Conducting project risk analysis, How to do it and how not to do it

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I want to tell you a few things about Michael Curran, the President of Decision Sciences Corporation, who was the real pioneer of what this paper is about, project risk analysis. In 1964 he was ensconced in a career at Monsanto Chemical Company reading the Harvard Business Review, Jan/Feb 1964 issue. He was reading an article by David B. Hertz, "Risk Analysis in Capital Investment."

This article has been so popular that it was republished in 1979 and has been reprinted many times since. Curran recognized that Hertz was talking about some particular technique most of us have some familiarity with. Although Hertz never used the term, he was talking about Monte Carlo Simulation and how it could be used to address key issues in the problem of capital planning.

Monte Carlo Simulation is a technique devised by two brilliant mathematicians, John von Neuman and Oscar Morgenstern, the co-developers of game theory. They developed this to answer a problem in particle physics in the Manhattan Project in the 40's.

Once von Neuman and Morgenstern developed game theory, it wasn't long before other scientists and engineers realized the power of Monte Carlo. But in the article Curran saw that for the first time someone was suggesting that we could use it in business practice. It made so much sense to him that in 1968 he formed a corporation to do this full time, Decision Sciences Corp. His firm has pioneered the field of project risk analysis in the United States.

Curran observed that there were not many building blocks that decision makers use. In no particular order units is one of them. Units of service required or rendered, *units* constructed, square meters of building space, etc. Another building block is *currency*, in whatever way you count it-- Euros, dollars, yen, etc. In some cases we see combinations of these things in the decision process, for example dollars/square meter.

Another is *time*. Time to complete a project, time to construct a building, etc. Again, combinations may appear, for example dollars/month or Euros/unit.

The decision makers however often do not adequately consider a fourth variable, risk. What is this fourth variable? What is risk? Here is one definition.

Risk: The degree of dispersion of variability around the expected or best value which is estimated to exist for the economic variable in question, for example a quantitative measure of the upper and lower limits which are considered reasonable for the factor being estimated.

Isn't that confusing? An engineer wrote that - and it is a part of an American National Standard. I guess engineers understand that but it is better to define it with an example - an example in plain English.

Risk (Plain English Explanation): I think it will cost $1 million, but there's a chance that it might be a little higher or a little lower.

Let's explore this fourth variable -- risk or whatever else you may call it -- by a thought experiment. Let's suppose you have an investment decision before you. You have to choose either Alternative A or Alternative B. All you know about Alternative A is it has an estimated return rate of 50%; with Alternative B, it's 30%. You know nothing else. You choose "A". It's a no-brainer.

But suppose someone comes along just before the decision is made to give you additional information. "A", with an estimated return of 50%, gives you a 15% chance of seeing it. With "B" you get a 90% chance of seeing it.

Do you want to change your mind? 90%+ will want to change their minds. What has changed your mind? The fourth variable, of course -- certainty or risk or probability.

Probability in certain quantitative decision making processes can make an immense difference in the final outcome. Probability. And that's what hurts us. We're dealing with the uncertainty world here. How can we pretend that uncertainty doesn't exist?

Now, if you're talking about the first 3 of these variables - units, currency, time - you're talking about the world of accounting. There is no uncertainty in accounting. It is precise. But if you include probability in your discussions, it is no longer the world of accounting. It is the world of decision making and there is a vast difference. In accounting, if all of the rows and columns don't add up, you work day and night to correct things so that they will. You remove the uncertainty. That can't be done in decision making. Uncertainty always exists.

You've got to become a risk analyst.

What does that mean? Do you need to sit in front of a computer and bite your nails? Does it mean you have to have all the courses in probability theory and statistics? Do you really have to go through all that? No, you don't.

You only have to understand what you already understand about probability theory, and I'm assuming you never had a course in it. You already understand 2 key issues:

1. The probability number can influence decisions; and
2. You can measure the variability of a quantity as a simple range.

It won't get lower than this; it won't get higher than that. A simple range to indicate the areas of risk and of opportunity.

Here is Curran's rule that you should follow:

> If you are worried about the degree of uncertainty in any bottom line and that uncertainty is the result of multiple numerical uncertainties, perform a risk analysis.

