DESIGN OF A LEARNING ENVIRONMENT

The Oil Producers' Microworld

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Abstract

New gaming software coupled to detail-rich readings (such as case studies and newspaper clippings) promise more effective ways for widespread dissemination of model-based insights. However, gaming-simulators have often been criticized for encouraging superficial thinking aimed solely at 'beating the computer' rather than understanding business and social problems.

To avoid the so-called 'video-game syndrome' it is necessary to embed a model in a workshop that includes briefing materials and a gaming protocol to encourage reflection, discussion and discovery.

This paper reports on a computer-based learning environment for the oil industry -- an oil producers' microworld. Game players (who need not be familiar with system dynamics) can take the role of different oil producers and create their own industry scenarios for oil price, production, OPEC quotas and crude oil reserves. The paper describes how participants are briefed about the oil industry, systems thinking and the model's feedback structure. Samples are provided of the gaming interface and model generated scenarios.

Introduction

We model to learn. But at best only a handful of people actually build a model and share the learning that comes from conceptualization, mapping, formulation and simulation. Now gaming simulation opens the possibility of widespread dissemination of model-based insights. A model built by a small team can be packaged in an attractive and user-friendly format for use throughout a company, a school or a society. In principle the insights derived by the original modelling team can be replicated for any group that works with the gaming software and accompanying courseware.

In practise there is a danger that the gaming simulator is treated as a black box whose structure is poorly understood. Simulations become an exercise in outwitting the computer and discovering weak points in the black box, rather than understanding the modelled business or social system.

Recent gaming simulations such as *Fishbanks* (Meadows et al 1989), *The People Express Management Flight Simulator* (Sterman 1988), *The Claims Game* (Kim 1989, Bergin and Prusko 1990), and *OwnerTransformLE* (Naumienko and Dlugosz 1990) have sought to circumvent the 'video game syndrome' through the design of gameware and workshop protocols. Gameware includes the materials handed to participants before and during the gaming simulation. It also includes the user interface -- the layout of symbols and information on the computer screen or gameboard. Workshop protocols include the pre-game briefing, the steps of play, the guidelines for teamwork and team decisionmaking, and the post-game debriefing.

This paper reports on the design of the Oil Producers' Microworld, a gaming simulation that allows participants to generate their own 25 year scenarios for crude oil production and price, and to experiment with alternative strategies for managing capacity, production and oil reserves of the global oil system. Particular attention is paid to the pre-game briefing that reveals to participants the model's feedback structure. There is also a description of the user interface.

Background to the Oil Producers' Microworld

The Oil Producers' microworld grew out of a modelling project with a team of senior managers and planners at Shell International Petroleum Company to improve group understanding of oil market behaviour for use in global scenarios. The project led to a system dynamics simulation model of the oil producers which produced new insights into the power and stability of OPEC, the dynamics of oil prices, and the investment opportunities of non-OPEC producers (Morecroft and van der Heijden 1992, Group Planning 1989).

The decision to develop a gaming simulator was motivated by Shell Group Planning's general interest in systems thinking and the specific desire to understand more about the 'packaging' of models for dissemination. The Oil Producers' microworld has been used experimentally in two internal training programmes.

Revealing Model Structure -- Recreating the Modelling Process

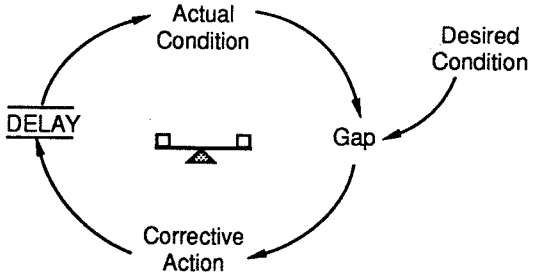
The conceptualization of the oil producers' model took place in three meetings of the original project team lasting three hours each. A lot of valuable learning takes place in such meetings. The team (in this case ten experienced managers and planners) generated the core concepts, vocabulary and architecture of the model.

The model is moderately complex. There are five sectors that represent OPEC, the swing producer, independent producers, the market and quota setting. The model captures the social, political and power motives of OPEC production policy, and the contrasting commercial logic of the independent producers. The algebraic model contains about 100 equations.

