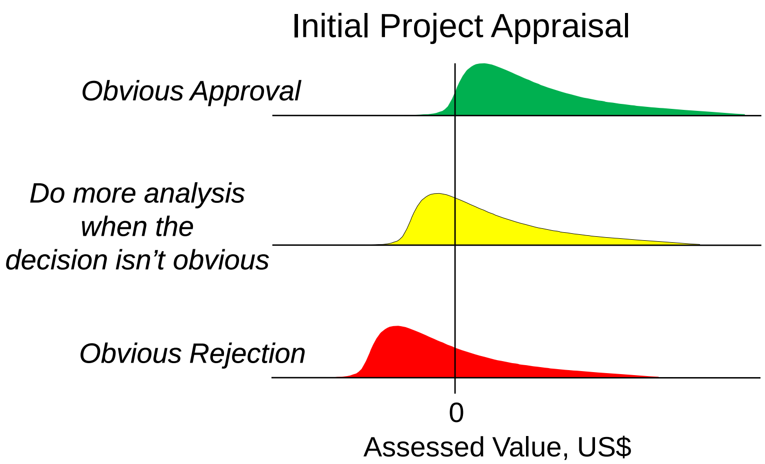
Resolving Decision Dilemmas

by John Schuyler

Most decisions are easy. Obviously good investment ideas are easily justified and funded, and bad ideas can be quickly rejected. Where we need time for deep thinking and analysis is when facing important decisions where the best choice is not obvious.



Decisions are often difficult when the best two alternatives seem approximately equal. A ***decision dilemma*** is a difficult choice situation. These quandaries typically feature large investment size, significant risk, commitment permanence, system complexity, outcome uncertainty, different stakeholder priorities, trade-offs among conflicting attributes, and/or poor information. In this paper I'll offer ideas to help you resolve decision dilemmas.

Three key concepts, where new to you, will enhance your professionalism and may improve your life:

1. Good decisions are distinguished from good outcomes.
2. Decision policy consists of a way to measure outcome quality or value.
3. Expected value (a calculation) consolidates possible outcomes into a single value for comparison.

Decisions

You will likely make thousands of decisions today. Fortunately, the vast majority of our decisions are easy—even automatic. Every word in writing a memo is a deliberate choice, as is every step in hiking uneven terrain. Our brains decide quickly and effortlessly in making most choices. Two recent, popular and complementary books about how the unaided mind works are by psychologist Daniel Kahneman[1] and neuroscientist Dean Buonomano.[2] Both authors suggest ways to avoid or minimize cognitive illusions and biases and to bolster the brain's reasoning capacity.

Decisions become easier when we apply a process and tools to extend our intuitive decision-making capabilities. Instead of trying to hold everything in our head, we can off-load much of the cognitive work by framing the problem, structuring a decision model, quantifying judgments, and calculating the value of each alternative.

Tools and techniques are available and apply to all manner of decision-making, including personal, government, business, and not-for-profit organizations. For space, this discussion focuses on for-profit enterprises. I will assume that you are a department manager or higher, project manager, or asset team leader charged with making business decisions.

Decisions are resource commitments. How do you assign people's time, materials, equipment, plant capacity, and other resources? Resource allocations should be done in a way so as to optimize your expectation for a quality future. We are mainly interested in what you consider to be important decisions and when there is time for careful consideration.

Key Concept #1: Distinguish between good decisions and good outcomes.

A ***good decision*** is one that is consistent with the values of the decision maker and all of the information available at the time. This is achieved by following a logical, consistent evaluation process.

A ***good outcome*** is merely a result when we are better off than before.

The distinction between good decisions and good outcomes is confusing for many people. The typical person judges—with perfect hindsight—the quality of a decision by the quality of the outcome. However, this view causes problems. Good decisions (e.g., drilling a quality prospect) can have bad outcomes (e.g., dry hole). And each of us occasionally makes a bad decision which turns out well by pure luck.

When do you know that you've made a good decision? At the time of the decision! You are assured of a good decision *whenever* you follow a logical process that reflects decision policy and what you know. You can sleep better at night assured that you've made the best choice with what you know at the time. You will learn later how the decision turns out.

Decision Analysis

The choice is simple when one alternative is clearly superior. Or, perhaps you face two excellent choices ("Chicken or fish?") and can arbitrarily pick one.

Whether the situation is simple or complex, what we seek are **logical, confident decisions.** These require deliberate thought and work, with analysis effort ranging from a little (five minutes) to a lot (several person-months). Often there is a time constraint, and the analysis effort must fit the time available.