The reason we can bring a powerful technique like Monte Carlo to bear on this problem and have managers understand it is due to the fact that business risk analysis is not rocket science. It's not the same. It is much simpler.

If you talk to these decision makers and ask what level of variance that are willing to accept in making decisions related to quantitative values involving risk, they inevitably will say 5 to 10%.

If you ask that same question of a rocket scientist he will ask if you are out of your mind. They can't tolerate errors for fear of the space vehicle going out into deep space instead of orbiting the earth or the target planet. They can't tolerate error.

It's a different world. Because it is a different world and because we are more tolerant of some error in most engineering or construction projects, we can de-escalate the requirements on the part of the user of Monte Carlo. You don't have to understand all the nuances and the intricacies of the technique.

You don't have to be a large company to benefit from this as was the case before the PC arrived. The only kinds of problems that were solved before the PC were big problems - big budgets, big problems.

All of that has changed.

Suppose you do a risk analysis and tell your management you have a 70% chance of success. You'd think they would jump for joy. They won't.

They'll say something like this, "Well, wait a minute. I have a 70% chance of success. That must mean I have a 30% chance of failure. What if this project goes does not meet its objectives? How much of a loss am I going to have to take? In other words, What's my exposure?"

There have been all sorts of attempts to answer that question, the most notable one being the worst case scenario wherein we take our plan and look at each item in the plan and make it the absolute worst we can imagine it ever to be and we calculate a whole new bottom line. We look at it and say, "Wow! That's terrible!"

Of course, it's terrible. That's the theoretical worst case scenario. It's so mathematically remote that at best it is useless; at worst it's misleading. It may actually scare people off unduly.

Anyhow, what we need is to have a good answer to this, not some theoretical answer. Guess what will give that to you? Monte Carlo Simulation.

If, for example, you have performed a risk analysis and told management that they have a 70% chance of success and that they have a 65% exposure. What does that mean? That means that the bottom line decision variable can erode by as much as 65% of the target value. That's what it means.

"Why?" will be the next question they'll ask. "Why will it be that way?" And specifically they want to look at a ranked list of risks and opportunities. The reason they want to look at such a list is so they can search for controllables, they can challenge the management team to come up with alternative strategies and tactics, and they can test these alternatives in a Monte Carlo environment.

It turns out Monte Carlo is not only a great tool for evaluating a current plan; it's a marvelous tool for evolving a better one. It's used that way all the time.

There are some follow-up questions we could address. On capital cost estimates, for example, when you ask your engineering estimators or quantity surveyors to give you answers, they always give you answers you don't like. Right? They are too vague. And then you understand why because at that very line above the last line of the estimate they put something in at the last minute. What's that called? Contingency.

Why is it often 10%? Because they don't know what to put in there. It's not scientific. They don't know what to put in there. Some companies even have a policy of 10% contingency in all estimates. They don't know why. They know that it is necessary to include contingency but they don't know how much, so they use 10%. It is a nice round number.

If you were using Monte Carlo you would know what to put in there because you would recognize that the amount of contingency needs to be balanced with the concept of confidence. Confidence in what? Confidence you won't overrun your budget.

Now if you want to have a lot of confidence, the contingency required will increase. Everybody understands that. The allocation of contingency may also be important. And the competitive tendering problem is certainly an exciting application of risk analysis. We all understand the problem with that, right? Bid too low and you get the work you should never have had. Bid too high and some competitor will come in and take it away from you and make money on it. Those are bad scenarios. They can be addressed very well with Monte Carlo.

When you sit down and look at risk analysis, you'll know how it's done. There are several ways to do it - heuristics, multiple linear regression, etc.

Just take my word for it. That problem was solved years and years ago. There are now software programs on the market, PC-based, that do Monte Carlo. Technically they're excellent. They all answer the 3 questions. That's what you really need to understand.

I could tell you all kinds of stories about how people have benefited from this.

In 1991, for example, there was a project of $254 million by Alcan that everybody and his brother thought was going to overrun. It didn't. It under-ran. And it was completed 2 months early.

Three other projects Alcan was managing at that same time were all completed 2-4% under plan. The CEO of Alcan said in Fortune, "Ever since we have been using these techniques, we've saved over a hundred million dollars in our capital planning."

In medicine there is something called iatrogenic disease. It's a disease given to the patient by the physician. Iatros in the Greek means physician. Iatrogenic disease in other words is physician-induced disease.

