Modeling in Simulation

Modeling

Simulation, like most analysis methods, involves systems and models of them. So in this section, we give you some examples of models and describe options for studying them to learn about the corresponding system.

1.1.1 What's Being Modeled?

Computer simulation deals with models of systems. A *system* is a facility or process, either actual or planned, such as:

- A manufacturing plant with machines, people, transport devices, conveyor belts, and storage space.
- A bank or other personal-service operation, with different kinds of customers, servers, and facilities like teller windows, automated teller machines (ATMs), loan desks, and safety deposit boxes.
- A distribution network of plants, warehouses, and transportation links.
- An emergency facility in a hospital, including personnel, rooms, equipment, supplies, and patient transport.
- A field service operation for appliances or office equipment, with potential customers scattered across a geographic area, service technicians with different qualifications, trucks with different parts and tools, and a central depot and dispatch center.
- A computer network with servers, clients, disk drives, tape drives, printers, networking capabilities, and operators.
- A freeway system of road segments, interchanges, controls, and traffic.
- A central insurance claims office where a lot of paperwork is received, reviewed, copied, filed, and mailed by people and machines.
- A criminal justice system of courts, judges, support staff, probation officers, parole agents, defendants, plaintiffs, convicted offenders, and schedules.
- A chemical products plant with storage tanks, pipelines, reactor vessels, and railway tanker cars in which to ship the finished product.
- A fast-food restaurant with workers of different types, customers, equipment, and supplies.
- A supermarket with inventory control, checkout, and customer service.
- A theme park with rides, stores, restaurants, workers, guests, and parking lots.
- The response of emergency personnel to the occurrence of a catastrophic event.

People often study a system to measure its performance, improve its operation, or design it if it doesn't exist. Managers or controllers of a system might also like to have a readily available aid for day-to-day operations, like help in deciding what to do in a factory if an important machine goes down.

We're even aware of managers who requested that simulations be constructed but didn't really care about the final results. Their primary goal was to focus attention on understanding how their system currently worked. Often simulation analysts find that the process of defining how the system works, which must be done before you can start developing the simulation model, provides great insight into what changes need to be made. Part of this is due to the fact that rarely is there one individual responsible for understanding how an entire system works. There are experts in machine design, material handling, processes, etc., but not in the day-to-day operation of the system. So as you read on, be aware that simulation is much more than just building a model and conducting a statistical experiment. There is much to be learned at each step of a simulation project, and the decisions you make along the way can greatly affect the significance of your findings.

1.1.2 How About Just Playing with the System?

It might be possible to experiment with the actual physical system. For instance:

- Some cities have installed entrance-ramp traffic lights on their freeway systems to experiment with different sequencing to find settings that make rush hour as smooth and safe as possible.
- A supermarket manager might try different policies for inventory control and checkout personnel assignment to see what combinations seem to be most profitable and provide the best service.
- A computer facility can experiment with different network layouts and job priorities to see how they affect machine utilization and turnaround.

This approach certainly has its advantages. If you can directly experiment with the system and know that nothing else about it will change significantly, then you're unquestionably looking at the right thing and needn't worry about whether a model or proxy for the system faithfully mimics it for your purposes.

1.1.3 Sometimes You Can't (or Shouldn't) Play with the System

In many cases, it's just too difficult, costly, or downright impossible to do physical studies on the system itself.

- Obviously, you can't experiment with alternative layouts of a factory if it's not yet built.
- Even in an existing factory, it might be very costly to change to an experimental layout that might not work out anyway.
- It would be hard to run twice as many customers through a bank to see what will happen when a nearby branch closes.
- Trying a new check-in procedure at an airport might initially cause a lot of people to miss their flights if there are unforeseen problems with the new procedure.
- Fiddling around with emergency room staffing in a hospital clearly won't do.

In these situations, you might build a *model* to serve as a stand-in for studying the system and ask pertinent questions about what *would* happen in the system *if* you did this or that, or *if* some situation beyond your control were to develop. *Nobody gets hurt, and your freedom to try wide-ranging ideas with the model could uncover attractive alternatives that you might not have been able to try with the real system.*

However, you have to build models carefully and with enough detail so that what you learn about the model will never[1] be different from what you would have learned about the system by playing with it directly. This is called model *validity*, and we'll have more to say about it later, in Chapter 12.

1.1.4 Physical Models

There are lots of different kinds of models. Maybe the first thing the word evokes is a physical replica or scale model of the system, sometimes called an *iconic* model. For instance:

- People have built *tabletop* models of material handling systems that are miniature versions of the facility, not unlike electric train sets, to consider the effect on performance of alternative layouts, vehicle routes, and transport equipment.
- A full-scale version of a fast-food restaurant placed inside a warehouse to experiment with different service procedures was described by Swart and Donno (1981). In fact, most large fast-food chains now have full-scale restaurants in their corporate office buildings for experimentation with new products and services.
- Simulated control rooms have been developed to train operators for nuclear power plants.
- Physical flight simulators are widely used to train pilots. There are also flight-simulation computer programs, with which you may be familiar in game form, that represent purely logical models executing inside a computer. Further, physical flight simulators might have computer screens to simulate airport approaches, so they have elements of both physical and computer-simulation models.

Although iconic models have proven useful in many areas, we won't consider them.

1.1.5 Logical (or Mathematical) Models

Instead, we'll consider *logical* (or *mathematical*) models of systems. Such a model is just a set of approximations and assumptions, both structural and quantitative, about the way the system does or will work.

A logical model is usually represented in a computer program that's exercised to address questions about the model's behavior; if your model is a valid representation of your system, you hope to learn about the system's behavior too. And since you're dealing with a mere computer program rather than the actual system, it's usually easy, cheap, and fast to get answers to a lot of questions about the model and system by simply manipulating the program's inputs and form. Thus, you can make your mistakes on the computer where they don't count, rather than for real where they do. As in many other fields, recent dramatic increases in computing power (and decreases in computing costs) have impressively advanced your ability to carry out computer analyses of logical models.

1.1.6 What Do You Do with a Logical Model?

After making the approximations and stating the assumptions for a valid logical model of the target system, you need to find a way to deal with the model and analyze its behavior.

If the model is simple enough, you might be able to use traditional mathematical tools like queueing theory, differential-equation methods, or something like linear programming to get the answers you need. This is a nice situation since you might get fairly simple formulas to answer your questions, which can easily be evaluated numerically; working with the formula (for instance, taking partial derivatives of it with respect to controllable input parameters) might provide insight itself. Even if you don't get a simple closed-form formula, but rather an algorithm to generate numerical answers, you'll still have exact answers (up to roundoff, anyway) rather than estimates that are subject to uncertainty.

However, most systems that people model and study are pretty complicated, so that *valid* models[2] of them are pretty complicated too. For such models, there may not be exact mathematical solutions worked out, which is where simulation comes in.