

OUR TEN YEARS OF WORK ON TRANSPARENT BOX BUSINESS SIMULATION

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ABSTRACT

Traditional business games are of the so-called black-box type (BBBS=Black box business simulator); that is to say, the internal structure which generates the results of the simulation after decision-making is not known. As a result, the player normally operates by trial and error and bases his decisions on the symptoms of the problem (the observed behaviors of the system's variables) and not on the real causes of the problem (the system's structure). Since 1988 José A.D. Machuca has insisted that the business games based on System Dynamics models should be *Transparent-box business simulators* (TBBSs). That means that, during the game, the user has access to the structure of the underlying model and is able to relate it to the observed behaviors. The *hypothesis* is that such *transparency would facilitate causal reflection and favor systemic learning* of business problems.

In 1990, the G.I.D.E.A.O. Research Group took action on this idea and centered one of its lines of research on this matter, with three main objectives: a) Creation of TBBSs, b) Introduction of TBBSs in undergraduate and graduate Management courses as well as in executive training, c) Experimentation in controlled environments in order to test the hypothesis mentioned in the above paragraph. Now, ten years after the birth of the idea, we would like to share in this paper the results obtained during that period.

1. About the need for transparency in Business Simulators (J.A.D. Machuca)

As is well known, the internal structure of a system is the main cause of the behavior observed in it. Consequently, an awareness of this structure helps understand the reasons behind this behavior and, in principle, should favor decision-making and an understanding of the phenomena observed, as well as greater knowledge of the system under study. My conviction of the importance of the use of the causal structure together with the observed behaviors as a vehicle for reflection aimed at a closer understanding of systems and for easier decision-making is as firm as it is long-standing.

For this reason, as I stated in a previous paper (Machuca et al., 1993, p.298), since 1988 I have been criticizing the use of *black-box business simulators* (BBBSs) and defending the creation of *transparent-box business simulators* (TBBSs), although my first publication on this topic appeared in 1990 (Machuca and Roman, 1990). *Transparency* refers to the possibility of relating the system's structure to its behaviour when using a Business Simulator. To facilitate transparency, the qualitative structure (for example, in the form of a causal-loop diagram) and even the main equations of the model on which it is based, could be at all times accessible in the computer to the user, who would therefore find it easier *to make decisions based on previous study of the possible causes of the different behaviors of the variables, and not only on observation of the latter, which are simply effects*. This possibility, however, is not offered by black-box games, which only allow access to the results that can be observed, that is, the effects or symptoms, but not the causal structure giving rise to them. With black-box games a trial-and-error procedure is usually followed, based on the mental models each player has of the case being examined. An added problem is that these mental models differ from one person to another, depending on his or her particular perception of the reality in question, and this generally entails serious communication problems (Machuca et al. [1993, p.301]; Sterman [1994, p.295]). This is one of the reasons why it is difficult to reach agreement in the debate on real problems relating to the functioning and behaviour of complex systems. The problem is further aggravated by the fact that these mental models are not made explicit by those taking part in this discussion, who only know their own mental model and assume that it is shared by the others. The consequences of this phenomenon can be observed when the case method is applied or when attending a meeting of the board of directors of any company. As a result, the mental model which the user of a business game has formed of the system represented by it may well not coincide fully with that of the game's creator. The player may therefore be making decisions based on a (simulated) reality different from the one he has formed in his own mind, thus facilitating neither decision-making nor correct learning (Machuca et al., 1993, p.301). All this leads me to the **hypothesis** that *by using a transparent simulation, the learning process and acquisition of a systems approach for decision-making would be improved* (Machuca 1991 and 1992).

Although other authors have subsequently touched on this topic, directly or indirectly¹, the idea has scarcely been put into practice in game-design. In my view, one of the most valuable tools that System Dynamics offers to the development of a systems dynamics approach was being lost (Machuca, 1992, p. 176).

In 1990 I put my idea into action, starting a line of research I called "Learning Laboratories in Computer-Aided Systemic Business Management," which has been and is

¹ See for example: Isaacs and Senge (1992, p. 195), Kemeny and Kreutzer (1992, p. 305), Morecroft (1992, p. 465), Peterson (1992, p. 117), Sy-feng and Young (1992, p. 765), Davidsen (1994, p. 305), Langley and Morecroft (1996, p. 301, 303), Grössler (1997, p. 370).

being sponsored within different complementary frameworks: regional (Junta de Andalucía—the Government of Southern Spain—as well as private and public companies), national (CICYT—Interministerial Commission of Science and Technology) and European (COMETT and Leonardo Projects). The main objective of this line of research was to create, develop and use TBBSs as well as to verify the hypothesis mentioned above. In my opinion, TBBSs should facilitate causal reflection and favor systemic learning of social and business problems, helping to prevent the “video game syndrome” which often arises in black-box games. I am currently coordinator of a European project researching along these lines called “New information technologies and transparent business simulators for improving business competitiveness.” The French company K.B.S and the University of Bergen are two of the partners of this project.