To recreate the problem structuring and discovery process of the original project team there is extensive pre-game briefing. The participants read recent press cuttings about oil markets and a short booklet *The Oil and Gas Industry in the 1990s* (Jennings 1988). The articles generate a shared vocabulary and knowledge base among the participants, that starts them thinking about the industry, in much the same way that the *People Express Case* (Whitestone 1983) prepares participants for the People Express Management Flight Simulator. Detail-rich industry information appears to be important for engaging participants with a gaming simulator which, by itself, is inevitably an abstract characterization of the industry. (note: Many business games still come with briefing materials describing a hypothetical company making widgets in an imaginary competitive industry. Such games rarely deliver new business insights. The model fails to come to life in the minds of the participants).

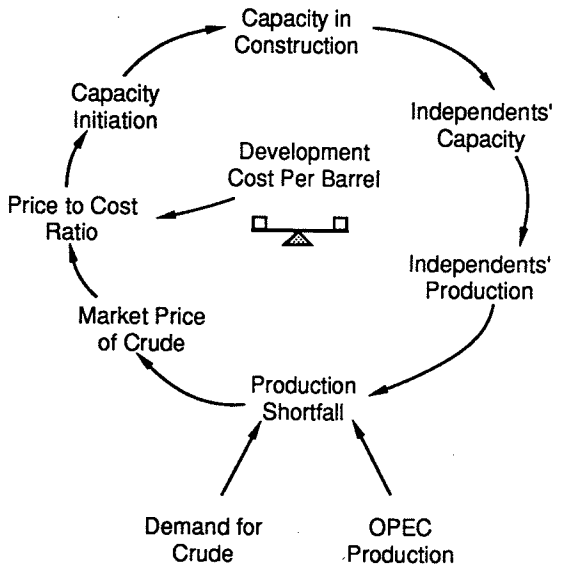
The participants spend two or three hours in a guided tour of the model's feedback structure. The starting point is the balancing loop archetype from *The Fifth Discipline* (Senge 1990). (If the participants are new to systems thinking and system dynamics, it is helpful for them to read chapter 5 "A Shift of Mind" beforehand). The *balancing loop with delay* is a template to begin to organize the complex web of connections, pressures and forces that orchestrate the balance of supply and demand in global oil markets.

The workshop leader shows participants the basic archetype in figure 1 and gives examples that link the structure with roller-coaster behaviour. He then moves to the specific example in the lower half of figure 1 that shows a balancing loop with delay 'outfitted' to represent a simple oil supply system. A what-if story to accompany the picture might be as follows: suppose there is a production shortfall of 5 million barrels a day - what happens? The picture suggests that the shortfall causes the market price of crude to rise. A higher crude price improves the economic incentives for independent producers to expand capacity. After a long construction delay (several years) new capacity comes on line allowing the independent producers to increase production and so reduce the production shortfall. The invisible hand of the market is at work.



Basic Archetype - Balancing Loop with Delay

adapted from Senge *The Fifth Discipline*



Outfitting the Archetype - Independents' Upstream Investment

Figure 1: Template to Organize Complex Web of Connections in Global Oil Market

A simulation of this partial model enables participants to see the story played out. They quickly realize that this loop alone is not sufficient to explain real oil market behaviour: Simulated price rockets to a peak of 160 dollars per barrel, and production varies in a twenty year roller coaster. Obviously the behaviour is implausible, but it is sufficiently engaging to draw participants into a closer look at the complete oil producers' model.

The next stage of the workshop recreates for participants the mapping exercise of the original project team. The oil world as conceived by the project team comprises not only the independent producers, but also a swing producer and other OPEC producers. These producers between them must, somehow, coordinate global oil supply and demand. Therefore the system's behaviour as a whole resembles a balancing loop with delay, but within the simple archetype there is much added complexity from the political, social and power factors that shape the capacity and production decisions of OPEC.

The workshop leader facilitates a discussion of the decision-making logic of the independents, the swing producer, the opportunist producers (the other members of OPEC), and OPEC's quota setting. The objective is to map the key influences and information flows that make-up the feedback structure of the full model, and to involve the participants in the mapping exercise.

