LEARNING AND UNDERSTANDING INNOVATION DYNAMICS: A GAMING APPROACH

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ABSTRACT

Innovation management is a special task in several respects. Its success is essential for the survival of the firm. It deals with highly dynamic processes, and it requires a viable strategy from the very outset. Analyses of innovation dynamics have shown that market forces usually do not allow the search for a gradual approach toward a successful strategy. Frequently technology advances rapidly and the market changes so fast that no second try is possible.

In such a situation, the artificial reality of a management simulator provides a powerful environment to learn about the system under investigation. It allows deeper insights into the problem situation. In its virtual world, it alleviates the development of an improved understanding of the intrinsic aspects, and leads to a better feeling for possible reactions of the market.

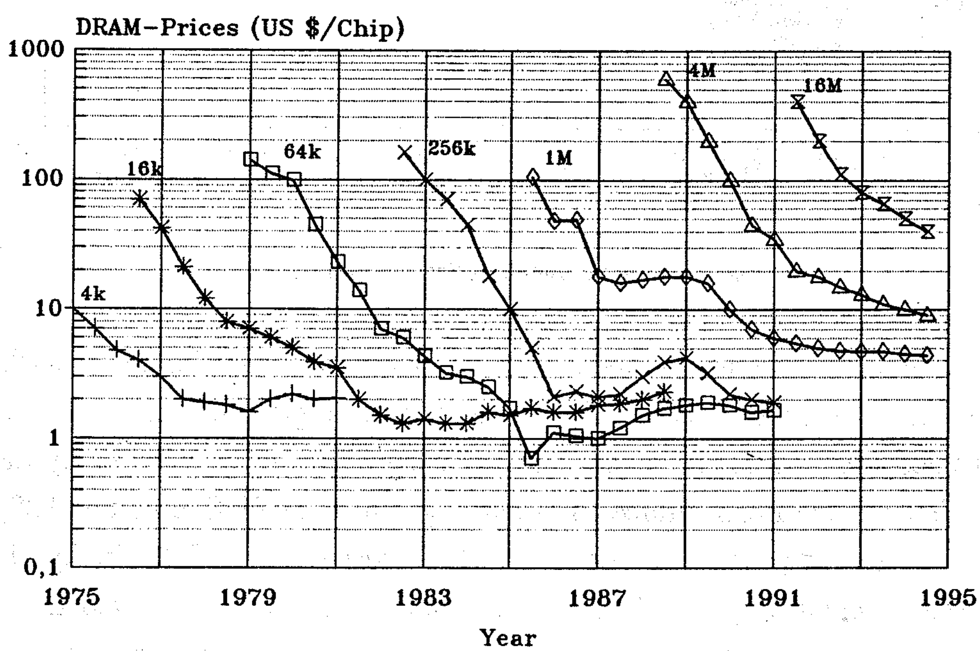
The paper presents the coarse structure of an Innovation Management Simulator (IMS). The players represent four competing companies. At the beginning of the simulation, all offer a comparable product, no firm holds a competitive advantage. Among other policies, they can – through resource allocation for research and development – create additional, non substituting products. The product life cycles with their time patterns of profits and sales, market shares, etc. are endogenous variables, influenced by the players' actions.

The decision to develop and launch a new product and the choice of the time for market entry are strategic variables of the players. Further decisions are required to budget product and process development, pricing and advertising, capacity allocation, personnel recruitment and financing. The game is played on a quarterly basis. The decisions are fed into a System Dynamics model, and the results provide the input for a new round of decision making.

The Dynamic Environment of Innovation Management

The rapid change in technology leaves very little time for high-tech firms to sell their newly developed products and to earn an appropriate return on investment. For the extremely fast advancing field of dynamic random access memory chips (DRAMs) e. g., each new generation comes along with a quadrupling of storage capacity. With large scale integration grew the number of manufacturing operations, and the cost for research and development (R&D) increased progressively. Approximately parallel grew the investment in production facilities.

According to Siemens data, in 1985 investment requirements for a state of the art factory were in the range of $ 50 million. Four years later they reached $ 250 million, and for the production of the 16 Megabit chip, upcoming in 1992, the amount needed exploded by an order of magnitude to $ 2.5 billion (Hofmeister1989; Schmitz 1991). DRAMs are manufactured by more than a dozen companies, and - despite their sophisticated design and delicate production processes - are traded like commodities. Competition leads to a sharp decline in prices immediately after the new product generation with its more advanced technology entered the market. The historic and projected data in Figure 1 illustrate the transition between several levels of technology and the associated price decay.



Source: Dataquest 4/90

Fig. 1: Price Development of Subsequent Levels of Technology.