Other matters which have attracted my attention during the last six years are the following ones:

- * how to promote the expansion of Systems Approach/System Dynamics to a large number of people in the absence of trainers who are experts in this approach.
- * how to be effective in training managers who, being overloaded with work, have little time at their disposal. This lack of time is particularly a problem if their training involves moving outside the place of business.

The above considerations led us to move to the creation of TBBSs which greatly facilitate *self-learning* and *distance learning*.

In the following sections, we will briefly comment on some of the results we have obtained.²

2. A controlled experiment to verify the suitability of TBBSs (Machuca, J. A. D. and Domingo, M. A.)³.

To verify the above-mentioned hypothesis we started a controlled empirical experiment in 1994 which lasted three academic years. A *secondary aim* of the experiment was *to compare the use of business simulators with traditional teaching methods*.

2.1. The sample

In order to guarantee the consistency of the results, we wanted to work with a wide sample, which was comprised of 234 individuals, chosen from a total of 550 applications received. In addition, every effort was made to make the *sample* as *homogenous* as

² Here we do not comment on a simulator which facilitates distance learning, (a friendly electronic version of the Beer Game which works over a network and via the Internet) because it has been already described in the System Dynamics Review (1997).

³ Partial results of this experiment were already published (see, for example, Machuca et. al. (1995 and 1997). We would like to thank Dr. J. L. Pérez de los Ríos, Assistant Professor of Statistics at the University of Sevilla, who gave us statistical support and advice.

possible so that the subsequent comparison would not be tainted by factors other than those whose effects we were attempting to assess. To reach this goal we chose people with the same academic background: students from the two last years in Business Management studies at the University of Sevilla. Moreover, the individuals with the best academic records were selected so as to have people with a similar level of knowledge.

The composition of the initial sample was the following: 54 people in 1994, 81 in 1995, and 99 in 1996, although, in reality, our work in 1994 was taken as a pilot study in order to refine the questionnaires, as well as the simulator and the procedure to be used. Thus, the final sample consisted of 180 individuals, who were organized into 60 groups of three, since we believed that the synergy produced by the group work would benefit learning. These groups were subdivided into two sets of 24 and 36 groups; while the first set worked with BBBSs, the second one worked with TBBSs.

2.2. *The tool*

We used a medium-complexity simulator representing a firm manufacturing a single product with a total of six decisions to be made related to the areas of production, personnel and finance (Machuca et. al., 1992). However, to allow the students to become familiar with the software, before using this TBBS, all of the groups played a very simple one in which only two decisions were made.

2.3. *The questionnaire*

We used a questionnaire covering different objective and subjective points:

a) *Objective points* (related to the understanding of the system's structure)

- a.1) Questions about basic knowledge (questions B1 to B7).
- a.2) Questions related to variables connected by relatively short chains of interactions (questions D1 to D4).
- a.3) Questions related to variables connected by longer chains of interactions (questions I1 to I3).

The aim of the above kinds of questions was to verify a *new hypothesis: The more complex a question is the more useful TBBSs are*. All of the questions were rated by us on a scale from 0 (completely incorrect) to 10 (completely correct), the most commonly-used kind of scale in our country.

a) *Subjective aspects*

- b.1) Questions linked to the student's perception of the increase in knowledge they believe they have attained through the use of the simulator (BBBS or TBBS) in relation to different topics previously studied through traditional methods of learning (questions S1 to S8).

b.2) Questions related to other points (to be compared with traditional learning), such as the student's possible increase in motivation or in general knowledge about the topics under study (questions S9 to S11).

The participants were asked to rate questions S1 to S11 using a scale from 0 (no increase) to 10 (maximum increase).

2.4. *The procedure*

As we mentioned, we tried to prevent the results of the experiment from being tainted by factors other than those whose effects we were attempting to assess. In order to do so we wanted to control the experiment as much as possible: We tried to make sure that all of the groups had the most similar conditions possible throughout the experiment, which had four stages. Thus, they all always played with one or more facilitators, whose job it was to make sure that the game was played the same at all times. These facilitators indicated when the decisions had to be made (so that all the players had the same amount of time); they insisted that the players who were using TBBSs use the transparency offered by the simulator (which is not a natural tendency, but rather an acquired one); they made sure that there was no communication among groups; etc.

The stages were the following ones:

a) *Grounding in Systems Approach.* All the students were initiated into the Systems Approach, with an emphasis on the differences between this approach and the Analytical Approach.

b) *Use of a very simple simulator.* They all played with such a game with the sole aim of becoming familiar with the software to be used

c) *Use of a more complex simulator.* In a session for all the groups, the system which they were going to simulate was explained in the traditional manner, without going into an explanation of the causal structure. They had previously been provided with the relevant written documentation. In a special session for the TBBS groups, the causal structure was explained to them as well as how to use it to find the causes of the behaviors observed. They were also provided with the relevant written documentation. In both this session and the one mentioned above, how the company functioned was discussed and the students claimed to have understood it. As the gaming sessions unfolded, modifications were gradually introduced into the games, activating new variables and relationships which made the structure more complex, and increasing the number of decisions the player could make; the demand was also changed.

