Analytical Tools & Techniques:

Decision Analysis Using Decision Tree Modeling

Analyzing the future outcome of a series of options or scenarios and their associated probabilities and costs can be a difficult task, particularly where a sufficiently complex problem precludes an intuitive answer. A probabilistic methodology called decision analysis can be used to quantitatively address this uncertainty. Decision analysis provides both an overall paradigm and a set of analytical tools to construct and analyze quantitative models of decision-making.

One frequently used form of decision analysis is a decision tree. Decision trees have long been used as an analytical tool in the fields of business, science and engineering, and public policy. Decision trees are being used with increasing frequency in law to analyze the merits of a case and the positions of the parties in an existing dispute, or to develop legal strategies and projections for transactional events.

Computerized decision tree analysis can provide an objective and flexible tool for decision making in legal disputes and transactions

In legal disputes, opposing parties tend to view the strength of their positions based primarily on their interpretation of the facts and merits of the case, and on the knowledge, experience and counsel of their attorneys. Unfortunately, this can lead to numerous obstacles to settlement including: positional bias, reactive devaluation, posturing, linkage to other disputes, risk aversion, and even emotional issues.[1] Decision tree analysis can provide disputing parties with an objective, analytical tool to deconstruct a dispute into its principle components, and to test assumptions, perceptions and probabilities of outcomes underlying not only their position, but the position of their opponents.

In legal transactions, an evaluation of future scenarios is often invaluable in making a business decision. Counsel and their clients can use decision tree analysis to address issues of risk aversion, risk transfer, and strategic planning by constructing decision trees with multiple alternatives and evaluating the impacts of their probabilities of occurrence on the expected costs of the outcomes.

An overview of the basic structure of a decision tree, the concept of expected value, and the utility of sensitivity analyses is presented in the decision tree primer **(Figure 1)**. There are three fundamental rules governing the effectiveness of decision analysis using decision trees: (1) All *options* available to the decision maker must be identified and be mutually exclusive, i.e., the decision maker can choose only one of the options; (2) All chance events or *outcomes* must be identified and be mutually exclusive, i.e., only one of the chance events or outcomes can occur, and (3) A decision tree must include all *pathways* (including all possible decisions and outcomes of chance events) that a decision maker might take through time.

Conceptually, the construction and analysis of decision trees is simple and straightforward. However, there are numerous inexpensive computer software programs, such as TreeAge™, Crystal Ball™, and PrecisionTree™, which facilitate more efficient analysis of decision trees, particularly where there are complex trees involved and /or where there is a desire to conduct iterative analyses to answer "what if" questions. **Figures 2 and 3** illustrate some examples of how decision tree modeling may be used.

As with any analytical tool, the value of the output is directly proportional to the quality of the input. Decision tree analysis, whether done by hand or by computer, should be conducted with realistic determinations of those quantities relevant to the situation being analyzed. In addition, the results of a decision tree analysis should not be used as a sole determinant in decision making.

Notes:

[1]For an excellent and thorough discussion on obstacles to settlement, see David P. Hoffer, *Decision Analysis as a Mediator's Tool*, Harvard Negotiation Law Review, Vol.1:113, Spring 1996.

Recommended Reading:

Robert T. Clemen, *Making Hard Decisions: An Introduction to Decision Analysis*. 2nd Edition. (Duxbury Press, 1996).

James R. Evans and David L. Olson. *Introduction to Simulation and Risk Analysis*. Second Edition. (Prentice Hall, 2002).

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The author, Doug Allen, is President of DOUGLAS C. ALLEN, P.A., a firm that provides strategic consulting services to businesses, legal counsel, investors, and insurers to help them define, quantify and manage their high risk exposures including environmental, product and mass tort, intellectual property, construction, and commercial litigation.

