**Decision Analysis: Part I**

Most people often make choices out of habit or tradition, without going through the decision-making process steps systematically. Decisions may be made under social pressure or time constraints that interfere with a careful consideration of the options and consequences. Decisions may be influenced by one's emotional state at the time a decision is made. When people lack adequate information or skills, they may make less than optimal decisions. Even when or if people have time and information, they often do a poor job of understanding the probabilities of consequences. Even when they know the statistics; they are more likely to rely on personal experience than information about probabilities. The fundamental concerns of decision making are combining information about probability with information about desires and interests. For example: how much do you want to meet her, how important is the picnic how much is the prize worth?

Business decision making is almost always accompanied by conditions of uncertainty. Clearly, the more information the decision maker has, the better the decision will be. Treating decisions as if they were gambles is the basis of decision theory. This means that we have to trade off the value of a certain outcome against its probability.

To operate according to the canons of decision theory, we must compute the value of a certain outcome and its probabilities; hence, determining the consequences of our choices.

These two last sessions presents the decision analysis process both for public and private decision making under different decision criteria, type, and quality of available information. This session describes the basic elements in the analysis of decision alternatives and choice, as well as the goals and objectives that guide decision making. In the subsequent sections, we will examine key issues related to a decision-maker’s preferences regarding alternatives, criteria for choice, and choice modes.

Objectives are important both in identifying problems and in evaluating alternative solutions. Evaluating alternatives requires that a decision-maker’s objectives be expressed as criterion that reflects the attributes of the alternatives relevant to the choice.

The systematic study of decision making provides a framework for choosing courses of action in a complex, uncertain, or conflict-ridden situation. The choices of possible actions, and the prediction of expected outcomes, derive from a logical analysis of the decision situation.

**Elements of Decision Analysis Models**

The mathematical models and techniques considered in decision analysis are concerned with prescriptive theories of choice (action). This answers the question of exactly how a decision maker should behave when faced with a choice between those actions which have outcomes governed by chance, or the actions of competitors.

Decision analysis is a process that allows the decision maker to select at least and at most one option from a set of possible decision alternatives. There must be uncertainty regarding the future along with the objective of optimizing the resulting payoff (return) in terms of some numerical decision criterion.

The elements of decision analysis problems are as follow:

1. A sole individual is designated as the decision-maker. For example, the CEO of a company, who is accountable to the shareholders.
2. A finite number of possible (future) events called the 'States of Nature' (a set of possible scenarios). They are the circumstances under which a decision is made.
3. A finite number of possible decision alternatives (i.e., actions) is available to the decision-maker. Only one action may be taken. What can I do? A good decision requires seeking a better set of alternatives than those that are initially presented or traditionally accepted. Be brief on the logic and reason portion of your decision. While there are probably a thousand facts about an automobile, you do not need them all to make a decision. About a half dozen will do.
4. Payoff is the return of a decision. Different combinations of decisions and states of nature (uncertainty) generate different payoffs. Payoffs are usually shown in tables. In decision analysis payoff is represented by positive (+) value for net revenue, income, or profit and negative (-) value for expense, cost or net loss. Payoff table analysis determines the decision alternatives using different criteria. Rows and columns are assigned possible decision alternatives and possible states of nature, respectively.
Constructing such a matrix is usually not an easy task; therefore, it may take some practice.

**Source of Errors in Decision Making:** The main sources of errors in risky decision-making problems are: false assumptions, not having an accurate estimation of the probabilities, relying on expectations, difficulties in measuring the utility function, and forecast errors.



Example: Tom Brown has inherited $1000.He has to decide how to invest the money for one year. A broker has suggested five potential investments: **Bonds, Stocks, or Deposit**.