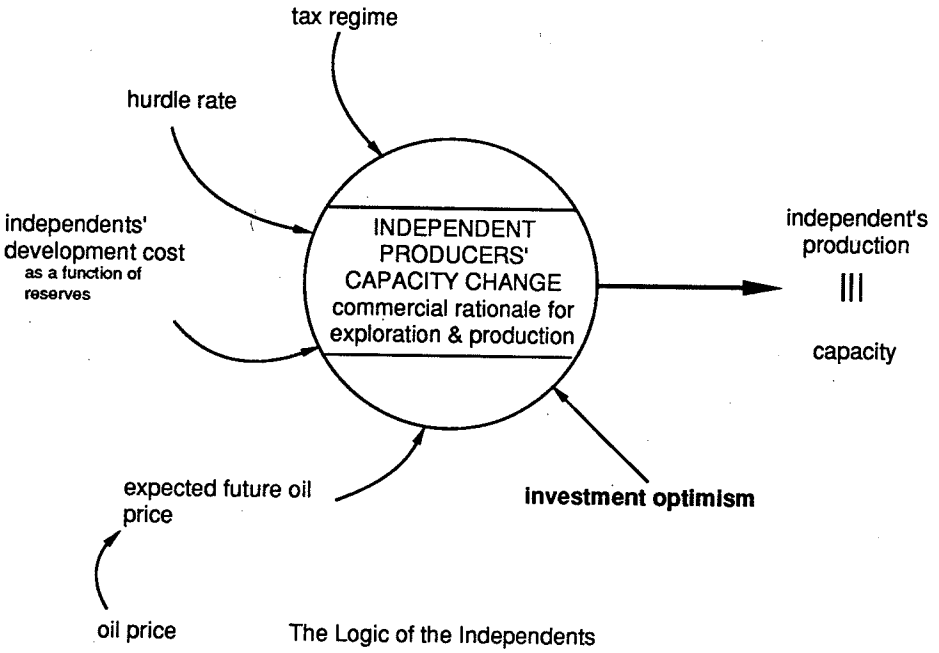
Imagine a mapping exercise for the independent producers. The workshop leader asks participants to name the factors that they think the independents consider when making upstream capital investment decisions. The comments are recorded on a whiteboard or flipchart. The result is a picture like the one shown in the top half of figure 2. The independent producers' capacity change depends on commercial criteria that include expected future oil price, independents' development cost, the hurdle rate (the rate of return required from capital investment projects), and the tax regime. Typically participants mention other influences, but the workshop leader homes-in on figure 2 because these particular factors are the ones identified by the original project team.

How do OPEC members agree on quota? The discussion leads to a picture like the one in the bottom half of figure 2. Participants recognize that to decide on quota, OPEC must first estimate total oil demand and production of independents. The difference between these two estimates is known as the call on OPEC, the amount that OPEC should produce to exactly balance supply and demand. Of course OPEC need not aim for an exact balance, and may choose to set a quota that is deliberately less than the call, or deliberately more. This strategic manipulation of the supply demand balance is represented by the cartel quota bias.

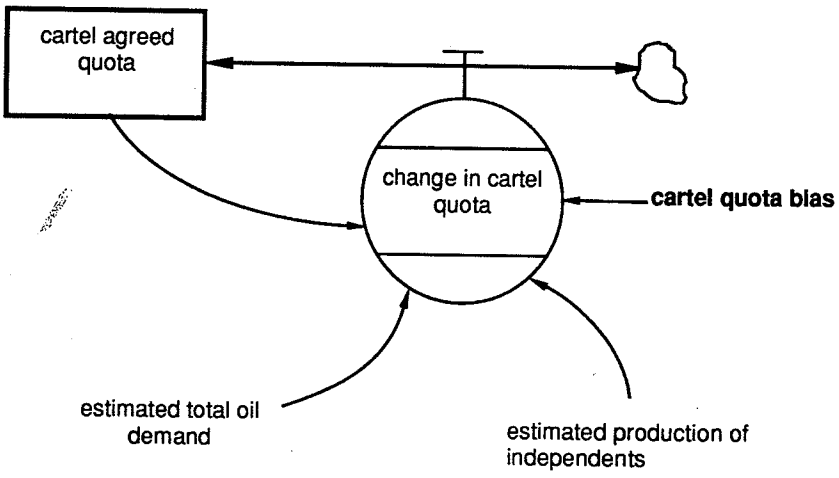
The exercise is repeated for the other producers. How does the swing producer set production? How do the opportunists set production? The discussion turns to quota, desired price (or marker price), market share, market power, revenue needs, social and political objectives, and a host of other related factors.

