Introduction to Influence Diagrams, Influence Tables and Decision Trees

We are faced with a decision. There are several alternatives. There are intermediate relationships between our decision and the final outcome (performance measure). Alternatives are intermediated connectors that move from the decision to the performance. Certain events or alternatives will influence our final performance measure, which quite often is profit. We need to learn how to structure the assumptions (explore the alternatives) that connect our decision through many possible alternatives to our ultimate goal of performance. There are three approaches which may be helpful – Influence Diagram, Influence Table and Decision Tree.

**Influence Diagrams** are pictures of the interrelationships between the decision nodes and the performance nodes. They may show what quantities are involved, how they are related to each other, how they are affected by alternatives and how they affect performance. Influence Diagrams are useful in framing assumptions (examining influences). An Influence Diagram builds a rather neat arrangement of your assumptions which in turn allows you to develop MS Excel spread sheets to solve the decision problem. An Influence Diagram by and of itself does not quantify any decision, but it does show interrelations between all of the nodes. One problem with an Influence Diagram is that it does not show a logical flow from left to right (Western mind thinking) beginning with the decision statement to the ultimate performance measure. The picture you draw can be rather random and is therefore sometimes hard to follow.

**Influence Tables** are usually displayed in an MS Excel workbook. An Influence Table displays a somewhat more logical flow. On the left of the table all items are listed that flow from a particular node. At the top of the table are all items listed that flow to a particular node. In other words, the items on the left flow to the items listed at the top. The cell intersection is marked by and “X”. When working with an Influence Table you still do not have a logical left to right flow; however, Influence Tables are somewhat easier to read. They too, however, must be converted to an MS Excel spread sheet to quantify the results of the decision.

Both Influence Diagrams and Influence Tables are useful in helping you frame or structure the assumptions associated with your decision choices. They serve a useful purpose in helping you think through the relationships in order to develop the methods to actually quantify the solution.

**Influence Diagrams Contain the following:**

- Decision Nodes.
- Intermediate or Quantity (a single value – usually) Nodes.
- Performance Nodes.
- Connectors
Influence Diagrams may be simple or extremely complex. There are several examples in many textbooks or you might find some helpful information on the web, although most of the information on the web is highly mathematical and well beyond the scope of this course. We will look at Treeage software that helps develop Influence Diagrams. One link you might want to view is [www.lumina.com/software/influencediagrams.html](http://www.lumina.com/software/influencediagrams.html). You may want to type “influence diagrams” in your browser window and review some of the sites.

If you draw Influence Diagrams, it is important you learn the “language” of an Influence Diagram. Certain shapes represent certain results. Those shapes are summarized in the following table. These are relatively consistent in the Influence Diagram world.

<table>
<thead>
<tr>
<th>Picture</th>
<th>Shape</th>
<th>Represents</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image" alt="Rectangle" /></td>
<td>Rectangle</td>
<td>Decision Node</td>
</tr>
<tr>
<td><img src="image" alt="Rounded Square or Square With Points Up" /></td>
<td>Rounded Square or Square With Points Up</td>
<td>Measurement or Performance Node</td>
</tr>
<tr>
<td><img src="image" alt="Oval" /></td>
<td>Oval</td>
<td>Alternatives of Intermediate Node (Quantities)</td>
</tr>
<tr>
<td><img src="image" alt="Oval with Tilde" /></td>
<td>Oval with Tilde</td>
<td>Uncertain Alternatives of Intermediate Node (Quantities)</td>
</tr>
<tr>
<td><img src="image" alt="Arrow" /></td>
<td>Arrow</td>
<td>Influences Between Alternatives, Intermediate Nodes (Quantities)</td>
</tr>
</tbody>
</table>
Simple Influence Diagram. Figure 3.1 simply shows the relationship from Price to Profit. The decision node of price flows to the performance node of profit. What we are saying is that the decision facing us is one of price. The decision might be to lower price or raise price or determine the price of a new product. The decision made about price will influence profit, our performance node.

![Simple Influence Diagram](image1)

More Complex. Figure 3.2 displays two other intermediate nodes – revenues and total costs. As we look at the decision of price we know that profit is not necessarily a direct relationship. There are usually more intervening nodes that ultimately influence the performance node, profit. In this case we have identified two – revenue and total cost which will also influence the performance outcome of profit.

