A tutorial introduction to TreePlan
1. **INTRODUCTION**

This document provides a basic introduction to decision tree modeling and the use of the TreePlan Excel add-in for building decision tree models. The following example problem is used to illustrate the modeling tools.

**Example problem**

A group of towns in the Pyrénées mountains intends to develop a ski resort. Two possible sites have been identified for this resort. The regional council is currently conducting economic and environmental studies on the merits of the two sites. A final decision on the location of the resort is not expected to be made for another year. Land values around the two possible sites are increasing as investors speculate that property values will go up sharply in the vicinity of the new resort.

ImmoTop, a private real estate developer, would like to build housing units near the new ski resort. To this end, they have identified parcels of land near the two sites. Current prices and estimated future values of developable land are summarized in the table below.

<table>
<thead>
<tr>
<th>Real Estate Acquisition Analysis</th>
<th>Parcel of land near location</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A</td>
</tr>
<tr>
<td>Current purchase price</td>
<td>1200</td>
</tr>
<tr>
<td>Present value of future cash flows if resort is built at this location</td>
<td>1500</td>
</tr>
<tr>
<td>Present value of future sales price of parcel if the resort is not built at this location</td>
<td>950</td>
</tr>
</tbody>
</table>

(Note: all values are in thousands of euros.)

ImmoTop can purchase land now either at site A only, at site B only, or at both. If land is purchased and the ski resort is not built in that location, the land is resold at a loss. If the land is not purchased now, it will not be available to ImmoTop later.

2. **DECISION TREES**

Decision problems can be represented in a graphical form known as a decision tree. Figure 1 shows the decision problem for ImmoTop represented in this format.

As shown in Figure 1, a decision tree is composed of a collection of nodes (represented by circles and squares) interconnected by branches (represented by lines). A square node is called a decision node because it represents a decision. Branches emanating from a decision node represent the different alternatives for a particular decision. In Figure 1, a single decision node (node 0) represents the decision ImmoTop faces about where to buy land. The four branches coming out of this decision node represent the four alternatives under consideration. The cash flow associated with each alternative is also listed. For example, the value
-1200 below the alternative labeled “Buy A” indicates that if the company purchases the parcel at location A, it must pay 1200.

<table>
<thead>
<tr>
<th>Land Purchase Decision</th>
<th>Resort Location</th>
<th>Payoff</th>
</tr>
</thead>
<tbody>
<tr>
<td>Buy A</td>
<td>A</td>
<td>1500</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>950</td>
</tr>
<tr>
<td></td>
<td></td>
<td>-250</td>
</tr>
<tr>
<td>Buy B</td>
<td>A</td>
<td>350</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>1100</td>
</tr>
<tr>
<td></td>
<td></td>
<td>-350</td>
</tr>
<tr>
<td>Buy A &amp; B</td>
<td>A</td>
<td>1850</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>2050</td>
</tr>
<tr>
<td></td>
<td></td>
<td>150</td>
</tr>
<tr>
<td>Buy nothing</td>
<td>A</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0</td>
</tr>
</tbody>
</table>

**Figure 1** The decision tree representation of the example problem.

The circular nodes in a decision tree represent uncertain events and are so-called event nodes. The branches emanating from event nodes (called event branches) correspond to the possible states of nature or the possible outcomes of an uncertain event. Figure 1 shows that each decision alternative emanating from node 0 is followed by an uncertain event represented by the event nodes 1, 2, 3, and 4. The branches from each event node represent possible locations of the new resort. In each case, the resort can be built at location A or B. The value attached to each branch from an event node indicates the cash flow that will occur for that decision/event combination. For example at node 1 the value 1500 next to the first event branch indicates that if the company buys the parcel at location A and the resort is built at this location, a cash flow of 1500 will occur.

The various paths in a decision tree end at the small vertical lines called terminal nodes. The payoff occurring at each terminal node corresponds to one way in which the decision problem can terminate: it is computed by summing the cash flows along the set of branches leading to each terminal node. For example, following the uppermost branches through the tree, a payoff of 300 results if the decision to buy the parcel at location A is followed by the new resort being built at this location ($-1200 + 1500 = 300$). You should verify the cash-flow values on each branch and at each terminal node before continuing.

