THE APPLICATION OF SYSTEM DYNAMICS (SD) SIMULATION
TO ENTERPRISE MANAGEMENT

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ABSTRACT

This paper presents the background and some of the lessons learned from a project in which System Dynamics (SD) simulation was applied in the enterprise environment. The organization simulated is a large commercial concern, developing and marketing new products as well as existing products in a highly competitive environment. SD simulation was used to examine business practices, validate corporate performance measures, train senior leaders in Systems Thinking, and to produce a forecast of long term profits and loss. The application of SD to enterprise simulation is not new; the scale of this application, and some of the techniques used for design and rollout make the project unique.

1   INTRODUCTION

This paper presents the results of a project in which SD simulation was applied to the problem of enterprise-wide strategic planning and management. While SD simulation is not a new discipline, its application to large scale problems is not yet common. In this paper, a large scale project is described, some methods for investing organizational leadership in a simulation tool are discussed, and some of the practical lessons that were learned in the project are enumerated.

2   PROJECT GENESIS

Several members of a Fortune 100 company had been introduced to SD simulation in a conceptual framework. They were faced with a growing internal management disconnect between strategic plans, performance, and the ability to learn from systemic responses in a timely fashion.

As with most manufacturing firms, this one had developed a series of performance metrics for the overall operation that were used to monitor success of programs and investments. The automated tools in use for planning did not lend themselves to user-initiated "what-if" analyses of any kind. The performance metrics in use did not seem to be presenting leadership with an accurate enough picture of the business to permit reasonable decision making in the short time periods required in the business segment of interest.

The leaders who had received exposure to SD simulation immediately recognized the value of bringing SD into the corporate environment. They saw an opportunity to teach senior leaders the value of viewing the business at the systemic level, and in learning to make decisions with a view of the entire enterprise's reactions to those decisions.

With this background, and recognizing that there were significant entrenched methods already in use within the organization, the project was begun in the spring of 1998. For its part, the corporation provided access to several key business planners as needed, and provided an internal engineer/analyst who worked directly on the project at slightly more than half of his time.

2.1 Why Simulation?

The first internal hurdle to overcome was the whole notion of using simulation at all, since existing automated tools were thought, by all but a few senior people in the organization, to be fully adequate for the task at hand. This was an extremely strong internal bias, difficult to weaken, let alone overcome.

To sell simulation as a viable methodology, it was necessary to appeal to the tools then in use, and to demonstrate that they could not support any kind of rapid sensitivity analyses. Further, the assertion was made (and proven during the senior leadership seminar discussed later in this paper) that the tools then in place would never have the capability to adequately address the need for real time analyses of financial options impacting strategic outcomes.

The ability that simulation brings to leadership to alter the world quickly, and from that altered state to view many potential alternative futures was the primary selling point

for simulation as a general approach to enterprise management. The notion that policy changes generated effects throughout the organization was not new to senior leaders; the demonstrated ability to see and understand the effects was totally revolutionary to them.

2.2 Why System Dynamics?

Having sold the notion of simulation to senior leadership, introducing the value of SD simulation was relatively simple. The three basic questions of SD were introduced within the context of assessing potential futures: what is flowing in a system, where does it collect, and what causes it to flow. Knowing the answers to these basic questions permits the development of a simulation, but just the development of the answers adds significantly to the knowledge base within an organization.

Every enterprise environment is a relational environment, with highly interdependent activities throughout the structure. Causal relationships are often understood yet overlooked in the daily grind of enterprise management. Yet, when the relational aspects of the enterprise are clearly demonstrated to leadership, and tools are put into their hands that not only recognize the relational foundation, but utilize it to derive significant analytical strength, the case for SD has been made.

Leadership was introduced to the three principal effects that SD simulation illuminates for its users: systemic feedback loops, systemic delays, and unintended consequences. Development of a simple, yet relatively robust, causal loop diagram (CLD) that encapsulated a portion of the business in which these three effects were rampant, produced the notion in leadership that SD was the right tool for this problem.

Development of a notional user interface using the corporation's terminology and notionally depicting effects of interest successfully demonstrated the necessity of a tool of this type for the analyses desired by the leadership.

2.3 Strengths of SD in the Enterprise Environment

There are some clear and definable strengths of SD simulation in the enterprise environment. Some of these strengths are not necessarily unique to SD, but some clearly are. No particular order is assumed.