![More Complex Diagram](image2)

Here the pricing decision influences revenues (intermediate node), which in turn influences the performance node of profit. Total cost is not influenced by price; therefore, no influence arrow between price and total cost is necessary. Total costs do, however, influence profit so there is an arrow between the performance node of profit and the intermediate node of total costs.
Still More Complex. Figure 3.5 displays a rather complex Influence Diagram. Note that a second decision node has been added – subcontractor. This might become necessary when the capacity of the company is exceeded and outsourcing some of the production must be considered.

Remember this is an Influence Diagram and not a flow diagram. Each decision node is noted as a square. There are two decision nodes in this Influence Diagram – price and subcontractor. There is one performance measure – profit. The other nodes are intermediate and reflect which intermediate events are influenced by other intermediate events and ultimately how they affect the performance node (profit). Also take note of the tilde in the Units Sold box. The tilde represents uncertainty.

Other relationships can exist when completing an Influence Diagram – two way influences and loops. Generally textbooks touch on these and we will not take the time to work through them at this point. Loops are usually eliminated by using a time period reference of n-1 or n+1 from a base period of n.

An Influence Diagram is not the following:

- A Flow Chart. (The arrow does not mean units flow from A to B)
- A Precedence Chart (The arrow does not mean "must be preceded by").
- A Representation of Hierarchical Structure (The arrow does not mean "is an element of" such as in an organizational chart.)
Sometimes drawing formal boxes, rounded squares and ovals is necessary for formal presentations, yet hand sketches may be just a valuable if you are dealing with preliminary idea development.

**Influence Diagram Tables:**

Another approach is to use an Influence Diagram Table to display the same results as the Influence Diagram. A table might look like the following:

<table>
<thead>
<tr>
<th>NODIES</th>
<th>Revenue</th>
<th>Units Sold</th>
<th>VC per Unit</th>
<th>Variable Cost</th>
<th>Total Cost</th>
<th>Profit</th>
</tr>
</thead>
<tbody>
<tr>
<td>FROM</td>
<td>Price</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Units Sold</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Revenue</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>VC per Unit</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Var. Cost</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Fixed Cost</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Total Cost</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The influence direction is from the **ROW** to the **COLUMN**. The column headings will be objects **into which** the influence arrows flow. The row headings will include only objects **from which** influence arrows flow. Notice the profit (performance measure) is only shown in the column headings. This is because all things eventually either directly or indirectly flow into the performance measure. The performance measure (profit) never flows into anything (except the pockets of the stockholders – hopefully). The table is read the same way as an Influence Diagram. For example, price (the decision node) influences revenues and units sold. Units Sold (intermediate node) influence revenues, variable cost per unit and variable cost.

Sometimes it is easier to use the table approach rather than the diagram approach. Either is an acceptable method of studying the intermediate complexities **between the decision node and the performance measure** (profit in this example). The intent and purpose of either the Influence Diagram or the Influence Diagram Table is to aid you in thinking through the problem and the interactions of all of the intermediary events from decision to performance.

**Structuring a Sequence of Decisions and Uncertainties Using a Decision Tree:**

Probably one of the more helpful approaches in structuring decision models is a Decision Tree, especially if there are **chronological sequences** of decisions that interact with uncertain quantities or events. Decision Trees may sometimes be easier than either an Influence Diagram or Influence Tree. You can actually apply values to the stages in the Decision Trees to calculate certain values. The
Decision Tree uses probabilities and outcomes usually expressed in dollars for making certain calculations called Expected Monetary Values (EMV). A positive EMV is good and the highest EMV often leads to the best decision path. The Decision Tree is more detailed than the Influence Diagram or Table.

In addition to Influence Diagrams, Decision Trees can also present the elements of a decision (paths or options available to the decision maker). It may be best to use the tree when there are a few distinct alternatives and a few distinct outcomes for other quantities (or uncertain events). As in Influence Diagrams, certain shapes in Decision Tree presentation represent certain events. Typically squares represent the decision node. Circles represent the chance node (uncertain events with uncertain outcomes) and triangles represent the outcome value or consequences (the end point-performance measure).