The return on each investment depends on the (uncertain) market behavior during the year, that is called the State of Nature: It might have **Growth, Medium Growth, No Change (same as is now), or Decline (i.e. Low).** Tom would build a payoff table to help make the investment decision.

|  |  |  |
| --- | --- | --- |
|  |  | **States of Nature** |
|  |  | Growth  | Medium G  | No Change | Low |
|  |  | G | MG | NC | L |
|  | Bonds | 12%  | 8 | 7 | 3 |
| **Actions** | Stocks | 15 | 9 | 5 | -2 |
|  | Deposit | 7 | 7 | 7 | 7 |

The States of Nature are the states of economy during one year. The problem is to decide what action to take among three possible courses of action with the given rates of return as shown in the body of the table.

**Decision Making Under Pure Uncertainty**

In decision making under pure uncertainty, the decision-maker has no knowledge regarding any of the states of nature outcomes, and/or it is costly to obtain the needed information. In such cases, the decision making depends merely on the decision-maker's personality type.

**Personality Types and Decision Making:**

**Pessimism**, or Conservative (MaxMin). Worse case scenario. Bad things always happen to me.

|  |  |  |  |
| --- | --- | --- | --- |
|  | B | 3 |  |
| a) Write min # in each action row, | S | -2 |  |
| b) Choose max # and do that action. | D | 7 | \*  |

**Optimism**, or Aggressive (MaxMax). Good things always happen to me.

|  |  |  |  |
| --- | --- | --- | --- |
|  | B | 12 |  |
| a) Write max # in each action row, | S | 15 | \*  |
| b) Choose max # and do that action. | D | 7 |  |

**Coefficient of Optimism (Hurwicz's Index)**, Middle of the road: I am neither too optimistic nor too pessimistic.

a) Choose an between 0 & 1, 1 means optimistic and 0 means pessimistic,

b) Choose largest and smallest # for each action,

c) Multiply largest payoff (row-wise) by and the smallest by (1-),

d) Pick action with largest sum.

For example, for = 0.7, we have

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| B |  | (.7\*12) | + |  | (.3\*3) | = | 9.3 |
| S |  | (.7\*15) | + |  | .3\*(-2) | = | 9.9 \* |
| D |  | (.7\*7) | + |  | (.3\*7) | = | 7 |

**Minimize Regret:** (Savag's Opportunity Loss) I hate regrets and therefore I have to minimize my regrets. My decision should be made so that it is worth repeating. I should only do those things that I feel I could happily repeat. This reduces the chance that the outcome will make me feel regretful, or disappointed, or that it will be an unpleasant surprise.

Regret is the payoff on what would have been the best decision in the circumstances minus the payoff for the actual decision in the circumstances. Therefore, the first step is to setup the regret table:

a) Take the largest number in each states of nature column (say, L).
b) Subtract all the numbers in that state of nature column from it (i.e. L - Xi,j).
c) Choose maximum number of each action.
d) Choose minimum number from step (d) and take that action.

|  |
| --- |
| **The Regret Matrix** |
|  | G | MG | NC | L |  |
| Bonds | (15-12) | (9-8) | (7-7) | (7-3) | 4 \* |
| Stocks | (15-15) | (9-9) | (7-5) | (7+2) | 9 |
| Deposit | (15-7) | (9-7) | (7-7) | (7-7) | 8 |

You may try checking your computations using [Decision Making Under Pure Uncertainty](http://home.ubalt.edu/ntsbarsh/Business-stat/otherapplets/ADuncertain.htm%22%20%5Ct%20%22new)

<http://home.ubalt.edu/ntsbarsh/Business-stat/otherapplets/ADuncertain.htm>

JavaScript, and then performing some numerical experimentation for a deeper understanding of the concepts, and stability analysis of your decision by altering the problem's parameters.

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**Limitations of Decision Making under Pure Uncertainty**

1. In decision making under pure uncertainty, the decision-maker has no knowledge regarding which state of nature is "most likely" to happen. He or she is probabilistically ignorant concerning the state of nature therefore he or she cannot be optimistic or pessimistic. In such a case, the decision-maker invokes consideration of security.
2. Notice that any technique used in decision making under pure uncertainties, is appropriate only for the private life decisions. Moreover, the public person (i.e., you, the manager) has to have some knowledge of the state of nature in order to predict the probabilities of the various states of nature. Otherwise, the decision-maker is not capable of making a reasonable and defensible decision.

