A PRIMER ON QUANTITATIVE METHODS FOR DECISION MAKING

By Jeffrey A. Robinson

Table of Contents

1.0 Introduction

There are many models and methodologies for decision-making in place in Motorola (M-Gates, NPI – New Product Development, the Six Sigma DMAIC process, 8-D, and many more) and there are a variety of tools to support these models as well (BSAP, xxx, etc.)

Unfortunately, while these models provide a structure for different decision making processes, for Strategic Planning, the development of Business Cases and Continuous Improvement, these models often fail to supply the detail necessary to make them useful to real-world practitioners.

The difficulty lies in the fact that these models tell managers and decision makers ‘what’ tasks to be done, but omit instructions on ‘how’ to do them.

The discussions that follow are provided to summarize a dozen or so techniques that are intended to supplement these business and engineering models. Most are quite simple and require little more mathematics than basic arithmetic, but have the advantage that they can quantify what are otherwise very subjective opinions. They are not new or revolutionary ideas. Indeed they are relatively dry and mundane practices quite common to other disciplines of business, marketing and problem solving.

They are documented here as examples of simple quantitative methods, which can be applied to planning and management activities in common engineering organizations.

Before jumping right into specific quantitative methods, however, some understanding of basic principles is essential. Most of these techniques apply different methods of quantifying and modeling aspects of risk and probability to predict likely outcomes for selection of appropriate alternatives and options in formal decision-making.

It is therefore important to understand and differentiate the difference between RISK and UNCERTAINTY.

1.1 Uncertainty and Risk

One problem for decision makers is that people rarely understand the real difference between *Uncertainty* and *Risk.* When things are uncertain, people almost always consider the situation risky. Risk, however, it something altogether different. Uncertainty merely alters the likelihood of a specific risk from manifesting itself. Indeed, low probability diminishes risk; it does not amplify it. It is the combination of probability and risk that provides the greatest semantic value to the decision-making process. It is the two concepts together which is important to assess in considering outcomes and alternatives.

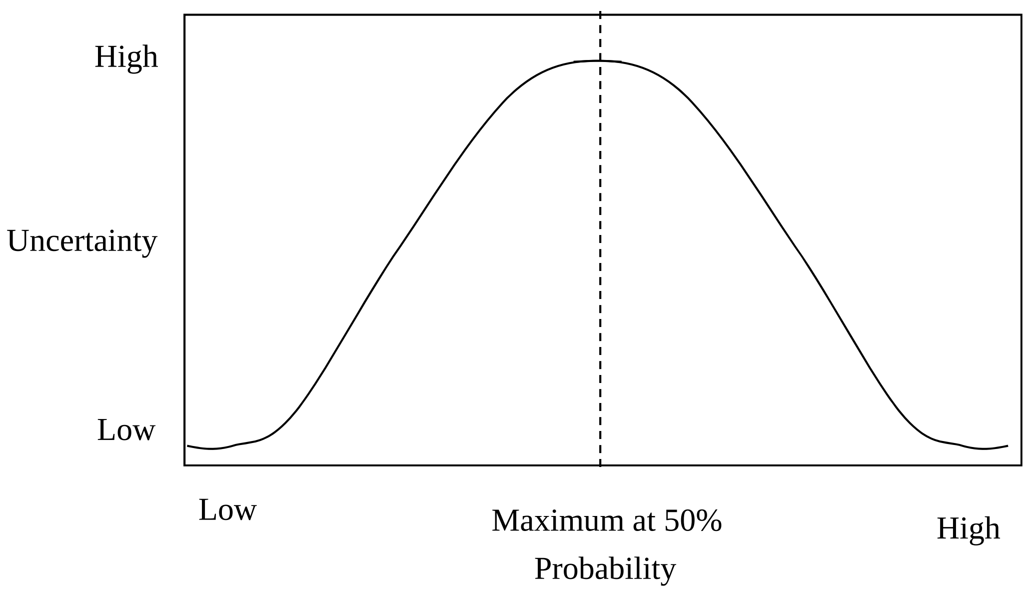
Thus, while these two concepts are very different, conceptually they become confused with one another and seem to become interchangeable and inseparable.

Risk is nothing more than the cost of a particular problem or alternative. Risk is the magnitude of loss (in time, money, effort or lives) associated with a specific choice or decision. It is how much will be lost (or gained) based upon different actions or alternatives, which might result from a decision that is made, or not made. (It is important to remember that taking no action and selecting no alternative is ALWAYS as valid alternative in any problem or decision-making processes.)

Probability, on the other hand is the outcome associated with different events. But it is not the same as uncertainty. Probability is the degree to which the associated risk (or quantified loss) is likely or probable. It is usually expressed as a number ranging from zero to one. Zero means there is no chance of an event occurring. One is absolute certainty that it will occur. It may also be represented as a percentage from zero to one hundred.

Probability is often confused with uncertainty and, while they are related, they are quite distinct from one another. Contrary to normal belief, high uncertainty does not occur when probabilities are low.

Indeed, when probabilities are very high or very low (nearly zero or almost one), there is absolute certainty. The greatest uncertainty lies in the range between these two extremes. It is in the middle where uncertainty is at its maximum, when the probability of a given event is 50:50. (See the graph below)