Decision trees are particularly suited to modeling situations that involve cascades of decisions and events, that is, multiple decision phases where future decisions may depend on previous choices and chance events.
2.1 Calculating Best Decisions

After computing the payoffs at each terminal node, we can apply any of several decision rules. For example, we could identify the maximum possible payoff for each decision and apply the so-called maximax decision rule. This consists of selecting the alternative that leads to the best possible payoff. Another rule, called maximin, consists of maximizing the minimum payoff obtainable. Maximin works by identifying the worst payoff for each alternative, and selecting the alternative leading to the maximum worst case payoff. Although it has been found that decision makers do sometimes pay attention to the best and, particularly, worst payoffs in dealing with risks, the maximax and maximin rules are limited because the best and worst payoffs may be very unlikely. These rules focus exclusively on the extreme payoffs, and thus ignore information about the whole distribution of possible outcomes. A compelling rule for evaluating risky decisions is the Expected Value (EV) rule – that is, to identify the decision with the best expected value. The expected value of a risk prospect is obtained by multiplying each payoff by its probability and summing the whole.

We can apply a process known as rolling back to a decision tree to determine the decision with the largest EV. Figure 2 illustrates this process for our example problem. Because the EV decision rule is a probabilistic method, Figure 2 indicates the probabilities associated with each event branch emanating from each event node: there is a 0.4 probability of the new resort being built at location A, and a 0.6 probability of it being built at location B. To roll back this decision tree, we start with the payoffs and work our way from right to left, back through the decision tree, computing the expected values for each node. For example, the event represented by node 1 has a 0.4 probability of resulting in a payoff of 300, and a 0.6 probability of resulting in a loss of 250. Thus, the EV at node 1 is calculated as:

\[
EV\text{ at node 1} = 0.4 \times 300 + 0.6 \times -250 = -30
\]

\[
\begin{array}{c|c|c}
\text{Land Purchase Decision} & \text{Resort Location} & \text{Payoff} \\
\hline
Buy A & A & 300 \\
-1200 & B & -250 \\
\hline
Buy B & A & -350 \\
-700 & B & -350 \\
\hline
Buy A & B & 400 \\
\hline
Buy A & B & -50 \\
-1900 & A & 150 \\
\hline
Buy nothing & B & 0.6 \\
0 & 0 & 0 \\
\hline
\end{array}
\]

Figure 2 Solving the decision tree.
The expected value calculations for the remaining event nodes in Figure 2 are:

- EV at node 2 = 0.4 × -350 + 0.6 × 400 = 100
- EV at node 3 = 0.4 × -50 + 0.6 × 150 = 70
- EV at node 4 = 0.4 × 0 + 0.6 × 0 = 0

The EV for a decision node is obtained in a different way. For example, at node 0 we face a decision among four alternatives that lead to events with expected values of -30, 100, 70, and 0, respectively. At a decision node we always select the alternative that leads to the best EV. Thus, the EV at node 0 is 100, which corresponds to the EV resulting from the decision to buy land at location B. The optimal alternative at a decision node is sometimes indicated by marking with an arrow, as in Figure 2.

You might wonder if it is necessary to include event node 4 in the tree shown in Figure 2. If ImmoTop decides not to buy either parcel of land, the payoff it receives does not depend on where the resort is ultimately built – regardless of where the resort is built, the company will receive a payoff of 0. Therefore, we could just terminate the decision branch to Buy nothing with a definite payoff of 0. This is what we will do in the TreePlan implementation of the model, covered next.

3. USING TREEPLAN

A spreadsheet add-in called TreePlan can help us create and analyze decision trees in Excel. We will use TreePlan to implement the decision tree presented above in Excel.

To load the TreePlan add-in, choose the Open command from the File menu and open the file named TREEPLAN.xla provided in your course material. To create a decision tree using TreePlan, open a new worksheet, then invoke TreePlan by choosing the TreePlan command from the Tools menu (or by pressing [Ctrl][T], which is the menu short-cut for calling TreePlan). In response, TreePlan displays the dialog box shown in Figure 3.