The groups playing with TBBSs had to make use of the causal-loop diagram and, if they considered it necessary, the principal equations of the model as these two tools are related to the observed behavior and provide a basis for improving subsequent decisions. In order to increase the amount of information obtained from the experiment, we did the following: Each year, once the simulations were finished, we formed a subset from the total number of BBBS users (5 groups in 1995 and 9 groups in 1996). These students were given a session similar to that given to the TBBS users regarding the causal structure of the

simulator, the Systems Approach, and so on. Afterwards, they were asked to play twice more, but with the TBBS version.

2.5. Filling out the questionnaire

After each simulation, every user (those of both the TBBSs and BBBSs) individually filled out, in the presence of the facilitator(s), the part of the questionnaire on objective points (see 2.3) related to the simulation carried out. After they were all finished, they answered the questions on the subjective points (see 2.3, b). The results from this form can be treated as *independent samples*, representative of the TBBS and BBBS users (see Section 2.6).

The students belonging to the subset which shifted from BBBSs to TBBSs filled out the questionnaires again after playing with the TBBS version. As a result, apart from the comparison between the TBBS and the BBBS users, based on the results obtained from the independent samples, we were able to make a different comparison based on the *related samples* that we had generated by having some of the BBBS users play with the TBBS version.

This procedure required that the facilitators dedicate an enormous amount of time⁴; however, we believe that it was worth the effort if it made the experiment more reliable.⁵

2.6. Statistical analysis of the results obtained

As we said before, the sample to be taken into consideration was made up of the students who played in 1995 and 1996.

First, we proceeded to verify the reliability⁶ of the questionnaire using the Cronbach's α coefficient. Various authors allow values between 0.55 and 0.7⁷. In our study, the results obtained (see table 1) reflect adequate interitem consistency.

Samples	Independent		Related			
	Objective aspects	Subjective aspects	Objective aspects		Subjective aspects	
Simulator	TBBS and BBBS	TBBS and BBBS	TBBS	BBBS	TBBS	BBBS
Cronbach's α	0,6235	0,7984	0,6163	0,5986	0,6384	0,6324

Table 1: Mesure of interitem consistency of the questionnaire

⁴ The total net time was approximately 364 hours for the entire experiment: these hours were shared throughout three academic years.

⁵ We would like to thank R. García Sánchez and M. M. González Zamora, members of our research team who collaborated on this arduous work, for their help.

⁶ For a discussion about the relevance of the different types of reliability see, among others: Anasatai (1997), Brown (1983), Gulliksen (1987).

⁷ See Nunnally (1978) and Van de Ven and Ferry (1979).

2.6.1. Analysis of the data obtained from the questionnaire regarding the objective aspects--independent samples.

Given that the results do not follow a normal distribution, we decided to use the equality of proportions test (Novales, 1997), with which we would obtain an approximate result, and the Mann-Whitney test.⁸

a) Equality of proportions test

For each of the questions on the questionnaire about objective points, the number of students in each of the experimental groups (Px for the TBBS users and Py for the BBBS users) who answered correctly was added up in order to compare them. The null hypothesis Ho: Px=Py was compared to the alternative hypothesis H1: Px≠Py at a significance level =0.05. Table 2 shows the results; here, the statistics with a minus sign (-) indicate that with the TBBSs better results are achieved than with the BBBSs. The next column indicates whether this value is significant (when P<=0.05).

	BBBSs		TBBSs		Statistics	Significativity (p)
	Correct	%	Correct	%		
B1	67	93,1%	103	96,3%	-0,9127	0,1807
B2	67	93,1%	96	89,7%	0,7953	0,2132
B3	53	73,6%	83	77,6%	-0,6021	0,2736
B4	67	93,1%	107	100,0%	-2,3180	0,0102
B5	52	72,2%	97	90,7%	-3,0814	0,0010
B6	57	79,2%	98	91,6%	-2,2639	0,0118
B7	64	88,9%	96	89,7%	-0,1758	0,4302
D1	32	44,4%	84	78,5%	-4,8137	0,0000
D2	45	62,5%	75	70,1%	-1,0516	0,1455
D3	47	65,3%	93	86,9%	-3,3345	0,0004
D4	35	48,6%	83	77,6%	-4,0568	0,0000
I1	52	72,2%	93	86,9%	-2,3684	0,0089
I2	29	40,3%	81	75,7%	-4,9798	0,0000
I3	39	54,2%	87	81,3%	-3,8899	0,0001
N	72		107			

Table 2: Results of equality of proportions test.

Except for question B2, the percentage of correct responses for the experimental group of TBBS users is always higher. It is worth noting that the greater the complexity of the questions asked, the greater the degree of significance, which affirms the hypothesis presented in Section 1.