Every enterprise environment has within its structure systemic delays. These delays usually develop over time in response to internal or external influences. In their gradual development, the system has gradually adapted to the delay, forcing a behavior that would otherwise not occur within the system. The delays become "normal" at some point in system evolution. Factors that are considered to be the norm are rarely questioned when investigation is entered in the pursuit of discovering enterprise efficiencies or cost savings. SD simulation provides the forum to effectively question "normal" behaviors and activities in

context. Not all delays are necessarily costly; sometimes the removal of a delay can be much more costly and destructive than leaving it in place and searching in other areas for efficiencies. By simulating the known delays in an enterprise, and providing the user of the simulation the capability to quickly change delay duration, it is possible to immediately gauge the short and long term impact of specific delays within the enterprise. Normally of interest is the real cost of delay elimination, a metric ideally suited to discovery in SD simulation.

Every enterprise contains feedback loops, communications paths and methods that impact behavior, often at the corporate level. SD simulation offers the enterprise analyst a tool to illuminate the impact of modifying or even eliminating these feedback loops. Both residual and transient impacts of feedback loop modification, elimination, or addition to a system are easily portrayed, analyzed, and understood.

Finally, every policy change, every behavioral change, every modification of delays or feedback loops produce consequences across the enterprise structure. Some of the consequences are anticipated and intended, others are unanticipated and unintended. Simulation in general, and SD simulation in particular, provide an ideal medium for the investigation of intended and unintended consequences. If the relational framework of the SD simulation has been properly constructed, systemic consequences of actions are quickly and clearly demonstrated.

3 METHODOLOGY FOR DESIGN

In this project, one of the intended outcomes was the transfer of Systems Thinking and the basics of System Dynamics to a portion of the business unit, as well as to the eventual user community (see below). To accomplish that goal, and to create a useful simulation at the same time, an approach was used that successfully engaged several key individuals over the course of the project.

An initial short course was given to key people in the business unit to set the stage for the simulation. In this initial instructional period (2 hours), the basics of Systems Thinking and SD were explained and many examples were used to solidify the learning. This session produced a core group with a common language and common vision for what the simulation would produce.

In a second session, the core group provided information on the enterprise, using their new knowledge and systems perspective. The product of this session was an initial causal loop diagram (CLD) which became the "story board" for all that followed. Over time, the CLD was refined as new understanding emerged. From the large, enterprise CLD, several smaller diagrams eventually emerged which were used as integral pieces of the final simulation (see figure 1). The core group began to think in terms of the nonlinear causality of their enterprise.
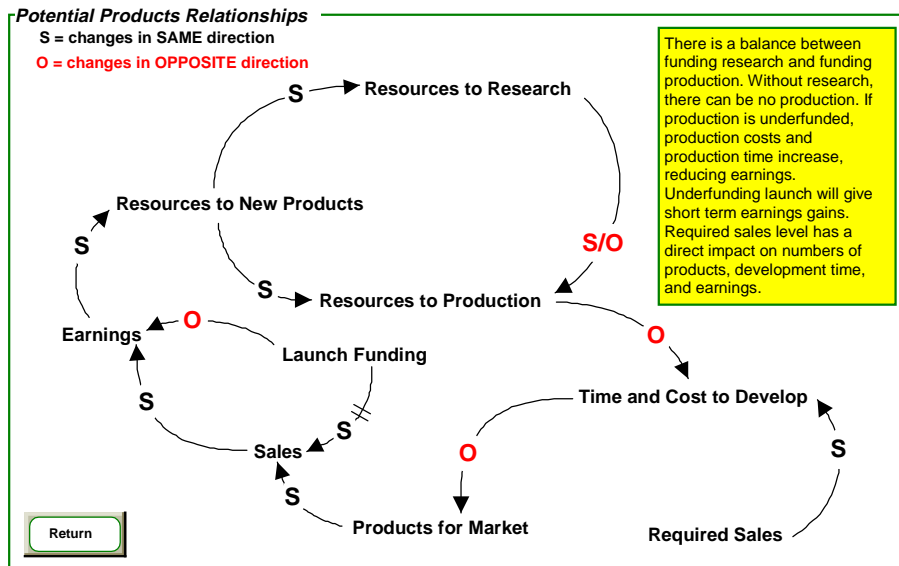
Figure 1: Example CLD

From the CLD, initial algorithms were constructed to depict the business processes. One of the individuals from the core group became the organization's expert on SD and simulation. He spent one or two full days each week working on design issues, simulation structure, interface requirements, and in the explanation of the business rules that described and bounded the enterprise. At every turn, the CLD was the pattern for all that was simulated.

