[SQUEAKING]

[RUSTLING]

[CLICKING]

RICHARD DE NEUFVILLE: And the graphical view here, it addresses the question of what is the right size of your initial project. And so I have four curves here depending upon the alpha. The alpha equals ones indicate that there's no economies of scale. And as we go lower, alpha means that there's lower exponent on the economies of scale, which means they are greater, and you get to a different design.

And as an extension of the garage case, you see that the optimal design here increases along with economies of scale. And there are certain fixed costs so that the 25 tons per day didn't seem like the best solution, and so 50 seemed to be the right one given the fixed costs and everything else. So all this is fairly straightforward from the garage case.

So there is a general lesson here that is we might digest them, is there's a trade-off between economies of scale and the plant size where anticipating future growth. This was not part of the MITx simple-minded homework assignment, but it is the kind of thing that you think about. And in this particular case, the economies of scale and the example problem weren't very large so that building over as large as you could over that time was not obviously to be a good example.

Now, here is, I think, a really interesting table that is we're now looking at the uncertainty. So as shown in this graph here, there is the projection that Keppel Offshore Marine was going for, which had been a use, which was there was growing, the red line, it sort of disappeared here, but it's here, and then leveling off over time over this 20 years.

And we had applied uncertainty parameters to have it vary around here. And, of course, that we had no special bases on it, but recognize those uncertainty, and it wasn't trivial, so here's the ones we are working with. Now, here's where we have the parametric analysis. So clearly the design depends upon the economies of scale.

So here is the four that we were looking at from none to about the most that I've seen in practice, but seemed to be appropriate as a range. And if we look to the optimal capacity in terms of tons per day, as I just showed you with the graph, the more economies of scale, the larger is the better design from the economic point of view.

The moment you impose uncertainty, very similar to the garage case, the optimal design shifts because you find out that, well, you build something too large for the demand, and you lost, and on the other hand if the demand was higher, you didn't particularly have a gain because you could only produce so much so that what you see here is systematically when we think about the design itself, the optimal design from a deterministic point of view and with an uncertain perspective can be lower.

Now, the amount it's lower here depends upon the uncertainty that we impose, granted, but the effect is it drives it slower. That is a kind of effect you can imagine happening that you can anticipate, and it may not happen if the uncertainty was less. Maybe the uncertain design for the higher economies of scale might be the same here, but and that's why it's the lower or equal, so this is not necessarily it, but it is in this case.

By the same token, we can think about the net present value of the project. So here is the NPV of uncertainty is ignored, and it goes through these values. And the moment we now recognize the uncertainty as such as we're given here, we see that again it is they are lesser than the ones with a deterministic analysis. So these are absolutely standard effects and the results from the flaw of averages as they apply here to capacity-constrained systems.

Now, this being lesser all the time when you recognize uncertainty, applies to this kind of situation. It does not apply necessarily where you have network effects such as Amazon, or internet, or Google where the non-linearity is playing the other way, but the point being is that it's a clear evidence of the flaw of averages. And the reason I bother spending time on the flaw of averages is precisely because it drives these kinds of differences in case of capacity-constrained installations, whether they're warehouses, or electric power plants, or whatever, this is the kind of effect you would expect.

So a general lesson too I'm suggesting to you is that when invested in capacity-limited facilities, the realistic analysis that recognize uncertainty contrast with the deterministic analysis. That is are if you deal with a deterministic analysis, you're dealing with basically a fairy tale. That's a rather rude way of talking about it maybe because people are doing this all the time, but the fact is you're dealing with an unrealistic situation, and you are consequently going to get the wrong answer.

And in particular, for the capacity constraints situation, the realistic answer is that you have lower expected value and probably smaller modules are economically optimal. And, all right, so I want to stop here again, Indra. Is there any question here that people would like to ask? I want to be sure that this point is understood, or if you debate it, that we can have the debate about it, and I can resolve any questions that might occur.

INDRA: If anyone has a question-- yeah, we have Joshua.

RICHARD DE NEUFVILLE: Joshua, go ahead.

