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SYSTEM DYNAMICS BASED SIMULATION AND GAMING: A CASE OF TRANSPARENT COMPETING COMPANIES [1]

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SITMECOM 1.0 PC is a multifunctional simulator that represents three companies competing in real time in the same market. Each firm can be simulated on a different computer, which is linked to the others in one of the following ways: via a direct cable connection, via a local area network, or via the Internet. We have also allowed for the possibility of having one computer play the role of the competitors, making it possible to use our simulator on a single computer without the need to be connected to any others. In the design process, we endeavor to fulfill three basic objectives:

To promote the system dynamics approach, since we consider it the most appropriate to use in order to analyze and study complex systems, such as companies. To fulfill this goal, one of the main features of this simulator is Transparency, that is, the possibility of relating the system´s structure to its behavior [2].

To provide attractive self-learning instruments which facilitate self-learning in Business Management with a systems approach.

To provide an user-friendly interface which does not require previous knowledge of computer science. In order to achieve this, we exploit the potentiality of new technologies in information and communications systems.

In our opinion, SITMECOM 1.0 PC offers clear advantages over traditional business games and bring an improvement to teaching and learning methods in Business Administration and Management. It has already been used in a course on Business simulation with a system dynamics approach at the University of Sevilla during two academic years (1997-1998 and 1998-1999) and, in our opinion, the obtained results were very satisfactory. However, in a next future we want to undertake a controlled experiment which would allow us to test our hypothesis about the advantages offered by our simulator.

Introduction

There are numerous examples which show the difficulty to deal with complexity of economic and business phenomena at the present time. It seems clear that the use of a systems dynamics approach would allow the study and treatment of organizational complexity in a more realistic way. The need for a systems approach is advocated in many disciplines in order to act in consonance with the long-term best interests of the system as a whole.

The lack of adequate teaching tools, as one of the reasons for our troubles in managing complexity, comes from the methods and tools used at present in virtually all business-management training centres: the traditional system of training, the case method and traditional business games. These methods and tools are insufficient to cope with the complexity characterizing business systems.

It becomes evident that it is essential to correct the deficiencies mentioned above and to provide managers and students with methods and tools which allow them to understand the way a company works in the most appropiate way, as well as to manage it, to cope with the business and economic problems already mentioned. In this sense, we agree with Forrester (1989) that management education will make real progress both in effectiveness and scope only when the use of system dynamics (SD) becomes widespread. This will enable us to go beyond the case method and, in our opinion, beyond traditional business games.

It is important to stress that, besides the characteristics mentioned in the previous section, system dynamics allows us:

- to take into account nonlinearities, which play a critical role on most real-life dynamic behavior;
- to include the qualitative information contained in managers' mental models [3], which is priceless for business decision-making; and,
- to use computer simulation, which can both reveal the behavior of complex systems and help to link that behavior to underlying structures.

Thus, the potential of system dynamics models is enormous. However, a person who has no previous knowledge of the field may take a long time before being able to use SD as an educational tool. The great development in software has made the process of building a model much easier. This might lead to the view that it is easy to build a good SD model in a short time; in reality such a thought is illusory. The most critical aspect of building a model of a social system is to find out the feedback structure which dominates human decision-making within the system. The possibility of relating the system's structure to its behavior is one of the main features of system dynamics because it helps to understand the reasons behind this behavior and should favour decision making and an understanding of the phenomena observed. This is not a minor task nor in easy reach of just anyone, in spite of the user-friendly software existing today. So, the system dynamics modelling process remains the best way for understanding how to manage a system under study. However, the use of such models by people who did not participate in model creation has some limitations for understanding and learning, especially if these people are not familiar with the SD modelling process. Other authors (Warren and Langley, 1999) agree with this opinion and say that time constraints in general management education rarely permit formal model-building.

For this reason, the birth of SD-based business simulators and SD-based interactive learning environments (ILEs) undoubtly represent a significant advance in the field of Business Management Training because their friendly design allows for the use of the System Dynamics approach to a wider range of people.

However, a certain use of ILEs can bring the risk of losing *transparency* [see: Machuca, 1991; Machuca, 1992 and Machuca el al., 1998], that is *the possibility of relating the system's structure to its behavior*, which is one of the main features of system dynamics models. Consequently, an awareness of this structure helps to understand the reasons behind this behavior, and, in principle, should improve decision making and an understanding of the phenomena observed, providing a greater knowledge of the system under study. If ILEs don't allow users to look for the causes behind the effects of their decisions, users will operate by trial and error as in traditional black-box games, often making decisions based on symptoms and losing one of the most powerful features of the system dynamics approach: the possibility of providing transparency in the sense defined above -that is , linking observed behavior with underlying causal mechanisms.