On several occasions throughout the project, several members of the core group were reassembled to review and comment on the work that had been done. This in process review methodology significantly enhanced the overall process and the final quality of the simulation. By using the core group as an internal review mechanism, there rose up in the organization a group of people who were trained on the simulation and intimately aware of the inner workings of the algorithms, simplifying assumptions, strengths and weaknesses.

It is worthy of note that this process, actually much like a rapid prototyping development approach, yielded a completed, validated, and useful enterprise simulation in 90 days. That kind of efficiency and corporate "buy-in" could probably not be achieved any other way.

4 INTENDED USERS AND IMPLICATIONS

In most simulation endeavors, the intended user community is a small subset within the organization, typically not decision-makers, and often far removed from the decision making layer within the organization. For this enterprise simulation effort, the intended user group, from the beginning, was senior leadership.

There are some implications of selecting senior leaders as the user group of choice in an enterprise-wide tool. The level of detail that would be anticipated in an engineering-

level simulation will not exist in one intended for high level use. This will lead some to believe that lower resolution is somehow related to lower usefulness. In fact, just the opposite is true.

When senior leaders are the intended user group, great care must be exercised in devising a user interface that is appropriate to their analytical needs. At the same time, the anticipation is that there will be a secondary group of users who will have deeper needs for interface flexibility and detail than the primary group. Hence, targeting senior leaders generally drives the requirement for multiple layers of interface functionality. Thus, the design of such a simulation is often more complicated than one designed for other users because of the necessity to provide both simple and complex interfaces and the underlying structure to support both. Figure 2 shows a typical interface for use by senior players.

An understated strength of SD simulation in the enterprise environment is the ability that the designer has to target senior leadership as the user group, and to devise a simulation structure that will meet their needs as well as one that will meet more in-depth needs of other, secondary, user groups.

5 ANTICIPATED RESULTS

At the beginning of this project, the primary intended result of the simulation was that it would be a financial model capable of generating a relatively robust profit and loss report. That end was met.

Along the way, as the design matured, it became obvious that there would be measures that could be generated and reported aside from the typical financial measures. For example, the structure had been included in the simulation to accurately represent the internal research
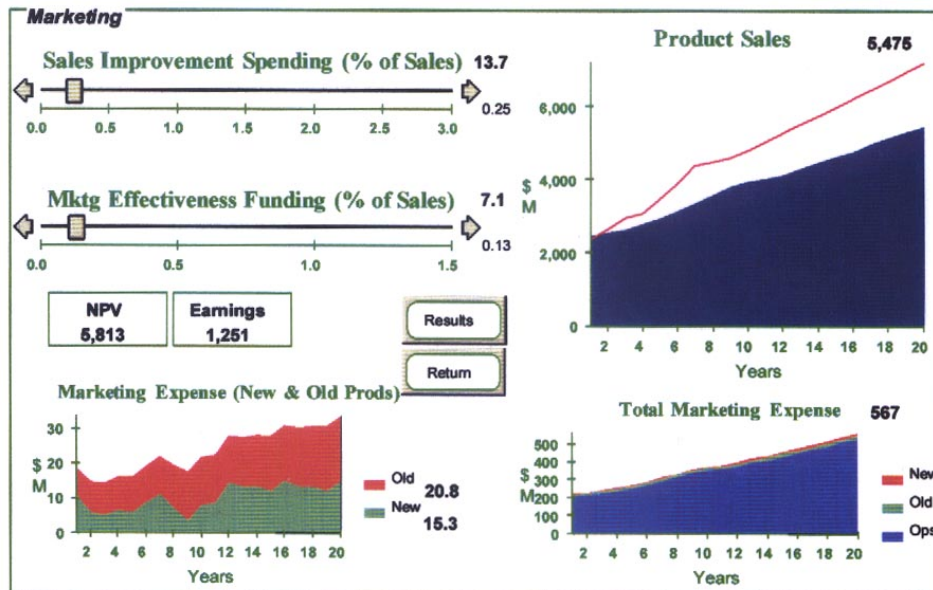
Figure 2: Typical Interface

and development activities that lead to new products. Hence, the measures associated with these processes are candidates for reporting and analyses. This sort of collateral generation of metrics occurred throughout the simulation development process. SD simulation design, due to its visual nature and visual mechanisms, lends itself to the sort of growth just described. Design team personnel, able to see the simulation and its interfaces quickly materialize, are able to just as quickly modify initial design assumptions to accommodate emerging analytical needs and opportunities.