A typical, yet simplified, Decision Tree for deciding if you are going to sue or not sue in a legal matter might look like the following:

Notice that there is a left to right flow in the diagram. The decision node is designated by a square – sue or not – and is first in sequence. If we do not sue, the “don’t” leg ends with a triangle which designates a terminus point. If we do sue, there are three possible outcomes – win, lose and have the case thrown out. The circle leading to these three options is an intermediate node. Each of the three legs of the sue branch end with a triangle, which is the terminus for each leg. The terminus points are the end of the decision model. Flow is from left to right in a logical manner (Western mind thinking again). For now ignore the “no payoff” comment at the end of each terminus. This will be addressed later. Ultimately probabilities and monetary values may be attached to these outcomes to give the decision maker insight into which is the more profitable leg or route to take in deciding if the suit should or should not be filed.

Contrasts: Influence Diagram or Influence Diagram Tables do not have a sequential order. Decision trees yield a sequence which leads to the performance node and thus the best decision. It is my personal belief that working with Decision Trees will prove to be more rewarding as you make business decisions than either Influence Diagrams or Influence Diagram Tables.
The main usefulness of the former two is in learning how to structure the model. The Decision Tree can then be applied to quantify the results of the model. All three play important roles in making business decisions.

<table>
<thead>
<tr>
<th>Influence Diagram (ID)</th>
<th>Decision Tree (DT)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ID tells more about the dependency among the variables</td>
<td>If there are a small number of paths, DT is easier</td>
</tr>
<tr>
<td>Arcs (Arrows) in ID show what influences what.</td>
<td>ID is more flexible.</td>
</tr>
<tr>
<td>ID may be better if a range of results exist for the</td>
<td>DT will be better than ID when the decision process</td>
</tr>
<tr>
<td>decision quantities and intermediated quantities.</td>
<td>has a number of uncertainties over time.</td>
</tr>
<tr>
<td>ID is more flexible.</td>
<td>ID does not require an order.</td>
</tr>
<tr>
<td>ID can be free form.</td>
<td>DT shows more detail and time relationships.</td>
</tr>
<tr>
<td>ID shows more about the structure than DT.</td>
<td>In DT not all possible paths through a decision</td>
</tr>
<tr>
<td></td>
<td>outcome sequence are always symmetrical.</td>
</tr>
</tbody>
</table>

**Formal Display Techniques:**
- Squares = Decisions
- Circles = quantities that range over some continuous interval.
- Rounded Square = Outcome which is the value or performance node.
- ID is helpful in model building for a DT.

**Formal Display Techniques:**
- Circles = Uncertain Events-Chance node.
- Squares = Decisions
- Triangles = Consequences or Outcome.

**Introduction to the Use of Treeage Software:**

There is helpful software available that aids you in preparing both Influence Diagrams and Decision Trees (other analysis also). This software is relatively inexpensive for the student version. The company also has as of this writing a 21 day free trial offer where you can download the program and try it. Access the software from [www.treeage.com](http://www.treeage.com). It is suggested you use the 21 day free trial (if still available) before deciding to purchase the software. All of the calculations provided by the software can be manually done, but you will find the small investment in the product (about $45) will save you much more in time, energy and effort when you come to the case analysis sections. This software has an excellent, user friendly tutorial which will walk you through the steps.
An Example:

Let’s walk through an example at this point assuming you have access to the software. We will not explore a step by step solution, but will rather present the problem and then show the output solutions in the form of an Influence Diagram and a Decision Tree. You need to print this section and then go to the Treeage software to complete the exercise. IF YOU DO NOT YET HAVE THE TREEAGE SOFTWARE, THEN YOU MAY SKIP THIS SECTION AND COME BACK TO IT LATER, ALTHOUGH YOU MAY WANT TO READ THROUGH THE APPLICATION.

The Opportunity: You have $1,000 to invest. You have two alternatives you are considering for that investment. You can invest in a CD which yields an APR of 5% for a gain of $50 for the year or you can invest in a more risky investment which may take one of three paths. You can experience a large increase of $500, which has a probability of 0.30. You can experience a small increase of $100 which has a probability of 40% (0.40). You can experience a large decrease of $6,000, which has a probability of 0.30. Notice the probabilities total the magic number of 1.00.