If you click the New Tree button, TreePlan creates a tree diagram with one initial decision node and two decision branches. As shown in Figure 4, this initial tree diagram is inserted in the spreadsheet near the cell that is active when TreePlan is invoked. Also note that TreePlan uses the vertical bar symbols shown in cells F3 and F8 to denote the leaves (or terminal nodes) in a decision problem.

TreePlan automatically labels the branches in the tree as Decision 1 and Decision 2. Later, we’ll change these labels to describe more accurately the decisions in our example problem. First, we’ll add two more decision branches to the initial tree shown in Figure 4.

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1 The figures in this tutorial were generated using a registered version of TreePlan. If you use an unregistered version of TreePlan, all the dialog boxes of TreePlan will indicate ‘(Tryout)’ instead of ‘(Professional)’, and the cell in the top left corner of the tree diagram area will indicate ‘TreePlan (Tryout Version)’. Other than that, there will be no differences between what you see on your screen and the screen shots in this document. See the “About TreePlan” box at the end of this document for further information.
Figure 3 Initial TreePlan dialog box.

Figure 4 Initial decision tree created by TreePlan
3.1 **Adding Branches**

To add a new decision branch to our tree:

1. Click the decision node (cell B5).
2. Press [Ctrl][T] to invoke TreePlan.

The dialog box shown in Figure 5 appears. Because we selected a decision node before invoking TreePlan, this dialog box displays the options for working on a selected decision node. Different dialog boxes appear if we select an event node or terminal node and then invoke TreePlan. It is important to understand that TreePlan is context-sensitive – that is, the dialog box that appears when you invoke TreePlan depends on what cell is selected when TreePlan is invoked.

![Figure 5 TreePlan Decision dialog box.](image)

To add a branch to the currently selected decision node, click the Add branch option, then click OK. A third branch is added to the tree, as shown in Figure 6.
To add the fourth decision branch to the tree, we can follow the same procedure:

1. Click the decision node (cell B8).
2. Press [Ctrl][T] to invoke TreePlan.
3. Click Add branch.
4. Click OK.

The four decision branches for this problem appear as shown in Figure 7. Notice that we changed the label on each branch to reflect the decision alternatives for ImmoTop.

### 3.2 Adding Event Nodes

Each of the first three decision branches in Figure 2 leads to an event node with two event branches. Thus, we need to add similar event nodes to the decision tree shown in Figure 7. To add an event node:

1. Select the terminal node for the branch labeled Buy A (cell F3).
2. Press [Ctrl][T] to invoke TreePlan.

Because we selected a terminal node before invoking TreePlan, the TreePlan Terminal dialog box appears as shown in Figure 8.

This dialog box displays the options for working on a terminal node. In this case, we want to change the selected terminal node into an event node with two branches, as shown in Figure 8. The resulting spreadsheet is shown in Figure 9.
Figure 7 Modified tree with four decision branches labeled for the example problem.

Figure 8 TreePlan Terminal dialog box.
In Figure 9, an event node with two event branches now follows the decision to purchase the parcel at location A. TreePlan automatically labels these branches as Event 5 and Event 6, but we can change the labels to whatever we want. The cells immediately above each event branch label (cells H1 and H6) are reserved to hold the probability of each event. By default, TreePlan assumes that the events have equal probability (that is, 0.5 in the case of two branches), but we can change these values to whatever is appropriate for our particular problem.

In Figure 10, we changed the labels and probabilities of the event branches to correspond to the events occurring in the ImmoTop problem. The procedure used to create the event node for the Buy A decision could be repeated to create event nodes for the decisions corresponding to Buy B and Buy A & B. However, because all of the event nodes are identical in this problem, we can simply copy the existing event node.

You might be tempted to copy and paste the existing event node using the standard Excel commands – but if you use the standard Excel commands, TreePlan cannot update the tree settings properly. As indicated in Figure 10, TreePlan provides a built-in option that allows you to copy a section, or subtree, of a decision tree to another part of the tree. It is important to copy subtrees using this command so that TreePlan can update the appropriate formulas in the spreadsheet. To create a copy of the event node:

1. Select the event node you want to copy (cell F5).
2. Press [Ctrl][T] to invoke TreePlan.
3. Click Copy subtree.
4. Click OK.
Figure 10 Using TreePlan to copy a subtree.

