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Expected Value in Project Management

There are so many analytical techniques and tools, some of which are very complex and require a lot of effort to perform and others which are very industry specific. One of the very simple techniques is expected value analysis. This analysis is a choice engineering method, which means that it is more of a mental exercise rather than a strict and formal project management process. At the same time, going through the expected value thinking process may significantly improve quality of decisions.

How to win a lottery

Questions regarding lotteries are pretty common fodder for us when people realize that our field touches on topics like risk and decision analysis. “So, if I buy lottery tickets and I know that chances of winning are supposedly really small, am I just throwing away my money or is there some way to boost my chances?” Needless to say, we are never short of advice, and it mostly follows these lines, “You would most likely get a better return using other investment vehicles, like savings account or bonds. On the other hand lotteries can be really fun as long as winning is not part of your retirement planning. So if you want to have it as part of your entertainment budget, go ahead, knock yourself out.” When really pressed, we may digress into more detailed discussion on expected value and whether anyone can justify playing the lottery, but by that point most of our audience will have moved on.

Let us assume that you bought 20 scratch-and-win lottery tickets. What would be the total return for all tickets if price for one ticket is $1? In other words, if you spent $20, how much should you expect in return? In fact, over the past several years, we have been conducting on ongoing experiment on this exact subject. When we have our presentations on risk and decision analysis, we buy $20 worth of scratch-and-win lottery tickets, which we give out at random to attendees. During the presentation, we have the attendees check their tickets. The results have

been very consistent. After spending $20 for tickets, the payout has usually ranged from $7 - 12 dollars: we have never won more than we spent on the tickets.

The theory behind this is very straight forward. Only a certain percentage from the ticket sales revenue goes toward prizes, normally around 50%. So the overall chance to win a lottery is around 50%. The rest is used to pay costs for marketing and sales, but the vast majority of the owner's take is pure profit that usually gets funneled into public goods or charities, so we do not feel so badly about the extended losing streaks that are common for those who play the lottery, "If it wasn't for the lottery, we would have to pay more taxes." Sort of like a bitter medicine with a tiny bit of honey. In this case, $0.50 is the expected value of playing one game. So why would people play under such measly payout conditions? Quite simply really, there is a small chance to win a prize that is exponentially larger than the cost of the tickets. It is because of the potential for the large payout we would also argue that playing the lottery is a rational behavior. When discussing this with an acquaintance who participates in an office lottery pool, who also happens to be both a professional statistician and avid gambler, he said "Of course I know all about odds, but somebody is winning!" Therefore, in each particular game, you may win more or less than the expected value. Risk takers hope that they will receive more than the expected value. Risk-averse people see the equation from the other side, and believe that the chances are that they will receive less than the expected and therefore do not play.

Expected value is not the prize you expect to win. If there is a million dollar lottery, the expected value is not the prize. Rather, expected value is an indicator or a measure that will help you make better choices in uncertain situations. Expected value is calculated by multiplying each possible outcome by its probability of occurrence and then summing the results. Expected value can be calculated based on any parameters that are possible to measure such as cost, price, duration, or number of units.

Situations when we can use simple expected value calculations arise all the time. When you buy a couch in furniture store for $1000, the salesman will probably offer you damage insurance for around $50. Without insurance, let's estimate that it would cost you on $200 to repair any damage. In addition, the chance that your couch will be damaged such that it will require a repair is 10%. In this scenario, the expected value of a repair is $200 x 10% = $20, which is significantly less than insurance cost. Therefore, unless you have five boys who like to bounce up and down on your couch with swords, forks and scissors, you should probably pass on the insurance.

Expected value will help you decide on a course of action in more complex cases. For example, lawyers us expected value when they make recommendations to their clients regarding possible legal actions. Would it be better to take a plea bargain and plead guilty to lesser charges or face the chance that you might lose at trial? Oil companies use expected value to calculate the volumes of oil and gas they can produce given uncertainties in petroleum reserves. Sales managers can use expected value to estimate sale figures. Governments are supposed to use expected value to estimate potential tax revenue. Since most governments are pathologically in debt, whether they understand the concept is open to question, or perhaps they just use an unrealistic probabilities (100%) when performing expected value analysis on revenues.

For project managers expected value is a simple and very effective analytical technique that can help us reduce the effect of many project illusions. It is a mostly simple mental exercise, and is is part of the project management process described in PMBOK® Guide, Chapter 11 (Project Management Institute 2009). How much will the project cost given the chance of delay? Since there is always a chance that a supplier may not be able to deliver components on time, which supplier should you choose?