We also have risk analyst induced risk. How do we get that? By violating some of the simple rules I am going to explain thus understating the true exposure in the decision. It's just the opposite of the other problem where we do the worst case scenario and it overstates the exposure. You're going to tell the management, "Hey, the profit probably won't go lower than that." And indeed it can go down much further. or, "Our cost won't go higher than that" and it goes to the moon. This differential, this lack of understanding of the problem of proper exposure, we term iatrogenic risk.

You know what? In your project estimate, your business plan, your forecast, your budget, whatever you call it, the uncertainty is concentrated in a select number of elements-- typically 10 to 20. And if you don't understand which ones they are, if you don't take the time and trouble to measure the uncertainty of each of them, if you don't take the time and trouble to combine those uncertainties into some bottom line uncertainty using a technique like Monte Carlo, you will never get to the right answer.

This particular phenomenon basically means what? Not everything is important. That's what it means. And that's what this is saying. Very few things are really important. I don't care about all those others. This is called variously the Law of the Significant Few and the Insignificant Many or the 80/20 rule. Others refer to it by the name of a person who has been most honored in the literature. Who might that be? Pareto. It's Pareto's Law.

Vilfredo Pareto was a brilliant Italian sociologist and economist. About 100 years ago he decided to examine how wealth was distributed from country to country. His conclusion was that in any given country a small percentage of the population would collectively account for most of the wealth. He published his findings, and the economists have been making hay out of this for a century. The fact of the matter is that this principle applies well beyond economics. It extends to such issues as the distribution of populations of people and much more.

Let's make some very simple observations. If you take your plan--let's make it a simple plan, a cost estimate - once you understand how this applies to costs, you can easily extend it to any problem situation. Let's say it's an estimate of cost of what it will take to renovate an office building. It's a conceptual plan, not a detailed estimate.

Let's assume that the conceptual estimate for the office renovation is $1 million. Let's further assume that of the $1 million, you have 3 components of cost: labor at $600,000, equipment at $300,000, and materials at $100,000. You and your project management team review this plan. You form a list, and on this list will be each element of your plan but in this specific order. The highest dollar value is at the top of the list, and the one that has the lowest is at the bottom of the list. They are all graduated in descending order in-between.

Think about that list for a moment. If you start reading down from the top of the list, you will find that it is an example of Pareto's Law. It won't take many elements, starting at the top, to collectively account for most of that million dollar bottom line. We know this from experience.

Is this example important in the proper management of the fourth variable. What do you think? The answer is "No." It's very important to understand that this list, although it is an example of Pareto's Law, is not the one we want to talk about. Guess what? He's so prevalent, he's in the plan in two distinctly different ways. That's the first way.

Let's talk about forming a new list. In this list we'll rank all the elements of the plan in a much different fashion. Each element will be on this list based on how much it can change your bottom line. And we don't care in which direction. I want to know only the amount of change, positive or negative. I don't care what the value of that change is or what its sign is. I only want to know its magnitude. That's where we put the element on this list. We end up with a new list - a much different one. The one at the top of the list is there because there is no other element in that plan that can change the bottom line by more than it can. That's why it's at the top of the list. All the way down, in descending order, according to what they can do to, or for, the bottom line.

With that list, we start looking down from the top. There's another Pareto effect. Specifically this effect. You look at the top of the list. It won't take many elements at all to collectively account for most of the uncertainty in your plan. Obviously this list isn't the same as the first list. This new list is the one we need to worry about.

The really important question is when do I decide to draw the line on that kind of a list? When do I decide if something is critical or not? It took Michael Curran 4 years to figure out, and he did it empirically. He looked at a lot of decision processes in industry, government, and education with a rule of thumb in mind. He had to come up with a rule of thumb so that people could tell whether something was critical or not - so they would know whether they need a range or not. He first published this is 1973. He has never had reason to change what he found out then. It has stood the test of time.

Here are the simple rules:

Critical elements are those which can cause bottom line changes greater than:

Bottom Line	Expense	Profit
Conceptual	±0.5%	±5.0%
Detailed	±0.2%	±2.0%

- Do not range non-critical elements
- Link strongly related elements

The first rule is "You better know when it is important and when it's not." That is when it's critical and when it's not. This is what you're looking at in here.