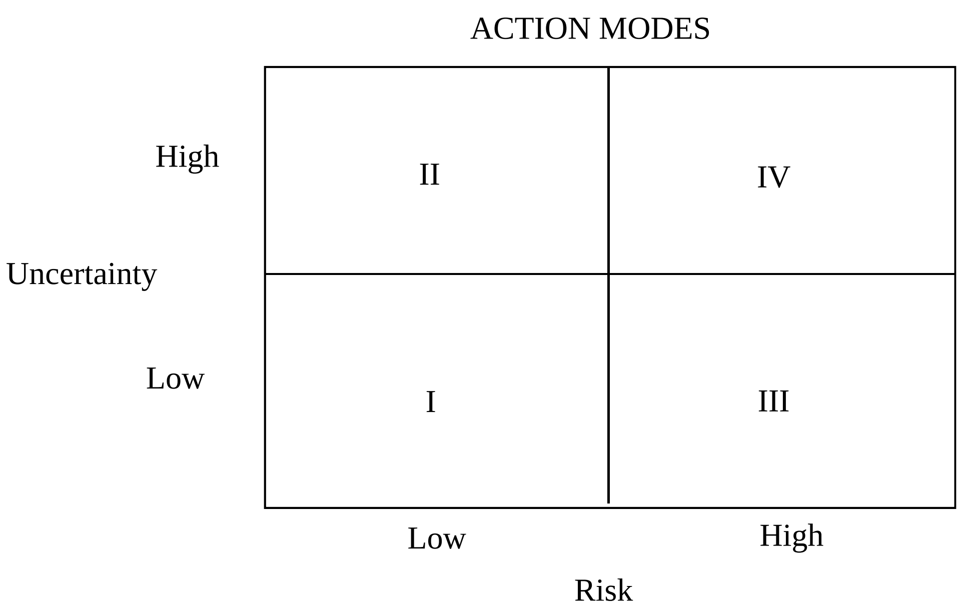
If we consider the situation where probability is very high or low, uncertainty is minimized. Events associated with these extremes are either very certain to occur or not. Uncertainty in these regions is very low. It is in the middle that uncertainty is the greatest; when the outcome is as likely to occur as not. (Remember then that uncertainty is not the same as probability.)

1.2 An Action Model for Risk and Uncertainty

How do risk and uncertainty relate to actual decision making? Which combinations of these factors simplify or complicate the decision making process?

Let's consider the different cases of these factors by reviewing a simple taxonomy of high and low uncertainty and risk. In that table below, four different combinations of risk and uncertainty are identified.

DOMAINS OF ACTION IN DECISION MAKING



Strangely, each of these domains or regions has a different type of optimum method for decision-making. For the sake of discussion each of these regions will be numbered.

Region I - Low Uncertainty/Low risk
Region II - High Uncertainty/Low risk
Region III - Low Uncertainty/High risk
Region IV - High Uncertainty/High risk

Let's examine these different domains individually.

Region I - Low Uncertainty/Low Risk

Let's create a fictitious problem that has low uncertainty and low risk.

Let's say we have a $100,000 machine in a factory that has broken down. Examination of the machine reveals that a part has worn out. However, the examination also reveals that the part is a single washer, one that can easily be replaced.

In this case, uncertainty is low, because we know exactly what type of washer needs to be replaced. The Risk is also low because the washer only costs 5 cents. Assuming that there are no additional difficulty ordering and receiving the part, the solution to this problem is simple.

Action: Just do it.

Buy the part and get back to work. Resolving this problem does not require and special analysis or techniques. You just implement the solution and do it. (Don't we wish all problems were this simple)

Region II - High Uncertainty/Low risk

Let's modify our original scenario and increase the uncertainty, but not the risk.

Once again, a machine in the factory has broken down. Again, a washer has worn out and needs to be replaced. Unfortunately, in this case, the manufacturer no longer makes that particular washer, but they do have a number of replacements parts in stock that might be interchangeable.

The problem now is that we don't know which part is the right one. There are many replacement washers that are available, but no one knows which one is the correct one. The good news is that each of them still only costs 5 cents.

If we narrow down the selection of possible replacement washers to, say, twenty or thirty, we now face a dilemma. We need to determine how to find the right washer. (Remember, the machine is worth $100,000; the replacement parts cost 5 cents each.)

Uncertainty is high, but risk (cost) is low.

Action: Guess and test empirically.

Buy an assortment of washers and try placing them on the machine. If the first washer doesn't fit, try the next one instead. If that one doesn't work, try the third. If there is no risk to buying or trying the wrong part, then the fastest way to find the right one may simply be to test the different alternatives and find out which one is the correct one.

Region III - Low Uncertainty/High Risk

In our next scenario, we have a new combination, high risk, but low uncertainty.

In this situation, our piece of equipment has again has broken needs a replacement part. Now, we know precisely which part needs to be replaced and, again, the manufacturer has the part available. However, the replacement part for the $100,000 machine is the main controller and costs over $50,000, more than half the price of the entire machine. Our problem now is to decide, should we buy the part?

In this case, the uncertainty is low (we know the part), but risk is high (the part is very expensive)

Action: Make a judgment.

In this situation, one must determine whether or not the cost of the part is worth the purchase. To answer that question one needs to determine several things.

How long before it takes to pay off the cost of the new part? Is there sufficient product going through the machine to justify the cost? Would it be cheaper to buy a newer machine? Or to have a replacement part tooled or a substitute found?

This is the scenario when quantitative measures can best be used to make the decision. The numbers will determine whether or not the decision to buy the part is the right one.

Region IV - High Uncertainty/High Risk

In our final scenario, we offer the worst case. Once again, our machine has broken down. This time, however, some part needs to be replaced but we're not sure which one. The cost of the replacement part could range from 5 cents to $50,000.

We finally have a situation where both uncertainty and risk are high.

Action: Analyze; conduct additional research.

In this case, it is not acceptable to use a trial and error method of buying replacement parts, because the cost can be too high. Similarly, we cannot conduct a cost/benefit analysis because we don't know what part needs to be replaced.

In this situation, either uncertainty or risk has to be reduced. Additional study needs to be done to identify which part have broken or how much it will cost to find out and fix it..