Trailing the leader's race to market by only a short time makes it difficult, if not impossible, for a firm to achieve a sound economic performance. In general, high expenditures for R&D and manufacturing equipment, short product life cycles and a dramatic decay in prices immediately after market introduction characterize the field of high-tech enterprises – a constellation that is called a *dynamic environment*. Here it is vital to have a clear and concise strategy; firms must build up in time the production capacity required; delivery must be fast when demand gains momentum. Only early in the life cycle, high prices can be charged. During this stage the firm must earn its return for the large prepayments made, for research and development expenditures, the investment in production equipment and facilities, and for the general risk taken.

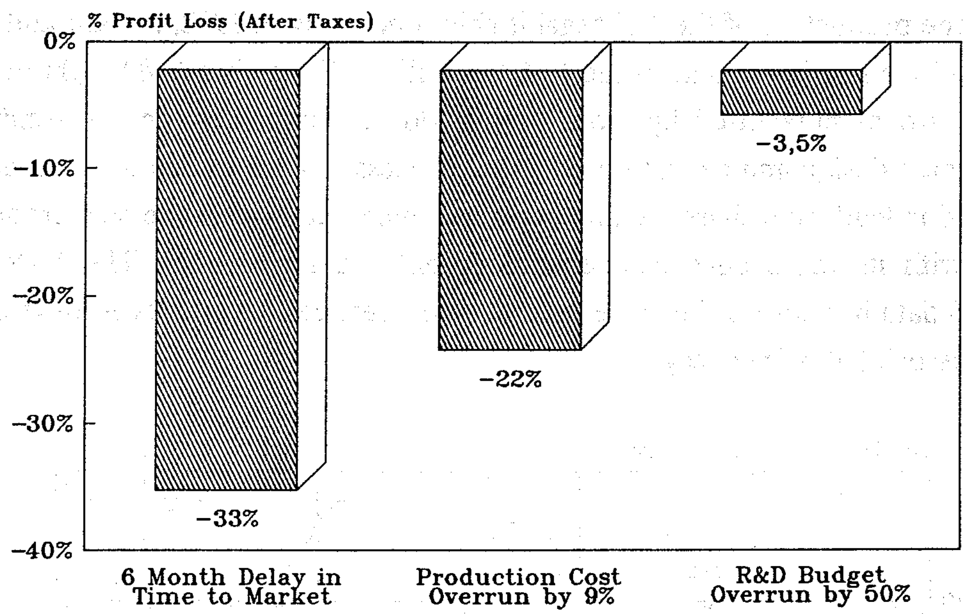


Fig. 2: Factors Influencing Profit Performance.

In a dynamic environment, speed with its crucial aspects of time to market and time to volume becomes a competitive factor of strategic dimension. A McKinsey study revealed that if market introduction of a new product is delayed by mere six months, this time span can reduce total earnings up to 33 % (Dumaine 1989). Substantial and sustained production cost overruns or exceeding the R&D budget by 50% have far less or even only marginal impact. Similar results are reported from other sources and are confirmed by own analyses. Figure 2 shows these impacts on profit performance and stresses the importance of a concise and well timed innovation strategy.

THE NEED FOR AN INNOVATION MANAGEMENT SIMULATOR

The kind of problem description provided in the above paragraphs might suggest a strategy of high pricing together with an early provision of production capacity. This, however, implies high fixed cost and little flexibility if demand were overestimated or the market is in its downswing. Furthermore, a policy of "skimming prices" during the introduction of a new technology might cause slow market penetration; it might impede innovation diffusion and the gain of market share. Without rapidly expanding production volume, only little benefits can be drawn from experience and learning processes. Entering a market early with an innovation allows the utilization of *pioneering profits*, but might also cause problems with quality control. These and other contradicting aspects involved in innovation management emphasize the need for a thorough understanding of the complex decision making situation with its multitude of parameters and their mutual interactions. A tool that allows managerial training and education in the form of a rehearsal situation would be very useful.

The speed of innovation diffusion and the risks of upcoming substituting products are not solely and not even mainly determined by factors outside the firm. Corporate strategy produces, or at least co-produces innovation dynamics. R&D resource allocation and the timing of market introduction, investment and production planning, cost management and pricing policies, product quality and delivery delays are key control variables.

Innovation management requires decisions with fundamental importance for the competitiveness and the long term viability of an enterprise. Decision making at this level of complexity cannot be automated, but it is possible to support it by means of formal models and computer based systems. Management games have this very objective. Through the artificial reality of applied causal models, a thorough learning process can be initiated. The expected benefits of such an endeavor justify the substantial efforts required. The interactions with computer simulation models allow insights into the behavior of systems. The gaming approach to management education and training combines the abstract investigations of theoretical science and the practical research of laboratory experiments. It constitutes a third pillar for progress toward more rational decision making.