How many times have you agonized over decisions? I've seen clients and have personally experienced decision dilemmas in areas of corporate strategy, capital investment, personnel (e.g., whom to hire), negotiation, competitive bid optimization, and product design. Investment decisions are often non-obvious when costs and benefits are hard to quantify, uncertainties abound, and there are combinations of decision variables (e.g., design, location, portfolio mix) to optimize.

Decision analysis (DA) is the discipline consisting of tools, techniques, and attitudes to help decision makers choose wisely under uncertainty.

The value of DA is in helping us make better decisions, because quality decisions are positively correlated with good outcomes.[3, 4]

DA was fairly novel a generation or two ago. It came into prominence during WWII when British and American mathematicians were helping the war effort. Ron Howard of Stanford University is credited with coining "decision analysis" in 1964. Today DA is near-universally taught in business schools. DA is a subset of the quantitative methods of operations research (management science). The distinction from other optimization methods is that DA explicitly recognizes risks and uncertainties in the calculations. DA is at the heart of *predictive analytics* and *big data*.

Don't be concerned about difficult concepts. For the most part, DA is straightforward and transparent. Often a decision dilemma can be resolved with a few minutes of clear thinking, a simple back-of-the-envelope diagram, and several easy calculations. The foundation calculation involves only multiplying and summing; I'll show you an example shortly.

Forecasting is the most important analytic problem in business. A decision model represents—at some level of detail—all possible outcomes for every choice. Looking at the choices, many potential outcome values and their probabilities can quickly overwhelm one's mind. We want methods that simplify decision-making yet maintain sufficient rigor.

DA Features

Decision situations have three characteristic elements:

- Objective(s). What are we trying to achieve and how do we measure the quality of the outcome?
- Decision variable(s). When are decisions to be made, and what are our choices? Decisions include go/no-go, timing, staffing, capacity, location, which technology to use, acquire more information first, etc.
- Risks and uncertainties. What events and variables beyond our control can affect the outcome?

The three elements above are identified in a preparation phase.

Framing

The most important part of problem-solving is setting up. The initial analysis phase is called *framing*. Russo and Shoemaker wrote an excellent tutorial.[5] In framing we craft a problem statement and a preliminary decision model by completing these typical tasks:

- Define the problem, scope, and objective(s).
- Identify stakeholders (considering their interests may require altering decision policy).

- Brainstorm for an initial list of alternatives.
- Identify chance variables that are believed important drivers of outcome value and uncertainty; identify, also, ways where actions and more information can lead to better judgments and ways to improve these risks and uncertainties.
- Organize the objectives, decisions, and variables into a structural *decision model*. Most often this takes one of these not-yet-quantified forms: decision tree, influence diagram, or flow chart.
- Document additional issues that have surfaced.

Decision Policy

Decision making is about trying to improve value. For a concise, logical decision policy we need only establish a suitable way to measure value.

Outcome Value
Staying within the business context, economic value derives from generating future net cash flow. The heart of a typical analysis is a cashflow model of the project, asset, business unit, or company. Upstream from the cashflow calculations, as needed, are sub-models for project schedule, operations, production rates, product prices, and inflation. The situation determines the appropriate level of modeling detail. You may stop the analysis as soon as you are able to make a confident decision.

For for-profit entities a common objective is to maximize net present value (*NPV*), and therefore, corresponding company value. And with the national oil companies with whom I've worked, creating monetary wealth is the dominant objective. Allow me to over-simplify for illustration and assume that maximizing *NPV* is the decision objective.

I am not intentionally ignoring or diminishing the importance of HSE and other social responsibilities. Being a good corporate citizen is consistent with maximizing shareholder value. However, for this brief discussion, let's ignore other dimensions that would lead us toward either assessing monetary-equivalents or crafting a multi-criteria value function.

Key Concept #2: Decision policy is expressed by the way outcome quality or value is measured.

Optimizing choice requires having a *single* metric to optimize. This can be as simple as *NPV*. Or it can be a crafted multi-criteria value function. Whatever the situation, we are all trying to optimize value in our decision making.

Features of DA

Three features distinguish DA from conventional analysis:

1. We use probability distributions to express—quantitatively—judgments about risks and uncertainties.
2. We have a way to measure value, such as *NPV*, that measures outcome quality in the context of the business mission. This measure *is* the decision policy.

3. We combine outcome values (using item 2) of several to many scenarios with their probabilities (incorporating item 1 judgments) to calculate expected values.

Outcome distributions can be difficult to compute, compare and value. Most of us are mentally ill-equipped for even simple calculations. Having a hand calculator or spreadsheet program provides enormous leverage.