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Figure 1
Decision Tree Primer

Decision Tree Structure & Terminology

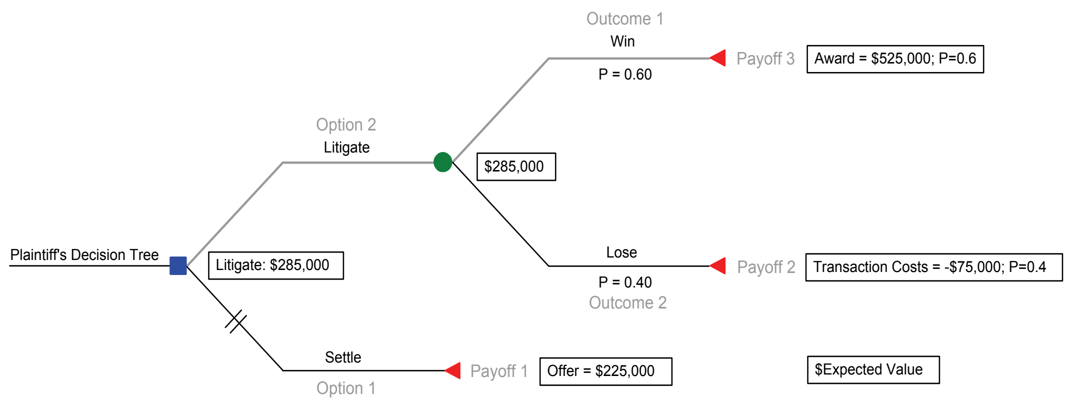

Figure 1a. A basic decision tree consists of a series of branches organized from left to right and connected together by one of three types of nodes: (1) a square (■) represents a **decision node** at which point a decision maker is faced with two or more options or choices. Branches emanating from a decision node represent the options or choices available to the decision maker. The decision maker can choose only one option; (2) a circle (●) represents a **chance node** over which the decision maker has no control. Branches emanating from a chance node represent the possible outcomes of the event. Each branch has an associated probability (P) of occurrence. The probabilities for all branches emanating from a chance node must sum to 1.0 (or 100%); (3) a triangle (◀) is sometimes used to represent a **terminal node** beyond which there are no further activities. The terminal node is also referred to as a consequence, or, when money is involved, a payoff, or net value. The probability of occurrence for an individual pathway of nodes and branches is the *product* of the probabilities along that pathway; the payoff value is the *sum* of the costs along that pathway.

Expected Value

The decision tree model facilitates the determination of the expected value (EV) of an event, the cornerstone of decision analysis. The EV represents a probabilistic determination of the outcome of many observations. In the plaintiff's decision tree, if litigation was carried out 100 times, the plaintiffs would win at trial 60 times and would receive an award of $525,000 for each win for a total gain of $31.5 million dollars. However, the plaintiffs would also lose 40 times and would pay transaction costs of $75,000 for each loss for a total loss of $3 million. The net for 100 trials would be $28.5 million, or, dividing by 100 trials, an average of $285,000. Thus the EV, or probability-weighted average, associated with the litigation option is $285,000.

The EV is calculated from right to left in a process often referred to as "folding back" or "rolling back". The EV for a terminal node is equal to its payoff. The EV for a chance node is the sum of the products of the probabilities and the payoffs of the branches emanating from the chance node. The EV for a decision node is equal to the value of its best option.

The expected value for each option in the plaintiff's decision tree in Figure 1a is determined as follows:

$$\begin{aligned} EV_{Option\ 2} &= [P(Win) \times Award] + [P(Lose) \times Transaction\ Costs] \\ &= [0.60 \times \$525{,}000] + [0.40 \times -\$75{,}000] \\ &= \$285{,}000 \end{aligned}$$

$$EV_{Option\ 1} = \$225{,}000$$

Initial comparison of the EVs for Option 2 and Option 1 suggests that litigation of this case would result in an expected value $60,000 (~27%) higher than the settlement offer. However, if the award of $525,000 for winning at trial excluded the transaction costs of $75,000, the net award would be $425,000 and the expected value of the litigation option would be $240,000, only $15,000 (~7%) higher than the settlement offer option. Although this example is simplistic, it does illustrate the importance of defining realistic probabilities and quantities in decision tree modeling. Conducting sensitivity analyses on uncertain quantities can also provide useful information to the decision maker.