Participants have by now shared in the process that defined the architecture of connections in the Oil Producers' model. It just remains for them to discover the feedback loops that are formed as the system of producers is put together. This final step is covered in pencil-and-paper exercises. Participants are presented with a set of feedback diagrams. But the diagrams are incomplete. There are phrases and words scattered over the page, but no connecting arrows. The task is to draw the connections, identify the archetype, and construct the corresponding 'story' of time dependent behaviour. For example, one diagram shows swing producer production, production shortfall, market price of crude, and the price gap (market price minus marker price). When connected it reveals a fast-acting balancing loop through which the swing producer exercises price control. Other diagrams reveal a reinforcing loop and a success-to-the-succesful archetype in OPEC quota bargaining and opportunists' capacity expansion.

By the end of the pre-game briefing the participants have a basic grasp of the key feedback loops included in the model and gaming simulator.



The Logic of the Independents



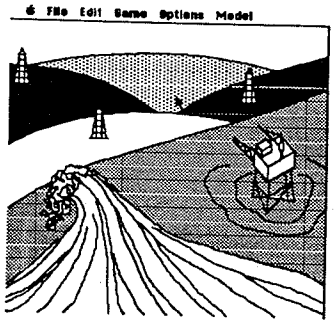
The Logic of Quota Setting

Figure 2: Recreating the Mapping Exercise of the Original Project Team

Design of the User Interface

The user interface was built with Microworld Creator (Diehl 1990) starting with equations imported from a STELLA model (Richmond et al 1987). As many readers may know, Microworld Creator provides a screen template that allows a game builder to design a tailored, graphic and user-friendly interface to the simulation engine of the modelled system.

Microworld Creator sets aside an area on the right of the computer screen for menus of decision variables, reports, graphs and tables. The remainder of the screen is used for window displays of reports and graphs. Within this pre-defined format, the game builder has great scope and flexibility to design the visual layout of information and reports in a way that will appeal to the user.



The Oil Producers' microworld opens with the picture on the left showing oil platforms, oil rigs, sea and sand dunes intended to stimulate thoughts of the global oil system. The decision variables are in the upper right of the screen as shown in figure 3. There are five variables that give the user access to parameters of the simulation engine. The Effect on Demand of GDP Technology and Environment (shown as EffGDPTcnolgyEnv) allows the user to create alternative demand scenarios. The other parameters allow the user to specify policy characteristics of the producers that represent aggressive, defensive, optimistic and pessimistic behaviour.

The choice of decision variables present many design options. Which of the many variables in the underlying model should be accessible to user teams? What role should the users play? Should users be an integral part of the feedback structure (as happens in the People Express Management Flight Simulator when users decide how many planes to buy, or how many people to hire in a given quarter)? Or should the users' role be to 'sit on the edge' of the feedback structure, manipulating the policy levers that control loop gain and dominance, leaving the loop structure of the simulation engine in tact.

The Oil Producers' microworld puts users in the role of the independents, swing producer and opportunists, manipulating policy levers. For example, the decision variable 'cartel quota bias' allows users to define an upward or downward bias in quota relative to the computed call on OPEC. A value of '0' is neutral, meaning that the simulated cartel agrees a quota that is equal to the call, with the intention of balancing supply and demand. A value of '-.1' means the cartel is setting a quota that is intentionally 10 percent less than the call. By design users are not allowed to set quota or production rates directly.

Figure 3 shows two reports that were designed as icons of the producers' decision logic. The Capex report shows a boardroom table seating a top management team from an independent producer. The team is deciding on capacity expansion in the first quarter of 1988 (the simulated date is shown in the top left of the picture). On the table is the information relevant to the independents: expected oil price, development cost, profitability and the hurdle rate. Out of the information comes the recommended expansion as calculated by standard project appraisal methods. The users are in control of management attitudes through the policy lever *capex optimism* which is displayed in the lower right of the report. When *capex optimism* is set to a value greater than 1, the independents are assumed to be bullish and approve more expansion than recommended. A value less than 1 represents pessimism. The final outcome of the capex deliberations for first quarter 1988 is shown as capacity initiation in the top right of the picture.

The Cartel report shows the Cartel members sitting round a conference table. On their table is an estimate of the call on the cartel, opportunists capacity and swing producer capacity. The *cartel quota bias* shown in the top right of the report is set by the users and determines whether the agreed quota is greater than, equal to, or less than the call on OPEC, as described above. A political bargaining process ensues that shares-out the agreed quota between the swing producer and the opportunists.