Key Concept #3. *Expected value* (*EV*) is the probability-weighted average of all possible outcomes.

This is item 3 in the above DA features list. *EV* is named for a centuries-old calculation, *mathematical expectation*. Note that *EV* is *not* the outcome value we expect.

EV consolidates a distribution forecast or estimate into a single, unbiased value for comparison.

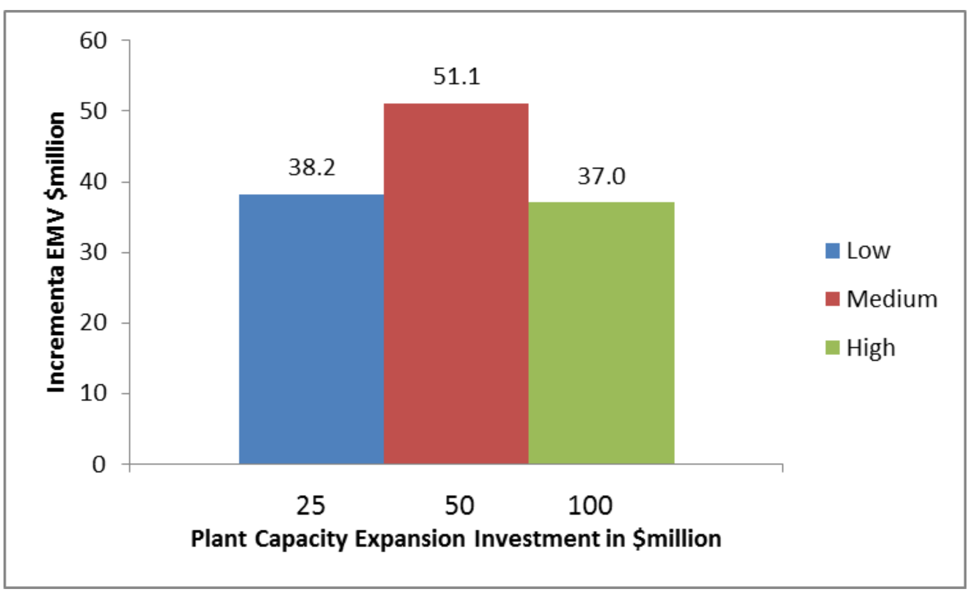
If our value measure (item 2 in the above features list) is *NPV* we give the *EV* a special name: ***expected monetary value*** (*EMV*).

EMV is EV *NPV*.

Over the years people from many companies have told me that they work for an *EMV company*. This means their company's decision policy is to choose the alternative having the highest *EMV*.

Then all we need for decision-making is the *EMV* for each alternative. (There is a bit more to this when recognizing risk aversion and in optimizing a portfolio.) The workhorse tools for *EV* calculations are decision trees and Monte Carlo simulation. Simple problems can be set up and solved as a payoff table.

The following bar chart summarizes an analysis of three alternatives. We can choose to invest either $25, 50 or 100 million in a plant expansion. In this figure, the better alternative clearly stands out by bar heights. The *EMV*s are shown above the respective bars:



When two best choices have similar values, this usually means more analysis work. A clear winner typically emerges after acquiring and applying more information and/or modeling in greater detail.

EV Calculation Example

Often, uncertainty is expressed by scenarios. However, scenarios do not mean much until probabilities are attached.

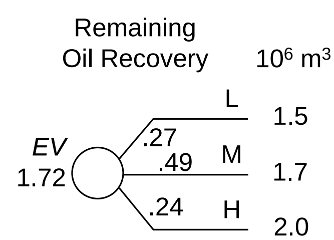
Consider a simple representation of Remaining Recovery volume for an oil reservoir. Our reservoir engineer identified Low, Medium and High outcome scenarios and assigned these values and corresponding probabilities:

	Remaining Oil Recovery		
	Low	Middle	High
Outcome, x_i, 10^6 m^3	1.5	1.7	2.0
Probability, $P(x_i)$	0.27	0.49	0.34

These volume outcomes equal 12.6, 10.7, and 15.6 10^6 bbl, respectively.

Note that the probabilities of all possible outcomes must always sum to one.

At the right is a *chance node* graphic as would be used in a *decision tree* to represent our engineer's judgment of Remaining Recovery under uncertainty. This three-level estimate is a simplification of a continuous range of possible oil recoveries.