Since the creation of our research group in 1989 (GIDEAO, Research Group on Computer-assisted Business), one of the main topics on which we have focused our work is the creation of business simulators that, based on a new design philosophy, bring an improvement to teaching and learning methods in Business Administration and Management

(see Machuca, 2000; and Machuca et al., 1998). In this design process, we endeavor to fulfill three basic objectives:

- To promote the system dynamics approach, since we consider it the most appropiate to use in order to analyze and study complex systems, such as companies, which are immersed in a rapidly and continuously changing environment (see Machuca, 2000). For this reason our simulators will include Transparency and are called Transparent-box Business Simulators (TBBS).
- To create genuine training tools and especially simulators; we want to provide self-learning instruments, and minimize the user's dependence on the facilitator in a traditional setting in order to learn (see Ruiz and Machuca, 1997).
- To provide an user-friendly interface which does not require previous knowledge of computers simulations. In order to achieve this, we exploit the potentiality of *new technologies in information and communications systems* (especially, multimedia technologies and the Internet). Achieving this goal enables progress on the first two.

Based on data collected by GIDEAO, we are convinced that this kind of ILE should facilitate causal reflection and favour the systemic learning process of business systems. Our experience so far has confirmed our hypothesis. Many doubts exist about the effectiveness of business simulators for business learning, as can be seen, for example, in a very well known review of the business gaming literature (Keys and Wolfe, 1990), which has already been quoted by other system dynamicists [4]. However, we want to stress that:

- these games were black-box games and, as we stressed in the previous section, this kind of game has serious pitfalls when it comes to coping with organizational complexity; and,
- there are some doubts about the security of the control over the experiments commented on in the mentioned review. So we can not be sure that those experiments are free of factors other than those whose effects had to be assessed.

A controlled, empirical, three-year experiment, undertaken by our Research Group at the University of Sevilla, involving 234 subjects, showed:

- on the one hand, the superiority of transparent-box business simulators over black-box business simulators in regard to the learning process. This is especially clear when dealing with knowledge related to an understanding of the structure and operation of the system under study; and,
- on the other hand, the improvement that both kinds of simulators produced in learning when compared to the traditional system of business teaching

This experiment and its results have been shown on a plenary session of the 1998 System Dynamics Conference (Machuca et al., 1998).

Brief description of SITMECOM

SITMECOM 1.0 PC is the last transparent-box business simulator that we have developed at GIDEAO. It represents three [5] companies competing in real time [6] in the same market; each firm is simulated on a different computer, which is linked to the others in one of the following ways: via a direct cable connection, via a local area network, or via the Internet. We have also allowed for the possibility of having one computer play the role of the competitors, making it possible to use SITMECOM 1.0 PC on a single computer without the need to be connected to any others. This means that one person and one computer are the minimum requirements to run the simulator, although operating in a distributed multi-player enviroment provides advantages such as motivation and realism.

Each company in this simulated enviroment is dedicated to the manufacturing and selling of only one product in a market which it shares with the other two. It is perfectly possible to

create distinct structures for each of the three competing firms according to the desired training objectives. However, in the version of SITMECOM described here, the structure is the same for all three businesses. This allow us to compare the management skills of the three competing teams. Although there is no reason why each company cannot be managed by a single player, our experience tells us, and the literature suggests (Salomon 1988, 1992 and 1993), that it is better to create teams in order to take advantage of the synergy created by group work, which improves the learning process.

The maximum length of the simulation time horizon is five years of forty eight weeks each, allowing for vacations. Weeks are the time unit for simulation.

During the game, the players sell their companies' products in order to satisfy their clients' orders. The total amount of these orders is called the *market demand*, for which the three companies compete. The *market share* that each company obtains will depend on the attraction of the products for potential clients. There are various factors that the manager (the simulator user) can avail himself/herself of in order to try to increase product attractiveness and, consequently, market share. They are the following: sale price, advertising spending, product quality, collection period for clients and service level of the company.

To understand the effects produced by these factors, we cannot loose sight of the fact that these effects also depend on the actions of competing companies at any moment. We also have to take into account that, as it occurs in the real world, the sensitivity of market share to the changes in the different factors depends on in which phase of its life-cycle the product is (Lambin and Peeters, 1981). With this in mind, the players should analyze which is the best way to act in each of these phases. With respect to *production activities*, the players need to manage several aspects related to machinery, materials, and workforce (capacity management, material planning, purchasing, hiring/firing, etc). To carry out these activities, the users of the simulator also need to deal with the *financial management* of their companies. In accordance with this, they have to plan investments and how to finance them, both in the short and the long term. Players also need to decide on cash management.

