Decision Theory

Refail N. Kasimbeyli

Chapter 1

1 Introduction

1.1 The First Rule: Know Your Problem

1.2 Fishbone Analysis

1.3 What is Decision Analysis

1.4 Model of the Decision Problem

1.5 Example: Developing a New Product

Introduction

A number of years back, Greg Wolfson, a former student, and his wife were in the Caribbean as Hurricane Andrew approached. Understandably, they were nervous about the possibility of being stuck on the Turks and Caicos Islands during one of the worst storms of the century. Should they stay on the Islands or should they try to make it to Miami on route back home?

If they stayed and the hurricane hit the Islands, then they faced having their vacation ruined or worse. If they left, then they gave up the rest of their vacation, incurred additional costs of getting last-minute plane tickets, and ran the risk of being caught in the hurricane while in Miami.

Fortunately, Greg had studied decision theory. Decision theory helped Greg and his wife to think systematically through their decision problem - stay or flee - and reach their best decision. This turned out to be stay, and a good thing too: While Miami was being battered by Hurricane Andrew, Greg and his wife were on a Hobie Cat, sailing the lovely turquoise waters of the Turks and Caicos Islands.

In this lecture note we examine some tools for problem solving, such as decision theory.

A word of caution: As powerful as these tools are, they are not a substitute for your own thinking. Rather, they are aids to your thinking.

Put another way, they are not magic formulae that can make your decisions for you (which is just as well, since otherwise someone would program a computer with them, which would likely do you out of a job).

1.1 The First Rule: Know Your Problem

Before you can solve a problem, you have to know what it is. This may seem so obvious that it hardly warrants mention. Obvious though it may be, the truth is that people are not always that good at identifying what the problem is. This may surprise you - after all, you have been solving problems in and out of school for as long as you can remember.

However, most of the problems we solve in school (and life) have been given to us. Were asked to solve problems that someone else has posed. But part of good management is identifying the relevant problems. An example may help to illustrate the issue.

Example 1 [Sterling Chemicals]: Sterling Chemicals, Inc. was founded in 1986 in a $213 million leveraged buyout of Monsanto Corporations Texas City plant. The plant is located on Galveston Bay and manufactures seven commodity chemicals and their coproducts.

The plant has the worlds largest styrene monomer unit, and is the only domestic producer of synthetic lactic acid and tertiary-butylamine. In 1987, its first year of operation, Sterling employed 950 people and had sales of $413 million.

At Sterlings Texas City plant, setting up scaffolding is the first task in most repair and maintenance jobs. If the required scaffolding is not available, the job falls behind schedule and tradesmen end up waiting rather than working. Currently, scaffolding is available for only 43% of scheduled jobs.

A carpenter with fourteen years experience described the problem as follows:

Carpenters always complained about not being able to find enough scaffolding. The shortages were so bad that we were spending more time trying to find scaffolding than we spent erecting it. The necessary scaffolding was never at the scaffolding storage racks near the project site, so we usually had to check storage racks throughout the plant. We calculated that $500,000 worth of labor was being spent each year looking for scaffolding.

A study found that for 57% of all maintenance projects there was not enough scaffolding available at the scaffolding storage area nearest the project site. This required carpenters to search other, nearby racks for the necessary scaffolding. In 24% of the cases, they had to ask the truck department to search the plant for the scaffolding needed.

In short, considerable time and effort were devoted to collecting the necessary scaffolding. Some think the solution is obvious - the plant does not have enough scaffolding. One estimate is that Sterling needs $100,000 worth of additional scaffolding.

Management is, however, wary about spending money on improvements unless it is absolutely necessary, so management wants further analysis and thought.

Problems: A problem is a question.

What was the problem at Sterling Chemical? The common answer is ”Sterling Chemical has too little scaffolding.” But that is wrong. The problem is ”Why is not scaffolding readily available?” A possible answer (i.e., *cause* of the problem) is that Sterling has too little scaffolding, but that is not the problem. A problem is something to be solved; it is a question, typically beginning with ”Why...”

