufacturing firm facing backlog problems. As seen in Fig. 3 the user is able to specify a number of control parameters using radio buttons and sliders. Feedback regarding the effectiveness of decisions is provided to the user via graphs, gauges, narrative or number displays as well audible signals.

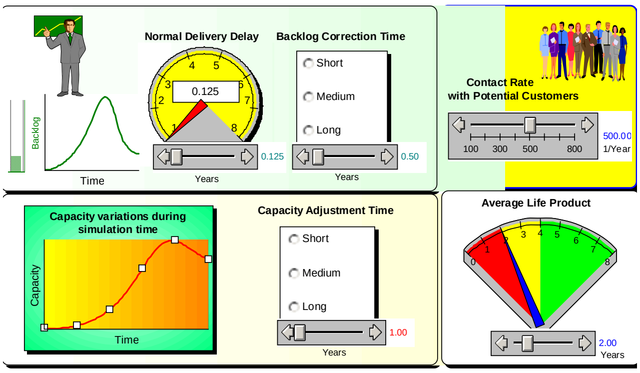

Fig. 3: The human computer interface of a Management Flight Simulator

Computer software should be used to present the simulation to the intended user giving him/her a variety of components available for manipulation. Also, the decision should be made whether the simulation is intended for a single or multiple users and whether it would be run locally on a PC platform, over the internet or another network.

3.6 Computer Simulation Testing and Validation

Testing can be performed in the form of a direct experiment, as suggested by Sterman (1987) [25] in his paper "Testing Behavioral Simulation Models by Direct Experiment", where subjects play a game and are given the same information set and freedom to make decisions in their own way. At the end the decisions made by the participants are compared to behaviour produced by the decision rules of the game.

Another method of testing is called hypothesis testing of the model parameters. That involves stating how the model should behave when a parameter is changed in a certain way, running the simulation with the changes, and comparing the model behaviour against the hypothesis. A further sensitivity analysis would involve checking whether the model is sensitive enough (and not oversensitive) to the changes in some parameters.

Also, some key performance indicators (KPI) can be set against which the behaviour of the system can be measured.

A series of questions are asked to validate the computer simulation model, which involves conceptual, structural, and behavioural validation. If some serious errors are identified during this stage, the model has to be reconstructed, going back to the first step. That is why it is advisable to perform some testing and validation at each stage of the model construction and to have domain experts available to progressively refine the model.

The basic sub-steps here as described originally by J. Forrester and P. Senge (1980) and then regrouped here as follows.

- Do basic de-bugging
- Ensure robustness
- Replicate reference behavior
- Test policies, sensitivities and scenarios

The purpose of passing the model through an increasingly sophisticated number of tests with simulation, is to increase confidence in the model. The breadth of the confidence building-tests in dynamic models stretches from tests of the model's structure, through tests of model behavior, to tests of the model's policy implications. In other words, having eliminated the obvious implausibilities, we focus attention to the finer aspects of performance. In our case, attention was focused on all of the model behavior characteristics that can be compared with the real system.

There is no single test that serves to validate a system dynamics model (see our previous discussion). Rather, confidence accumulates gradually as the model passes more tests and as new points of correspondence between model and empirical reality are identified (Barlas and Carpenter, 1990). Therefore, seen like this, validation includes transferring confidence to persons directly or not directly involved in model construction. It is this need that steps 5 (Implement) and 6 (Challenge) from figure 2 are to satisfy.

The must for complying with the necessity of this confidence building process, has led to emphasize the importance of choosing the right mapping language, for achieving the transition from the individual to the congregate cybernetic strategy map. We discuss the subjects of philosophical and epistemological roots of model validation, relevant here, in the third part.

In this example special attention was given to establish if the intrinsic structural elements were capable of producing the Reference Behavior Patterns expected from various sectors and the original problem definition.
The policy/strategy testing unfolded in workshops tracing out answers to the questions pertinent to the objectives outlined below:

- How would policies work under a variety of altered scenarios?
- What would be the hidden potential of different tactics to achieve a better quality? Learning through intensive training? Specific marketing initiatives for awakening customer awareness? Other?
- What demands would the different policies put on the system structure?
- Should "sales attractiveness" be emphasized or "customer satisfaction" and at which points in time?
- What would be the best quality index to set or, in general, what measures should be undertaken so that the company materializes the plans for growth?

The last two steps of the modeling process as presented in figure 1, "Running" and "Feedback", are discussed next.

3.7 Running

The final objective is to perform a what-if analysis testing various policies. The activities at this stage can range from simple change of one variable to complete redesign of a decision rule, a policy scenario or the whole strategy by a decision maker.
After completing the testing step (in fact something we never complete in an absolute sense), we were concerned with implementing the results of the effort. A critical component of successful implementation was the effective communication of the acquired insights to others - many of whom did not have any connection with the mapping or modeling process.

Actually, implementation should be continuous throughout the process. People who will experience the change must be involved in thinking it through. We found that involving a critical mass of stakeholders from the very outset, greatly enhances involvement. Ways of achieving participation are to involve these people at least in the steps of focusing the effort, mapping-reviewing and conducting policy tests with the model. The objectives are basically to enhance assimilation of the model's structure and model's behavior.

Practical ways of achieving this can be the use of mapping sectors, pictures, text or even a film suggesting the underlying structural groupings and relationships. For instance, by typing descriptions in the document fields within the dialog boxes available in the software entity, people can "visit" these dialog boxes and read the assumptions rather than having to de-code them from algebraic representations.

Another way is to facilitate interactions with the model. By facilitating user interaction we can draw stakeholders into ownership of the process. The used software offers the facility to make a control panel (a special sector) which enables people to change parameters in the model from one location of the diagram, without having to wander around looking for the variables they may wish to test. Like this, we may organize an array of sensitivity set-ups and investigate any change of variation (e.g., minimum and maximum for each selected variable). The last step was again the purpose of reinforcing confidence in the model's use.

3.8 Feedback

There is no learning without feedback, without knowledge of the results of our actions. Thus, a good Management Flight Simulator should analyse the output and provide feedback to the user on why did certain events occur during the simulation, and what could be the meaning of the outcomes.

The framework presented in this paper is very flexible, and allows going up a step at any moment if some changes are required.

The final step in testing process consists of taking a fresh look at the structure of the model. The basic questions to consider are: What would happen if we replaced this cloud with a stock? Is it likely to alter the policy conclusions that we have reached? In other words, we take a critical look at both the external and internal boundaries we have chosen.

4 Conclusions

This paper presented a framework for developing Decision Support Systems with the aid of Management Flight Simulators, which are based on system dynamics methods. As shown in this paper while there are still debates going on about validity of the use of Management Flight Simulators for organizational learning and decision making, they continue to be one of the best methods available for resolving the complexity of large systems. Computer simulations become an indispensable tool when a real-world experiment would be too costly, time consuming, unethical, or unfeasible in any other way, helping us to discover through our own actions how the whole system will react, even if the effects should be seen in a century time.

Organizations may vary in their ability and willingness to adopt and invest in the "flight simulators" development, but with the increasing number of tools and software available for creating a microworld, it is hard to remain skeptical about their use, even for novice computer users. And with employment of such technologies as virtual reality, mobile internet, 3D graphics, artificial intelligence and Web, users experience is becoming more enhanced and closer to the real-world decision-making setting.

Finally, the proposed framework could serve as a generic method for developing realistic management flight simulators. In such computer-based simulators knowledge can be captured, internalized, shared and plausible scenarios may be tested prior to implementation to solve management problems in feedback controlled cybernetic way.

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