Criticality depends on 2 things. It depends on the nature of your bottom line--is it a cost or a profit type of line? Profit here doesn't necessarily mean what it means in accounting. In the risk analysis concept, profit is any variable which, when it gets higher and higher in value, it makes you happier and happier. Labor productivity is a good example of such a variable.

If the bottom line is cost, as it is in our simple example of the office renovation problem, we look at the first row in the table. The next question is, "What is the nature of the planning process?" Have you measured everything you can reasonably be expected to measure here? Do you have a detailed plan? Or, in this case, a conceptual plan.

So we're looking at ±0.5%. What that tells you is that number should be multiplied by your bottom line of a million dollars, and your answer is $5000. That's where the cutoff is. Anything in our plan that can change our bottom line up or down by at least $5000 should be deemed critical, should be given a range, should be paid the respect it's due.

Because of our friend Pareto you won't find many - typically 10 to 20. This is true even with the largest of decisions.

In our office renovation project what we are saying is, "Applying this principle, a change equal to or greater than $5000 at the bottom line qualifies the element as critical." $600,000 of our million dollar plan is in labor, $300,000 in equipment, and $100,000 in materials. How do you decide whether something is critical or not? Not by developing some crazy list, but by starting at the top of the pyramid and going down as far as necessary to find all of them. Always start at the top, never in the middle, or worse yet, at the bottom. That will produce a horrible outcome.

Question: Can you change the bottom line up or down by at least, in this case, $5000? I'll repeat - Can you change the bottom line up or down by at least $5000? If you are asking that question of the bottom line itself, and your answer comes back No, that obviously tells you there's not enough uncertainty in this decision to warrant this kind of treatment. Forget about doing a Monte Carlo. It's a waste of time.

If, on the other hand, the answer comes back Yes, that doesn't necessarily mean you've found a critical element. It means you are given permission to ask the same question of the numbers that support this number. So I say, "Yes, it's possible for that to change our bottom line by $5000." Then I go to the numbers that support this one and go to the next level down, asking the same question in turn of each of those numbers. For example, if I'm looking at materials, I'll ask the same question. "Can you change the bottom line by at least $5000?"

I don't care if this thing changes. What matters is if it can change by at least $5000. If the answer is *No*, it has no critical elements. How could it?

Eventually one of two things will happen. As you go down through the pyramid, you'll get to one of two conditions. One condition, which is not so frequent, is that a number looks critical. You look below the number to see what supports it, and there isn't anything there. What you've managed to do is discover a critical element at the very lowest level of detail.

Much more frequently you will find elements at the higher end of the pyramid. And you get to a point where the answer is Yes. You look at the numbers that support that number. Each may have its own variability, but when you ask each the same question, not one of them has sufficient variability to change the bottom line by $5,000 or more. That means you go back to where you were, the one number that represents the others, and you call that number your critical element. That is the far more frequent event.

You'll find these at various levels, but primarily in the middle level or top. One thing for sure, you won't find many because of Pareto.

What about all the other elements? We need to understand there is a planning philosophy that works to the detriment of people who employ it. It goes like this: The boss says, "We want a good plan." What does that mean? Most people interpret that to mean a plan that's neither optimistic or nor pessimistic. You don't want to be too far out either way. How do you get there?

Here's the philosophy. We'll get there if we take every piece of our plan and stick the target right in the middle - don't make it optimistic - don't make it pessimistic - stick it right in the middle. You put your plan together that way, and you won't have to worry. When this plan hits the real world, sure, something will go wrong, but you'll be able to look around and find something else going right to counteract it.

Since we have so many elements in our plan, it'll be a wash.

Do you recognize this thinking? It's called various things - the Pluses will equal the Minuses, and the more mathematically inclined refer to it as the Sum of the Deviations will approach zero. Others incorrectly call it the Law of Large Numbers. Whatever you call it, it's fallacious. It makes the assumption that uncertainty is spread evenly and equally around your plan. It isn't. It's concentrated, typically in 10 to 20 items. That's why it's wrong.

Once we've identified those 10 to 20 elements, you can take the Pluses and Minuses approach to the rest of them, and you won't get burnt - *unless there is a pervasive bias in the plan*. Then you'll have to make some adjustments up or down to take that into account. But for that vast number of things that aren't critical, simply freeze them. If you have a little bias in the plan, freeze them a little higher or lower as appropriate.