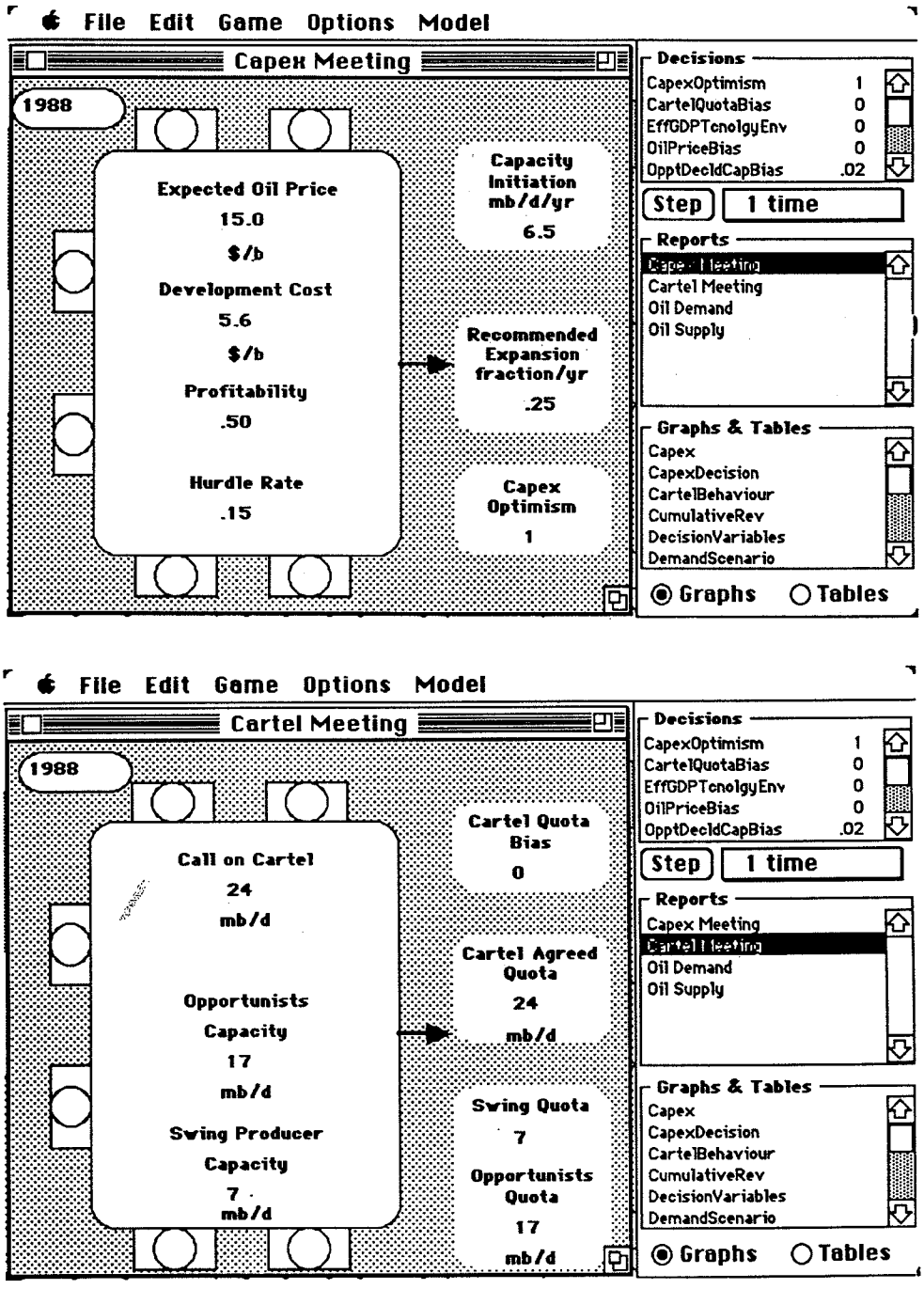


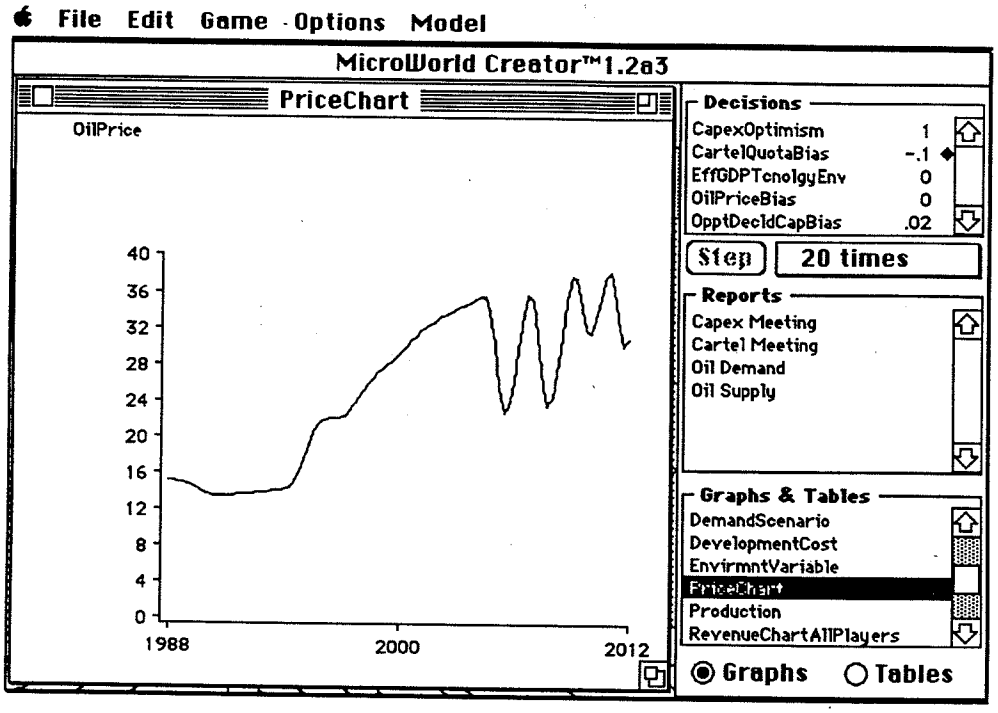
Figure 3: Reports Generated by the Oil Producers' Microworld

The graphs and tables are designed with scenario-making in mind. Scenarios are internally consistent stories about alternative futures intended to stimulate what-if thinking in the organization. The game builder organizes and displays variables, and sets the scale of axes in such a way as to facilitate the construction of stories. A satisfactory arrangement of graphs takes time and is achieved through trial and error with many simulations.

Figure 4 shows typical output from the microworld. There are two graphs taken from a supply squeeze scenario. The supply squeeze is created starting in 1994 by causing OPEC to set quotas that are 10 percent lower than the call from the market (cartel quota bias set to -.1 as indicated in the decision window) The quota restriction is maintained from 1994 to the end of the simulation in 2012. The opportunists are assumed to produce at quota. The independents are assumed to adopt a neutral capex policy, meaning that they expand capacity at exactly the rate recommended by project appraisal methods, rather than being optimistic or pessimistic. External pressures on demand from the economy, technology and the environment are assumed to be neutral. In other words, in the absence of price changes, demand stays constant at 50 million barrels per day. I will leave it to the reader to construct a story that goes with these simulations. But for comparison, a version of the story can be found in Morecroft and van der Heijden (1992).

Conclusion

Gaming simulation can bring the insights of systems thinking within the reach of everyone, not just modellers. The persuasive power of model-based insights lies in the opportunity that simulation provides for people to experience the future, and to role-play in a microcosm of their world, as Meadow's pioneering work has demonstrated (Meadows 1989b, Meadows 1984). Microworlds are the tools of the learning organization and the learning society, giving us the means to experiment with the design of business and social policy in the safety of simulated experience. But to realize this potential we need to design our gaming simulators, microworlds and learning laboratories to encourage systems thinking, informed experimentation, and creative scenario making. This paper contributes to the quest for improved design by describing a briefing protocol that communicates model structure and a user interface that supports informed role-playing.



