The Green World Management Flight Simulator

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Abstract

Today decision-makers cannot avoid incorporating sound environmental policies into their business plans. All organizations, both business and non-profit, typically must stand out as 'environmentally responsible' as the society at large moves toward a general agreement regarding a sustainable development based on green values. Business organizations in particular should integrate environmental considerations into the general mission of the company, either using existing structures within the company, or creating new ones. Increasing public pressure to improve environmental performance gives companies less time to create a structured decision-making systems that implements such policies. To achieve these goals, people need to understand the linkage between business and environment. A SD-based interactive learning environment (SDBLE), intended to help decision-makers improve their understanding is analyzed in this paper. We expect that the proposed SDBLE will help learners recognize key leverage points in the system, better understand the dynamic effects of policy implementation over time, and understand the effects of proactive versus reactive approach to meet increasing societal environmental pressures.

Background

Today business environmental performance assessments are increasingly based on the firm's attitude towards the needs and expectations of both governmental institutions and customers. However, most companies have yet to realize the existing linkage between business and the environment, and the potential risks and opportunities it implies (Porter and van der Linde, 1995).

Quite often 'environmental' issues - such as pollution reduction - can be successfully turned into a business opportunity. Decision-makers have to realize that a change is needed in their own mental models, concerning perceived relationships between business activities and their environmental impacts (Sterman, 1989). Quite often managers misperceive the 'time' dimension in fostering their strategic control processes (Lorange, 1996). A reason that may explain this phenomenon is that, in real life, they get in touch with the results of their decisions only after the response of the system can be observed. Very often, the action taken by the manager and the response of the system are separated in time and space (Bakken, et al., 1994). Increasing public pressure to improve environmental performance gives companies less and less time to create structured decision support systems that naturally integrate environmental and business strategy considerations. Managers involved in business planning seem to have problems dealing with environmental impacts created by their policies.

According to Epstein (1996), "...environmental costs have grown very large and very fast, and most managers and their corporations have found themselves unprepared to deal with them. Many corporations are, usually, crisis prone rather than crisis prepared. Most of them use significantly out-of-date techniques in environmental management and costing. Someone even doesn't know how can be structured an environmental management system. Usually they don't make decisions based on the same rational evaluation of options those would be required for other capital investment decisions".

In order to help decision-makers better understanding the impact of their decisions different kind of tools can be used. The most important among them are:

- Environmental Management Systems (EMS);
- Life Cycle Analysis Systems (LCA); and
- Environmental Accounting Systems.

An EMS is a particular structure that allows the company to monitor and manage waste production through the "activity chain" (raw material acquisition, production, shipment, consumption, disposal). Life Cycle Analysis Systems and Environmental Accounting Systems are two methods designed to support activities that improve business decision-making. These two management support tools are useful in estimating internal and external "green costs" and, when it is necessary, internalizing the external green costs. This process, in fact, is at the base of a sound Environmental Strategy. A company, by internalizing environmental costs, pays for the impact on the natural environment. By doing so, a company shows its concern regarding social problems like waste production and pollution.

The current literature is still divided regarding how to use the above-described tools. Porter and van der Linde (1995), for instance, describe many cases where environmental problems were addressed by using these tools as a way to create competitive advantage (see in the mentioned article the experience of Dow Chemical (California), 3M, and Du Pont). On the other hand, Hunt and Auster (1990) speak clearly in favor of a proactive behavior, i.e. creating strategic conditions to avoid potential future problems related to the natural environment. In between these two positions, there are many shades of gray. Azzone, Bertelè and Noci (1997) mention cases in which success depends upon the initial characteristics of the scenario. Thus, having information tools, like LCA, could be enough to reach satisfactory results, but sometimes an additional step, requiring a learning process, is necessary.

An EMS could help decision-makers in filling the gap caused by misperceptions of dynamic aspects of the relevant system. On the other hand, an LCA system is effective in providing information about the current state of the system, whereas information about the potential future state of the system is needed. However, accounting tools are not sufficient to support decision-makers in understanding how to manage environmental problems. In fact, accounting tools capture only one corporate management perspective (Bianchi, et al., 1998).