⁸ This is a good approximation of the Wilcoxon test (see Conover, 1981), which is the most commonly accepted one for cases like ours. We used the Mann-Whitney method because it is the one which uses SPSS software, which is what we used for the statistical analysis of our results.

b) Application of the Mann-Whitney/Wilcoxon test

Due to limits on space we present the aggregated results of all three types of questions asked together in Table 3.

Questions	BBBSs		TBBSs		Signif. (P)
	Mean	Stan.dev.	Mean	Stan.dev.	
B1 to B7	8,8254	1,0150	9,3711	0,8437	0,0001
D1 to D4	6,0764	2,8055	8,1472	2,1057	0,0000
I1 to I3	5,7176	3,2268	8,1776	2,4620	0,0000

Table3: Results of Mann-Whitney/Wilcoxon test (objective aspects for independent samples)

The results clearly confirm the conclusions of the previous section. The TBBS users again got better results and the significance of the results was great; likewise, in this experimental group, there was less dispersion in the results surrounding the mean value. Again, as the questions became more difficult, the superiority of the TBBS became more evident.

2.6.2 *Analysis of the data obtained from the questionnaire about subjective points— independent samples (questions S1 to S11; see 2.3)*

For all the questions on the questionnaire the results for the TBBS users were superior. When all of these results were submitted to the Mann-Whitney/Wilcoxon test, a significance smaller than 0.05 was yielded in nine of the eleven questions and also in the average of the eight questions on the increase in understanding (S1 to S8, see Table 4), among which are the two questions, mentioned above, with a significance of more than 0.05.

Questions	BBBSs		TBBSs		Significance (P)
	Mean	Stand.dev.	Mean	Stand.dev.	
S1	5,62	1,88	6,32	2,41	0,003
S2	5,94	2,28	7,39	1,43	0,000
S3	5,82	2,06	7,07	1,95	0,000
S4	5,87	2,35	7,76	1,53	0,000
S5	5,27	2,17	6,07	2,11	0,009
S6	5,49	2,27	6,13	1,96	0,065
S7	6,31	2,07	6,86	1,82	0,168
S8	6,07	2,29	7,05	1,86	0,044
Mean (S1-S8)	5,82	1,73	6,82	1,09	0,000
S9	6,92	1,73	7,7	1,62	0,018
S10	6,74	1,86	7,86	1,59	0,002
S11	5,28	1,91	6,72	1,56	0,000

Table 4: Results of Mann-Whitney/Wilcoxon test (subjective aspects— independent samples)

2.6.3. *Analysis of the data obtained from the questionnaire about objective points—related samples*

Remember (see 2.4) that in the present case the groups that make up the sample first used the BBBSs and filled out the corresponding questionnaire; later, after receiving adequate training, they went on to use the TBBS version and then filled out the new questionnaire. In this section, we compare the results from both questionnaires by means of the Mann-Whitney/Wilcoxon method. The results of both tests appear in Table 5. As this table shows, results similar to those of the independent samples are obtained. Due to lack of space, we will not make any further comments about this, except to say that it confirms our hypothesis.

Questions	BBBS		TBBS		Signif. (P)
	Mean	Stan.des	Mean	Stan.des.	
B1 to B7	9,0170	0,8642	9,5272	0,9869	0,0111
D1 to D4	6,3155	2,9213	9,0060	1,4351	0,0000
I1 to I3	5,6587	3,0995	8,5238	2,4706	0,0001

Table5: Results of Mann-Whitney/Wilcoxon test (objective aspects—related samples)

2.6.4. *Analysis of the data obtained from the questionnaire about subjective aspects—related samples*

In this case the students gave their perception of the improvements of the TBBSs over the BBBSs on a scale of 0 (no improvement) to 10 (maximum improvement). In Table 8, a clear preference for the TBBSs can be seen, both in regard to the students' increase in understanding (questions S1 to S8) as well as other aspects, notably the increase in motivation (question S9).

Questions	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11
Mean	6,737	6,737	6,316	6,842	4,211	4,263	6,723	6,638	7,063	6,250	6,438
Stand.dev.	1,408	1,881	2,237	2,243	3,225	2,600	2,530	2,279	1,873	2,709	1,809

Table 6: Results of descriptive analysis (subjective aspects—related samples)

3. SITME 1.0: A “self-learning facilitator” transparent-box business simulator (J.A. D. Machuca, J. C. Ruiz)⁹

In this section, we comment on one of our most representative TBBSs, SITME 1.0., which we began in 1991 and finished in 1995. While designing and developing it, we mainly took into account the transparency necessary, which we talked about in Section 1, along with other aspects related to the improvement of the learning process. We refer primarily to the growing need for self-learning (E.U. Commission, 1996); we have made such learning easier thanks to the use of new computer information technologies.