1.2 Fishbone Analysis

Once we have identified the problem we wish to solve, we need to solve it. There are many methods of solving problems and it is beyond these notes to cover all of them. Instead, the focus in these notes will be on two methods.

One, which we will take up later is decision analysis, which is useful for solving decision problems (this was the type of analysis employed by Greg Wolfson). The second, which is better suited to more open-ended problems, is fishbone analysis.

Figure 1.1 illustrates what fishbone analysis is all about.

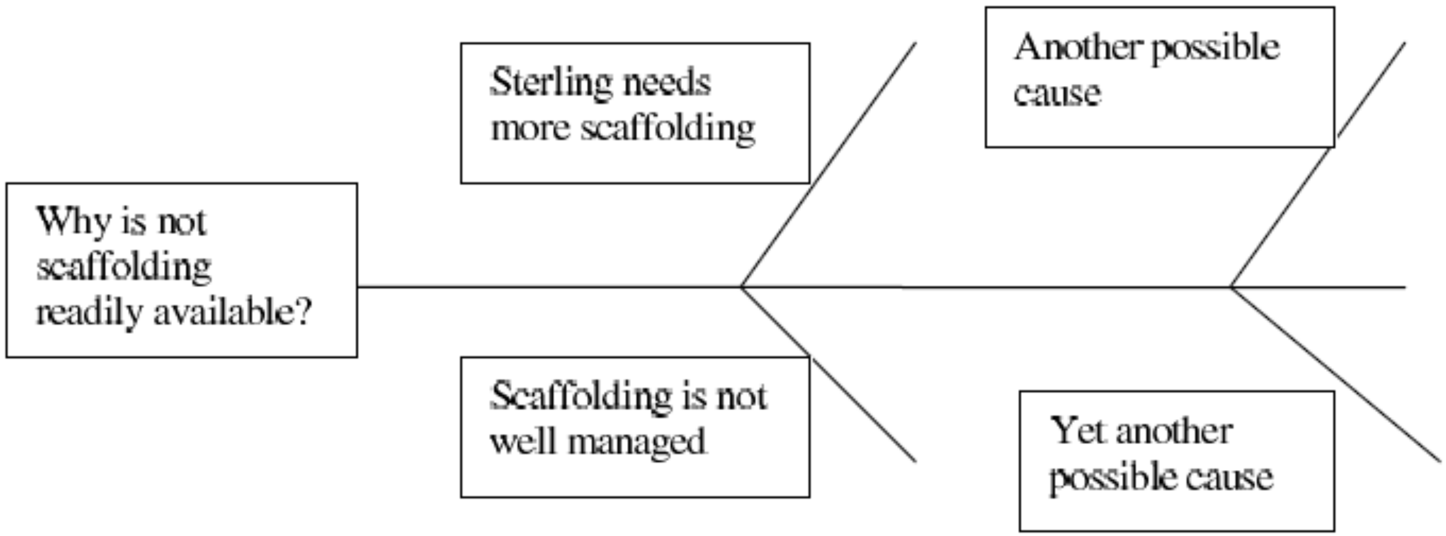

Figure 1.1: **Fishbone Analysis.** A problem (e.g., ”why is not scaffolding readily available”) is put in a box (”the head”) and then possible causes are suggested (”the ribs”), with those closest to the head being seen as the most likely.

The problem - e.g., ”Why is not scaffolding readily available?” - is put in a box at the front of the diagram. Then possible causes for the problem are listed. Here two have been given ”Sterling needs more scaffolding” and ”Scaffolding is not well managed.” Room has been left for other possible causes.

If you have some imagination, you can see why this is called fishbone analysis the diagram resembles a fish’s skeleton. Observe the problem to be solved is the ”head” of the fish and the possible causes are the ”ribs.” Typically, possible causes that have the greatest likelihood of being the true cause are put closest to the head. Less plausible causes are put further from the head.

Once your fish is drawn, the next step is to investigate each of the possible causes, starting with the ribs closest to the head. Following that course of action, consider the first rib: ”Sterling needs more scaffolding.” How do we know if this is the cause? One answer is to inventory the scaffolding and check. This is, in fact, what Sterling did after drawing its fish.

