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RICHARD DE NEUFVILLE: So the first portions of it, the title is the "Drivers of Flexibility." That is, through our exploration of the fact that the forecast is always wrong, that there's uncertainty, and the observation that we need to explore what might happen, there are certain factors that make it much more likely that we should have flexibility to not.

And on the other hand, there are things that act against it. There are reasons why flexibility is either not desirable or, the most important thing I want to emphasize, why there are certain factors in the practice of engineering, the paradigm of engineering as we have it that act against the idea that we should be flexible. And this is what this topic is about. That is, what are the issues that are for and against flexibility and how we might deal with them? We can come back to some of the implications later on. But for the moment, I want to address these five issues.

So a key aspect of flexibility is to delay the design and management decisions. That is say, all right, we're prepared to do something. For example, in the garage case, we are ready to add extra floors if it seems appropriate. But we're not going to act on it until we know what's happening. We're not going to, quote, "pull the trigger," is a expression often used in practice on it until we know that the circumstances are definitely right.

So there are, however, a way of thinking about it of saying, well, why mess around? We're going to need this. Why don't we build it now? Why shouldn't we just make up our minds, do it right, rather than dithering around and not knowing what we're doing? Why don't we take action and be real leaders? So this is the discussion I'd like to address.

So I got to call out five factors, which are driving for and against the desirability of flexibility. The basic one, of course, is their uncertainty. If we didn't have uncertainty, if we absolutely knew what was going to happen, then we should optimize for that one particular state. But the fact is we don't know what's going to happen. Not only we don't know what's going to happen next year or the year after or the year after that and so on, but we don't know in what sequence. And next year may be good and next year after that may be bad or vice versa, and those have different implications for the profitability of the value of the system as a whole.

The second one is this notion of economies of scale, which I want to go into in more detail. But it basically says, if you build it larger, it is cheaper per unit to build it. And therefore, don't mess around with small, uneconomical units of capacity. Go for the big thing, save yourself money, and don't delay.

The third one, which is directly opposite to that, is the discount rate, which basically says, if you delay decisions, if you build the capacity later on, you'll be doing it at a discounted rate in terms of the present so that it's cheaper to build something in the future than it is now on a present value basis. Adding to that effect is this notion of learning, that, if you are doing something reasonably new that you haven't made millions of already, you're building a power plant, for example, of a new design and then you're going to build another one or an oil platform that, when you use the same design second time, third time, fourth time, you've figured out or the team, the company has figured out ways to organize things better, maybe some design improvements, but the cost per unit typically decrease often significantly when you repeat the same design, the same module. So the practice of having modules, there's an advantage to it.

And then finally, there's this notion of competitive gaming, which is quite complex, which I'm not going to go into detail here but to suggest what it is. But the basic idea is that sometimes an organization or a group or an individual wants to scare away its competitors by saying, I'm doing it and I'm going to be the leader in this area. And if you try to compete with me, you'll lose. So at some point, it is an acceptable and desirable strategy to act first now, be number one, and get the benefits of that. On the other hand, it also means you're more likely to make the mistakes but still that notion of their strategic reasons to play in the game of competitive games to not delay. So these are four elements I want to discuss in the next little while.

So first of all, I want to revoke the notion of uncertainty a bit. So a lot of people will use uncertainty and risk as sort of equivalence, which implies, since risk is saying, oh, this is a bad thing, you don't talk about the risk of winning the lottery. I mean, this is a good thing. But you talk about risk in terms of bad things. I risk failing my exam. I risk losing my way. I risk losing some money, whatever.

So I think that the notion of thinking of uncertainty as risk is not a good mental state. Because it leads to the idea, if risk is bad, I'm going to try to stamp it out. Stew Myers used to use that expression. I'm going to stamp it out. It's not good. We're going to eliminate it. Well, first of all, you can't eliminate. But then secondly, the uncertainty can be good, that you are developing a new product and maybe it will be a winner, that the uncertainty of your gain, it can be exactly what you want.

If you're a startup, you know from the data that most startups fail. If you're simply going on the basis that startups fail, you should never get involved in it. If you're risk-averse, never get involved in it. But the attractiveness of startups is that they may break through and that upside uncertainty is what drives that kind of activity. And I encourage you to talk about uncertainties in general rather than risk and recognize that we're talking about a range of future possibilities.