[SQUEAKING]

[RUSTLING]

[CLICKING]

RICHARD DE NEUFVILLE: Another one I want to talk to you about, because it's very common in certain forms of engineering, is a robust design. It sounds better if I have a robust design, that seems very positive. We wouldn't want a weak design, would we? So it's a very positive affect.

What it means technically in the way it's used is a product whose performance is minimally sensitive to factors causing variability. So for example, it basically says that the standard deviation around a average performance is smaller. And that is a useful thing in many cases.

So here I have the green and the red. And the green is more robust, its standard deviation is less. And that's useful if you're trying to do various things. For example, if you're trying to tune in to a signal, a radial signal or whatever, you want something that you can really hone in on and keep on. Or if you're fitting parts together, a standard example would be fitting a steel axle into a steel wheel for making-- for railroad cars, and you want to have the tolerances as small as possible so it fits well.

But as a general thing, this is not what you necessarily want. For example, if we're in a startup, we want to limit the downside, for sure, but we want the standard deviation to the upside to be as high as possible. That is, we'd like to say, all right, our good design is not one that is this tight design here, but one that eliminates the downside, yeah, but that stretches off the upside. And it would be even better if this had a higher standard-- a greater standard deviation more towards the upside.

And in fact, that is the notion of a lot of flexibility design is you're trying to do two things. As with the garage case, you're trying to limit the downside, limit the losses, but give as much chance as reasonably possible for the upside. So the notion of robust design being a good design is very valuable in some situations, but really isn't what we want in general. That is, we want to limit the downside, maximize the variability of the standard deviation caused by the upside.

So once you think about it in those terms, it's fairly obvious. But in fact, it's not necessarily the obvious thing if you talk about-- if you look at design books and others that talk about what they want and we really ought to have a robust design, it has a limited applicability. But for system design under uncertainty, it is not the most useful guidance, in my opinion at least.

So in general-- and I will get more into these next time-- what we we're looking for is a way of showing the dimensions of choice that we'd have. So in this particular one, it refers to the case by Rania Hassan doing satellite design. And she had various alternatives-- a rigid fleet where the elements could move and then other alternatives-- and they had some measured performance-- expected value, the standard deviations, such as for robustness, the value of flexibility, the amount of cost that you'd have to pay, the present values, the maximum possible gain, the maximum possible loss, all elements that you might think of.

And just to illustrate that, in general, we would somehow want to display or make obvious the range of parameters and to think about what is the best-- the preferred trade-off. And so in this particular case, we've surrounded in red boxes the one that is the best by each measure. And then you can see that, without going into the detail, that this particular one seems the best overall but is not necessarily the best in all circumstances.

And it's perfectly reasonable to expect that people could look at this or think about this and say, hmm, there are trade-offs between different designs, which ones do I choose? And that choice is not one that's meaningful to be optimized, because how many units of standard deviation offset how many units of expected value is not something that is mathematically defined in any useful way.

So what is the takeaway for the method? It's that expected value is not a sufficient measure. I've said this before, but I want to emphasize it. Although that we've used it a lot as a way to get into the material of dealing with uncertainty in an initial way, we want to think about it in a more subtle way. So to think about the maximum and minimum that happen, we want to be able to compare alternatives.

Some of these things we can't show graphically that much, such as the capital expenditures or the benefit-cost or various measures, the value of flexibility. So there are different ways to think about it. And what I want to leave you with for today is that valuation of a system design over its many dimensions is not at all obvious.

There's a lot of subtleties about it, as Flynn alluded to very correctly. And we need to think about ways in which we as analysts and managers can identify the dominant solutions, the ones that are clearly better than others, and discard the others and then think about what the trade-offs are along that curve.

If you want the dominant curve, the Pareto optimal curve, you have to think about what are the ones that we want to keep and explore as to the relative merits and to help the people we're working for, either our bosses, or ourselves, or a more general public, as to what is the preferred design or where there's a negotiation between them.