

## TIPS FOR SUCCESSFUL PRACTICE OF SIMULATION

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### ABSTRACT

Succeeding with a technology as powerful as simulation involves much more than the technical aspects you may have been trained in. The parts of a simulation study that are *outside* the realm of modeling and analysis can make or break the project. We explore the most common pitfalls in performing simulation studies and identify approaches for avoiding these problems.

### 1 INTRODUCTION

If you've been charged with performing a simulation study, you may not know it, but you have quite a challenging job on your hands. (Be sure to share this with your boss for a bit of professional sympathy or, if you're lucky, a well-deserved raise.) To succeed with the task you've been assigned, you'll need an incredible combination of both quantitative and qualitative skills, a lot of support from many areas of your organization, and a suite of tools and techniques to enable your work.

Much has been written and researched in the last area, resulting in a mind-boggling array of modeling/analysis techniques and software for performing simulation studies. Your selection of the methodology you'll use and the supporting tools to do the work will contribute to the success of your project.

Regardless of the approach you're taking and the product you're using, though, succeeding with simulation requires much more. As it turns out, many of these supplementary aspects can influence your likelihood of doing a good job more greatly than the traditionally discussed methods and tools available to you.

### 2 WHAT DOES "SUCCESS" MEAN?

First, it's important to identify how success will be defined. In the best scenarios, a successful simulation project is one that delivers useful *information* at the appropriate *time* to support a meaningful *decision* (see Figure 1).

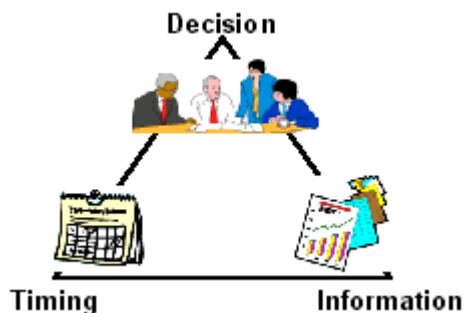


Figure 1: Elements of Success

#### 2.1 The Right Information

The most important aspect of presenting the right information is to look at it from the perspective of the audience for which it's intended. Think about *what* they need to know and *why* they need to know it—in the context of what they're going to do with this information to deliver value to your business. Try to anticipate the questions they might ask. And remember, their view of the system you're studying is bound to be different from yours, so take the time to introduce them to how you look at things, and explore how this differs from their perspective. You may need to create more elegant animations or design custom reports, for example, to communicate what you're doing and what you've learned easily and effectively.

The nature of the information that's needed may vary, even at different times within a project. When you embark on your simulation journey, one of your first tasks should be to define this as explicitly as possible, keeping in mind that there are many constituents who may have an interest in your work.

Those who make and influence decisions will certainly be interested in the data that's typically associated with a simulation study (cycle times, costs, resource utilizations, etc.). Beyond this obvious information, though, may lie other types that are equally important. Animation of the simulated process might be key to the success of the study, by supporting model validation and influencing decision-

makers. Options that were unexplored or quickly discarded should be documented so that others know both what you did (or didn't do) and why you made those decisions.

You also should trust that instincts you've developed about the system might be as or more valuable than those of the "experts" with whom you've consulted. One of the great benefits of assigning someone to perform a simulation study is the perspective they have on the system. While the people who are performing or implementing a process/system have a mastery of great detail concerning their area, the simulation analyst gains a higher-level overview—while still understanding the process at a fair level of detail.

## 2.2 The Right Timing

The timing of when you are able to deliver meaningful information also is critical to a project's success. A high-fidelity answer that's too late to influence a decision isn't nearly as good as a rough-cut estimate that's in time to help.

Note, too, that this applies throughout a study, not just at its completion. If you can provide preliminary insights into a system's behavior early in a project, the owners of the design might change the options they consider or adjust the focus of the simulation efforts.

## 2.3 The Right Decision

The third aspect of succeeding may be out of your control, but is important for you to understand. Namely, for the project to succeed from your efforts, you need to influence an important decision. Wonderful simulation work, advanced analysis, and eye-grabbing animation, all completed on-time still are of no value if they aren't delivered to the *right person* in the *right context*.