So, in general, players have to make decisions in the main business areas, which gives SITMECOM 1.0 PC a *multifunctional character* [7] and makes it different from other business simulators that concentrate the decision process on a single area of the company (normally, marketing) and that include the other areas only marginally.

In the following sections we will attempt to clearly show how this simulator operates as well as demonstrate its potential for training. We will also show how the objectives mentioned in the Introduction are fulfilled.

Working with SITMECOM 1.0 PC

In the previous section, we briefly commented on the basic aspects of SITMECOM 1.0 PC. We now describe its functioning.

Initial conditions of the simulation

The game facilitator usually begins by setting up the initial conditions of the simulation. The facilitator establishes the initial values of some decisions by each of the three companies, and describes the environmental characteristics of the game. These conditions, affecting the three simulated companies, can only be modified by the facilitator. The screen that appears in Figure 1 shows the most relevant ones.

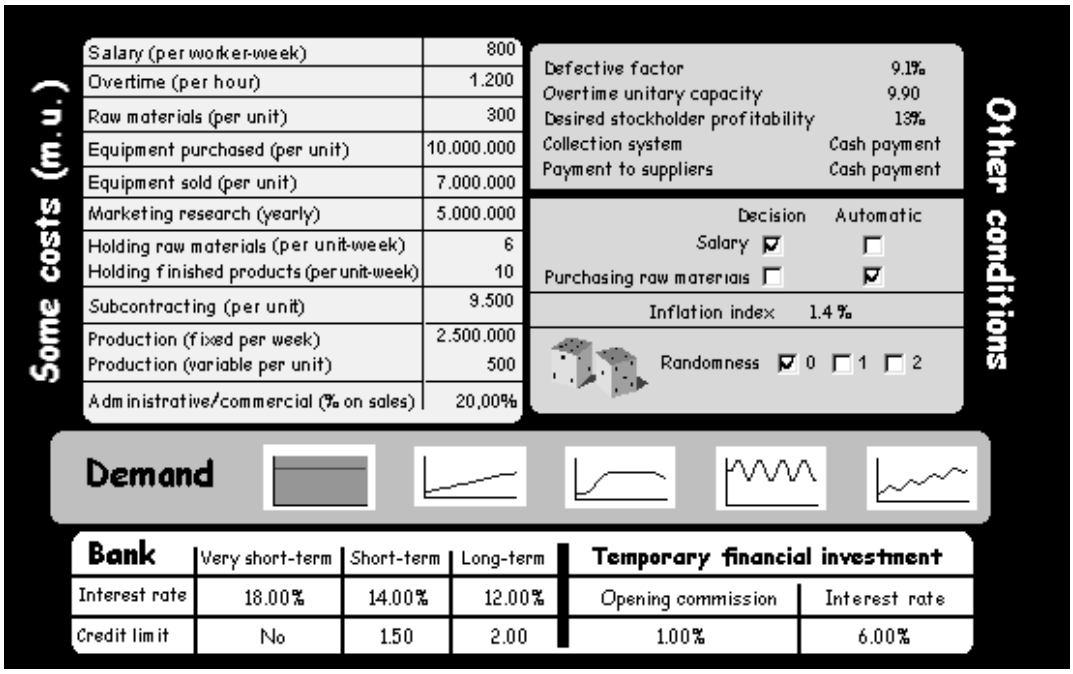

Figure 1: Conditions of the simulation.

As shown in Figure 1, SITMECOM 1.0 PC offers five *types of market demand*: one of a stable character, another of constant growth, a third corresponding to the classic life cycle of a product, and lastly, two types of seasonal demand.

Another basic element to be considered is the *financial environment* in which the simulation takes place. This is established by defining the interest rates and commissions for the different types of credit, as well as the maximum level of debt that the companies will be permitted, which is dependent on the equity of the company.

The third element involves the *initial cost structure*. Except for the cost of the workforce, which can be modified by the users during the simulation, the rest of the costs will be controlled by the facilitator at all times.

The last set of conditions that determines the environment has a heterogeneous character.

Lastly, the facilitator will establish *other options* that will alter the level of difficulty facing the players during the simulation. The choice will depend on the users' knowledge in Business Administration and Management. For example, for users at a lower level, the facilitator selects a stable randomless demand, a cost structure that makes losses less probable, collection and payment periods that do not end up in severe financial problems, and automation of decisions on salaries and purchasing of raw materials. As user's experience increases, it is advisable to increase the level of difficulty, opting for demand patterns and conditions that make the management of the simulated companies more demanding.