This TBBS simulates the behavior of a hypothetical firm making a single product. It considers aspects related to Operations Management, Personnel Management, Financial Management and Marketing. The player is given the task of making decisions in these areas, one of the primary objectives of the game being the *understanding of the workings of the business system in all its complexity, based on a study of the underlying causes of the effects* produced after decision-making during the game. Another basic objective is *to show the close inter-relationships between the different functional areas of the firm, making the user aware that a decision in one particular area will have consequences in the other areas as well as in the general behavior of the company.*

At the beginning of each simulation the facilitator of the game must make up to 15 of decisions. These decisions make up the environment in which the business will work (price of raw materials or machinery, subcontracting, short- and long-term interest rates, the firm's credit limits, the sort of demand there is likely to be for the product, how long the simulation is to last or the frequency with which information will be received from the simulator, etc). Throughout the simulation only the facilitator of the TBBS will have access to these decisions in order to change the environment framework if he/she judges it necessary. This can be done from the computer used by a player or from another computer linked to the player's computer by a local network.

Throughout the simulation, the user can make up to 16 decisions which we have grouped into the four business areas mentioned above. The player uses a menu to select the area; the decisions appear in the Control Window (Figure 1). Using the mouse, the decisions to be made are chosen, changing their previous value and also indicating how many periods to simulate. These decisions can be made at any moment within the time limits set for the complete simulation.

⁹ We would like to thank M.A. Domínguez Machuca and A. Ruiz, who collaborated during the first modelling stage.

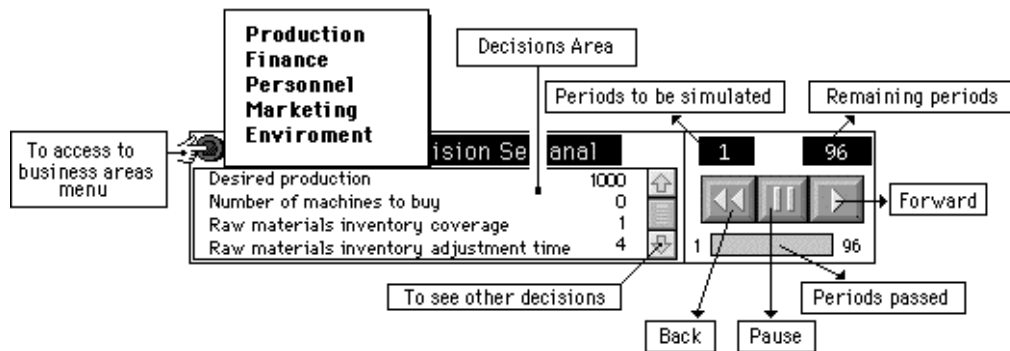


FIGURE 1. Control window

The information offered by the interface is one of the fundamental bases for decision-making on the part of the player. We will now go on to analyse the different types of information incorporated into our transparent-box business game. The incorporation of the causal-loop diagram (linked to variables behavior) into the interface is one of *the basic elements for achieving transparency* in our simulators, and one which we have paid particular attention to. Although, as is well known, causal-loop diagrams lack the identification of level and flow variables (Forrester, 1994, p. 202), in order to prevent this danger we have used symbols to allow a clear identification of the above mentioned kind of variables. Other elements are the access to the main equations of the model representing the business system under study, a hypermedia training help module, and various reports which will be commented on below.

3.1. Information on the causal loop diagram

In this TBBS, owing to the complexity of the model under simulation, the corresponding causal-loop diagram is sufficiently extensive to surpass the physical boundaries of the computer screen; we have therefore chosen to represent it in two different versions: a reduced one (RCLD) occupying just one screen, dispensing with the names of the variables represented, and another, more detailed one (DCLD), which offers the user more complete information. When the mouse is positioned on one of the variables of the less detailed causal-loop diagram (RCLD), the complete name appears in an independent window. It is also possible to search for a specific variable by choosing from an alphabetical list; when clicked on, the variable is identified in the RCLD by sound and visual effects. Then, clicking on the highlighted variable in the diagram accesses the more detailed causal-loop diagram, to facilitate the analysis of the information about the structure of the model.

When the mouse is positioned on one of the variables of the DCLD, all the others influencing it change color (see Figure 2). Should the player wish to do so, it is also possible to observe in highlighted form those variables influencing those directly linked to the variable being analysed (see Figure 3). In this way we make it easier to analyse the causes of the behavior of the variables belonging to the model.

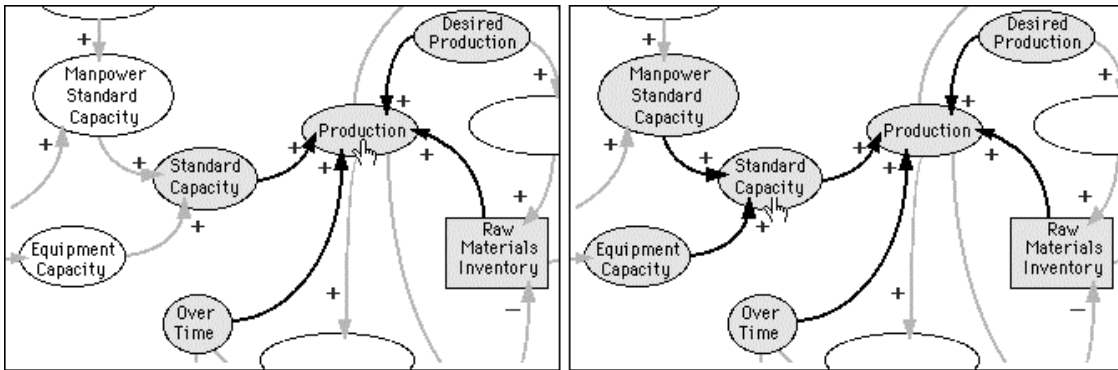


FIGURE 2. Looking for the causes (first step). FIGURE 3. Looking for the causes (second step).