A useful tool to support decision makers better understanding the structure of relevant systems can be based on an approach that improves their mental models, that is helps them detect weak points in their day-to-day framing of different problems/issues. An underlying premise associated with the use of such models/tools it is that organizational learning will improve future competitive performance (Senge, 1990). Furthermore, it is increasingly argued that a need for continuous learning is triggered when organizations are facing uncertainty, higher turbulence and more rapid changes. (Funke, 1991).

These are characteristics of a contemporary corporate scenario. The natural environment is more and more becoming a competitive issue, since environmental aspects increasingly affect marketing activities or costs drivers. Again, corporate environmental problems are often a source of uncertainty and turbulence in the corporate environment. New environmental problems become evident, new environmental laws are passed and existing ones are changed. The environment increasingly enters the corporate technological situation as corporations look for technological alternatives to minimize the environmental impact of their process and products. This implies that organizational learning, as a concept and company practice, is of vital importance in improving corporate environmental performance.

System dynamics (SD) is a methodology that can be used to stimulate the learning process. It can be used to develop interactive learning environments (ILEs). Combining traditional management case studies with a computer-based interactive learning environment may significantly stimulate management analysis and diagnosis processes (Langley, 1996). Such tools (also called management flight simulators, MFS or microworlds) can enhance learning by allowing managers to compress time and space in policy development, to experiment with various strategies, and learn from simulated deployments by reflecting on the outcomes (Sterman, 1994; Senge and Sterman, 1994; Graham et al., 1994; Bakken et al., 1994).

The System Dynamics Approach

The SDBLE (named The Green World MFS) presented here is primarily intended to be used in undergraduate or graduate management education in the field of environmental management studies. It can also be used by company managers or any other decision-makers involved in planning.

One of the main purposes of The Green World MFS is to provide learners a better understanding on how departmentalized versus holistic management approaches in policy design may differently impact a complex system, thereby generating different behavior patterns of key variable. By using the SDBLE, learners may be able to understand the dynamics of the decision-making process within a complex system. After interacting with the learning environment, learners are expected to be able to formulate coherent overall policies for the management of this complex system, and to justify their policies. They should be able to transfer to a familiar everyday situation the generic insights obtained through understanding of the "Limit to Success" system archetype.

The Green World MFS is a System Dynamics based Interactive Learning Environment. System Dynamics is a methodology used to describe, analyze, and better understand complex dynamic systems (which evolve over time), that share the same characteristics, including feedback loops, time delays, non-linear relationships, uncertainty and vagueness (Forrester, 1961). The main underlying assumption behind SD is that the structure of a system (defined in terms of its elements and interrelationships among them) determines its behavior and, therefore, its response to different control actions or policies. An Interactive Learning Environment is an instructional resource, which has several important characteristics. It situates the user in a simulated 'arena' replicating a real world problem, providing a safe environment for testing strategies and policies (Senge and Sterman, 1994). Learners are encouraged to design strategies, implement them, observe their simulation results, and to comment on how their decisions and policies influenced the results user interface provides reports, graphs and tables to show the results of an interactive simulation.

The challenge for learners is not only to sustain corporate activities, but also to earn a reasonable financial return from the implementation of their strategic plans. Questions that learners should be able to answer at the end of the learning process are:

1) How can they meet both, short-term growth and long term business sustainability, pressures?
2) Are they able to design 'robust' policies that serve the market in quantity, satisfy customers in quality, take care of the environment, develop the business, and maintain their ability to obtain sufficient financial resources?

Architecture of the ILE

The ILE has been designed to be used by 5 learners simultaneously. Four of them play the role of top managers of four different corporations. All companies are situated in the same community. The fifth learner plays the role of a community administrator.

Usually educational business games require learners to deal with competitive pressure, often the market. Few business games address the conflict between different stakeholders.