Decision tree calculations and sensitivity analyses alone may not be a sufficient basis for the plaintiffs to select a decision option and formulate a strategy. The degree of risk the plaintiffs are willing to assume should also be factored in. For example, plaintiffs who are risk-adverse may decided to settle for the lower amount simply to avoid the uncertainty of a trial. In this case, although the decision tree analysis suggested litigation as the preferred option, other factors might favor settlement over litigation.

Sensitivity Analysis

Probabilities assigned to chance events and quantities included in payoffs are rarely known with certainty and precision; they are usually best guesses or estimates. A sensitivity analysis provides a means of assessing how the results of a decision model are affected by variations in one or more of the uncertain quantities relevant to the decision. A sensitivity analysis can be performed on one, two or three variables simultaneously. However, a one-way sensitivity analysis is the most common.

Figure 1b shows a one-way sensitivity analysis for the plaintiff's decision tree in Figure 1a. This line graph contains one line for each decision option. The horizontal line represents the settlement offer (Option 1). It remains constant because the settlement offer of $225,000 is independent of the outcomes of any of the chance events in the plaintiff's decision tree. The sloping line represents the litigation scenario (Option 2). The expected value of the litigation option changes as the probability of a win at trial changes.

The point at which the two lines cross (P = 0.50; EV = $225,000) defines the threshold values. At this point, both decision options have the same expected value of $225,000. To the left of this point (for P < 0.50), the EV for the litigation option is always less than the EV for settlement. Accordingly, settlement would be the preferred strategy. To the right of this point (for P > 0.5), the EV for the litigation option is always greater than for settlement. This would suggest that the litigation option is preferable to settlement.

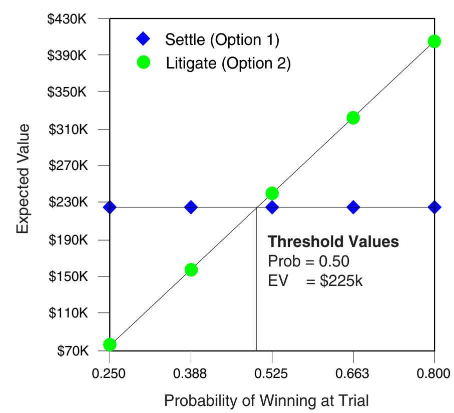

Figure 1b. One-way sensitivity analysis of Option 2.

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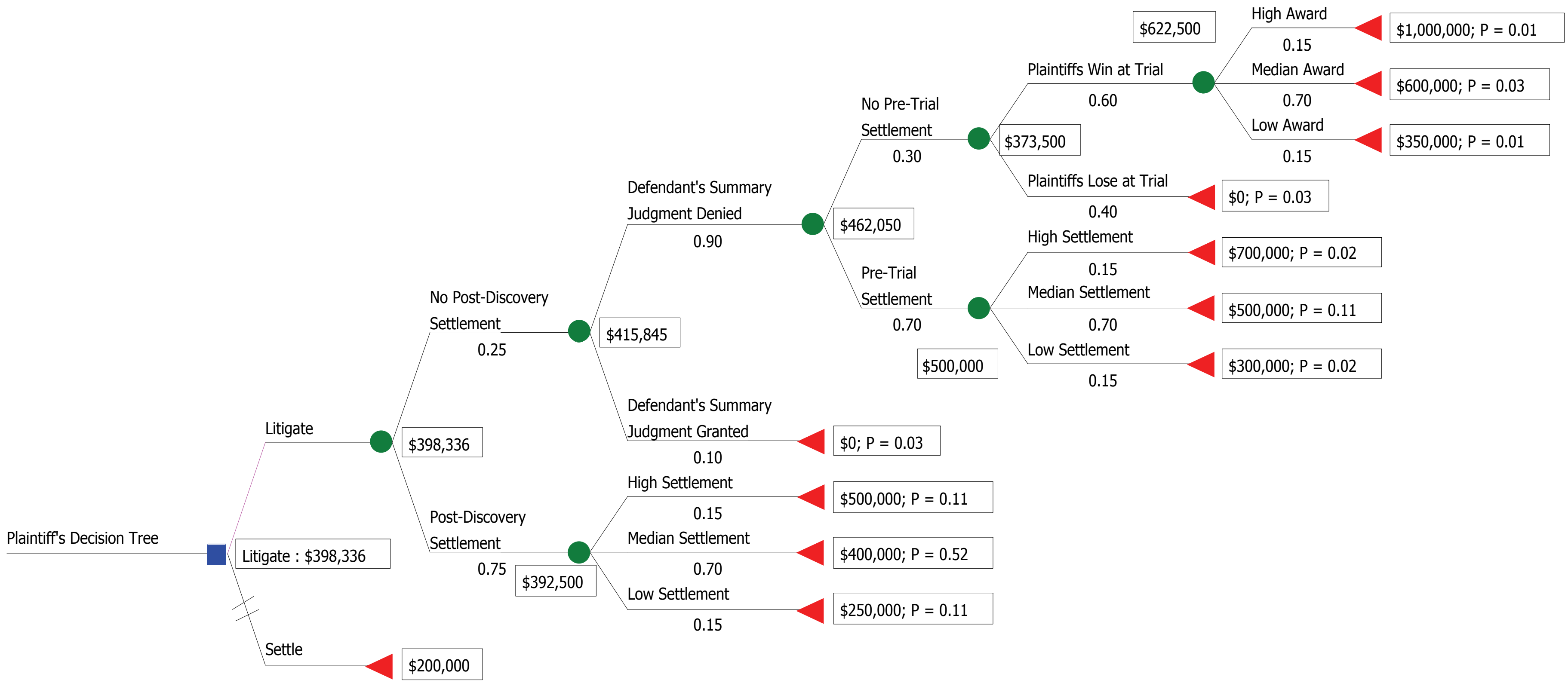
Figure 2