To help to understand the relationship between the structure of the system and its behavior, one can also analyse the behavior of the different variables graphically, within the causal loop diagram, by visualizing a small diagram which will display the evolution of the variable selected¹⁰, allowing the causes of the behavior to be detected at a glance (see Figure 4).

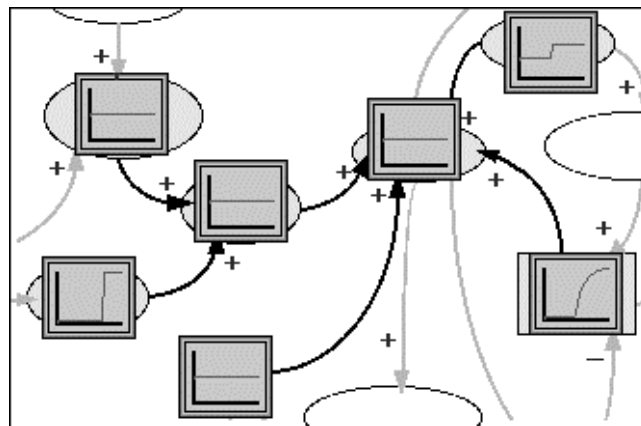


FIGURE 4. Investigating the relation structure/behaviour

Although the behavior of the different variables can be seen more precisely on the screen in the form of larger-scale graphics (see section 3.3), *this initial examination* has the advantage of being carried out on the causal structure, thus *facilitating a systemic understanding of the relationship between the system's structure and its behavior*, the main objective of our TBBSs.

¹⁰ The first time we saw this feature was in the 1993 System Dynamics Conference (Kemeny and Kreutzer (1992)).

3.2. Training help module

We have created a hypermedia mouse-tracking system that allows the user to access all kind of information: when clicking on the name of any variable (the name can appear in any graphic, table, report, causal diagram, etc.), a hypertext textual description of that variable appears, showing, in highlighted form, the variables related to the one clicked on, as well as the graphics, tables and reports. This feature can enlarge the learner's knowledge about the variable under study (see Figure 5). This system is also linked to the model equations and to the causal diagram (see figure 6).