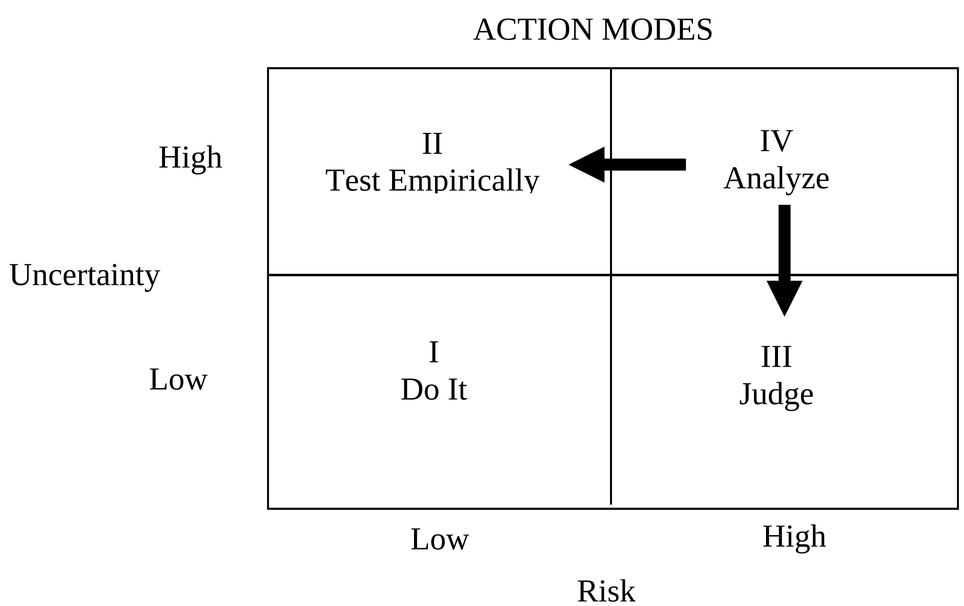
Possible methods of analysis might include: examination of machine specifications, review by product engineers, identification of the problem part and determination of the repair or replacement cost or maybe even the custom creation or retooling of that part In any case, multiple alternatives need to be identified and evaluated.

Remember, the purpose of analysis is to either to

- Reduce uncertainty (and revert to a Region III action mode) or to
- Reduce risk (and revert to a Region II action mode).

At first glance it seems as though the combination of high risk and high uncertainty actually promotes inaction (at least while some subsequent analysis is performed). However, the amount of analysis (and hence the degree of inaction) is itself limited. For instance, if the cost of delay or the cost of analysis exceeds the total cost of the machine, then it would be simpler to just buy a new machine. The very act of not deciding or of performing extensive analysis becomes certain and the decision reverts to a Region III decision scenario of high cost and low uncertainty.

Action Model Summary



Note, each domain has a different decision making strategy.

- In Region I, you simply implement the obvious solution.
- In Region II you can perform empirical test and find the right solution by trial and error.
- In Region III, you may use quantitative methods to make formal judgments.
- In Region IV, you need to go through a full analytical decision-making process (setting objectives, identifying and weighing alternatives, selecting alternatives, etc.).

For instance, it would be inappropriate to perform a comprehensive analysis in the case of Scenario I. In such a case (low uncertainty and risk), the decision is an easy one.

Similarly, it would be unnecessary to perform a full decision analysis in the case of Scenario II, since it would be faster to just buy the cheap parts and try them out.

The only domain where extensive analysis is appropriate is region IV. Indeed, the purpose of analysis is to reduce uncertainty or risk sufficiently to drive the problem into a domain where action is appropriate.

Unfortunately, many managers do not adequately distinguish risk from uncertainty and confuse these different domains. When this confusion between uncertainty and risk occurs, relatively simple decision methods become confused with the full decision analysis associated with Region IV. Sometimes, quick, easy solutions get bogged down in a decision processes that are both unnecessary and inappropriate.

When the distinction between risk and uncertainty is not understood, or when decision makers are unwilling to accept either one, then the process of making decisions becomes are arduous one. When uncertainty and risk blur and merge, managers become incapable of making decisions, unless they are the simple ones (low risk and low uncertainty).

This often leads to a phenomenon called 'the paralysis of analysis'.

Ultimately, managers need to differentiate and distinguish risk from uncertainty and recognize when different types of decision making processes are appropriate.

2.0 Theories of Decision Making

2.1 The Ideal Decision Making Model

Let's review the elements of the ideal decision model. Under perfect conditions the ideal decisions process would contain four elements.

- Perfect information
- A fixed and clearly defined objective or problem
- Unlimited time and money
- Unlimited Cognitive ability

What do these mean?

The first item, perfect information, means you have all the information you need, nothing missing, nothing extra, nothing in error, nothing ambiguous. Obviously, this is almost never going to happen.

The second item references a fixed and clearly defined objective or problem. Again, this is an ideal that is rarely manifested in the real world. In most cases, not every one may agree there is a problem and those who do many have as many different interpretations of the problem as there are participants. Also, during the course of the decision making process, the problem may grow or change. As people learn more about the problem, they may discover other related problems (or issues) and these, in turn change the nature of the problem or objective. Often, simply changing the member involved in the decision making process can change the nature of the problem being addressed.

The third element of the ideal decision making model, unlimited time and money, is obviously also not realistic. There is never unlimited time or money associated with a decision. Most commonly there are time constraints. If a patient is dying, the attending physicians may not have the luxury to review all options or the patient may die before the optimum solution or treatment is found. Similarly in business, most decision or problem come coupled with deadlines that dictate the selection of a course of action within a specified time period. Correspondingly, the limits on how much money is available to implement solutions may also limit the alternatives that can be considered.

The final element, unlimited cognitive ability, is also unattainable. It really doesn't take a lot of data before individuals reach 'information-overload' and start actively filtering data. The human mind is only capable of absorbing or processing so much data before people start oversimplifying and compartmentalizing their thought processes to shortcut the decision making task. Additionally, there are other psychological processes that adversely affect ideal information processing in human decision making, including such things as: stereotyping, halo effect, perceptual defense, risk aversion, deliberate and unconscious filtering, personal preferences, historical precedence, and cultural or political considerations.