Let's return to our discussion on lotteries. If your idea of winning is getting more money out than you put in, than our recommended strategy is "Don't do it." However, if you find that you cannot help yourself, here we have another suggestion. Pick an number that appears to be non-random (e.g. 1,2,3,4,5, …). It will not increase your chances of winning, but if you win, you will be less likely to share the prize with someone else. Why? Most people think that these numbers are not random enough and don't select patterns. In reality, 1,2,3,4,5 is as random as any other combination of numbers.

How project managers ignore expected value

The advantage of expected value is that you do not need to perform any complex calculations. You simply multiply probabilities on possible outcomes for different scenarios and then compare the results. Even though it is simple, people do not bother to do these calculations even though substantial sums may be at risk.

In 2005, an administrative law judge Roy L. Pearson filed a civil case in the District of Columbia. He claimed that a dry-cleaning company had lost his trousers. Over a period of time, the owners of the dry-cleaning business made three settlement offers of $3000, $4600, and $12000 respectively, all of which were rejected by Pearson. Claiming the shop's "satisfaction guaranteed" sign misled customers; Pearson sought $1,500 for every day the dry-cleaning operation was in business over a four year period of time or $54 million. Needless to say, the case generated a significant amount of attention and ridicule. Fortune magazine listed the case at #37 in its "101 Dumbest Moments in Business" of 2007 (Fortune 2007). Eventually, after years of working its way through the legal system, a federal court rejected Pearson's appeal (Alexander 2009). Pearson must be a real risk taker. What was the chance that he would be successful in getting $54 million for a lost pair of pants? We imagine that he was probably angling for a lavish settlement rather than public humiliation. One can always make the case that the Pearson did perform an expected value analysis, it is just that his assumptions must have been horribly skewed, so perhaps he is now working for the government providing tax revenue forecasts. In any event, Pearson's poor decision regarding the expected value of his legal actions, only managed to increase the misery of not only himself, but the unfortunate owner of the dry cleaning business. As it turned out, the pants in question were never really lost, the dry cleaners had merely misplaced them temporarily.

While it may surprise some of our leaders, union leaders often have a good understanding of the underlying business situation facing their employers and use this knowledge to negotiate realistic compensation packages. On the other hand, there are also many examples where they ignore expected values and reality. In 2007, union members employed by the Greyhound bus company in Western Canada went on strike (Komarnicki 2007). One week into the strike, after it

had caused millions of dollars in lost revenue and wages, the union accepted a new offer from the company. Notably, this offer was less than the original offer that had sent the union to the picket line. Union leaders probably were so overwhelmed by their membership's negative emotions towards management that they acted rashly without first performing an analysis that should have included an expected value for their final decision.

Intentionally or unintentionally overlooking expected value analysis is very common in project management. Large construction projects may have to go through an environmental assessment, which could be a long and very expensive process that would significantly delay the project; and therefore, increase project cost. A valid question may be to ask what value the assessment actually brings to the project. Does it actually protect the environment or would be better to just save the money spent on the assessment and spend it on activities that actually protect the environment? It is possible to make a calculation based on expected value principle, however the validity of the bureaucratic procedures are rarely scrutinized.

Although in some industries, such as oil and gas or pharmaceutical expected value analysis is performed quite routinely, it is seldom seen others such as IT. IT project managers calculate the cost and duration of projects, but often forget that there is always a probability that something may not work according to plan. Failure to include the notion of probability to the analysis is one of critical mistakes in project planning.

Incorrect Probability and Incorrect Expected Value

There is another issue with adoption of expected value approach. How can we sure that the estimated probabilities and outcomes are correct? For example, you have decided to purchase a new home and have two options: (Figure 1):