The ILE proposed here includes several companies that try to match market needs, maximize shareholder value, and a public administration, whose only target is quality of life for the community with a particular focus on the environment.

Brief description of the scenario

The market

Only a limited number of actors are competing on the market. The market is sensitive to the changes in:

- Price,
- Quality and
- Availability of the product.

The price elasticity of demand is constant. The quality of the product is measured in terms of pollution created throughout the product's life cycle. Public sensitivity towards this problem is a variable influenced by the pollution level in the natural environment, and by social aspects like unemployment. Sensitivity to availability is due to the short life of the product, thus causing frequent re-purchase of the product.

Competitors

The companies that are competing against each other are similar. They produce the same kind of goods for the same market. All companies start with the same initial market share. Further, all the plants of these companies are situated in the same community, from which they recruit the workforce necessary for the production process. Learners can choose to compete against one to three competitors. Competitors may be other human learners, or the computer. All learners have the same set of the decision levers as well as the same relationship with both the community government and the market.

Government

The role of the community government is to take care of the community's livelihood. To do that, government administrators constantly monitor crucial aspects of community "life" such as:

- the economy, as represented by community employment level, and
- environmental issues.

There are many interrelationships between the companies' and the government's responsibilities. The government requires the companies to pay taxes on profits because the companies' plants are within the community's territorial jurisdiction. The government also makes rules that encourage companies to eliminate potential, rather than create real, environmental problems. Feedback from the company to the community includes jobs, tax payments, and pollution. Sound management is expected to optimize all these aspects.

The environment

The role of the natural environment in this context is quite complex. In their every-day activities companies make use of non-renewable natural resources. Further, the result of the production and consumption of goods is pollution. Up to now, societies have enjoyed growing affluence, but in the process, have exploited the world's resources by developing manufacturing industries to support such affluence. These efforts have contributed to global warming and other phenomena that sometimes cause rapid deterioration of the global environment. To halt this deterioration everyone, company managers included, must recognize the critical need to care for the global environment and to sustain efforts to preserve this environment.

Managers should be interested in sustainability, first as human beings interested in the future of the planet, and second in order to avoid potential public sanctions that could lead, sooner or later, to a reduction of profitability.

The company

Learner takes a role of a top manager at the head of a medium to large sized company where the core business is the production of small goods such as cosmetics or similar. The company's market is concerned with price, quality and availability. Therefore learners must be concerned with these attributes of their company's products. Learners may choose different levels of difficulty; the level of difficulty affects the set of decision levers that the learner will use. All the policies behind these decisions are set in the model. The company is a capital intensive one, but learners also need to manage in a way that avoids bottlenecks in workforce and raw material availability, both of which can reduce profitability.

The reason for this architecture is, as discussed earlier, to give a feel of reality to the simulation model. We believe that a realistic game will motivate the user to be more involved in the learning environment, which should improve the learning process.

As mentioned earlier, the ILE contains two levels of difficulty. The first difference between the two levels is the set of decisions learners can make. The easier decision set influences short-term behavior; the more difficult decision set influences long-term behavior. In other words, users more quickly observe the effects of their decisions when using the simpler difficulty level than when using the advanced difficulty level. The second difference is that learners using the simpler level see causal loop diagrams showing the portions of the system that their decisions will impact, whereas advanced level learners can see the corresponding stock and flow diagrams. The reason for this difference is that novices may not understand stock and flow diagrams as well as causal loop diagrams.

Here is a description of the two levels of difficulty available in the SDBLE. This particular architecture responds to Gagne's (1985) learning prescription for limiting the amount of information the learner must store in the learning process.

The simple level

Availability is the delivery time of goods to customers. The user can reduce availability as long as the market accepts it. The reason learners would want to increase their delivery time is that, by so doing, they reduce stress on their production capacity. On the other hand, more availability (shorter delivery time) leads to increases in desired production capacity, a bigger gap between desired and actual capacity, higher upgrade expenses, less cash and a reduced investment capacity.