If you're adept at corporate politics, you'll probably find it easy to figure out who the right people are and to what extent they overlap with those who've been identified as important decision-makers. (Surprisingly, sometimes these lists differ.) If not, then as your project moves forward, you should work to identify where the power is and tailor your communications to put the right information in front of these individuals.

When you present any information from your study, you also must consider the decision environment: where are the sensitive areas, what preconceptions exist, and what's really important. Many simulation studies are initiated to "prove" that a planned course of action is right. If your analysis concludes to the contrary, then the environment you'll be walking into will be significantly more challenging than cases where there are open minds. In such a situation, which you should try to discover early in the project, you should allocate extra time for additional analysis after your project is "complete," just in case you

find out that the existing wisdom was misguided and need extra ammunition to make your case.

## 3 WHERE COULD YOU GO WRONG?

To reach this goal of succeeding with simulation, two questions seem most relevant, namely how can things go wrong and what should you do to make them go right? As often happens, while you may not have control over all of the relevant aspects of your work, it can be invaluable to understand the importance of them as you plan your efforts and design your reports and presentations.

### 3.1 Tackling the Wrong Problem

Sometimes, the biggest mistake is made at the outset of a simulation study. If your organization or client has picked the wrong problem to explore with simulation, you might be put at a high risk of failure before you've made your first mouse click.

One of the interesting places where this occurs is when simulation is used to prove what's already "known" or decided. In some firms, certain thresholds of capital acquisition require a simulation study, though it might be initiated well after firm commitments to a particular course of action have been made. If you're charged with one of these types of projects, you're either really lucky (i.e., the plan that's already in place is right) ... or you're in a very dangerous situation. Unfortunately, you won't know which is the case until you complete your work.

Particularly because of the animation that accompanies most simulation studies, another danger presents itself when identifying candidate projects. Once an analyst becomes adept at performing simulation studies, he/she can fall into the trap that "when you have a hammer (simulation), everything looks like a nail (career- or business-enhancing opportunity)." Certainly, many problems require simulation; the needed decisions can be effectively made only by looking at them through the perspective of a simulation analysis. However, other problems can be readily solved using other tools, such as queuing analysis, optimization, or simple spreadsheet calculations. When you're about to embark on a simulation project, step back and double-check that simulation's the best tool for the job. If something simpler can provide the same quality of results, then avoid the cost of the simulation study and use the appropriate tool.

The most common types of misguided simulation studies, though, are those where the scope is too ambitious or ill-defined. It's difficult to figure out where the boundaries should be in a complex system, since often it seems that everything could be an important factor on performance. You must work hard early in a project to discover what to exclude from the study; while it's hard to say "no," it can be critically important to be willing to do so.

### 3.2 Working on the Right Problem ... at the Wrong Time

To increase the chance of providing a good answer at the right time, you may need to think carefully about when to start a simulation project and whether to put the brakes on, even if you've established momentum. If the designers of the system/process are still considering widely differing ideas, or are brainstorming for how to solve some of the fundamental problems in the system, then it may be premature to perform more than a rudimentary analysis.

It's more difficult to identify timing problems once a project is under way. If there are regular and significant changes to the nature of the project, you'll feel the effects since you'll have to rework your model. It's hard, though, to know whether or when you should pause the simulation work to let the project team do some more preliminary design. Or, it may be that your best value is to use simulation for very rough-cut analysis, putting on hold the more detailed study that initially was chartered.

There's also danger on the other side of the timing spectrum, where a simulation study is started too late to be successful. This often begins with a panicked call from a project manager, who says that he/she "absolutely must have a simulation done starting now!" Of course, the natural response is to bring simulation to the rescue! Unfortunately, the cavalry riding over the hill are seldom carrying laptops with completed, validated, and verified simulation models.

If you're presented with a request like this, you should carefully lead the project manager through what is feasible to be of value. Often, this will involve intense negotiating, where the project manager wants a detailed, thorough analysis done quickly and the simulation analyst must focus on what's can reasonably be done so that the project starts out with attainable goals.