Plaintiff's Decision Tree for Dispute Settlement-Litigation



This generic decision tree illustrates how decision analysis could be used by plaintiff parties in deciding whether to litigate or settle a dispute. The tree incorporates post-discovery and pre-trial opportunities for settlement as well as the potential impact of a summary judgment motion. The probabilities and costs (i.e.., the potential awards) assigned to the various outcomes in this tree represent the more typical situation in which the plaintiff's case tends to get stronger as the case evolves. Expected values assigned to the settlement and award sub trees of the litigation option increase as litigation proceeds to trial and the pressure on the defendants to settle increases. In this example, the $200,000 assigned to the Settle branch represents the best the plaintiffs could expect to receive at this point. This settlement value could either be in the form of a demand by the plaintiffs, an offer by the defendants, or the best the plaintiffs could expect after limited settlement negotiations. The probabilities and expected values assigned to the tree result in an expected value of $398,336 for the Litigate-Settle decision node. Excluding a consideration of transaction costs and the plaintiff's risk profile, the results of this decision analysis indicate litigation would be the preferred settlement strategy. It should be noted that there are situations in which a plaintiff's case gets worst as it evolves. This may result from a lack of facts obtained during discovery or changes in the law. In these situations, the plaintiff's strategy may be to avoid or minimize the risk of losing at trial. Accordingly, the probabilities and expected values assigned to this decision tree would be adjusted to reflect this situation. In any decision analysis, the selection of probabilities and expected values (and to a lesser extent the structure of the decision tree itself) needs to be realistic.