**Decision Making Under Risk**

Risk implies a degree of uncertainty and an inability to fully control the outcomes or consequences of such an action. Risk or the elimination of risk is an effort that managers employ. However, in some instances the elimination of one risk may increase some other risks. Effective handling of a risk requires its assessment and its subsequent impact on the decision process. The decision process allows the decision-maker to evaluate alternative strategies prior to making any decision. The process is as follows:

1. The problem is defined and all feasible alternatives are considered. The possible outcomes for each alternative are evaluated.
2. Outcomes are discussed based on their monetary payoffs or net gain in reference to assets or time.
3. Various uncertainties are quantified in terms of probabilities.
4. The quality of the optimal strategy depends upon the quality of the judgments. The decision-maker should identify and examine the sensitivity of the optimal strategy with respect to the crucial factors.

Whenever the decision maker has some knowledge regarding the states of nature, he/she may be able to assign subjective probability estimates for the occurrence of each state. In such cases, the problem is classified as decision making under risk. The decision-maker is able to assign probabilities based on the occurrence of the states of nature. The decision making under risk process is as follows:

a) Use the information you have to assign your beliefs (called subjective probabilities) regarding each state of the nature, p(s),

b) Each action has a payoff associated with each of the states of nature X(a,s),

c) We compute the expected payoff, also called the return (R), for each action R(a) = Sums of [X(a,s) p(s)],

d) We accept the principle that we should minimize (or maximize) the expected payoff,

e) Execute the action which minimizes (or maximize) R(a). The following numerical example, makes it clear that expected value is the mean, i.e. arithmetic average:

**The Expected Value** (i.e., averages):

Expected Value =  =  (Xi  Pi),     the sum is over all i's.

Expected value is another name for the mean and (arithmetic) average.

It is an important statistic, because, your customers want to know what to “expect”, from your product/service OR as a purchaser of “raw material” for your product/service you need to know what you are buying, in other word what you expect to get:

To read-off the meaning of the above formula, consider computation of the average of the following data

2, 3, 2, 2, 0, 3

The average is Summing up all the numbers and dividing by their counts:

(2 + 3 + 2 + 2 + 0 + 3) / 6

This can be group and re-written as:

[ 2(3) + 3(2) + 0(1)] / 6 = 2(3/6) + 3(2/6) + 0(1/6)

which is the sum of each distinct observation times its probability. Right?

**Expected Payoff:** The actual outcome may not be equal the expected value. What you get is not what you expect, i.e. the "Great Expectations!"

a) For each action, multiply the probability and payoff and then,
b) Add up the results by row,
c) Choose largest number and take that action.

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | G (0.4)  |  | MG (0.3)  |  | NC (0.2)  |  | L (0.1)  |  | **Exp. Value** |
| B | 0.4(12) | + | 0.3(8) | + | 0.2(7) | + | 0.1(3) | = | 8.9 |
| S | 0.4(15) | + | 0.3(9) | + | 0.2(5) | + | 0.1(-2) | = | 9.5\* |
| D | 0.4(7) | + | 0.3(7) | + | 0.2(7) | + | 0.1(7) | = | 7 |

**The Most Probable States of Nature** (good for non-repetitive decisions)

a) Take the state of nature with the highest probability (subjectively break any ties),
b) In that column, choose action with greatest payoff.

In our numerical example, there is a 40% chance of growth so we must buy stocks.

**Expected Opportunity Loss (EOL):**

a) Setup a loss payoff matrix by taking largest number in each state of nature column(say L), and subtract all numbers in that column from it, L - Xij,
b) For each action, multiply the probability and loss then add up for each action,
c) Choose the action with smallest EOL.

