How can simulation be used for decision support?

Questions about using simulation for building a DSS are reasonably frequent in my Ask Dan! email. So this column has been in the works for some time, but my summer research project on advanced decision and planning support motivated me to move this column to the “front burner”. Coincidentally, I received an email on Friday, July 4, 2003 from John Walker (http://jbwalker.com). John wrote “I appreciate your newsletter. Keep 'em coming!” Thanks for the positive feedback. Also, John thought I might be interested in a June 16, 2003 interview with Eric Bonabeau at CIOInsight.com. Eric is the founder of Icosystem Corp., Cambridge, MA (http://Icosystem.com). Icosystem develops agent-based models and simulations. Agent-based or multi-agent simulations are the "latest and greatest" technology or approach in the simulation toolkit. Before I discuss agent-based simulations, let's review the basics of simulation. According to a number of sources, simulation is the most frequently used quantitative approach for solving business problems and supporting business decision making. That generalization may be true, but simulation is still the province of management science "specialists". Simulation has not been made "manager friendly".

Simulation is a broad term that refers to an approach for imitating the behavior of an actual or anticipated human or physical system. The terms simulation and model, especially quantitative and behavioral models, are closely linked. From my perspective, a model shows the relationships and attributes of interest in the system under study. A quantitative or behavioral model is by design a simplified view of some of the objects in a system. A model used in a simulation can capture much detail about a specific system, but how complex the model is or should be depends upon the purpose of the simulation that will be "run" using the model. With a simulation study and when simulation provides the functionality for a DSS, multiple tests, experiments or "runs" of the simulation are conducted, the results of each test are recorded and then the aggregate results of the tests are analyzed to try to answer specific questions. In a simulation, the decision variables in the model are the inputs that are manipulated in the tests.

In my DSS book (Power, 2002), Chapter 10 on Building Model-Driven Decision Support Systems notes "In a DSS context, simulation generally refers to a technique for conducting experiments with a computer-based model. One method of simulating a system involves identifying the various states of a system and then modifying those states by executing specific events. A wide variety of problems can be evaluated using simulation including inventory control and stock-out, manpower planning and assignment, queuing and congestion, reliability and replacement policy, and sequencing and scheduling (p. 172)."

There are several types of simulation and a variety of terms are used to identify them. When you read about simulation you will find references to Monte Carlo simulation, traditional mathematical simulation, activity-scanning simulation, event-driven simulation, process-based model simulation, real-time simulation, data-driven simulation, agent-based and multi-agent simulation, time dependent simulation, and visual simulation.

In a Monte Carlo or probabilistic simulation one or more of the independent variables is specified as a probability distribution of values. A probabilistic simulation helps take risk and uncertainty in a system into account in the results. Time dependent or discrete simulation refers to a situation where it is important to know exactly when an event occurs. For example, in waiting line or queuing
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problems, it is important to know the precise time of arrival to determine if a customer will have to wait or not. According to Evan and Olson (2002) and others, activity-scanning simulation models involve describing activities that occur during a fixed interval of time and then simulating for multiple future periods the consequences of the activities while process-driven simulation focuses on modeling a logical sequence of events rather than activities. An event-driven simulation also identifies "events" that occur in a system, but the focus is on a time ordering of the events rather than a causal or logical ordering.

Simulation can assist in either a static or a dynamic analysis of a system. A dynamic analysis is enhanced with software that shows the time sequenced operation of the system that is being predicted or analyzed. Simulation is a descriptive tool that can be used for both prediction and exploration of the behavior of a specific system. A complex simulation can help a decision maker plan activities, anticipate the effects of specific resource allocations and assess the consequences of actions and events. In a business simulation course, text materials usually focus on static, Monte-Carlo simulations and dynamic, system simulations (cf., Evan and Olson, 2002).

In many situations simulation specialists build a simulation and then conduct the special study and report their results to management. Evans and Olson (2002) discuss examples of how simulation has been used to support business and engineering decision making. They report a number of special decision support studies including one that evaluated the number of Hotel reservations to accept to effectively utilize capacity to create an overbooking policy (p. 161-163), a Call Center staffing capacity analysis (p. 163-165), a study comparing new incinerating system options for a municipal garbage recycling center (p. 176-179), a study evaluating government policy options, and various studies for designing facilities. Examples of model-driven DSS built with a simulation as the dominant component include: a Monte Carlo simulation to manage foreign-exchange risks; a spreadsheet-based DSS for assessing the risk of commercial loans (cf., Decisioneering Staff, 2001), a DSS for developing a weekly production schedule for hundreds of products at multiple plants; a program for estimating returns for fixed-income securities; and a simulation program for setting bids for competitive lease sales (cf., Evan and Olson, p. 190).

Sometimes in an effort to provide decision support an actual small-scale model or ecosystem is built and then it is "used in a simulated environment". For example, a physical model of an airplane may be built so that it can be tested in a wind tunnel to examine its design properties. Today a computer simulation might be used in place of a "physical model" for much of the design testing. The case "Product development decision support at Lockheed Martin" by Silicon Graphics Staff posted at DSSResources.COM October 16, 2002 is an example of this use of simulation.

Agent-based or multi-agent simulation does not replace any of the traditional simulation techniques. But in the last 5 years, agent-based visual simulations have become an alternative approach for analyzing some business systems. According to Bonabeau, "People have been thinking in terms of agent-based modeling for many years but just didn't have the computing power to actually make it useful until recently. With agent-based modeling, you describe a system from the bottom up, from the point of view of its constituent units, as opposed to a top-down description, where you look at properties at the aggregate level without worrying about the system's constituent elements."
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Multi-agent simulations can be used to simulate some natural and man-created systems that traditional simulation techniques can not. Bonabeau asserts agent-based modeling works best in situations where a system is "comprised of many constituent units that interact and where the behavior of the units can be described in simple terms. So it's a situation where the complexity of the whole system emerges out of relatively simple behavior at the lowest level." Examples of such systems include shoppers in a grocery store, passengers, visitors and employees at an airport or production workers and supervisors at a factory. What is the objective of an agent-based simulation? According to Bonabeau, "the objective is to find a robust solution" -- one that will work fine no matter what happens in the "real world".

A simulation study can answer questions like how many teller stations will provide 90% confidence that no one will need to wait in line for more than 5 minutes or how likely is it that a specific project will be completed on time and under budget? With a visual simulation decision makers or analyst can observe an airplane in a wind tunnel, a proposed factory in operation or customers entering a new bank or a construction project as "it will occur".

Based on my observations over the past 25 years, simulation has been used much more for one-time, special decision support studies than it has been used as the model-component in building a model-driven DSS. This is and can change with increased ease in creating visual simulations. Visual simulation means managers can see a graphic display of simulation activities, events and results. Will Wright's games "The Sims", "SimCoaster" and "SimCity" (cf., http://thesims.ea.com) are the precursors for advanced, agent-based, model-driven DSS. I am continuing my research on boids, sims, swarms, ants and other such agent technologies. So perhaps in another Ask Dan! I can discuss in more detail complex, realistic visual simulations based upon behavioral models. My sense is that current technologies can support development of complex, "faster than real-time", dynamic, agent-based, model-driven DSS for a wide variety of specific decision situations.

References


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