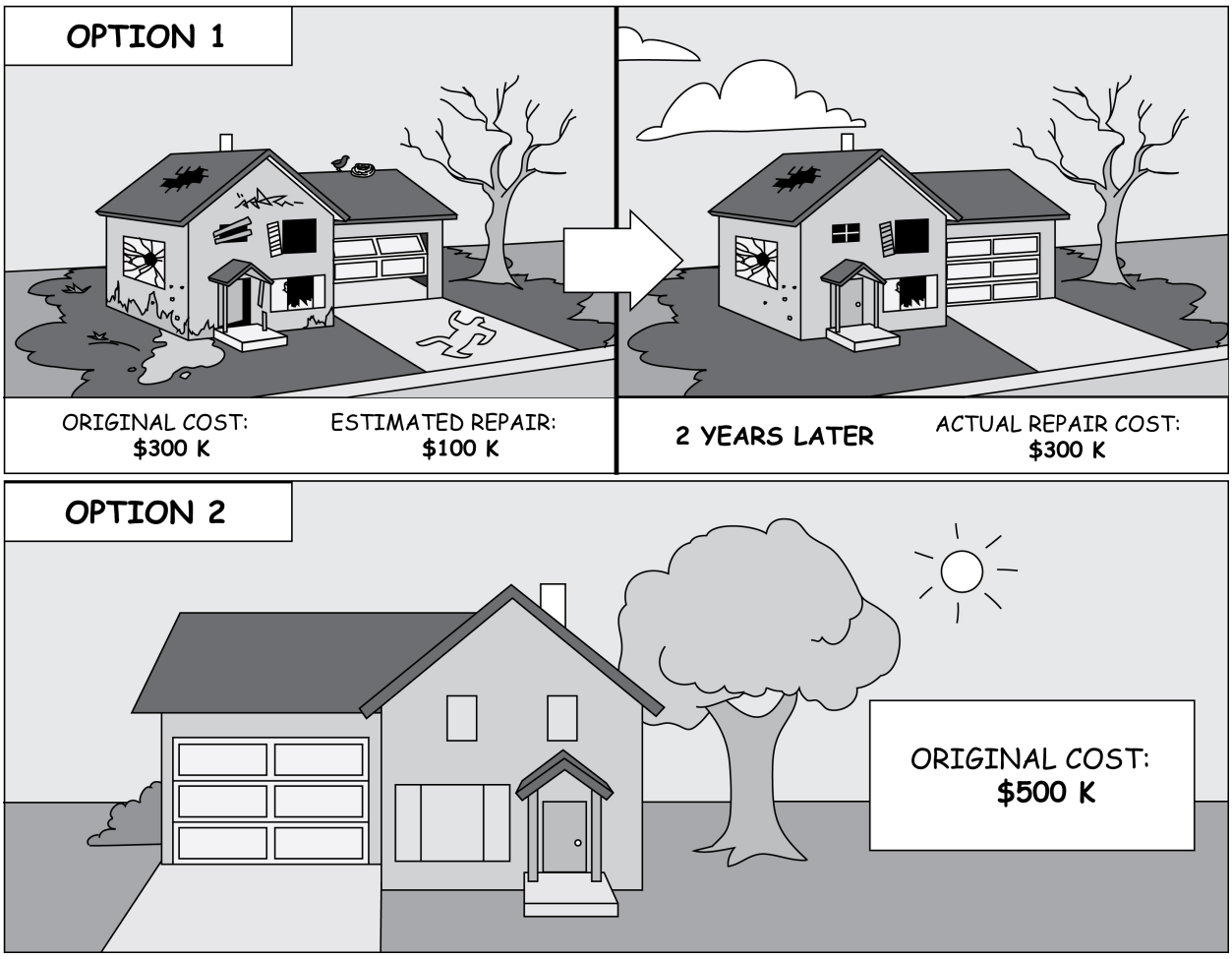

Figure 1. Two options to repair a house

a. You can purchase a home for $300,000, but it will require an additional $100,000 for renovations.
b. You can purchase a brand new home for $500,000

If everything was straight forward, the first option would be the obvious choice, even taking into account the hassles of managing the renovations: you would save $100,000. But in reality, nothing is ever this straight forward. While the home sales price is determined, the cost of renovations is subject to multiple uncertainties. Because you would like to make the renovations and at as low a cost as possible, you may dismiss evidence that costs could be significantly higher. The contractor has warned you that they have no idea what shape the house is in until they start to remove some of the flooring and walls to reveal the underlying wood frame. It could be in pristine condition, but there is a chance given the age of the house that there will be significant rot, outdated plumbing, or electrical systems that are not up to current building codes. If any of these conditions are present, it will drive up the cost of the renovations, and if more than one of these conditions is present, and this is likely given the age of the home, it will significantly drive up the cost. In the end, you determine that there is really only a 20% chance

that the cost will be $100,000, and an 80% chance that the cost will be $325,000. Therefore, the expected cost of the renovation would be:

20%*$200,000 + 80%*$325,000 = $300,000.