Now, what are we going to do with the items which have been identified as being critical? Give them a range and make an estimate of the probability that each item can be accomplished within the original plan, that is, for a cost item, the probability that it can be accomplished at a cost no greater than the originally estimated amount.

And how do we do that? The very best way is get everybody involved. Everyone who understands the criticals should be there contributing to the process - well almost everybody. The one exception for that is, if you have a person who has undue influence on the group, don't invite him. Don't invite him or her because it will taint your result, particularly if that person is the boss.

Let's do our own job and let's put down all of our rationale on why we think this range and probability are the way they are and now we can defend them more readily. We want to be prepared. We want to say, *"This is the way it is."*

The process here is not as time-consuming as you may believe. In many cases, good risk analyses can be performed in a matter of hours. In some cases, it may take a day or two. When you get beyond two days, there is probably something going wrong. You are trying to reinvent the world or something like that.

That's not to say there aren't cases where it will require a lengthy period of time to do a risk analysis. But in the normal course of events, that doesn't occur. We make the decision today. That's important. This is not some ivory tower theoretical thing. This is a thing you can do very readily. This should be a decision based upon the collective experience of our group of people who understand the variables.

If you ask a very inexperienced manager to range this critical element, you are going to get what? You are going to get a very big range. Lack of experience breeds excessive conservatism.

If you ask the estimator or quantity surveyor who came up with the figures, you are going to get a narrow range. It is human nature to defend your estimate. To agree to a wide range is akin to admitting failure.

If you recognize these human weaknesses and structure the ranges properly, this is what you will learn:

- The probability of having a cost overrun;
- How large the overrun can be (the exposure);
- What to do now to: capitalize on opportunities; and reduce risk;
- How much contingency to add to our estimate to reduce the residual risk to an acceptable level.

There are some excellent pieces of software which you can use to perform risk analysis. Three of the best are REP/PC, @RISK, and Crystal Ball.

- REP/PC, Decision Sciences Corp., St. Louis, MO - Stand-alone software with iatrogenic risk protection. Input: ranges. http://www.uncertain.com/.
- @RISK, Palisade Corp., Newfield, NY - Spread-sheet based software. No iatrogenic risk protection. Input: Probability density functions. http://www.palisade.com/.
- CRYSTAL BALL, Decisioneering Corp., Denver, CO - Spread-sheet based software. No iatrogenic risk protection. Input: Probability density functions. http://www.decisioneering.com/.

Of these, I personally prefer REP/PC for engineering and construction work. I have used it successfully on projects as high as $1 billion and even higher and with long construction schedules, some exceeding 10 years.

All three packages however are excellent if applied properly but there are limitations with all of them which must be considered.

However, failure to properly identify the critical variables, or to assume that some variables are critical when they are not, will yield an incorrect analysis and will understate risk. REP/PC has proprietary algorithms in the software to detect improperly identified critical variables. The other two pieces of software do not protect you against this. You must follow the rules outlined earlier for identifying the critical variables. The software itself will not do this job for you.

REP/PC requires the ranges and probabilities for the critical variables as the input. This program unfortunately is a DOS program and is not available in a Windows version. That however is not a serious limitation for versions of Windows up through Me which support DOS. Unfortunately Windows XP does not support DOS and it is rapidly becoming the most common computer operating system. For practical reasons, that means that any company desiring to use REP/PC must maintain at least one computer equipped with Windows Me or an earlier version of Windows.

@RISK and CRYSTAL BALL are fully Windows compatible and link directly to Excel or other spreadsheet software but do require that probability density functions be identified for each critical variable. This is generally not a problem, however, because of the fact that we are not dealing with rocket science. High precision is not required for the typical projects cost engineers and project managers work on. If the probability density functions are undefined (as will usually be the case), a simple triangular distribution can generally be safely assumed for each critical variable. This assumption is sufficiently accurate for cost work.

Risk analysis is not difficult to perform properly and the benefits in project planning are great if the analysis is properly done. However, if it is not done properly, the results can be disastrous as the analysis can severely understate risk and lead to unsatisfactory conclusions about project viability.