If management wants to play a major role in controlling the future course of the company - and not simply adjust to predetermined behavior modes -, it must have a thorough understanding of the system. Management games, which try to match these aspirations must be based on a comprehensive and causal approach to model building. To achieve insights into the processes under investigation, the factors that cause system behavior must be represented. If requested by a player, the used models must explain and help to understand why specific behavior modes occur. Only then, they can constitute meaningful tools to improve managerial decision processes.

Innovation management with its aspects on planning and control is seen as a learning process about the system and its environment. Insights into the dynamics of the system under investigation, neither forecasts nor predictions, are the objective of such a task. Through the process of iterative cycles of "playing" the intrinsic properties of the problem will be better understood. An *a priori* experience for the actual course of actions will be gained in the virtual reality of the game (Milling 1990b).

To meet these ambitious objectives, a management gaming simulator should foster training in three areas:

- Improve decision making;
- Teach Systems Thinking;
- Encourage Cooperative Learning.

Decision making under time pressure is a daily managerial routine. Due to the real life consequences of the actions taken, usually no rehearsal of this process is feasible. In spite of the vital importance of their policy choices, management and especially senior management acts always "on line". On the job training, learning by doing or trial and error are hardly possible. Available and proven techniques from information gathering to decision assessment and evaluation can only seldom be acquired and tested without immediate and very real repercussions. Here, management gaming provides a very useful setting. All actions taken occur in the virtual reality of a computer model only. Trainee activities, like the mentioned on the job training etc., highlight potential benefits of the approach.

During the game, each group of players is confronted with interrelated decision making requirements, and it is difficult to understand how they interact and how the whole system will react. To improve the performance, the group must identify and collect relevant information. The team members must derive alternative courses of action and evaluate their expected consequences. A feeling for complex system behavior should be gained.

Successful corporate management requires specialization, the separation of tasks, which finally lead to "Taylorism", and the delegation of decision making. But the same developments bear the risk of failure through uncoordinated activities; management becomes futile without coherent and unambiguous action. Especially in the dynamic environment of innovation management this (potential) gap between isolated operations and coherent strategy has to be closed. Team or Cooperative Learning is necessary to define and to achieve the overall corporate objective (Senge 1990; Argyris 1990). Management games work as catalysts in such a process. They counteract narrow specialization, lead to improved communication between different corporate functions, and encourage the identification and the pursuit of shared values and overall objectives.

Gaming Structure and Process

To achieve the objectives mentioned above in the peculiar innovation environment, a corporate simulation game was developed. The Innovation Management Simulator tries to model business situations, economic developments, and entrepreneurial decision making under market mechanisms and competitive pressures. It is based on a System Dynamics model, which was already documented elsewhere (Milling 1986). Opposite to standard simulation experiments, decision making is an iterative process of human intervention into the gaming procedures.

The game focuses on product innovations, which finally determine market shares, growth and profitability of a firm. The development of new products and their diffusion in the market have to utilize effectively and efficiently the resource potential. The model links intra-firm decisions with external consequences. On the demand side, the factors influencing product purchase, e. g. perceived product quality, pricing, advertisement, delivery delays or market growth, are included. On the supply side all relevant control variables for the strategic management of innovations are provided

(Kortlüke 1991; Milling 1990a). The factors influencing demand – they also represent the major decision parameters for management – are listed in Figure 3.

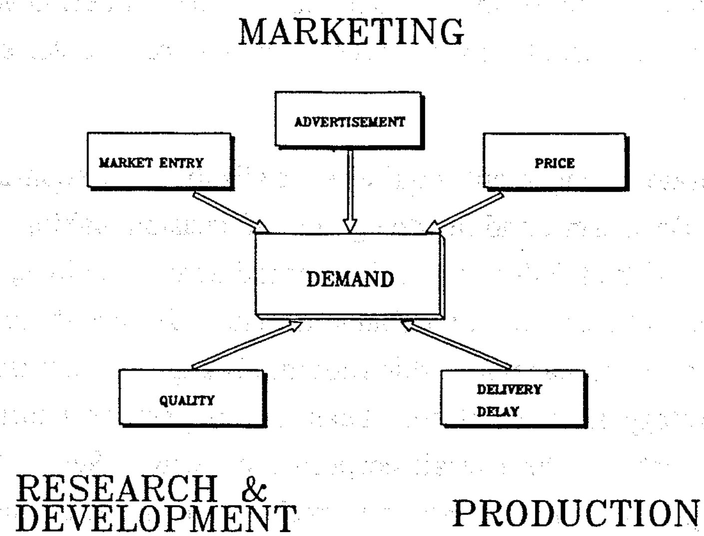


Fig. 3: Factors Influencing Demand in the Innovation Management Simulator.