Figure 11 Using TreePlan to paste the copied subtree.
This creates a copy of the selected event node on the clipboard. As shown in Figure 11, to paste a copy of this subtree into the decision tree:

1. Select the target cell location (cell F13).
2. Press [Ctrl][T] to invoke TreePlan.
3. Click Paste subtree.
4. Click OK.

We can repeat this copy-and-paste procedure to create the third event node needed for the decision to buy the parcels at both locations A and B. Figure 12 shows the resulting spreadsheet.

![Figure 12](Figure 12 Decision tree with three event nodes.)

### 3.3 Adding the Cash Flows

To complete the decision tree, we need to add the cash flows that are associated with each decision and event. TreePlan reserves the first cell below each branch to represent the partial cash flow associated with that branch. For example, in Figure 13 cell D6 represents the partial cash flow that occurs if ImmoTop buys the parcel at location A, and cell H4 represents the partial cash flow that occurs if the company buys the parcel at location A and the resort is built at that location. The remaining partial cash flows for each decision are entered in the appropriate cells in Figure 13 in a similar manner.
3.4 Determining the Payoffs and EVs

Next to each terminal node, TreePlan automatically created a formula that sums the payoffs along the branches leading to that node. For example, cell K3 in Figure 13 contains the formula =SUM(H4,D6). Thus, when we enter or change the partial cash flows for the branches in the decision tree, the payoffs are updated automatically.

Immediately below and to the left of each node, TreePlan created formulas that compute the EV at each node in the same way as described earlier in our discussion of rolling back a decision tree. Thus, cell A20 in Figure 13 indicates that the largest EV at the decision node is 100. The value 2 in the decision node (cell B19) indicates that this maximum EV is obtained by selecting the second decision alternative (that is, by purchasing the parcel at location B).

![Figure 13 Completed decision tree for the example decision problem.](image)

3.5 Other Features

The preceding discussion of TreePlan was intended to give you an overview of how TreePlan operates, its capabilities, and some of its options. Most of the other TreePlan options are self-explanatory, and you can obtain descriptions of them by clicking the Help button available in all the TreePlan dialog boxes. The Select and Options buttons available in all the TreePlan dialog boxes presented earlier lead, respectively, to the two dialog boxes shown in Figure 14.

At times we might want to select all the instances of a certain type of element in a decision tree. For example, we might want to select all the partial cash flows and display them in a
currency format, or we might want to hide all the EV values. The TreePlan Select dialog box shown in Figure 14 is designed to simplify this process. By selecting an option in this dialog box, all the elements of the type chosen will be selected automatically in the spreadsheet, enabling us to format them all at the same time.

The TreePlan Options dialog box serves two purposes. By default, TreePlan assumes that we want to analyze the decision tree using expected values. However, another technique (described later) uses exponential utility functions in place of expected values. Thus, this dialog box provides options for selecting whether TreePlan should use expected values or exponential utility functions. Also by default, TreePlan assumes that the EVs it calculates represent profit values and that we want to identify the decision with the largest EV. However, in some decision trees the expected values could represent costs that we want to minimize. Thus, this dialog box provides options for maximizing profits or minimizing costs.

![TreePlan Select and TreePlan Options dialog boxes.](image)

**Figure 14** TreePlan Select and TreePlan Options dialog boxes.

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**About TreePlan**

The developer of TreePlan, Dr Michael R. Middleton, graciously allows the Tryout Version to be distributed for educational purposes at no charge to you. If you plan to use this software package for more than 15 days, you are expected to pay a nominal registration fee. Details on registration are available near the end of the TreePlan help file, which you can access by clicking the Help button in any TreePlan dialog box, or by visiting [www.treeplan.com](http://www.treeplan.com).

This document is adapted from “*Spreadsheet Modeling and Decision Analysis*” Chapter 16, by Cliff T. Ragsdale. Second Edition. Copyright © 1998 by South-Western College publishing.