When Sterling inventoried its scaffolding, what it found " ... was that we had more than enough scaffolding on site, but that it was frequently in the wrong place at the wrong time." In fact, Sterling had 133 extra units of scaffolding.

Clearly, the proposed cause, ”Sterling needs more scaffolding,” is wrong. Moreover, the evidence from inventorying the scaffolding supports the proposed cause ”Scaffolding is not well managed.” So Sterling investigated this. What it found was that various teams were hoarding scaffolding. As one carpenter put it:

We all knew that there were guys out there who hoarded scaffolding. If you ever needed a cross brace, you knew that Charley would have some. And if you needed a ladder section, you knew that Bob was a specialist in those. They hoarded what they used frequently so that they would not have to go scavenging. But this caused shortages at other storage racks.

As a consequence, Sterling adopted changes to its scaffolding management that all but eliminated shortages (necessary scaffolding was immediately available 97% of the time). Observe that by deploying fishbone analysis, Sterling avoided jumping to the ”obvious” but false solution of buying more scaffolding.

At the very least, then, this analysis kept Sterling from wasting $100,000. Furthermore, to the extent additional scaffolding would not have fixed the availability problem, it potentially saved Sterling even more.

1.3 What is Decision Analysis

The first rule of decision making: Know your goals (objectives).

In many cases, solving your problem involves choosing among alternatives. Your objective is to choose the alternative that is best, where ”best” depends on what your goals are.

Indeed, the first rule of decision making is to know what your goals are.

For example, if your decision problem is which movie to see at the multiplex, then ”best” means ”most entertaining” (assuming being entertained is your goal).

Although the first rule of decision making may strike you as obvious, you would be surprised how often people start making decisions without thinking through what their goals are.

For instance, obeying the first rule can often be a problem when a committee makes a decision, because committee members can have different goals. Sometimes the committee members recognize their differences in advance, but sometimes they are unspoken.

Occasionally committee members believe they are in agreement with respect to their goals when, in fact, they are not (you’ve likely had conversations that began ”it just didn’t occur to me that you wanted ...”).

Psychology also plays a role here. You may not, for example, want to admit to yourself what your true goals are - perhaps because they are socially unacceptable - so you convince yourself that your goals are something else.

Unfortunately, it is beyond these lecture notes to make sure that you obey the first rule. All they can do, as they have just done, is point out that obeying the first rule is not as easy as it may at first seem.

Having identified your goals, you next have to identify your alternatives. For some decision-making problems, your alternatives are obvious. For instance, if you are deciding which movie at the multiplex to see, then your alternatives are the movies playing plus, possibly, not seeing any movie at all.

For other problems, however, identifying your alternatives is more difficult. For instance, if you are deciding which personal computer to buy, then it can be quite difficult to identify *all* your alternatives (e.g., you may not know all the companies that make computers or all the optional configurations available).

Fortunately, there are ways to overcome, at least partially, such difficulties, as we will see later. We will even study the *decision* of whether you should expend resources expanding your list of alternatives later in these notes.

Your choice of alternative will lead to some consequence. Depending on the decision-making problem you face, the consequence of choosing a given alternative will be either known or uncertain.

If you are driving in your neighborhood, then you know where you will end up if you turn left at a given intersection. If you are investing in the stock market, then you are uncertain about what returns you will earn.

Typically, we will suppose that even if you are uncertain about which particular consequence will occur, you know the set of possible consequences. For instance, although you don’t know what your stock price will be a year from now, you do know that it will be some non-negative number.

Moreover, you likely know something about which stock prices are more or less likely. For example, you may believe that it is more likely that your stocks price will change by 20% or less than it will change by 21% or more.

Sometimes, however, you may not know what all the possible consequences are. That is, some possible consequences could be unforeseen. To give an example, the author once met a vineyard owner who was proud of his green farming techniques. Unlike many of his fellow vintners, he used pesticides that killed only the bad bugs, leaving the good bugs - those that ate the bad bugs - alive.