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| --- |
| **Loss Payoff Matrix** |
|  | G (0.4)  |  | MG (0.3)  |  | NC (0.2)  |  | L (0.1)  | EOL  |
| B | 0.4(15-12) | + | 0.3(9-8) | + | 0.2(7-7) | + | 0.1(7-3) | 1.9 |
| S | 0.4(15-15) | + | 0.3(9-9) | + | 0.2(7-5) | + | 0.1(7+2) | 1.3\* |
| D | 0.4(15-7) | + | 0.3(9-7) | + | 0.2(7-7) | + | 0.1(7-7) | 3.8 |

**Computation of the Expected Value of Perfect Information (EVPI)**

EVPI helps to determine the worth of an insider who possesses perfect information. Recall that EVPI = EOL.

a) Take the maximum payoff for each state of nature,
b) Multiply each case by the probability for that state of nature and then add them up,
c) Subtract the expected payoff from the number obtained in step (b)

|  |  |  |  |
| --- | --- | --- | --- |
| G | 15(0.4) | = | 6.0 |
| MG | 9(0.3) | = | 2.7 |
| NC | 7(0.2) | = | 1.4 |
| L | 7(0.1) | = | 0.7 |
|  | + |  | ---------- |
|  |  |  | 10.8 |

Therefore, EVPI = 10.8 - Expected Payoff = 10.8 - 9.5 = 1.3. Verify that EOL=EVPI.

The efficiency of the perfect information is defined as 100 [EVPI/(Expected Payoff)]%

Therefore, if the information costs more than 1.3% of investment, don't buy it. For example, if you are going to invest $100,000, the maximum you should pay for the information is [100,000 \* (1.3%)] = $1,300

**I Know Nothing:** (the Laplace equal likelihood principle) Every state of nature has an equal likelihood. Since I don't know anything about the nature, every state of nature is equally likely to occur:

a) For each state of nature, use an equal probability (i.e., a Flat Probability),
b) Multiply each number by the probability,
c) Add action rows and put the sum in the Expected Payoff column,
d) Choose largest number in step (c) and perform that action.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | G | MG | NC | L | **Exp. Payoff** |
| Bonds | 0.25(12) | 0.25(8) | 0.25(7) | 0.25(3) | 7.5 \* |
| Stocks | 0.25(15) | 0.25(9) | 0.25(5) | 0.25(-2) | 6.75 |
| Deposit | 0.25(7) | 0.25(7) | 0.25(7) | 0.25(7) | 7 |

**A Discussion on Expected Opportunity Loss (Expected Regret):** Comparing a decision outcome to its alternatives appears to be an important component of decision-making. One important factor is the emotion of regret. This occurs when a decision outcome is compared to the outcome that would have taken place had a different decision been made. This is in contrast to disappointment, which results from comparing one outcome to another as a result of the same decision. Accordingly, large contrasts with counterfactual results have a disproportionate influence on decision making.

Regret results compare a decision outcome with what might have been. Therefore, it depends upon the feedback available to decision makers as to which outcome the alternative option would have yielded. Altering the potential for regret by manipulating uncertainty resolution reveals that the decision-making behavior that appears to be risk averse can actually be attributed to regret aversion.

There is some indication that regret may be related to the distinction between acts and omissions. Some studies have found that regret is more intense following an action, than an omission. For example, in one study, participants concluded that a decision makers who switched stock funds from one company to another and lost money, would feel more regret than another decision maker who decided against switching the stock funds but also lost money. People usually assigned a higher value to an inferior outcome when it resulted from an act rather than from an omission. Presumably, this is as a way of counteracting the regret that could have resulted from the act.

You might like to use [Making Risky Decisions](http://home.ubalt.edu/ntsbarsh/Business-stat/otherapplets/DaRisky.htm%22%20%5Ct%20%22new)

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JavaScript E-lab for checking your computation, performing numerical experimentation for a deeper understanding, and stability analysis of your decision by altering the problem's parameters.