Numeracy Nugget #7: When Planning to Procure – Pick Any Two

George Rebane

When someone (especially in government) needs to procure some major good or service, there inevitably arise questions of what should it do, how much will it cost, and when will it be ready. And inevitably most such procurements will not meet the expectations when the procurement project was first adopted. This is so because of a number of things which come up to frustrate the original procurement plan – e.g. Murphy's Law and all that.

Some of the problems in procuring complex things like a new business computer network, a building extension, or a freeway on-ramp cannot be predicted and, therefore, avoided. But there are some fundamentals about procuring complex stuff that everyone should know which will avoid the really big headaches that people and organizations seem to suffer again and again. Here we are interested in communicating the simplest of these concepts to government officials and the concerned citizens who keep track of such procurement activities.

Returning to the original questions about buying something, we'll now couch them in more formal terms. The three most important factors of procurement are –

Specification – this is the documentation that spells out stuff like how the thing/service is built or set up, how it will work, what it will do, how to operate it, how to maintain it, and how long it should last. If the thing/service is something brand new that needs to developed, then there is a well-tread development framework that must also be planned. Being ignorant of how to develop the thing/service will really cause cost and time overruns (and careers, unless you're a politician). We will discuss the system development cycle in a future Nugget.

Cost – this is not simply the final tally of the dollars spent. Cost also includes how much money will be paid when for what deliverables or milestones. It may additionally include the procuring party's involvement (staff hours) in such things as testing, verification, installation, and training.

Schedule – again this is often more than just a circle around a calendar date when all will be finished. For procuring complex stuff the schedule will also include intermediate milestones when certain parts will be finished, installed, and/or their proper working demonstrated. Including milestones will reduce risk all around by letting the buyer see how the whole thing is coming together and thereby making sure that what is delivered is what was ordered.

Keeping in mind these important factors – spec, cost, schedule – it should be obvious that for anything except the most simple, well-known, and often bought items, one cannot dictate all three of these to a seller and expect to be satisfied. For example, you can't go to Boeing and arbitrarily tell them to build for you an airplane that carries 500 people, goes 1,600 mph, costs less than $10 million apiece, and will be finished in three months. Or for that matter, a kitchen remodel that satisfies the owner's dream and the architect's blueprint, costs $100,000, and is finished in six weeks.

Well, that's not exactly true. Of course you can always dictate such things, but here's the rub. We see inexperienced or naïve buyers (again, mostly in government) constantly attempting to procure stuff by confidently specifying all three factors, and then wind up being disappointed. In private industry, such mistakes are cause for career changes. In government this approach causes delays, finger pointing exercises, and eventual tax increases to cover overruns. So then, what can be done?

Pick Any Two! The main takeaway in any complex procurement process is that you can only specify any two of the three factors. If you pick a tight spec and a tight schedule, then you should be prepared to pay the added cost it entails and do the work to verify that the added cost will really get you there. Same goes with the requirement for a tight schedule and a not-to-exceed cost. The seller will then have to describe and demonstrate what the system will do for the time and cost constraints the buyer imposes. And so on. In short, the buyer must explicitly recognize the risks involved and explicitly plan how to handle them.

At this point the intelligent reader may say, "But of course, how else can the world work?!" Well, dear reader, there are legions of people involved in procurement who don't understand these simple concepts crowned by the dictum 'Pick Any Two'. For proof examine a recent procurement that your local county or city has undertaken. Or for a better entertainment value, just attend a local government meeting where the procurement of some system or item of local infrastructure is being discussed. Five will get you ten that you will hear all three factors being nailed into the procurement process as if they were carved in stone. And you may be the only one there to raise a hand and ask how they can expect the project to deliver on all three of the stipulated factors - specification, cost, and schedule. But when you do this, be prepared for disdain and rebuke from those so questioned.

Solution to NN6 Problem: We restate the problem. You pay $1,000 to play a game of dice consisting of a maximum of twenty throws. The game ends when you throw double sixes (boxcars). Each time you miss throwing boxcars you lose $50 from your original $1,000 investment. When you hit boxcars the casino will double the money you have left. For example, if you threw box-cars on the third roll you would have $900 added to the $900 you had left after the first two rolls and walk away with a total of $1,800. What are your odds of walking away a winner? What is the amount you would expect to win in this game (i.e. the average winning after playing the game a large number of times)?

The solution depends on a very straightforward and yet widely applicable way of looking at achieving a success after a given number of attempts each having a probability of success that depends on how many failures preceded the successful event. The probability of throwing boxcars (two sixes) on any given throw is 1/36 since there is only one way out the thirty-six equally probably ways that two dice can land to give boxcars. (The second die can land in any of six ways for whichever face of the six faces that the first die shows, therefore 6*6 = 36.)

For example, what is the probability that the dice will first yield boxcars on the fourth throw. Well, that requires three throws of no boxcars followed by throwing boxcars. The probability of throwing something besides boxcars is simply the complement of the probability (1/36) of throwing boxcars, or 1 – 1/36 = 35/36. Pretty straightforward. Each throw is independent of the other throws, so we multiply the probability of these three independent events together to get $(35/36)*(35/36)*(35/36) = (35/36)^3 = 0.9190$. This is the probability that the first three throws will yield no boxcars. Then the fourth independent throw must now yield the desired boxcars to create the desired event of 'first boxcars on fourth throw'. As we saw above, the probability of throwing boxcars on any given throw is 1/36 = 0.0278. We multiply the above 'no boxcars in three throws' probability by this probability to get $(35/36)^3 *(1/36)$ =).9190*0.0278 = 0.0255 which is the probability of getting the first boxcars on exactly the fourth throw.

In a similar manner we can compute the probability of getting first boxcars on exactly the *N*th throw from the formula $(35/36)^{N-1}*(1/36)$ where $N = 1, 2, 3, \ldots$. According to the problem statement the winnings from the *N*th throw are $2*[1000 – (N-1)*50]$. So then the expected amount won on the *N*th try is simply the winnings times the probability of winning on the *N*th throw. This is the formidable looking but straightforward algebraic formula $(35/36)^{N-1}*(1/36)* 2*[1000 – (N-1)*50]$ which can easily be programmed into any spreadsheet and replicated in a column for the number of dice throws *N*. The total expected winnings is just the sum of the individual expected winnings as *N* get very large, actually as *N* approaches infinity.

But in the stipulated casino game you start with a $1,000 and would run out of money after 20 turns of losing $50 on each unsuccessful turn. So your total expected winnings would be to compute and sum the above expected per turn winnings for $N = 1, 2, \ldots, 20$. If you do this on a spread sheet you will quickly see that the expected winnings or value of this casino game is $492.41 which means that the casino would win an average of $507.51 for every gambler willing to risk $1,000 to play the game. Lots of fun but a loss even in the short run since the probability of coming out a winner at some level is only 0.246 or less than one chance in four.

My hope, dear reader, is that you now see how this same approach can solve a wide variety of problems for computing either the probability of success or expected gain from a sequence of independent events each having a known probability of success and a computed payoff.

NN7 Problem: There are three regular light switches on the first floor one of which operates a light bulb in the attic. Each is wired in the standard way with the up switch position denoting ON and the down position denoting OFF. Can you figure out which switch operates the attic light if you are allowed only one trip up to the attic to check the light bulb? Hint: This is not a trick problem with some cutesy answer, but to solve it you should incorporate all you know about light bulbs and switches.