A consequence of this, which was unforeseen by the vintner, was that if he successfully killed the bad bugs, then the good bugs would be left with nothing to eat and would starve.

Un-goals: A good manager tries to identify unintended consequences.

By their very nature, unforeseen consequences are difficult to identify prior to making your decisions. And for the same reason, it is difficult to predict which consequences will be unforeseen by others. As a practical manner, one way to *help* identify unforeseen consequences in your own decision making is to think about what your ”un - goals” are; that is, the consequences you would like *not* to happen.

For instance, an un-goal of the vintner was to kill the good bugs. Another way to identify unforeseen consequences is to reframe your way of thinking about your goals. For instance, instead of thinking about not killing the good bugs, think instead of helping the good bugs to survive. Reframed in this way, the adverse consequence of killing the good bugs' food supply might be more apparent.

As you will (should) learn in organizational behavior how we think about a problem is very much tied to how the problem is framed. It is beyond the scope of these notes to discuss framing effects fully, but it is worth pointing out they exist.

What is decision analysis?

Decision Analysis (DA) involves the use of a rational process for selecting the best of several alternatives. The ”goodness” of a selected alternative depends on the quality of the data used in describing the decision situation. From this standpoint, a decision-making (DM) process can fall into one of following categories.

1. Decision-making under certainty in which the data are known deterministically.

2. Decision-making under uncertainty in which the data cannot be assigned relative weights that represent their degree of relevance in the decision process.

3. Decision-making under risk in which the data can be described by probability distributions.

4. Decision-making under conflict where the environment consists of rational opponents with conflicting interests.

5. Decision making in multicriteria environment, where the alternatives should be evaluated with respect to several criteria.

In effect, under certainty, the data are well defined, and under uncertainty, the data are ambiguous, Decision-making under risk thus represents the ”middle-of-the-road” case. Decision-making under certainty deals with the situation when the consequences of alternative decisions are known with a reasonable degree of certainty.

This decision making environment enables formulating helpful mathematical models (linear programming, integer programming, nonlinear programming, etc.) with objective functions that specify the estimated consequences of any combination of decisions.

Although these consequences usually cannot be predicted with complete certainty, they could at least be estimated with enough accuracy to justify using such models (along with sensitivity analysis, etc.).

However, decisions often must be made in environments that are much more fraught with uncertainty. Here are a few examples.

1. A manufacturer introducing a new product into the marketplace. What will be the reaction of potential customers? How much should be produced? Should the product be test marketed in a small region before deciding upon full distribution? How much advertising is needed to launch the product successfully?

2. A financial firm investing in securities. Which are the market sectors and individual securities with the best prospects? Where is the economy headed? How about interest rates? How should these factors affect the investment decisions?

3. A government contractor bidding on a new contract. What will be the actual costs of the project? Which other companies might be bidding? What are their likely bids?

4. An agricultural firm selecting the mix of crops and livestock for the upcoming season. What will be weather conditions? Where are prices headed? What will costs be?

5. An oil company deciding whether to drill for oil in a particular location. How likely is oil there? How much? How deep will they need to drill? Should geologist investigate the site further before drilling?

These are the kinds of decision making in the face of great uncertainty that *decision analysis* is designed to address. Decision analysis provides a framework and methodology for rational decision making when the outcomes are uncertain.

1.4 Model of the Decision Problem

We adopt the following standard form of a decision problem for decision analysis. The decision maker is faced with

1. A set of r alternative actions $A = \{a_1, a_2, ..., a_r\}$;

2. A set of q states of nature $S = \{s_1, s_2, ..., s_q\}$ where s_j is usually treated as a random variable whose probability of occurrence $P(s_i)$ may be known;

3. A set of rq outcomes or results of his actions, which is denoted by an action-environment pair (a_i, s_j), i.e., $Q = \{(a_1, s_1), ..., (a_i, s_j), ..., (a_r, s_q)\}$;

4. a set of rq payoff values, which may be in terms of monetary values or utility, $U = \{u_{11}, \ldots, u_{ij}, \ldots, u_{rq}\}$, where $u_{ij} = \omega(a_i, s_j)$ and ω is the payoff function defined on the outcome set Q;

5. the decision criterion to be optimized, $f(a_i)$, where f is a real-valued function defined on A.