The *Mark Up* decision allows learners to set the price by marking up unit production cost. The price is also weighted looking at the Inventory/Desired Inventory ratio: a value of this ratio larger than unity decreases the price, and vice versa. An increase in mark up leads to a decrease in orders, because of the market sensitivity to price. However, depending on the demand/price relationship, increasing mark-up may increase or decrease revenues and profits.

Marketing Budget Allocation primarily addresses advertising and also impacts recruitment time required to attract uncommitted potential customers. It is expressed in terms of percentage of revenues. Increasing the percentage increases marketing expenditure only if revenues are close to, equal or larger, than before the increase. Marketing expenses have a positive effect on revenues, because the more is spent on marketing, the more product awareness in the marketplace about the product. On the other hand, marketing expenses have a negative effect on profit since they increase costs.

Research & Development Budget Allocation addresses expenditures on both product quality and the impact of the product on the environment. By increasing R&D expenditure the learner will get a product that requires fewer natural resources. Of course the more one invests in R&D, the less the marginal return on the investment.

Life Cycle Analysis Structure Control allows learners to enable or disable the structure that minimizes the production of pollution. By enabling this structure the learner automatically invests in new "cleaning capacity" as production rates demand. Enabling the pollution control structure has a double impact on the system: there are immediate negative effects on profitability due to environmental management system costs. However, delayed positive effects include less profitability risk due to reduced government sanctions and a better company image resulting in more orders.

The advanced level

Learners are encouraged to fully understand the simple level before playing the advanced level.

Production Capacity Velocity Adjustment
The meaning of this decision is best illustrated by an example. Assume there is a gap of 1000 products per unit of time between one's actual and desired capacity. If one sets the value of this parameter to 10, it means that one would like to correct 1/10 of the gap per month. To quickly correct the gap in order to be able to rapidly follow market changes is expensive, and may lead to overcapacity if the changes to which one is responding are momentary. On the other hand, responding too slowly can give market share to one's competitors.

Cleaning Capacity Velocity Adjustment
Once again, the meaning of this lever is best illustrated by an example. If there are 5000 tons of waste that must be rendered inert, and the value of this parameter is set to 10, it means that one would like to correct 1/10 of the gap per month. Quickly increasing cleaning capacity is expensive. However, reducing the company's waste output can have increasingly positive, but delayed, market effects.

Target Quality
For the purposes of this ILE, the quality of the product is the amount of waste that the product generates in its life cycle, from raw material acquisition through disposal. In the Research and Development Department experts study how to reduce the impact of corporate activities on the environment. The higher the target, the more immediate investment required to achieve a given amount of waste reduction, but, again, higher quality targets have delayed positive marketing effects. Setting the target quality decides the company's attitude towards environmental issues.

Borrowing Fraction of Financing
To carry on corporate activity, learners need financial sources. Usually they are of three kinds:

- Internal finance (net profit plus all costs that are not expenses, like depreciation)
- Borrowing, and
- Equity market issues.

Learners can decide between the last two sources, since the first one is implicit in the structure of the ILE. By setting the value to 1, one borrows all that is required. By setting the value to 0, one obtains all required funds with equity market issues. Values between 0 and 1 provide a mix.

The role of the external agent

The ILE requires a facilitator. The facilitator:

- Familiarizes learners with the background of the learning environment.
- Selects the level of difficulty and starts the game.

- Helps to solve technical problems associated with the game.
- Debriefs the learners at the end of each run.

The facilitator may also choose to use the observer function to electronically observe learner interaction with the learning environment. The facilitator may also interact with the ILE, not against the learners, but as a government regulator. As a regulator he can change income and waste production taxes.

The goal for the learners

Each learner will compete against one to three other learners. Their activities will be closely monitored and influenced by the decisions of public administrator.

> **First task:** learners have to sustain their business for 10 years.
>
> **Second task:** each learner should attempt to accumulate the largest cumulative profit over the ten years.