A primary anticipated result from the simulation was that "what-if" analyses would be easy, intuitive, and fast. All three of these objectives were met in the simulation.

It was anticipated that the simulation would be easily migrated to other groups within the organization. Initial use has verified this to be so; groups of people who did not participate in design activities seemed to quickly acclimate to the simulation environment and begin to use it effectively very quickly.

6   THE ROLL OUT

The roll out for this simulation was done in a relatively unique fashion. A day-long session with about 30 senior leaders from around the world was used as the backdrop for introduction to simulation.

The group was divided into teams, and the teams were facilitated by organization members who had been previously trained through participation in the design process. The teams were given tasks to accomplish in line with the general thrust of business planning/strategic planning that the workshop had been organized to address. Teams competed against one another to achieve sales and revenue goals by developing long term strategies, then implementing them with the simulation.

Results were displayed and discussed at the conclusion of each part of the exercise.

The simulation was designed to stress the interdependence in the organization by imparting a system perspective to its users. To facilitate that dynamic, the teams were continually realigned during the day, from a narrow tactical focus to an increasingly strategic/system focus. At each level, the basic tasks remained the same, but with a different focus or world view in operation.

At the conclusion of the exercise, the senior leaders had achieved a few notable outcomes through the use of the simulation. First, they had been given a new language to describe their business, and the language became a shared language in short order, permitting the sharing of ideas across former barriers of language and understanding. They began to realize the importance of the systemic interdependencies that had always existed in their business, but that they had ignored in times past. This realization caused them to begin to plan differently than they had in the past, being much more aware of long term unintended consequences. They literally began to plan for, and think in terms of, the long term because they had discovered the relational view of their shared business.

Finally, these leaders began to see and understand the lasting value of using simulation to understand the physics of their business. Causal relationships began to drive decision making and also analyses of results. Profit and loss were viewed as part of a continuum rather than an isolated event. Existing measures of performance came under very close scrutiny because the simulation gave graphic indication that they were all lagging indicators rather than leading indicators.

The simulation was rolled out to the initial user community through a hands-on exercise that exposed the

users to all facets of the simulation environment by allowing them to apply it to their actual business in real time. This type of rollout is consistent with the design process employed throughout the project.

7 LESSONS LEARNED

A project of this magnitude will always generate many lessons. A few of the most notable are listed here. When SD is applied to enterprise simulation, it is critical to invest as many people in the organization as possible with the basics of Systems Thinking and System Dynamics early in the process, and to refresh their knowledge often.

It is critical to have access to a knowledgeable member of the organization on a routine and consistent basis throughout design and validation of the simulation. This facilitates developing a reasonable set of assumptions, and lends instant credibility to the simulation among organizational users.

Teaching organization members to read and use causal loop diagrams is a deliverable at least as powerful as the simulation itself. This new perspective on organizational physics and interdependence is foundational to the use of the simulation, but more importantly affords the organization the opportunity to devise and test new methods of management almost immediately.

Senior leaders can be a primary user group for a simulation. This may be a revelation to some readers. Of course, knowing that they would be the user group while the simulation was being designed allowed it to be constructed in a way that encouraged acceptance and use. But, it is noteworthy that the leadership of this organization readily used the simulation in the facilitated roll out exercise, and found it useful for planning following the exercise.

A simulation, especially an SD simulation, has its value in forcing people to learn about their enterprise, not in deriving answers. In fact, if properly constructed, an enterprise simulation should generate far more questions than answers, forcing its users to dig deeper into organizational innerworkings, broadening their individual and collective understanding, and generating new behavior at personal and corporate levels.

8 SUMMARY

In summary, this project proved to be an exceptional application of the SD methodology in a non-traditional venue. The final product was well received and used to corroborate budget decisions and investment decisions then in process. Corporate performance measures were placed under scrutiny by the simulation's outcomes, forcing an evaluation of what was measured and why. In short, the introduction of SD to the enterprise simulation environment resulted in outcomes consistent with what would be expected from much smaller applications of the methodology.

AUTHOR BIOGRAPHY

JOHN F. AFFELDT is a Senior Associate at Booz•Allen & Hamilton in McLean, Virginia. He holds a B.S. in Physics from the University of Scranton, and an M.S. in Operations Research from the Naval Postgraduate School. His primary interest in simulation is organizational dynamics and the development of corporate performance measures. Mr. Affeldt has been involved with SD simulation and its practical application to real world problems for more than 10 years. His clients have been from the Federal Government and private industry, with applications ranging from the simulation of personnel training systems to large scale financial simulation.