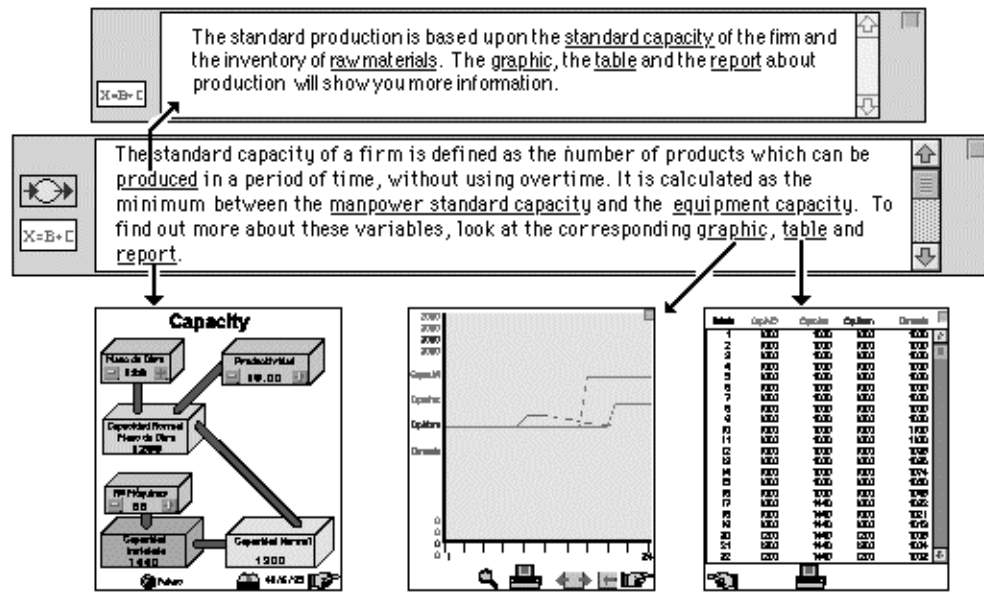


FIGURE 5. Training help module: Access to reports, graphics and tables

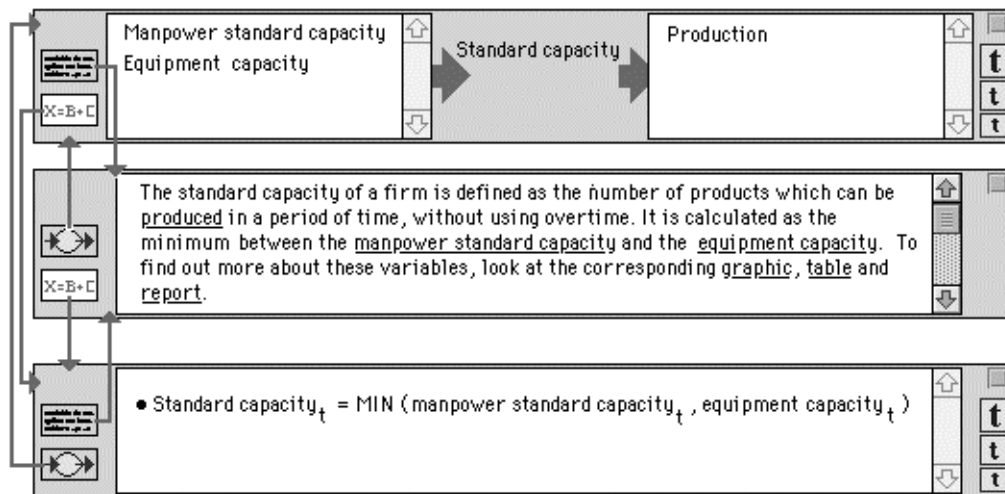


FIGURE 6: Training help module: access to equations and “textual diagram”

This hypertext system is available at any moment of the simulation, providing the player with a conceptual help system which improves the learning process. This formative help module is essential for various reasons. Among other things, it allows:

- * access to the explanation of concepts and relationships which the user might not be familiar with or might have forgotten over time (imagine, for example, financial concepts for someone who works in production).
- * the user to learn without a teacher. This facilitates self-learning at work or even at home. Moreover, this training is completely flexible, so that, thanks to the hypermedia system, the user can navigate according to his or her needs.
- * the user to gain a deeper understanding of the model used by the simulator (e.g. access to the main equations of the model)

3.3. *Other characteristics*

Another module of our interface is specifically devoted to the graphic representation of the evolution of different variables. The player can see the corresponding numerical values from any point on a curve with the use of the magnifying glass. It is also possible to manipulate the size or colors, print the graphic, and so on. There are 10 predefined graphics and, in addition, the player can define as many graphics as he wants to represent by selecting the variables he/she wishes from the complete list included in the simulator; we thus give each player complete freedom to study the variables he considers important to his decision-making process. The information which is represented graphically under the previous heading can be visualized and printed numerically in table format, showing the values adopted by the variables in the course of the simulation.

Our interface contains information screens that are specific to the model. The player can access these at any point since the reports are updated period by period. The user can also select the information for the last period simulated or for any previous period. We have incorporated into some reports a "what if..." system. For example, Figure 7 shows the report on Capacity, containing icons with the + and – signs, which allow the player to consider, in a preliminary examination, the behavior of the variable *standard capacity* if the values of some of the following variables are changed: *productivity*, *manpower* or the *number of machines*. What we offer here is, therefore, a simulation tool to be used before decision-making.

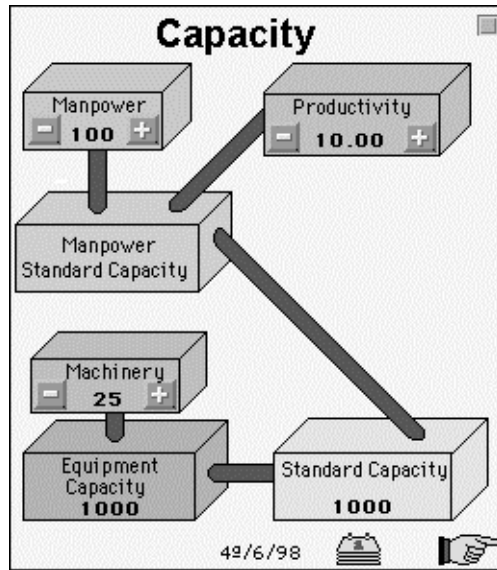


FIGURE 7: Capacity Report

Given the ongoing interaction between player and interface, we have incorporated the possibility for the player to decide to *move backwards*, that is, go back a number of periods in the simulation until he finds himself where he wants to be, in search of more suitable decisions with which to rectify those considered erroneous. The simulation can also be stored on disk, to be recovered any time later; this allows two simulations to be simultaneously activated in order to compare the behavior resulting from different policies.

We have also incorporated a *help feature* for interface use; by activating it, the player can get help with how to handle the business game at any stage. The various possibilities offered by the interface (graphics, tables, reports, causal-loop diagrams, etc.) are activated by using the mouse to select the corresponding option from the system of menus incorporated. We have incorporated *moving graphics*, sound and video in some of the modules of the interface, in an attempt to make the information on offer to the player as user-friendly and motivating as possible.