After this analysis option b) buy a new home becomes much more attractive than option a). This is why it is so important that probabilities are estimated as accurately as possible. If you underestimated the probability that the house would require more extensive renovations, not only would you be out of pocket a lot more money, but you would have to live with the reality that you paid an extra $100,000 to live in a worn out home, an issue that would probably become a popular topic of discussion with your spouse. So performing expected value analysis before making decisions not only saves projects, but can do wonders for your marriage as well.

Large projects have the same issue with assessing probabilities. The “Big Dig" was the unofficial name of the Central Artery/Tunnel Project (CA/T), a transportation megaproject in Boston and is a good example where the expected value analysis would have contributed to better, less costly decisions. The Big Dig had at the time the dubious record of being the most expensive highway project in the U.S. Originally in 1985, total project cost was estimated at $2.8 billion (in 1982 dollars), by 2006 total accumulate costs were over $14.6 billion ($8.08 billion in 1982 dollars) (Kwak 2008). Cost overruns were mostly attributed to politics, added scope, and problems with oversight. In particular, inflation and growth in scope added $2.7 billion, environmental compliance added $3.0 billon, and an accelerated schedule added $0.6 billion. One issue that arose during the project was that the project management plan was based on inadequate survey of the central artery. To save time and money, project planners took a risk and did not perform detailed survey of this key feature of the project. With great hindsight, we can now say that, as in many cases, this attempt to save money lead to spending more. The failure to perform a comprehensive survey had a direct cost to taxpayers of $26 million and perhaps much more due to indirect effects. Another serious issue was related to the large number of water leaks in the tunnels. The contractors used a proven technology called “slurry wall panel” to create the tunnels, but in this particular case, the technique led to approximately 1,100 leaks that needed remediation. Risks were not only technical in nature, but political as well. Local politicians caused an uproar when they discovered the water leakage in the tunnels. In reality, the extent of the leakage was insignificant and did not pose and threat to the integrity of the tunnels. Nevertheless, the project team was forced to bend to accommodate the concerns of the politicians and contractors were ordered to seal all of the leaks. In the end, it was the cumulative effect of all these events the caused the huge cost overruns. Expected value analysis of different technological scenarios would potentially discover the level of exposure these risks represented and help the project team select a better plan for the project.

How to choose a scenario based on multiple conflicting objectives

So we have shown how you can calculate the expected cost, expected duration, and expected effort for different project scenarios. But how can we apply this same technique if decisions must be made using different objectives: cost vs. safety, finish time vs. quality, duration vs. technological advancement.

There are quite a few different multi-criteria decision making techniques ((Virine and Trumper 2007). Here is a one of simple ways how you can approach these types of problems. Let's assume that you are faced with a choice: hire a contractor or proceed with the project internally (Table 1):

	Hire a contractor	Proceed with project using internal resources
Duration	5 months	7 months
Cost	$180,000	$40,000
Probability of success	50%	60%
Expected Value	$90,000 or 2.5 month	$24,000 or 3.6 month

Table 1. Expected Value Calculation

So 1.1 month of project acceleration would cost you extra $64,000. Does it make sense to do it? It depends on your project or your company particular situation. If you have significant budget and you have firm deadline, you probably should hire a contractor. If you don't have extra money, but you may complete project later, the second scenario will be appropriate. The problem happens when you don't have both time and money. In this case, you may need to perform analysis using multi-criteria decision-making techniques.

If you would like to perform this type of analysis, you should identify some objectives you would like to achieve. Here is a list of common objectives:

- Minimize cost
- Minimize project duration
- Maximize safety
- security
- Minimize legal problems
- Maximize use of advanced technology
- Minimize public relations problems
- Maximize quality
- Minimize impact to the environment

There could be many other objectives; for example, you could ensure that you can operate in different geographical areas or jurisdictions, ensure high employee satisfaction, and others. The idea behind all multi-criteria decision making techniques is that you assign weights or/and calculate priority for different objectives, and then measure your project performance against these objectives taking to an account these weights or priorities. For example, safety could be five times more important than cost. Or one month of work would be equivalent to

$50,000: would you rather spend extra $50,000 or delay project for 1 month? After you assign weights, you may calculate score for each project alternative. The score can be in any units: dollars, duration units, or just points, since it may be hard to assign dollar or duration values to such objectives as safety or security.

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