AUDIENCE: Professor, just looking for clarification. When you say that for capacity-limited facilities or whatnot, you're taking away the upside because you can only go up to that capacity. And so the uncertainty that's presented only provides you the downside up to that mean or the average.

RICHARD DE NEUFVILLE: And that's the major effect, yes. I mean, you can think, well, maybe we could raise our prices for it, so maybe we could compensate for if it's this tight demand. That implies there's no competition, of course. But so the major effect is in that direction. And of course, there are exceptions and modulate, but that is the main effect that one can account for, yes. That's what I meant to say. Are you concerned about that or just validating it, or how are we thinking about?

AUDIENCE: I think that makes a lot of sense. I appreciate the clarification. I think it's just how do you then absorb the risk associated with allowing yourself to get the upside? To get above the mean with capacity, any business would have significant risk in that case.

RICHARD DE NEUFVILLE: Well, that's where the modularity comes in because this is recognizing uncertainty, but it also means that, OK, well, we're going to allow for flexibility, and we say, right. If demand is picking up, we're going to put it ends some more modules. Now, in the garage case, the starter set was waited two years to see if the growth was there. Well depending upon the business, and depending on how long it takes to add the capacity, you might decide to do it earlier, or later, or whatever.

But the idea is, OK, if we've planned this correctly, we haven't forgone the upside opportunity. We just are going to make sure that it's around. So if we're starting here in year zero, year one, we're not going to build all the way up for here. We're going to say, well when year 3 comes around and it looks like the demand is really growing, we're going to add capacity. We haven't closed it off, but in that particular year when there was demand was higher than we were at capacity for, well, we didn't gain as much, but we'll catch it up somewhat later on. So but, yeah, that's what I'm saying.

For those of you who operated things, I mean, you have to realize that capacity, there's the plate capacity on the production facility, and then there is the actual capacity because there's a glitch, or you have to close it for maintenance, or so forth. And on the other hand, you can have produce more than the plate capacity because you decide to work overtime and forgo maintenance for a while that you had assumed, and so forth.

There are a lot of ways in which capacity is not like this cup of coffee, which will only take so much and you can't get any more into it. But it's more like a capacity of people on a bus or on a subway car. Well, it may say capacity for 20 standing and 30 seating, but you all situations where you had greater capacity, and others where right now, you're not allowed to sit close together, so the capacity is actually smaller.

So capacity, in practice, is quite a bit of a fluid thing, yes. So I'm trying to point to the general phenomenon here, but the ways in which in the real world it gets to be complicated, yes, absolutely. And right, my work now with this Moroccan company is exploring exactly those kinds of issues.

So just to say that I'll pass over this slide, which is simply to say that once you move to thinking about not just the combination of size and timing, but also add that other dimension of location, and in this case of five possible locations, that the complexity of the analysis increases greatly, and so the analysis is more complicated, but that's just as a footnote.

So now let's look at the optimal design here, and this is, again, very similar to the garage case where the building at large and fixed, has this performance here for these numbers and expected value quite reasonable, but it could be if you build it and nobody comes, the way it was the first years of the salting plant, you can have a big loss, and you're capacity limited to a certain amount.

If you had a flexible modular solution where you allowed yourself to time the increases of capacity according to the demand, you weren't going to lose very much because you started small, and there was not so much to lose, and the losses were several couple of million dollars by this comparison. But if the demand really picked up, you could expand, expand, expand, so that you had a much better performance overall, and in this case, as often happens, but not necessarily, the flexible demand compared with the inflexible demand perform was better overall.

So that was that. It was those target curves for that comparison. And note, by the way, that the increase in value, so of course, this is not guaranteed, but in this particular case, was from about 14 and change to about 21, which is about 50% increase in value. So that with no new technology, no sort of miraculum involved, simply by recognizing uncertainty, you could increase the prospective expected value by 50%. It's really quite remarkable, and, of course, there are details about how it actually going to work out, and so forth, but it emphasizes the great prospects for flexible design under some circumstances.