4. SITECOM 1.0: A multi-functional simulator of competing companies¹¹ (J.A.D. Machuca and M.M. González)¹²

As a next step in the development of transparent box simulators, taking the model of the TBBS mentioned previously (SITME 1.0) as a basis we incorporated a key element from the business environment—competition—in order to complete the relationships and elements that affect the way a business works. This makes the simulator more real and brings the user closer to the complex workings of businesses these days. Thus, the new simulator we are working on, created for use on a PC, and whose initial prototype could be finished in July, represents three industrial companies¹³ dedicated to making the same widely-used product which compete for orders in a common market. The philosophy of use of the simulator, is similar to the one described in the previous section (from the decision-making process to the observation of results based on graphics and tables to the use of a causal-loop diagram and a training help module). Therefore, we will not re-explain that process, but rather we will dedicate the following paragraphs to pointing out the fundamental differences between the competitive simulator and the one that served as a starting point for its development.

4.1. New decisions and events

Just as with the simulator described previously, each of the companies comprises four areas—production, finance, personnel and marketing—, but the number of decisions to be made by the player has been increased to a total of 24. To these decisions, add another 13 decisions concerning the business environment, which serve to configure the environment conditions at the outset of the game.

Along with the changes mentioned regarding the decisions, certain events which were not thought of in the SITME 1.0 simulator but which make the simulation more realistic are modelled in this one. Among them, the following are worth mentioning:

- * The possibility of problems with the machinery. The preventive maintenance decision has been created in order to try to diminish such problems.
- * The possible existence of defective products, which form part of the final inventory.
- * Leave-taking by workers, (when workers take time off, there are fewer people to do a job that was planned for more).

4.2. Competition factors

As was previously mentioned, the fundamental characteristic of the game stems from the fact that there is competition among the simulated companies. The number of customer orders depends on how attractive the company's product is compared to those of its competitors. Based on certain elasticity coefficients, this depends on the function of the sales price, the quality, the payment period, the quality of service offered by the company, and the image created through advertising; the definitive market response to each of these

¹¹ A simulator of this kind was developed by Davidsen and Myrtveit (1994).

¹² We would like to mention J.C. Ruiz who is also collaborating in this work.

¹³ This number can be increased; there can be up to ten companies without much difficulty.

factors takes time to see. Moreover, because of the interdependence of these factors among the different competitors, the consequences of a certain company's decision can not be known until the other companies make their decisions and the market reacts to them, generating a dynamic behavior that imitates what could happen in reality.

4.3. Demand

In regard to the market demand, one can choose (at the beginning of the game) between one that represents all of the phases of the classic product life cycle (introduction, growth, maturity and decline) or another from a specific phase (growth or maturity); one can also choose a demand with stationary factors and add (or not) different degrees of randomness to any of the possibilities mentioned. These make up the initial demand, which will then be affected throughout the game by the actions of the players, that is, by the service level, price policies, quality investment policies, and advertising of the different companies.

4.4. Decision levels

The simulator is presented as a useful instrument for improving decision-making. In developing it, two levels of decisions have been taken into account: strategic and operative¹⁴ decisions. Both types can be employed simultaneously during the simulations. At the strategic level the players look to the future and try to make an analysis of their possible decisions based on a series of hypotheses about the decisions of their competitors (e.g. regarding the price or quality of their product); in this case a real interaction with the rest of the virtual companies would not be produced, but rather the results would depend only on the hypotheses put forth and the decisions made by the company. This process allows the player to consider and analyse different hypothetical scenarios, by asking themselves, "What would happen if...?" As soon as the players consider it appropriate, they can abandon the strategic level and move on to the operative level. Here the decisions made by the players have real effects both on their own companies as well as their competitors'. At this decisional level there is competition in real time, so in each decision period all the players have to make their decisions before the game simulates the results derived from them.

4.5. Operation using a network

This competitive game is played using the possibilities offered by new information and communication technologies. Thus, although each company has to be simulated in a different computer, the connections necessary for creating a competitive game in real time are achieved through a local area network or even through the use of the Internet. Consequently, the different players can be far away from each other, or even in different countries if the Internet is used. By using these technologies, the simulations also become more realistic, and thus, the users may become more motivated. This should make these new tools more effective as teaching tools.

¹⁴ Terms used by Davidsen and Myrtveit (1994, p. 17).

4.6 Experimentation

As a result of the innovative nature of these transparent-box competitive business simulators, it will be necessary to complement the development of these products with empirical tests of their value. To do this, it will be necessary to design experiments that allow us to test our hypothesis that the use of such simulators improves training and understanding of business systems in an ever-changing environment

5. Final remarks

The aim of this paper has been to present only some of the results of our research during the last ten years; for reasons of space we have had to be very brief. In the near future, we will further develop this paper, amplifying its content and analysing other works related to our research.

In our judgement, the results from our experiment demonstrate the superiority of TBBSs to BBBSs in regard to the learning process, especially in relation to complex questions linked to an understanding of the structure and operation of the system under study. However there are still several points to study and test; we would encourage everyone who is interested to work along these lines, carrying out truly controlled experiments which will continue to shed light on this subject.

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