The Model

The model at the core of this ILE was not based on a real case study. The architecture of the system represented by the model is the result of our understanding of a typical medium sized company environment. Most of the sectors in the simulation model are based on classic structures taken from existing system dynamics models described in the literature, except for the life cycle analysis sector, which was created as a part of this work. Here follows a short description of the main model sectors.

The product life sector, starting with the raw materials and finishing with the disposal rate, is based on the structure presented in Lyneis (1980) work. Some modification was required to adjust the original framework to the structure we desired. From the raw material acquisition through the disposal stage the production process is completely represented, including production as an inflow to inventory. The shipment rate decreases the inventory level and increases the amount of product in the hands of the customer. More specifically, the shipment rate is a minimum function of the inventory and of the backlog. Backlog is increased by incoming orders and decreased by the delivery rate, but also by the order cancellation rate (customers cancel orders if they are not satisfied with the delivery delay).

The financial structure included in the model is based on that of the Rütli Management Flight Simulator (Davidsen and Myrtveit, 1994).

The work force segment is based on the structure built by Abdel-Hamid and Madnick (1991). Two levels are represented in this sub-structure: the new workforce and the experienced workforce. Newly hired workers increase the level of the new workforce. As workers gain experience and skills, they move into the experienced workforce through an assimilation rate. Experienced workers train the new workforce. However, when the experienced workforce is occupied training new employees, less of their time is dedicated to the production, thus their productivity is temporarily reduced. When layoffs are required, both experienced and new workforce stocks are reduced. However, layoffs initially affect the new work force more than the experienced work force.

A reference market is influenced by the elasticity of demand and by the "green" quality of the product. The level of potential orders is increased by the discards rate (the consumption rate), as well as by the recruitment rate that works as long as the market is not saturated. The potential order level is also increased by the aggregate cancellation rate. It is reduced only by the order rate. The expected order rate is forecasted by using Sterman's (1987) trend structure.

The research and development segment is based on a non-linear relationship between productivity of the R&D investments and the ratio of effective to target quality.

Life Cycle Analysis (LCA) is a very important sector of the model. This sector simulates the production and the dissipation of waste. The amount of waste produced is accumulated in a stock. The process is monitored for each stage of the product life. Learners can influence both the production of waste and the cleaning process, (a process that makes waste inert). The levers provided to the learners are:

i) enabling the whole LCA System (through a check box), which results in continuous cleaning capacity development and use, with obvious financial implications;

ii) R&D budget allocation impact on the generation of waste along each stage of the life cycle, calculated as a percentage of corporate revenues;

iii) Target quality enabling the learner to set a target for the "green" quality of the product as compared to average "green" quality of similar products in the marketplace;

iv) The rate at which the effective cleaning capacity is adjusted to the desired cleaning capacity. This has a strong impact on the financial situation.

The second pair of decision parameters is provided only in the advanced level. A longer period of time, compared to the first pair, is needed to observe the reaction of the system to these decisions. The cleaning process costs are proportional to the cleaning rate. In general, some of company's expenses are related to reducing waste production. A basic assumption is that all the expenses in R&D are related to minimization of pollution production. On the other hand, there are expenses related to the cleaning process e.g., costs of building cleaning capacity and the cleaning process costs. The cleaning process costs are proportional to the amount of waste processed. A learning curve effect (Sterman, et al., 1996) reduces the cost per ton of waste processed.

Conclusions

Managing complex systems requires policies that respond dynamically to the changing conditions. A good understanding of the linkage between business and environment helps managers to integrate environmental issues into their business planning. A lot of tradeoffs are involved in environmental issue decisions. Implementing an environmental program can be expensive in the short run, but can create competitive advantage in the long run. A genuine understanding of the business environment structure is needed to develop and implement an environmental program tailored for particular business conditions. The purpose of The Green World MFS is to create learning conditions that improve the mental models of learners, by letting them experiment with new policies, thereby allowing them to gain insight into the dynamic aspects of a company's environmental decisions. The aim of interaction with The Green World MFS is not just to perform well in the simulated environment but also to be able to transference the experience and insights to the real life situations.

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