### 3.3 Missing the Warning Signs of the "Data Woes"

Ask any experienced simulation analyst what the most aggravating, challenging, dangerous aspect of a project is, and you're likely to hear "data" in reply. According to Ricki Ingalls, manufacturing strategy manager for Compaq Computer, "It's the data management that takes up most of the time ... getting the data, running it, then analyzing it" (Andel 1999).

The data woes are somewhat analogous to the story of Goldilocks and the Three Bears: you can have too little, too much, or just the right amount ... and still find yourself in trouble.

#### 3.3.1 Too Little Data

Most often, if there are problems with data, it's a lack of information. Service times, yield probabilities, defect rates,

rework percentages, and many other important aspects of a system's dynamics may not be collected for other business purposes. Because getting this data can be very time-consuming, it's critical to establish your data needs as early in a study as possible and to assess whether the data exists immediately. Your estimated project duration might vary by 100% or more, based on what you find when you go looking for numbers.

#### 3.3.2 Too Much Data

In your search for data, you may find the opposite problem, that there's far too much of it. While the particular information you need may exist, even perhaps electronically in a database or spreadsheet, you may spend days trying to locate it amidst all the other data that's with it.

In this circumstance, it's imperative to find help from someone who is knowledgeable about the data and whom you can educate about your exact needs. Depending on how the data will be used, you may also need some help from IS in extracting the data. For example, if you'll be using a tool that fits distributions to data for use with simulation, then you'll probably need to transfer the data to an intermediate form. If so, ask for these resources early so that they don't become an impediment to keeping your project moving forward on-schedule.

#### 3.3.3 Just the Right Amount, But What Does It Mean?

Sometimes, you may actually run across a case where the amount of data closely matches your needs. When this happens, it'll look like smooth sailing.

However, when you look at the data, be sure to understand what it *really* means. What you think of when you say cycle times, for instance, may be very different from the data that's stored in a cycle-time table, which might include waiting time, breakdown times, and other properties that are modeled separately in simulation.

### 3.4 Letting the Window of Opportunity Close

The greatest and most widely discussed risk of failure with simulation is that you won't finish the job on time. Creating a valid, useful simulation model is essentially a software development project, with similar risks and challenges. Returning to our definition of success, the timing of the information can be as important as the quality of the information—if the decision's made before you start your analysis, you might as well archive your files and move on to something else.

There are myriad reasons why simulation projects are late in delivering results. Four particular pitfalls seem worth special consideration.

### **3.4.1 Getting Lost in Detail**

One of the easiest traps to fall into is getting hooked on modeling. The art of simulation involves assessing what level of detail is required to support the project's goals. It's tough to do this right, though, because often you can't tell whether the detail is needed until you've developed it; and once the work is done, it's hard to justify removing it if it's unimportant.

Whenever possible, err on the side of keeping the model simple, unless you have the luxury of significant slack in your schedule. It's usually more important that you are able to perform some level of analysis of a system in a timely fashion than to run the risk of having no results to deliver when they're needed.

To avoid this trap, find a colleague who can frequently listen to you review your work. For most projects, it's worthwhile to sit down with this person at least two or three times a week, usually for only 15 minutes if you organize the discussion well. Sometimes, the time will be worthwhile for the insights *you* find by having to explain what you're doing to someone else, even if he/she doesn't directly question or contribute anything.

If the detail is being driven by those external to the project (e.g., decision-makers, clients), then carefully prepare an explanation of the risk to the project schedule associated with the added detail. If possible, perform a sensitivity analysis on the area in question; if significant modifications (e.g., 15-30%) to the process don't significantly change your decision variables, then it's unlikely that capturing the fine nuances of the system will be meaningful.

Sometimes, the need for additional model fidelity is driven by a desire for more realistic animations. While many simulation analysts view this as of minor value for meeting their goals, the quality of the animation can be very important in effectively communicating project recommendations. Once again, early planning and communications can be critical, so that you can build a reasonable project schedule that incorporates sufficient time for all aspects of the effort.