You first decide you want to develop an Influence Diagram. Open the treeage software and go to file. There you will select “Influence Diagram” You will then use the buttons at the top and far right of the tool bar to draw the following Influence Diagram. The decision node will be “How Do You Invest $1,000?” The performance node will be “Profit”. The only thing that will influence the outcome (performance node) will be what happens in the market or “Market Conditions.” The Influence Diagram as developed by the treeage software will reflect the following graphic.

![Influence Diagram](image)

This is a relatively simple Influence Diagram. Drawing it in treeage software was also quite easily accomplished. Chapter 3 in the Treeage tutorial will walk you through the steps.
You next decide that you need to look at the possible decision to see which might be the most effective decision. You now believe a Tree Diagram is the best solution to analyze all possible outcomes. This too is done by using the treeage software. Open treeage and go to file. This time you will select Tree Diagram. Next you will begin building the tree by using the node buttons until you get a final outcome that looks like the following. Right now for this portion of the Decision Tree payoff and probabilities will be ignored. We will also ignore the final step called rollback where the best decision leg is identified. These steps will be added one at a time in succession. In real situations, you will do the actual Decision Tree with all of this information included at the same time.

**Step I: Create the Basic Decision Tree with All Possible Outcomes.**

![Decision Tree Diagram]

At this point, notice the difference in the Influence Diagram and the Decision Tree. The Influence Diagram is relatively simple and shows how one node influences another node. The movement is from the decision node to the performance node. The Decision Tree is somewhat more complicated in that it includes all of the possibilities associated with the decision you need to make “How Do You Invest $1,000?” Also notice that the Decision Tree designators are slightly different – a square node is a decision, a round node is an uncertain event and a triangle is a terminal point or leg.

Note that the decision node in the Influence Diagram is shows as the decision node for the Decision Tree. The Market Conditions in the Influence Diagram is shown as Large Increase, Small Increase and Large Loss in the Decision Tree. There is compatibility between the Influence Diagram and the Decision Tree, but the Decision Tree gives more information and allows you to calculate the best path for the best decision given the information as stated in the problem.
You can now add more to the Decision Tree by using the payoff amounts given in the original problem statement. Now the Decision Tree will look like the following:

**Step II: Add the Payoffs for Each Leg of the Decision Tree.**

![Decision Tree Diagram]

The next step will be to add the probabilities to this Decision Tree.

**Step III: Add Probabilities for Each Possible Risky Investment Outcome.**

![Decision Tree Diagram with Probabilities]

Information in the case indicated the probability for a large increase of $500 was 30%, for a small increase was 40% and for a large loss was 30%. These percentages or probabilities total 1.00, which they must.
The final step is to use the *roll back* command to apply the probabilities to the outcomes to determine the best decision. The best decision will maximize the profit from the investment. It is a weighted average of the probabilities times the monetary value (payoff).

**Step IV: Roll Back**

Here the expected monetary value (EMV) is positive at $10 for the risky path and positive at $50 for the CD. In this instance, the risky path is not the best decision. Investing in the CD yields a larger EMV. Notice the double lines on the risky path. This indicates this path should not be selected (cut off from consideration).

It is worth noting there is a difference in monetary value and expected monetary value. Using the risky path as an example, you have monetary values of =$500, +$100 and -$600, but you have an expected monetary value of +$10. In reality we would never experience the EMV (expected monetary value).

Okay, you say. So what is the +$10?

This value is a weighted average of the payoffs (monetary values) times the probability of that particular outcome occurring. If this weighted average is positive, then the anticipated profit is positive. However, in this case the expected monetary value of the CD is larger, so we would select the CD as the investment.

In reality you would never present the four steps separately as shown above. You would do Step I, II and III at the same time. After completing those three, you would then use the Roll Back command to determine the best decision. As the Decision Tree gets more complex this software technique is quite valuable.

If you want to know how to do these calculations manually, please contact the professor for separate instruction or use the method in the textbook.