Thus, the ideal environment for decision making never exists. Therefore, the questions is how to make good decisions when:

- We don't have perfect information and cannot determine what data is missing, unnecessary or wrong.
- When the problem or objective may not be not clearly defined or when it changes during the course of the decision making process.
- When the decision process is constrained by time or monetary constraints such that we may not be able to identify, evaluate or implement ideal solutions.
- When decisions are limited to the cognitive abilities, experiences, and skills of individuals whose opinions, preferences and qualifications vary greatly.

In such situations, we need to apply formal (and in most cases quantitative) methods and techniques to supplement human decision making to make it more reliable, consistent and effective.

2.2 Open and closed decision models

A 'closed' decision model is a situation in which all of thee components and influencing factors involved in the resolution of the problem can be clearly identified. An example of a closed decision model is an engineering problem with numeric inputs. In such case, one may be able to apply mathematics to determine the solution. For instance, one may be able to calculate how many addition servers one may need on a network or how many more disks one may need to buy to accommodate a given increase in utilization or load.

The model is closed, because the problem domain can be clearly defined and bounded.

An 'open' decision model, on the other hand, is one which has undefined influencing factors. There may a large number of complicating issue or far ranging impacts that may not be clearly identifiable. Generally, the larger (and the less technical) the problem, the more likely it is to be an 'open' problem. Efforts to bound the problem may require those involved to deliberately ignore certain aspects or elements to reduce the domain of the decision making process. The difficulty with this is that while the problem may be simplified, it may result in oversimplification and the selection of a solution that does not, in fact, address all the elements of the original problem.

Closed decisions are generally much easier to resolve than open ones. The tendency, however, is to take open decisions and transform them into closed decisions by simply ignoring specific aspects to make the process easier.

2.3 Type of Decisions

Traditionally there are two overall types of decision making; Category I and Category II.

Category I decisions are decisions that have been made before. The factors in these decisions may be well understood and there may be considerable experience in having made these types of decisions before. These are decisions were a formal process or method for identifying and selecting alternatives may have been established. Such decision, therefore may be considered routine and algorithmic, even though large amounts of money (or risk) are involved.

Examples of Category I decisions might be:

- Approving bank loans
- Assigning grades to students after taking an examination
- Calculating Return-on-Investment or
- Conducting assessments

Category II decisions, however, are different. Category II decisions are those that may not be recurring. They may be one of a kind or new situations that require higher level decisions to be made. Indeed, decisions may have to be made how and who will even make (or participate in making) the choices.

Category I decisions are often relegated to personnel outside of management. Category II decisions are sometimes considered the proprietary domain of managers. People who make such decisions thus accept a higher level of personal risk in accepting the responsibility for such decisions.

Finally, regardless of the type, there are two different possible objectives to the decision making process. Decision makers may be seeking 'the best possible' solution or one that is simply 'good enough'.

'Maximizing' decisions are those that seek the best or the optimal decision. Maximizing decisions usually require a limited number of clearly defined alternatives with clear quantifiable outcomes. (Note: it is rare that open-decision models can seek a maximizing outcome, since it is difficult to consider all possible factors and outcomes. Maximizing decisions are most often associated with simpler, closed-decision models.)

Far more common are 'satisficing' decisions. These are decisions that seek, not the best solution, but rather an adequate one. In such a case a smaller set of alternatives may be considered. The selection of possible solutions may not be exhaustive and not all may be formally evaluated. The solution, therefore, may not be the best, but then again the cost of finding the optimal solution may not be worth the cost of exhaustive analysis.

An example of a 'maximizing-decision' is the selection of the best alternative from a set of possible choices. The degree to which the decision is truly maximizing depends upon the completeness of the selection set.

An example of a 'satisficing-decision' might be the approval process the FDA uses to approve a drug. The approval does not imply that a drug, which passes their review is the best. It merely means that it is acceptable enough.

3.0 Quantitative Methods

3.1 On the Need for Formal Methods

There are several advantages to using formal mathematical methods.

1. Using a formal decision making process improves accuracy of decisions (it helps ensure that no critical factors are skipped or forgotten
2. For those participating in the process, it clarifies the reasons why the specific conclusions were reached
3. It provides a formal framework to assist others in understanding the decision making process (.i.e it helps explain and justify your conclusions to others)
4. It helps quantify what can otherwise be very subjective decisions
5. Also, people are generally poor judges of probability and poor estimators of statistics. The use of formal methods significantly improves the accuracy of decision making.

Examples of some of these techniques are provided in the sections below.

1 - Payoff Tables

One method of reconciling uncertainty and risk is through the use of EXPECTED PAYOFFS. An EXPECTED PAYOFF is the product of possible gain (or loss) and the probability of that occurrence.

The EXPECTED PAYOFF of a lottery ticket, for instance, is given by the possible winnings times the probability of winning. For example, if the chance of winning $6,000,000 is one in 12,000,000, the EXPECTED PAYOFF is

$$6{,}000{,}000 \quad \times \quad \frac{1}{12{,}000{,}000} \quad = \quad \$0.50$$

Thus, if the ticket costs one dollar, it is not worth the probabilistic value of its purchase.

PAYOFF TABLES allow the representation of more complex sets of possibilities and actions. A PAYOFF TABLE is a two dimensional matrix.

One axis is EVENTS, things that will occur and are not under control of the participants. The other axis is ACTIONS, different choices or possible actions of the participants.

Each cell in the matrix contains the possible return (gain or loss) of each EVENT.

Note, probabilities are associated with the different EVENTS. These probabilities need to sum up to 100%. They may be assigned arbitrarily; they may be based upon historical data, or upon the best guesses of experts (benchmark, Delphi or wide-band Delphi.

The EXPECTED PAYOFF for each row (ACTIONS) is the sum of the products of the individual payoffs and their respective probabilities.

Where there are “i” EVENTS, and “j” possible ACTIONS, then Payoffs are assigned to each combination of ACTION and EVENT, P_{ij}.