### **3.4.2 Leaving Analysis for the End**

There's a common misconception that performing a simulation study involves a sequence of steps (e.g., project definition, model formulation, verification, validation, analysis). To the contrary, all elements of a simulation project should be performed repeatedly throughout the effort, growing in scope as the model progresses.

In the traditional view, projects suffer from too strong a focus on the model (and perhaps the animation), so that after the inevitable delays and problems, there's no time left to run scenarios. Instead, the analyst is faced with a

presentation deadline that's firm and little time to experiment, analyze, or think.

Instead, you should schedule the project in complete phases. Intermediate milestones, spaced no more than about two weeks apart in a medium to large project, should include specific goals for the model, animation, data, and analysis. By the time you reach the last 25% of your time on the project, you should have addressed the basic analysis issues of run length, warm-up time, etc. and should already have performed preliminary analysis on the model for a number of different scenarios.

### **3.4.3 Having Too Much Fun with Animation**

If you've ever used PowerPoint, you'll understand this concept. At the point where you've drafted all of your content (i.e., the important stuff), you probably feel like you're almost done. Then it's time to adjust the fonts and slide transitions, to add figures and clip-art, and to twiddle with the custom animations. Surprisingly, you might find that the "prettying up" of your presentation takes more time than drafting the materials in the first place!

Animation holds a similar attraction in simulation studies. With the mouse in-hand, you can easily fall into the trap of adjusting, tweaking, and enhancing the animation far beyond what's needed, just because of its entrancing nature. (Some readers may not identify with this; if so, consider yourself fortunate!) As with many other addictive behaviors, the only treatment for endless animation is a recognition of the risks and discipline in your work.

### **3.4.4 Testing at the End of the Project**

As with analysis, verification of the model must be performed throughout a project. Because it's even more tedious and uninteresting than analyzing the simulation, it's easy to leave testing for late in the project.

Don't do it! Simulation can be a powerful influence on decision-makers. If you reach conclusions based on a faulty model, you've done a greater disservice to your organization than if the simulation had not been performed at all.

Think about a test plan early in the project and revise it as you progress. Delivering a "state of the model" assessment, which grades the various segments of the model regarding quality and completeness, should be a standard part of your simulation project at each milestone.

## **4 HOW CAN YOU SUCCEED?**

With all of these challenges, it's a wonder that anyone could possibly do all this! But there are a few simple habits you can develop that can boost your likelihood of success substantially.

#### **4.1 Establish a Clear Focus**

The success or failure of a simulation study begins with establishing a reasonable scope and the subsequent planning of the project. The study's specification must be formalized by obtaining sign-offs on focused objectives. Failure to obtain these commitments, or establishing objectives that are too vague, can set the project up for failure before it begins.

In many cases, the decision-maker or project initiator—we'll refer to him/her/them as "the client," though they're often internal to your organization—doesn't know what to expect from the simulation team. Likewise, often the simulation team doesn't know what is expected of them. It's extremely important that the client and the simulation team agree and adhere to the scope of the project. If the scope changes, these modifications must be agreed upon and their impacts acknowledged by the client and simulation team. The simulation project manager must obtain schedule and cost relief if additional resources, time, or personnel are required to complete the simulation on-time and according to the new specifications.

The project should also encompass animation at the appropriate level of detail. The animation demonstrates an understanding of the system being studied and provides credibility with senior management; therefore, it should always be a consideration while planning the scope and schedule for the project. Many times, the client may even be less interested in the actual results; but if it the animation looks impressive, at a minimum, the simulation team gains instant credibility with any output results that follow.

#### **4.2 Plan Carefully and Thoroughly**

Once the project scope has been established, as mentioned earlier, you should identify data requirements. The earlier that you get a handle on what data is needed, the sooner data gathering may begin. As any simulation professional knows, data collection and analyses often take longer than building the model itself.

Given the objectives of the project, prototypes of the output reports may also be designed and agreed upon so that the modeler is sure to calculate the appropriate statistics during the simulation. Unnecessary amounts of rework can be avoided if the modeler knows ahead of time what statistics need to be collected. The difference can even be as simple as only having to use a different modeling construct; e.g. a Batch versus a Match module in Arena®.

