[SQUEAKING]

[RUSTLING]

[CLICKING]

RICHARD DE NEUFVILLE: What is simulation? Simulation is a way of replicating the outcomes of an uncertain process. That is, we know the forecast may be wrong, we're looking at different possibilities, and if this were to happen in the terms of the forecast in, say, the demand for cars or the amount of liquid fuels consumed, here's the way we would deal-- here's the way the system would deal with it, here's the value of the system or the sales or the losses or whatever.

It's often called Monte Carlo simulation. Why is this? Because Monte Carlo is a European gambling hub. It's the Macau or the Las Vegas of the-- actually of the 1900s and 1920s. It was the place at that time, and therefore, it is designed to show about-- it's associated with luck and chance and uncertainty. That's why it's called Monte Carlo simulation as opposed to a deterministic simulation.

So we don't use the Monte Carlo very often because it just adds to the language, it makes the words longer. But it's the uncertain aspect that we're talking about.

So what it does. It provides us with a sample that is a distribution of what might happen if-- under some uncertainty. So think of it like you're flipping a coin and it comes up heads, heads, tails, tails, heads, heads, tails, heads, tails, whatever. That it will give you a distribution of the frequency of the possible outcomes that will occur.

And the way it operates depends upon the underlying uncertainty with a process. In the coin toss, it is the probability that the coin comes up heads or tails, which we normally call 50%, but maybe there is a particular bias in the coin that you're flipping because of a neck or whatever, it might not be that.

Now Monte Carlo simulation as it's practiced can work with any distribution, any distribution. It's no need to go for some analytically intractable distribution such as the so-called normal distribution or j-distribution or uniform distribution or binomial distribution.

It can be regular. That is, one of these normal distributions. Or irregular, what you observe, which might be the distribution of rain or monsoons in India which have a different intensity and timing and so on and there are reasons why they might not be nice and-- nice, simple distributions.

And it can be continuous or not. It could be bimodal. It could be mostly about one outcome or mostly about another outcome, sort of a two-state device with uncertainties. So the simulation works for any distribution that's available and it can be worked for lots of things being uncertain.

So if you're thinking about running a company and you are thinking about your income, there might be distributions of the demand for it in terms of how many. There might be a distribution in terms of the prices for it. There might be distributions in terms of the productivity of your production process. So it can calculate it for two, three, four, more possible distributions.

Now we tend to keep those numbers simple to focus on the main aspects of it, but it's perfectly possible to have a large number. I have a former student now who is working on a spreadsheet that, as I understand it, has 20,000 entries on it-- lines to it. To me that seems absurd, but the company is billing by the hour, so maybe it's a good thing to have a lot of work to do.

But in any case, the point is it can work with almost any distribution, it's not limited by some mathematical formula or limited to a particular approach. And I say that because there are other forms of dealing with uncertainties where really it assumes that you have a particular distribution or particular aspects of distribution.

So for example, those of you who might be in supply chain or have otherwise dealt with it, you might be using dynamic programming. Dynamic program is a very powerful way of thinking about what might happen in the future, but it has very strict assumptions about it which, in fact, don't apply to the kind of problems that we're dealing with here.

To give it a name, it assumes passive independence. That is, there is nothing management can do to change the situation, which is, of course, exactly where we differ.

So simulation has not been part of standard engineering education. Why is that? It's because it implies if you're going to do it in a way that really makes a lot of sense, you want to have lots of different samples. If you're looking at different things happening, you want to have lots of flips of the coin, so to speak. You might want to have 1,000 repetitions.

Well, modern computers can do it. 20 years ago they couldn't. So simulation has not been-- Monte Carlo simulation has not been part of engineering practice. So it's now possible.

Secondly, the model basically can be very simple, a spreadsheet is very powerful, s and you can get it with an Excel add-ins that can do it. The garage case template which I've provided is an example of that. They are very slick versions available. @RISK is one of them. The case I'll be talking about later on has another one called Crystal Ball. So there are various forms of it.

The slick versions often don't allow you to do the kind of flexibility analysis that we'll be talking about in the course, but just to give you-- there's a range of it. And there are, of course, other simulations that are possible. Systems dynamics models, queuing models, neither of which really apply to the kind of issues that we're dealing with in terms of system design and management, but I don't want to exclude them from the listing.

So what do you need for it to do a simulation? You need distributions for the key parameters, which, in general, observed, estimated, assumed, or guessed. Let's think about some examples.

Observe. For example, the river flow. If you're trying to build an electric power hydrodam-- hydropower dam for the Nile as they have done now in Ethiopia, you'd like to know something about the uncertainties about how much water is going to come down and how fast you could fill up the dam and how does that all work? So you can have observations of that for the past 50 to 100 years depending on where you are.

So a river is an observable distribution. And it may have some peculiarities. It doesn't have to follow any kind of normal or Gompertz or other curve, it is what it is.

It can be estimated. That is, if you're trying as in the mining case which I'll show later on today, you can consult the experts who have designed processing plants and who can have their best estimates of how this particular one is going to work out. And so you can have a technical model of it, and that estimates the performance of the situation.

It can be assumed. That is, you may have forecast of prices of your product because you know something about the competition, somewhat about how they behave and so forth so that you make forecast ahead assuming various aspects of the market, the actions of your competitors, the demand for your product, and so forth.

Or it simply may be guess. Your production may depend upon the possible environmental rules. If you're into renewable energy, the rules on taxation and environment and so forth may be affected by national legislative-- or local legislation, and we don't have observations of how they behave in those situations in the past, but we could go to people who understand the legislature or the process and they might tell you whether it's a 50% chance or a 10% chance. And it may be useful to you, but it's clearly guessed.

So we do the best we can. And in defense of dealing with things which are guesses, I would say that guessing there's a chance is better than ignoring a chance, which is a form of guess also, but with a lot less information about it. So there's no claim that these distributions can be-- are perfect or scientific in that way, but we have to deal with the world as it is and recognize that their chances and uncertainties is in the right direction.