Again, the *EV* is a probability-weighted average. For this discrete distribution *EV* is a sum-of-products calculation:

$$EV = \sum_{i=1}^{n} \mathrm{P}(x_i)x_i = 0.27 \times 1.5 + 0.49 \times 1.7 + 0.24 \times 2.0 = 1.72\ 10^6\ \mathrm{m}^3$$

where x_i is a possible outcome, and $\mathrm{P}(x_i)$ is the probability of x_i.

1.72 10^6 m^3 is our best, single-point estimate of Remaining Recovery. Actual outcomes will vary, some too high and others too low. However, over many similar forecasts the average error will be near zero. This is what we mean by an ***unbiased estimate***.

This calculation is so common that Microsoft Excel features a **`SUMPRODUCT`** function. If we have a continuous distribution there are approximation methods to solve an integral version of the *EV* equation.

Simple Decision Tree Example

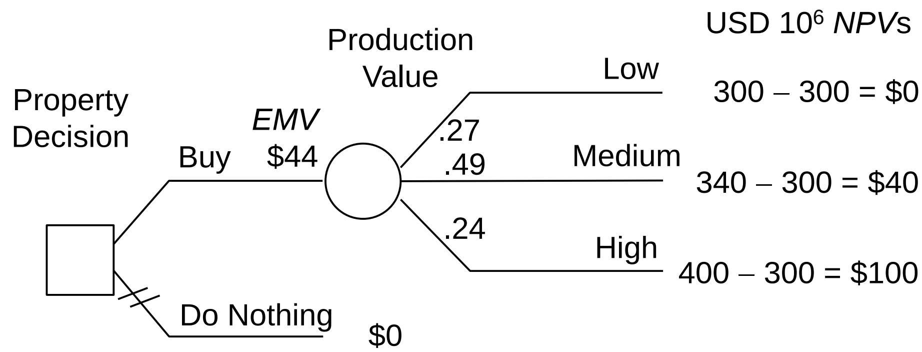
Suppose the oil recovery example, above, represents the engineer's assessment of the Remaining Recovery of an oil-producing property. The property is being offered for sale at $300 million, non-negotiable. You have sufficient funds and this property is compatible with your existing operations and corporate strategy. Should you buy it?

First, let's convert the Oil Recovery volumes into *NPV*. For this type property you presently value the oil in the ground at US$200/m^3 ($32/bbl) *NPV*.

Converting the oil volumes into *NPV*s we have this revised table:

	NPV of Remaining Oil Recovery		
	Low	Middle	High
Outcome, x_i, $million	300	340	400
Probability, P(x_i)	0.27	0.49	0.34

We now can set up a small decision tree analysis:



The reference case is the Do Nothing alternative whose *EMV* = *NPV* = $0.

The *EMV* for the Buy alternative is calculated by multiplying outcome *NPV* values by their probabilities and summing:

$$EMV = \sum_{i=1}^{n} \mathrm{P}(x_i)x_i = 0.27 \times \$0 + 0.49 \times \$40 + 0.24 \times \$100 = \$44 \text{ million}$$

So, buying this property for $300 million adds $44 million to your company's *EMV*. Of course, the actual outcome will be above or below that amount.

Here is the meaning of the *EMV* and why it is an unbiased value estimate. If we could somehow purchase many identical (and statistically independent) properties for $300 million each, this would increase the company's *NPV* in a look-back analysis by about $44 million per acquisition.

Comparing Outcome Distributions

Suppose your project team has prepared a DA on three alternatives for a plant expansion project. The analysis team used ***Monte Carlo simulation*** to develop forecasts of *NPV* for each alternative. The team presents you with two best choices for a plant capacity expansion. The calculations produced two frequency distributions which can be compared using an overlay chart. (For clarity, only the best two alternatives are shown.)