It's also imperative that you plan the project at an appropriate level of detail. The project manager should develop a project plan using a work breakdown structure. This approach is characterized by breaking major tasks into smaller ones with task times and the resources required to complete each task.

Examples of major tasks that should be accounted for in the plan are:

- gathering and analyzing data,
- building the model,
- animating the model, and
- analyzing the output.

An example of a breakdown for gathering and analyzing data would be:

- a) gather arrival data,
- b) gather process time data,
- c) analyze arrival data,
- d) analyze process time data.

The manager should also schedule milestones for each of these major tasks, in addition to milestones for sub-tasks. The schedule must be continuously reviewed by the project manager and should also be reviewed by project members. The client must be given frequent updates concerning the schedule: how the project is proceeding and whether or not milestones are being met.

#### **4.3 Build a Realistic Timeline**

Typical downfalls to avoid in managing simulation projects include underestimating time for three main tasks:

- data collection,
- verification, and
- performing analysis runs.

As mentioned earlier, data collection inevitably takes longer than anticipated. If the schedule is getting tight, another pitfall is to do less verification or to only do a top-level verification. Particularly in cases where the model includes complex logic, or where the model scope or system design changed significantly during the project, the process of verifying that the model actually does what you think it's supposed to do (a/k/a debugging) can be tedious and very time-consuming. When you create the project schedule, you should be sure to build verification time in at regular intervals; for a large project, as much as 20% to 30% of the time set aside for modeling should specifically be assigned as testing and debugging time. If appropriate time is not allotted for verification, the time may "bleed" into time that was allocated for analysis runs.

Until the first true analysis run is performed, the computing time required for a run is unknown, which still does not account for the number of replications, a warm-up period for a non-terminating system, and multiple design points in an experiment, let alone the appropriate analyses to determine all of the above. In an effort to finish the project on schedule, the impulse reaction is to do fewer or shorter runs, which may produce invalid results. In addition, often

not enough time is allowed for an appropriate sensitivity analysis of the system in order to supply the client with the value the simulation project intended to provide. The irony is that the results of the simulation are the reason the project was undertaken in the first place!

To avoid this pitfall, design the details of your analysis at the first opportunity, no later than when the model is about 75% complete. Then reassess the time you've set aside for final analysis, based on how long your runs will take, as well as the new perspectives you have on how many scenarios you'll be evaluating. In projects where you'll be performing optimization analysis, this would also be a good time to begin refining the number and search ranges for your controls (input variables) and to perform some initial optimizations to predict how long they'll take when the model is completed.

#### 4.4 Constantly Review and Reassess

The model and other deliverables should be reviewed early and often, with more intensity as the project nears completion. Structured walkthroughs with colleagues and clients are ideal for discovering problems with logic or errors in the model. In a structured walkthrough, the modeler steps through the modeling constructs and explains model logic, how areas were abstracted, and what assumptions were made. Colleagues may point out easier ways to accomplish portions of the model or even point out an incorrect interpretation of the system under study. In addition, the simulation team should review the model specifications, data analyses, animation, output reports, and client presentations.

Throughout the duration of the project, flexibility is important. As situations arise such as scope changes, problems with the data collection, or lack of subject matter expert availability, the simulation team must look for new ways to solve problems or work around them. More importantly, as these situations arise they should also be questioned regarding whether or not they are consistent with the true motivation for the project.

### 5 WHAT CAN YOU DO NOW?

While all of this may sound good "for my next project," there are many tasks that may be accomplished immediately. If your simulation methodology doesn't already have one, draft an outline for a typical simulation project and use this as a template for the work breakdown structure of current and future projects (see Kelton, Sadowski, and Sadowski 1998). Condense current and future project goals to reflect easy-to-remember slogans such as, "It's the cycle time stupid" in order for the entire team to remain focused on the goals. Conduct a peer review, or structured walkthrough, as soon as an opportunity presents itself. Finally, consult some of the references listed in this paper to gain additional insights into how to succeed as a simulation analyst.

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