We see that *flexibility* can be obtained by means of the initial simulation conditions, including the possible automation of certain decisions. In this way, the facilitator can adapt the simulator to the educational needs of the current target audience (See, for example: Collins, 1991; Collins et al., 1989; Spiro and Jehng, 1990; Spiro et al., 1992).

Decisions during simulation

Once the facilitator has established the initial conditions of the simulation, the players take on the role of the board of directors of each competing firm, making decisions in the following business areas: production, finance, personnel and marketing. As previously stated, the

simulation could be carried out either by just one player or by a team, depending on the user's knowledge and/or the objectives of the training program.

Graphs and tables

The values that are assigned to each variable of interest throughout the simulation can be shown in graphs and tables. SITMECOM 1.0 PC can display a total of 15 graphs (and their accompanying tables as well). Each of them focuses on different factors of relevance to business management. Thus, one can observe the behaviors of production (i.e., production, stocks or capacity), finance (i.e: working capital, operating margin and cash), personnel (i.e., hiring, firing or capacity) and marketing (i.e., market share or potential sales).

Incorporation of transparency

In *traditional business simulators*, which are of the *black-box* type, the typical behavior of a player is reflected in the *make-decisions and observe results* loop. In most cases a trial and error method is adopted, where the decision process is based on the observed symptoms (observed results) of the behavior of the business system, instead of being based on a fundamental recognition of the underlying causes. We argue, however, that the learning process will improve if the players investigate the causes which account for observed behavior (i.e, when they undertake an authentic causal analysis and thus strengthening their ability to relate the observed behavior to the structure of the simulated system).

To achieve these conditions, SITMECOM 1.0 PC incorporates a fundamental tool for systemic reflection: a causal-loop diagram. Beside each variable there is a graph showing its evolution, which allows for a connection between the structure of the business system and its observed behavior. This behavior is accompanied by the user's free access to the main equations of the simulation model. These two characteristics were already included in a simulator that we previously developed for the Macintosh environment (see Ruiz and Machuca; 1997). This feature makes SITMECOM 1.0 PC a *transparent-box business simulator* [See note 2].

The reports of SITMECOM 1.0 PC

As it occurs in the real world, the reports on the simulated businesses attempt to help with their management. Most of these reports supply information about different aspects of the firm that each user manages —a few of them allow the user to obtain information about the market and about competitors. Some of them allow "what if..." analyses, providing the users with some forecasting of future behavior. We have incorporated a total of 21 reports related to the main business areas:

- Production (quality, capacity, workforce capacity, shipments, equipment, production, productivity)
- Finance (balance sheet, banking, profit, long-term financing, self-financing, profit and loss account, ratios, summary, surplus distribution, cash)
- Personnel (overtime, workforce)
- Marketing (marketing research, competition)

Final remarks

SITMECOM 1.0 PC fulfils the first of the objectives commented on at the introduction of this paper: to facilitate the use of the system dynamics approach to understand solve problems

derived from business complexity. This is achieved thanks to the features of multifunctionality and transparency and because of the competitive nature of the simulator.

The user-friendly design of the simulator minimizes the need for computer experience. The simulator comes with a *hypertext help* (typical in a Windows environment), in which hypermedia characteristics have been incorporated; the structure of the help is based on the description of each variable in the simulator, textual as well as mathematical (the corresponding equation). Thus, in the description of each variable, there appears hypertext links that points to descriptions of the related variables, as well as hypermedia links that allow access to the graphs, tables or reports which can help improve the understanding of the variable currently analyzed. These features help us accomplish the other desired objectives: *easy use and effortless self-learning*.

A more complete description of SITMECOM 1.0 PC, as well as of the ideas commented on in the Introduction, can be found on Machuca, 2000 and González et al., 2000.

Notes:

[1] Developed within the framework of the Leonardo Project E/96/2/1468/PI/II.1.1.A/CONT and CICYT project TAP98-1546-CE.
[2] See: Machuca (1992 and 2000) or Machuca et al. (1998).
[3] A recent definition of mental model has been proposed by Doyle and Ford (1998, p.17): "a mental model of a dynamic system is a relatively enduring and accessible, but limited, internal conceptual representation of an external system whose structure maintains the perceived structure of that system.
[4] See, for example: Warren and Langley, 1999 and Lane, 1995.
[5] This figure can be raised to ten without much effort.
[6] When simulating real time, it becomes necessary to sincronize the decisions of the different teams which are playing the game, since the simulated time is the same for all of them.
[7] This characteristic already existed in the simulator SITME 1.0 MAC, with was previously developed by our research group (Ruiz, J.C and Machuca, J.A.D., 1997).

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