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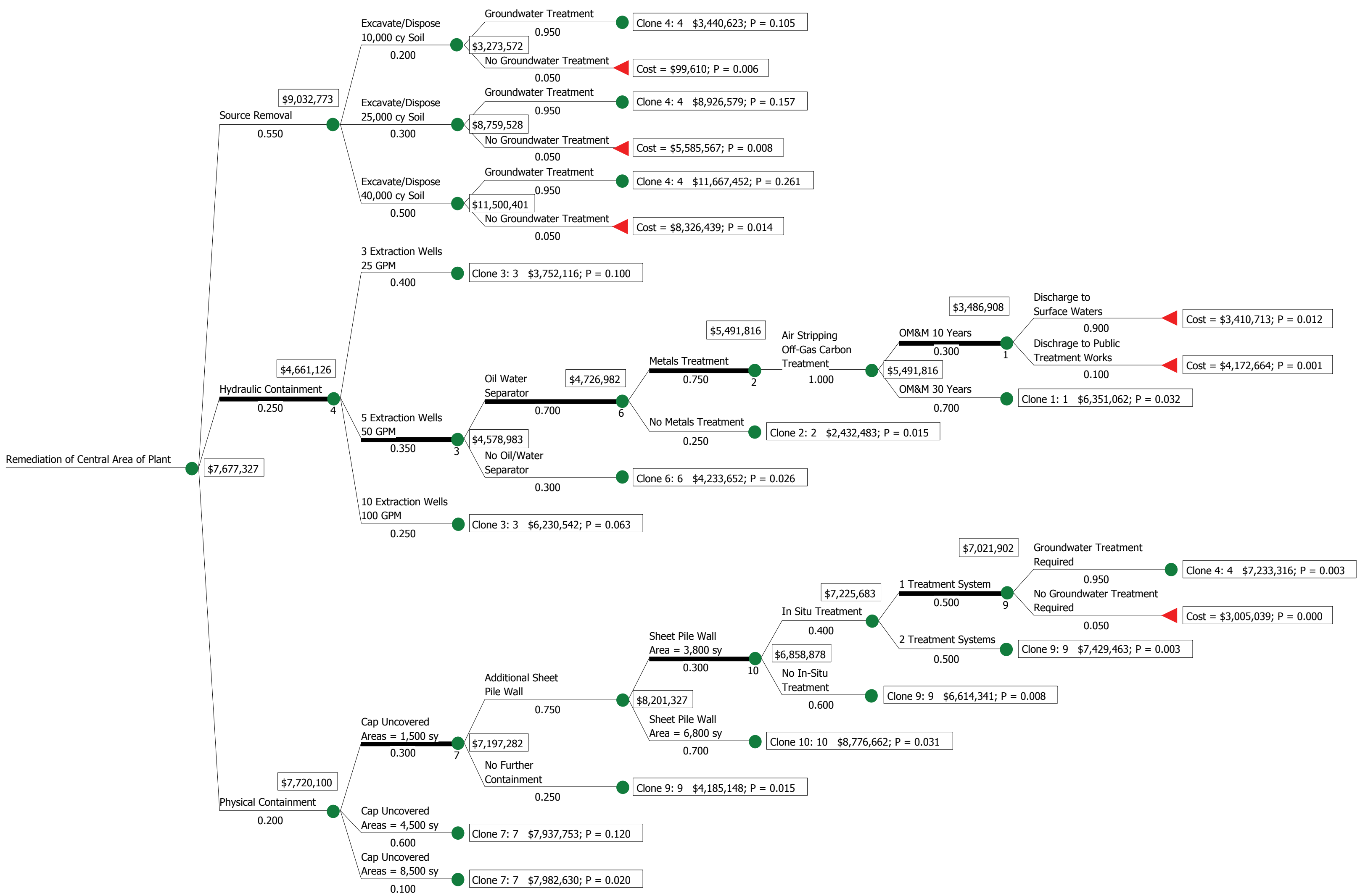
Figure 3

Future Cost Projections for Insurance Claim Valuation



Decision tree analysis was used to project future expected costs as part of an environmental insurance coverage claim prepared by an insured party and presented to its insurer. This moderately complex decision tree analyzes a series of potential alternatives or scenarios for remediating a portion of a plant site where there is contaminated soil and groundwater. There are a series of three possible remedial alternatives or outcomes: (1) excavate and dispose of contaminated soil (Source Removal), (2) extract and treat contaminated groundwater (Hydraulic Containment), and (3) cap contaminated soil areas (Physical Containment). Each of these alternatives has a probability of occurrence. Furthermore, each of the three alternatives consists of additional outcomes with their own associated probabilities of occurrence. The cost and probability for each remedial alternative or scenario is shown at the ends of the decision tree branches. Note that the outcomes of individual scenarios range from $99,610 to $11,667,452 with probabilities of occurrence of 0.6% and 26.1%, respectively. Given the entire range of possible alternatives, their associated costs, and their probabilities of occurrence, this model projected future expected costs of $7,677,327 to remediate the central area of the plant. Although the calculations shown in this decision tree can be performed using a hand-held calculator, a computerized analysis is much more efficient for complex trees such as this one.

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