The EXPECTED PAYOFF for a particular ACTION, E_j, is thus given by

$$E_j = SUM_i (P_j * p_i)$$

The ACTION with the highest EXPECTED PAYOFF is the optimal action.

Example Problem:

Say you run a business that rents snowmobiles to different local resorts every winter. You lease however many snowmobiles you want from dealers at a cost of $35 each and transport them to resorts where customers who want them can rent them from you for $50 each.

Your potential profits are thus $15 for each snowmobile that you successfully rent. However, there is risk.

If you lease too few, you lose the potential $15 profit for each customer you turn away. If you lease too many, however, you lose the $35 that you paid to the dealer. Leasing the correct number of snowmobiles is therefore critical to maximizing your profits.

Let’s say that, historically over the past one hundred winter weekends (over the past decade) the number of customers who have rented snowmobiles is given by the following table:

Number Rented	Number of weeks
10	5
11	10
12	17
13	20
14	25
15	15
16	5
17	3

Note: there were always between 10 and 17 snowmobiles rented by the local resorts.

The following PAYOFF TABLE could thus be constructed.

		Event									
		10	11	12	13	14	15	16	17		
Percent		5%	10%	17%	20%	25%	15%	5%	3%	100%	Excepted payoff
	10	150	150	150	150	150	150	150	150		150
	11	115	165	165	165	165	165	165	165		162.5
	12	80	130	180	180	180	180	180	180		170 Optimal action
Acts	13	45	95	145	195	195	195	195	195		169
	14	10	60	110	160	210	210	210	210		158
	15	-25	25	75	125	175	225	225	225		134.5
	16	-60	-10	40	90	140	190	240	240		103.5
	17	-95	-45	5	55	105	155	205	255		70

Each cell shows the monetary return for that combination of snowmobiles leased and rented.

The EXPECTED PAYOFF of any given ACT is the sum of the payoffs times the respective probability of all the possible EVENTS.

For the case of leasing 13 snowmobiles, for instance, would be given by:

45*.05 + 95*.1 + 145*.17 + 195*.2 +195*.25 = 195*.15 + 195*.05 + 195*.03

or $169.00

The **optimal decision** or **optimal act** is given by the choice that yields the highest EXPECTED PAYOFF.

In this case, the best choice would be to leasie 12 snowmobiles, since that action yields an EXPECTED PAYOFF of $170.00.

The Price of Perfect Information

However, more can be done with this information. Given this table of payoffs and probabilities, one can even calculate the PRICE OF PERFECT INFORMATION.

That is, how much money should you spend on market research to determine what the number of rentals REALLY will be this winter.

For instance, the resorts might be willing to solicit guests about their intentions regarding snowmobile rentals when they make their reservations. Of course, they might want to charge a fee for this service. And while having this information would definitely improve your bottom line, the new question is HOW MUCH SHOULD YOU SPEND FOR THIS INFORMATION?

The answer to this question is again buried in this table of information.

If you knew that the events would be…you would be able to select the appropriate (and maximum payoff, for each event. Your payoff in each case, would be thus be maximized. While there is still a variable probability of how many guest will rent snowmobiles, by paying a fee to the resorts, you could adjust your action accordingly.

The expect payoff for always selecting the best act is given by the values on the diagonal of the matrix (those highlighted in yellow).

This would be given by

150*.05 + 165*.1 + 180*.17 + 195*.2 +210*.25 + 225*.15 + 240*.05 + 255*.03

or $199.50

The price of perfect information, or the price you should pay for this improved market research, is the difference between this maximum set of payoffs and the optimum payoff calculated earlier

Thus the perfect information, = $199.50 – $170.00 = $29.50

2 - Opportunity Loss Tables

An OPPORTUNITY LOSS TABLE is similar to an EXPECTED PAYOFF TABLE expect that instead of showing possible gains, the value of each cell is given by the difference between the possible return and the optimal ACTION for that event.

The values here are the difference between what WAS made and what could have been.

		Events									
		10	11	12	13	14	15	16	17		
		5	10	17	20	25	15	5	3	100	Excepted opportunity loss
	10	0	15	30	45	60	75	90	105	49.5	
	11	35	0	15	30	45	60	75	90	37	
	12	70	35	0	15	30	45	60	75	29.5	Optimal action
	13	105	70	35	0	15	30	45	60	30.5	
Acts	14	140	105	70	35	0	15	30	45	41.5	
	15	175	140	105	70	35	0	15	30	65	
	16	210	175	140	105	70	35	0	15	96	
	17	245	210	175	140	105	70	35	0	129.5	

As before, the expected opportunity loss is the sum of the probabilistic returns for each action.

Optimal act is the action with the lowest opportunity loss

Note: the lowest opportunity loss is the optimum act and is the same action specified by the payoff table.

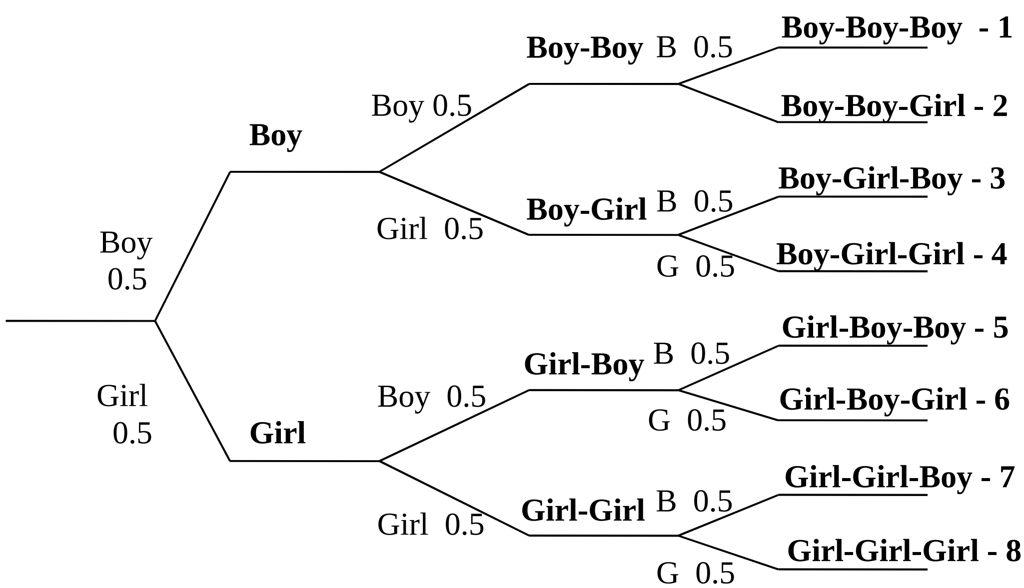
Moreover, the magnitude of the minimum opportunity loss equals the price of perfect information.