Four teams (representing the boards of directors of four corporations) compete by developing, manufacturing and marketing functionally similar products. Each firm starts with only one product on the market. The firms will research and develop new products with different levels of technological sophistication and different potential for further improvements, depending upon the R&D budget provided. All decisions in the areas of production, finance, R&D, and marketing with their impact on cost and revenues are made by the teams, and are then fed – as exogenous inputs – into the gaming model. Figure 4 gives an overview over the coarse structure of the model for each firm. The endogenous variables reflect the main controls for the team members. The elements in the outside box are influenced indirectly by the corporation's own actions and the behavior of the competitors. They also can be monitored by the game supervisor.

The Innovation Management Simulator runs on IBM PC, PS/2 or compatibles with 640 KB memory and DOS 2.0 or higher; furthermore Professional DYNAMO plus, Version 3.1 is required. The Prolog-written user interface is provided as an EXE-file. A menu-driven installation routine makes the set up simple and fast. Different information is provided for the game supervisor and the groups of players. During the game session, the teams do not have to have direct access to a PC, they can provide their decisions either on paper or on a disk. IMS is currently available in German only, but it needs little language knowledge to play after the briefing is done.

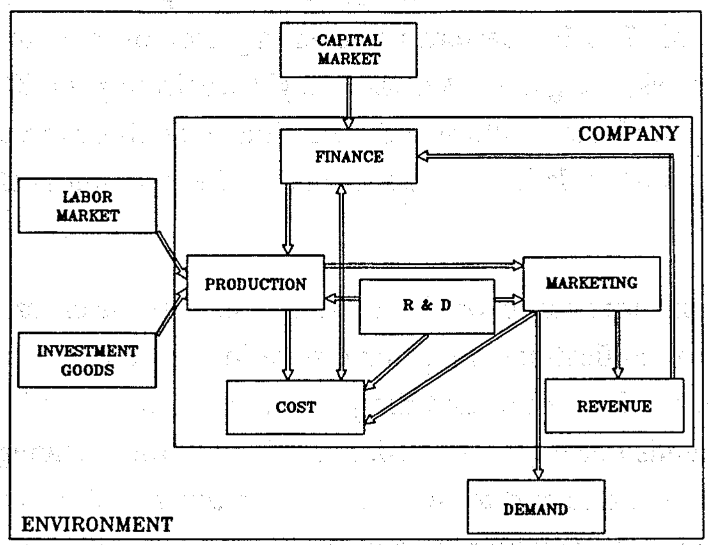


Fig. 4: Coarse Structure of the Innovation Management Simulator.

IMS consists of three parts: the control panels or user interfaces, with different information either for the game supervisor or the groups of players, and the actual simulation model written in DYNAMO. Interactions with the game are done through the panels. The game starts with an initial set of parameters that defines – as the built-in default setting – equal conditions for all firms. The supervisor can monitor the performance during play time by changing factors like labor supply, wage and interest rates, inventory costs, depreciation periods, etc. Furthermore the market response function for quality, price, advertisement and delivery delays can be modified. The game is mainly driven by the actions of the four teams. Their competing and frequently contradicting objectives or strategies create unexpected behavior modes.

Each period of decision making and simulation compares to one quarter of a year in reality. After each period reports are printed. They provide the input for a new round of decision making and are distributed to the teams in a briefing session with additional information about recent developments in the economy or in technology. The teams are left free to organize themselves the way they want it, but usually each player takes over responsibility for a specific function, e.g. production or R&D.

Decisions are made during a simulated board meeting. It starts with a discussion of the results, an analysis of possible reasons for discrepancies between planned and actual performance, and ends with the choice of the future course of action. These decisions are either filled in a form or are typed in a computer. The game runs usually over an equivalent of 12 to 16 quarters, i.e., over a period of three to four years. With two meetings per week; the game takes six to eight weeks to play. This time frame is especially suited for students; it allows sufficient time to go through the relevant literature, to develop support tools like spread sheets for the decision analysis, and to prepare the meetings.

With increasing experience of the players, the supervisor can make through external parameter modifications the gaming situation more difficult to control. Sudden changes in the market occur, and the prediction of the future developments on the basis of past trends becomes a hazard. Disturbances force management to adjust long term corporate policies and to reevaluate their courses of action. Past solutions have to be reconsidered permanently, and management must learn to cope with a dynamic environment.

The game is tested with management students in academic education. It runs stable and generates for all experienced sets of input factors a meaningful behavior. It encourages the participants to search for efficient tools or techniques to fasten and to improve decision making. It has demonstrated its potential to gain a better understanding of complex system behavior. It teaches lessons about the possibilities, respectively the limitations to control these systems effectively. And it initiated and alleviated the processes of cooperative learning.

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