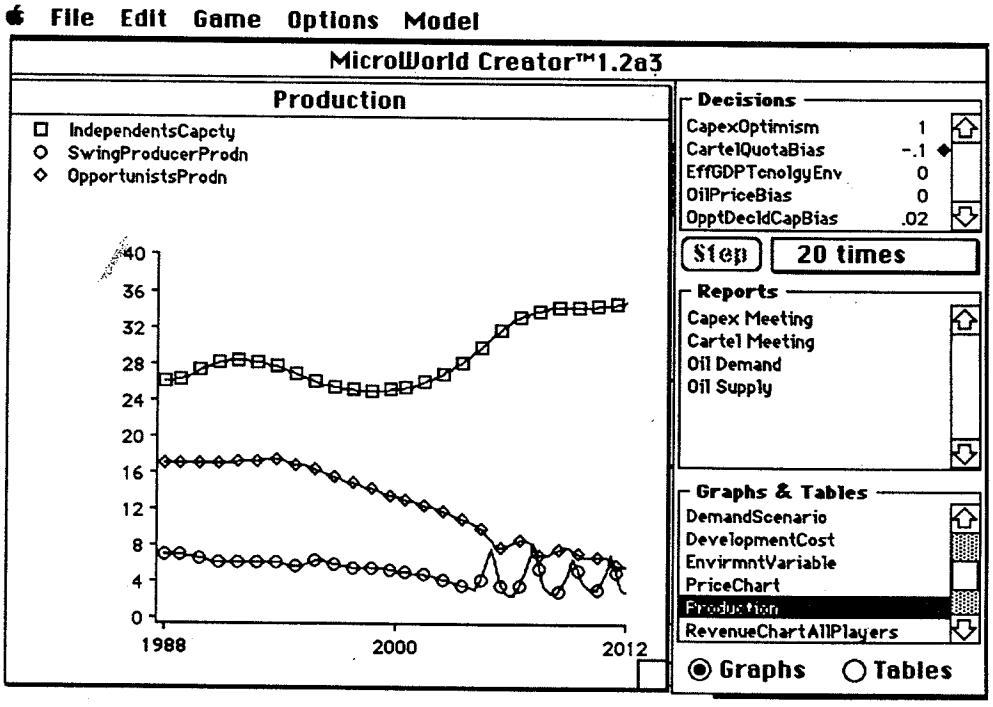


Figure 4: Supply Squeeze Scenario

References

Bergin R., and G.P. Prusko 1990, "The Learning Laboratory", *The HealthCare Forum Journal*, 33(2), 32-36.

Diehl E.W. 1990, *Microworld Creator*, Microworlds Inc, PO Box 1400, Cambridge, MA 02142, USA.

Kim D. 1989, "Learning Laboratories, Designing Reflective Learning Environments", in *Computer Based Management of Complex Systems*, (editors P. M. Milling and E. O.K. Zahn), 327 - 334, Springer-Verlag, Berlin.

Group Planning 1989, "1989 Scenarios, Challenge and Response", *Group Planning Publication (confidential)*, PL 89 S12, Shell International Petroleum Company, London, SE1 7NA, UK.

Jennings J.S. 1988, "The Oil and Gas Industry in the 1990s", an address to the Third Annual North Sea Conference of the British Institute of Energy Economics, London, 27th June 1988, *Shell Publications*, Public Affairs, Shell International Petroleum Company, London SE1 7NA, UK.

Meadows D. L., T. Fiddaman , and D. Shannon 1989, *Fishbanks Ltd*, A Microcomputer Assisted Simulation that Teaches Principles for Sustainable Management of Renewable Resources, Monograph from the Institute for Policy and Social Science Research, Hood House, University of New Hampshire, Durham, NH 03824, USA.

Meadows D. L. 1989, "Gaming to Implement System Dynamics Models", in *Computer Based Management of Complex Systems*, (editors P. M. Milling and E. O.K. Zahn), 635 - 640, Springer-Verlag, Berlin.

Meadows D. L. 1984, *Strategem 1*, A Management Training Exercise on Long-Term Economic-Environment Interactions, Monograph from the Institute for Policy and Social Science Research, Hood House, University of New Hampshire, Durham, NH 03824, USA.

Morecroft J.D.W., and K.A.J.M. van der Heijden 1992, "Modelling the Oil Producers", *European Journal of Operational Research*, 57, 1.

Naumienko E., and M. Dlugosz 1990, "Gaming Simulation and the Challenges of Eastern Europe", presented at XXI ISAGA Conference, Durham, New Hampshire, July 1990, available from E. Naumienko, School of Management, Warsaw University, Szturmowa Str. 3, 02-678 Warsaw, Poland.

Richmond B.M., P. Vescuso, and S. Peterson 1987, *STELLA for Business*, High Performance Systems, 45 Lyme Road, Hanover NH 03755, USA.

Senge P.M. 1990, *The Fifth Discipline*, Doubleday Currency, New York.

Sterman J. D. 1988, *People Express Management Flight Simulator*, software and documentation available from author, Sloan School of Management, MIT, E52-562, Cambridge MA, 02139, USA.

Whitestone D. 1983, *People Express (A)*, case number 483-103, HBS Case Services, Soldiers Field Road, Boston MA.