3 - Decision Trees

Decision trees are a graphical method of representing sets of alternatives based upon possible outcomes. Alternative outcomes can be shown adjacent to one another.

One advantage of this approach is that dependent outcomes can be represented as chains of events. The final product can often appear to be a tree-like structure with each branch terminating in different outcomes with different associated probabilities of occurring. The probability of all outcomes is the product of the probabilities of each branch and the sum of all the probabilities should equal 100 percent.

Here is an example of a decision tree based on three events. The birth of children. For each event, there is a 50-50 chance of having a boy or a girl.



From this one can see that eight different outcomes result (2 x 2 x 2 = 8) and that the probability of each of these eight outcomes is 0.125 (0.5 x 0.5 x. 0.5 or 1/8), which makes sense since each outcome has an equal probability of occurring.

Moreover, this decision tree can be used to answer more complex questions, such as.

What is the probability of having more boys than girls?
(events 1, 2, 3,5 or 0.125 x 4 = 0.5 or 50%)

What is the chance of having a boy older than a girl?
(events 2, 3, 4, 6, or 0.125 x 4 – 0.5 or 50%)

What is the chance of having a girl with at least one younger brother?
(events 3, 5, 6, 7 or 0.125 x 4 = 0.5 or 50%)

What is the chance of having a child with two siblings of the opposite sex?
(events 2, 3, 4, 5, 6, 7 or 0.125 x 6 – 0.75 or 75%)

What is the chance of having a girl with two brothers?
(events 2, 3, 5 or 0.125 x 3 = 0.375 or 37.5%)

Thus, one can use these chained of probabilistic events to calculate likelihoods of different combinations of events.

However, the events and outcomes in such trees do not have to have equal probabilities, and it is in these situations that decision trees are often the most valuable.

For example:

A project manager in charge of a new product release faces a dilemma. he is to introduce a new product line but has several options.

The project manager can hurry to release the product before Christmas, but there is a higher chance that the bugs will not be worked out of the new software and releasing a product that has bugs could prove disastrous, but if the product is sound the sales would be much greater. If they wait until April for the release, the likelihood of having system problems is lower, but sales for the entire year will also be lower due to the delay.

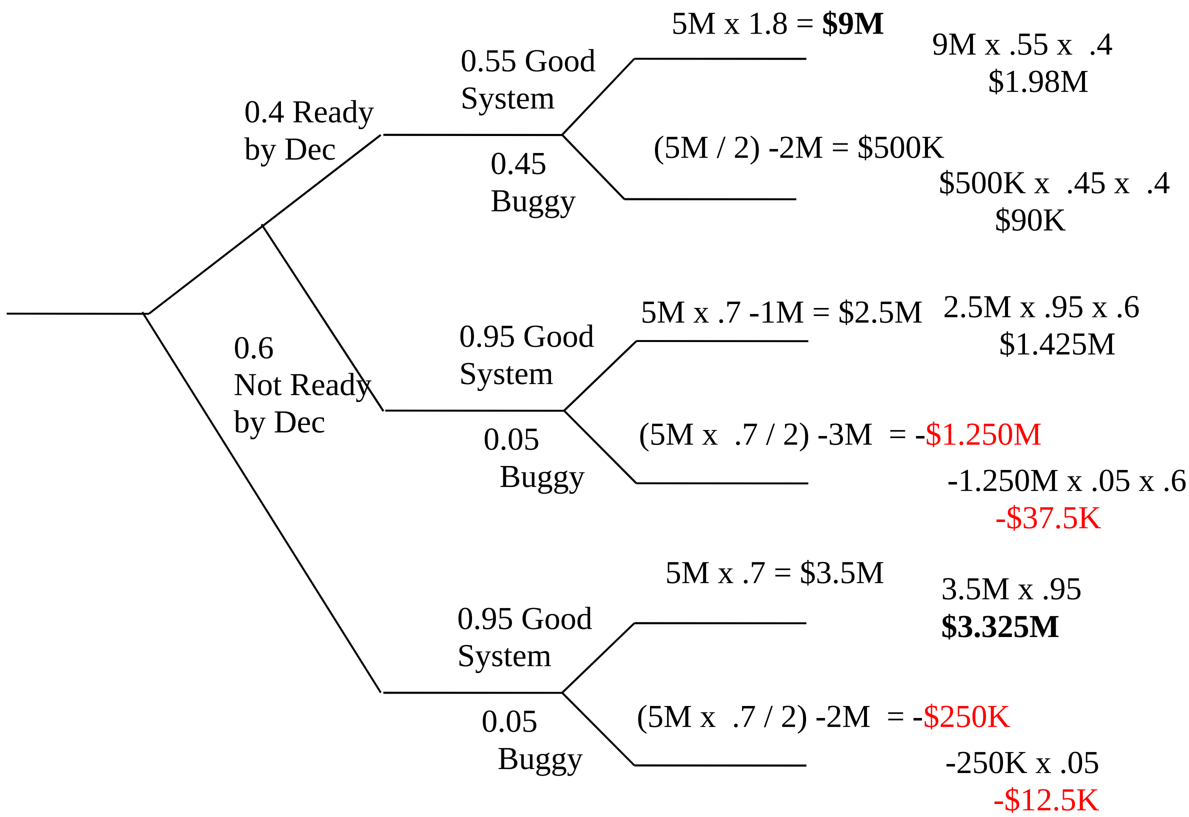
What should the project manager do?