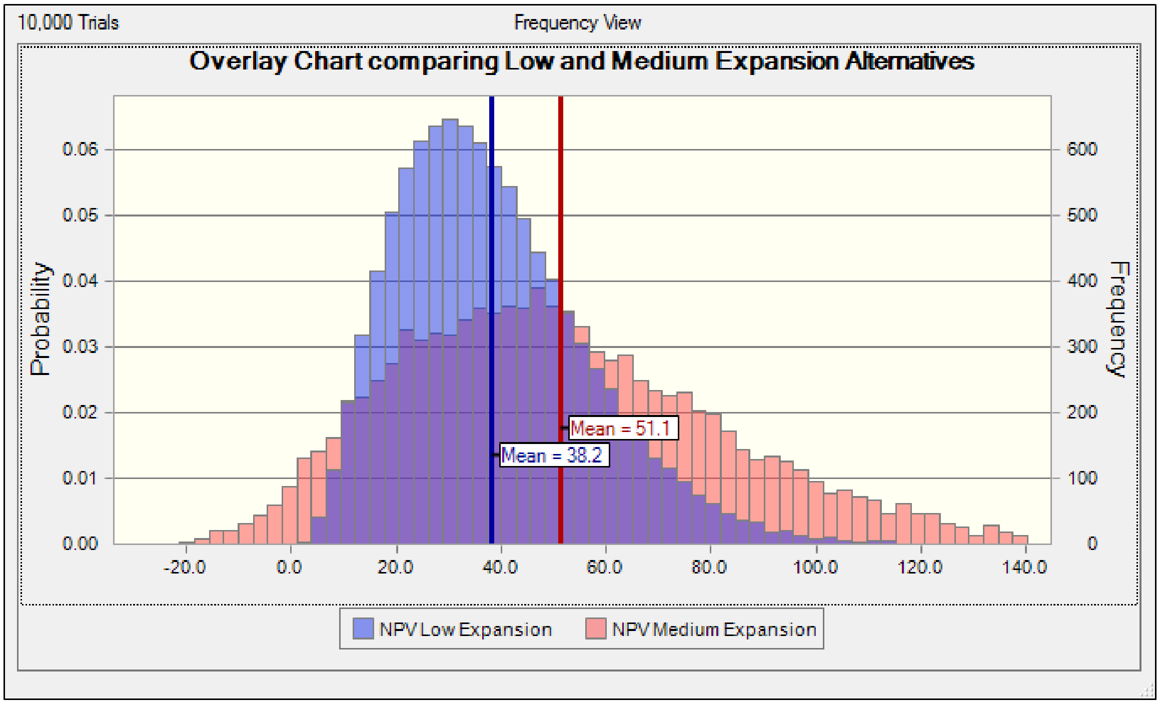


Chart produced using Crystal Ball®, a product of Oracle Corp.

Often comparing distributions is difficult. Try to ignore the *EMV*s for the moment, labeled here as synonymous *means*. Which choice is better? If the company is risk-neutral (typically, widely-held companies or those whose investors are well-diversified), then the best alternative is the one with the highest *EMV*. The *EMV* lines and values shown make the decision obvious for an “*EMV* company.”

As with most investment choices, to make more money (*NPV* or *EMV*) a company usually needs to take more risk. Note that the Medium Expansion alternative (red) is more-risky (wider distribution) than the Low Expansion alternative (blue). If the company is conservative, then the blue Low Expansion alternative might be perceived as superior because it has less uncertainty despite its lower *EMV*. Risk vs. value tradeoffs are often a contributor to a decision dilemma. A clever way is available to implement a conservative risk policy. This extra step revalues each alternative as its *certainty equivalent*—the cash-in-hand value.

Life-Long Learning

A good decision is defined by the process, not by the outcome. As organizations flatten, decision authority is usually delegated to lower-levels. This places decisions in the hands of those people close to the action. Thus, those persons most knowledgeable about projects are empowered to make good and faster decisions.

The delegating manager retains a role in decision quality control. He or she wants to remain sufficiently involved to ensure that the company’s DA process and decision policy are being followed.

The *EV* calculation is the foundation for analyzing decisions under uncertainty, yet most people are unaware of the simple calculation.

Decision-making is a skill to be continually learned and practiced. Perhaps nothing is more important to your organization's success and your personal success. Yet most people have never received formal training in decision-making. Incredibly, most are self-taught.

As soon as children learn fractions, they can begin to understand probabilities and how to use them. I'm pleased to see growing attention to developing these skills in our youth, such as efforts by Decision Education Foundation (www.decisioneducation.org).

John Schuyler and Tim Nieman teach the foundation and advanced decision analysis courses for PetroSkills.

John Schuyler, CAM, CCP, CMA, CMC, DRMP, PE, and PMP, is an analyst, trainer, and investor. He has over 39 years of experience in management, economic evaluation, consulting, and teaching, mostly in the petroleum industry. He is the revisions author of *Decision Analysis for Petroleum Exploration, 3.0 Edition*, author of *Risk and Decision Analysis in Projects, Second Edition*, several DA course notebooks, and over 40 articles, papers, and handbook chapters. He has B.S. and M.S. degrees in mineral-engineering physics from Colorado School of Mines and an M.B.A. from University of Colorado at Boulder. For questions you may contact: john.schuyler@petroskills.com or visit www.maxvalue.com.

This white paper is excerpted from *Decisions with Risk*, a forthcoming small book for executives.

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