The decision maker is confronted with the problem of choosing an alternative action a_i that optimizes the decision criterion $f(a)$. An action a_i may be a simple and explicit alternative (such as choosing among several different projects (1, 2, ..., r) or it can be more complex (such as choosing a strategy, which is a rule for taking action based on the information about the environment).

A state of nature s_j is an aggregate representation of all relevant uncontrollable (by the decision maker) factors surrounding the decision problem. A particular outcome (a_i, s_j) comprises controllable and uncontrollable parts and results from taking a particular action a_i (controllable) in a particular state of nature s_j (uncontrollable).

A value of payoff for each outcome u_{ij} or $\omega(a_i\,,\ s_j\,)$ reflects the decision maker's preference for that particular outcome. More precisely, the payoff value is a measurement of the decision maker's preference for each outcome. This may be done subjectively or objectively.

A useful compact form of presenting *A, S, Q*, and *U* is the *payoff matrix* presented in Table1.1.

	s_1	s_2	...	s_q
a_1	u_{11}	u_{12}	...	u_{1q}
a_2	u_{21}	u_{22}	...	u_{2q}
...	...	...	...	...
a_r	u_{r1}	u_{r2}	...	u_{rq}

Table 1.1: Payoff Matrix

Finally, a decision rule for choosing the ”best” available action is specified in this case in terms of the decision criterion f to be optimized. There is a variety of common decision rules which will be discussed below in Section 1.1.4.

1.5 Example: Developing a New Product

A company is considering launching a new product. The marketing manager of the company, after gathering and considering a considerable amount of data, projects that there is about 75% percent chance that the demand for this product will increase by 20% from the current level within a one year period and about 25% percent chance that the demand will fall by 5% from the current level within the same period.

The managing director of the company is considering three possible alternative actions:

1. do nothing

2. operate with the existing machines in the plant, but put employees on overtime; or

3. buy additional machines.

After possible levels of demand and responses to them have been identified, the accounting department of the company makes a thorough cost-benefit estimation for each option and each level of demand, yielding the following estimates of profits or payoff:

If the level of demand actually rises at the projected rate, the profits for next year will be $1.5, $2.0, and $2.1 million for options 1, 2, and 3, respectively. On the other hand, if the level of demand falls at the projected rate, the estimated profits for next year will be $1.4, $1.4, and $1.0 million for options 1, 2, and 3 respectively.

What we have just described is the situation of a decision problem that is amenable to the decision analysis procedure. In terms of our standard terminology, this decision problem can be written in a compact form.

For the set of alternative actions $A = (a_1, a_2, a_3)$, where a_1 denotes continue to operate as before, a_2 institute overtime, and a_3 buy additional machines; and the set of states of nature $S = s_1, s_2$, where s_1 denotes the level of demand rises by 20% and s_2 the level of demand falls by 5%, we have the payoff matrix shown in Table 1.2.

Table 1.2: Payoff matrix for the example

	Level of demand (millions of $)	
Action	$s_1[P(s_1) = 0.75]$	$s_2[P(s_2) = 0.25]$
a_1	1.5	1.4
a_2	2.0	1.4
a_3	2.1	1.0

If the philosophy of the company is to maximize profit, an appropriate decision rule that can be used is to maximize expected monetary value (EMV). That is, we shall choose a course of action which yields the maximum expected profit.

From the payoff matrix, the expected profit

for option a_1 is

$$0.75 \times 1.5 + 0.25 \times 1.4 = 1.475,$$

for option a_2 *is*

$$0.75 \times 2.0 + 0.25 \times 1.4 = 1.85, \qquad \leftarrow \textit{maximum}$$

and for option a_3 *is*

$$0.75 \times 2.1 + 0.25 \times 1.0 = 1.825.$$

Hence, according to the specified decision rule, the company would choose option a_2 (overtime), which yields the highest EMV. Several other commonly used decision rules could have been used, as will be discussed in a later chapter.