Let's map out these options.

Let's say the product is expected to produce $10,000,000 is sales and that there is a 40% chance of completion the product by Christmas, but that at that time there is also a 45% chance of having serious bugs in the product.

If the product is not ready, the company looses one million dollars in pre-Christmas advertising.

On the other hand by April there will be a 100% chance of having the product ready with only a 5% chance of serious problems, but yearly sales would be reduced by 30%. If problems do occur a recall of the product would cost at least 2.5 million and reduce total sales by 50%. But if the product makes the Christmas rush, without bugs, sales could increase by 80%.



The highest payoff is to push for a December release despite possible bugs and get a chance at making a $9million dollar return., but the highest expected payoff recommends a bug free release in April.

Overall? Go for December? or wait for April?

Go for December release	1.98 + .9 + 1.45 - .0375 = $ 4,.292,500
Wait for April	3.325 – 0.0125 = $ 3,312,500

The net result is to go for the December release even if risky and even if it is not ready in time/\.

4 - Weighted Attribute Analysis

This technique is known by several names; weighted attribute analysis, multiple variable analysis, or net attribute analysis.

It is a technique that can be used to evaluate different alternatives quantitatively, even when there may be strong preferences based upon complex factors.

In this technique, you identify different factors and weight them accordingly. You then assign values to each of the categories for the different scenarios or alternatives. Each different scenario then produces a score which is based on the sum of the weighted scores. The scores can be used to quantitatively compare the different cases under consideration.

This has the advantage of quantifying what may otherwise be very subjective opinions. While the results are still subjective, the nature and magnitude of the subjective differences in opinions are now revealed by the different weights and scoring values assigned by different stakeholders.

Here is an example of how this can be used.

Consider a company that is considering moving their manufacturing facility to one of two different locations. There are pros and cons for each site.

The first site has a better location and is more convenient to employees, but it is expensive. The other site, however, is further away and would increase commuting time for existing employees, but it is cheaper, it has some extra features like a parking garage and a small recreation area and it also has a better IT infrastructure.

First, the factors that will be considered are listed and assigned weights. Then they are scored.

Factors	Weight	Site 1 – score (1-10)	Site 2 – score (1-10)	Site 1 weighted score	Site 2 weighted score
Site Location	20	9	7	180	140
Cost	25	6	8	150	200
Convenience to employees	10	9	6	90	60
Décor	15	7	9	105	135
IT Infrastructure	15	7	9	105	135
Extras (gym, parking, etc.)	10	5	8	50	80
Lease terms	25	6	5	150	125
Total				**830**	**795**

In this case, Site 1 wins out over site 2. however, if the weightings are changed, the results could change as well.

In this type of analysis virtually any number of factors can be considered. The sum of the weights do not have to add up to 100 and any scale can be used for assigning values (1-5, 1-10, 1-100, etc.)

Also see the mathematical models in Lytinen, K. and Hirschheim, R "Information systems failures – a survey and classification of empirical literature" Oxford Surveys of Information technology, Vol 4, 1987 pp 257-309

5 - Best-Case, Worst-Case, and Most-Likely

One methods of dealing with uncertainty in projects tasks is to apply a method called "Best-case/worst-case/most-likely"

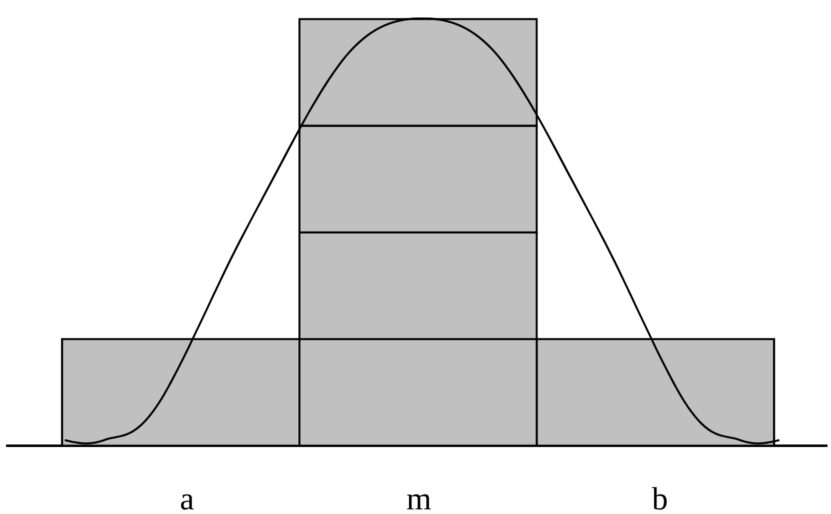
This is a form of scenario analysis in which the range of possible outcomes is evaluated and estimated. The disparity between these different cases helps define the "variance" of the project and its associated tasks.

a = optimistic time value
b = pessimistic time value
m = most likely time value

Once these have been estimated the "Expected time for each task can be calculated using the following formula.

Expected time (TE) = (a + 4m + b)/6

This is a binomial approximation to a normal distribution where the most likely value is weighed four times more heavily that the best and worst cases.



Correspondingly, the variance of a task thus defined is given by

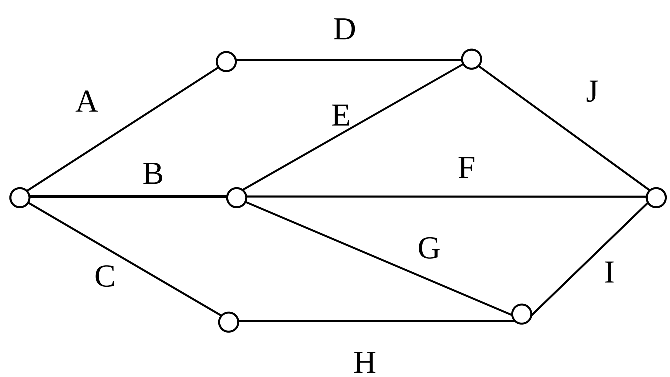
$$\sigma^2 = ((b - a)/6)^2$$

Finally, the standard deviation, σ, is the square root of the variance, or $\sigma = (b - a)/6$

The following set of tasks illustrates this application.

	a	m	b	predecessors	TE	variance
A	10	22	22	-	20	4
B	20	20	20	-	20	0
C	4	10	16	-	10	4
D	2	14	32	a	15	25
E	8	8	20	b	10	4
F	8	14	20	b	14	4
G	4	4	4	b	4	0
H	2	13	16	c	11	5.4
I	6	16	38	g, h	18	28.8
J	2	8	14	d, e	8	4

Since the critical path is the set of tasks (A-D-J), the time for the



critical path is the sum of the durations for these tasks. The expected completion time of the project, μ, is give by:

$$\mu = A + D + J = 20 + 15 + 8 = 43 \text{ days}$$

When given a set of tasks, the overall variance of the set is the sum of the variances of the individual tasks.

$$\mu = \sum \sigma_i$$

When applied to a series of tasks such as those associated with a project, one can calculate the probability of completing the projects by a given time. Fortunately, one need not consider all of the tasks, merely those on the critical path. Xxxx insert citation

For instance, the probability of completing a project in a desired time D is given by

$$Z = (D - \mu)/ SQRT(\sigma_\mu^2)$$

Where:
D = desired project completion time

μ = the critical path time of the project (the sum of the TEs for the activities on the critical path

σ_μ^2 = the variance of the critical path, the sum of the variances of the activities on the critical path

Z = the number of standard deviations of a normal distribution

Thus, in accordance with the calculations previously described

variance	$\sigma_\mu^2 = 4 + 25 + 4 = 33$
	$\mu = 43$
standard deviation	$\sigma = 5.745$

If the desired completion date is 50 dates, what is the probability that we can do this

$D = 50$

And therefore

$Z = (50 – 43)/5.745 = 1.22$ standard deviations

Referencing a cumulative single tail probability table, one finds that a Z of 1.22 equates to a probability of 0.8888

Thus there is an 88.88% chance of completing the project on the desired date of 50 days.

7 - Scenario Analysis

(*****This is a technique that models selected scenarios. While perhaps not exhaustive, this approach can be used to assist in decision making because the most likely, the most visible or the most risky scenarios can be played out and compared with one another.

I need to find a good example for this one Best Case/Worst Case/ Most likely is a good example of this.)

8 - Sensitivity Analysis

(*****Insert notes here…when dealing with models involving multiple variables, that contribute to a specific output, this method identifies which factors are the most important

start with nominal, i.e. typical values, and change one variable in your model to see how the final output changes. Do this with the other variables in turn and you can find out which variables are the most important, i.e which ones are the most sensitive factors affecting the output.

illustrate with surface response plots

9 –Return on Investment and Payback Period

***** insert standard definitions here

NPV – net present value
ROI – return on investment
Payback Period
IRR – internal rate of return

10 - Calculating Priorities (FMEA)

***** insert standard write-up on FMEA here

Severity
Probability
Detectability

RPN Relative Priority Number

11 - Heuristic Methods

(***** insert discussion here on scenario comparisons and discovery techniques

provide example of heuristic methods involving different scheduling algorithms in testing to optimize cycletime or throughput)
different loading conditions may result in different outcomes depending on which scheduling algorithm is used

4.0 On Planning

***insert general discussions here on the nature of planning, both strategic and tactical

The purpose to plan is to decide
The purpose to decide is to act

The different between a judgment and a decision is action

Strategic versus tactical

On complex planning - Elaboration index
    Specificity, measurability, conditionality

"The Logic of Failure", Deitrich Dorner

5.0 Displaying Decision Results

***provide examples of each

5.1Tables

Payoff Tables
Opportunity Loss Tables

5.2 Charts

Pareto
Decision Trees
Tornado Chart

5.3 Surface Response Analysis

3-D plots

5.4 Bubble Charts

ROI models would be good here

5.5 Mind Mapping

***get an example of a good mind map
and add reference to tool software

Bibliography

Logic of Failure
Etc.

Additional Topics----------------------------------

Framing the Problem

The questions you ask can often preclude the answers you want
He who frames the question wins the debate

The wording of the problem (or opportunity) statement can facilitate or prohibit appropriate decision making.

Example:

An organization with a large manufacturing database was growing increasingly slower over time and decided to remedy their problem by upgrading their CPUs

Newer, faster CPUs could process information more than two times faster than the current processors and everyone agreed that the newer CPU's would remedy the problems of slow response time and slow reports.

The new CPUs were purchased and installed. Unfortunately many problem arose because of the switchover. Accounts and privileges were changed, automated reports and jobs stopped running, logistics problems abounded and it took nearly 90 to work out the kins in the system. However, after everything was brought back to normal functioning, the system was just as slow, if not slower, than before.

The problem was their problem statement.

The team had defined the problem as "the computer is running too slow" Framing the question this way led to only one plausible solution; Upgrade to a Faster Computer. Faster.

While there was some analysis performed, it was little more than aq cost justification for the new CPUs. What the team forgot to ask was "Why is the computer running slow"

If appropriate causal analysis had been performed, someone might have remembered that there are several reasons why computers run slow.

In general terms a computer slows down when it runs out of critical resources, most often this is CPU processing capability, memory or I/O bandwidth.

In this case, the computer system was slow because of unusually high disk I/O activity. In fact, the CPu was only using about 20% of the available CPU second it had available, because the disks were so busy. The disks were bottlenecked and averaged about 80% of maximum capacity.