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Project Schedules and Decision Trees

What is Decision Tree?

Burglars usually lack good judgment, let alone any expertise in decision analysis. Case in point, Harry and Marv, the two would be burglars from the movie Home Alone (1990). Based on how they selected their targets, it would be safe to say that neither has a degree in decision analysis from Stanford or Duke. What kind of process would lead them to choose to rob a home in the Chicago suburbs, when it was occupied, granted it was a young boy, if they had a choice to break into another unoccupied home nearby? It may be that they constructed a simple **decision tree** (Figure 1) to help them select which home they should consider for their burglary project. Perhaps, this is the process that Harry and Marv used to develop their decision tree:

1. They identified the decision they wanted to make: they needed to choose which home they would break into.
2. They identified the criteria for the selection of the home: Harry and Marv wanted the home to be as “loaded” as possible.
3. Let’s assume that three houses (1, 2, and 3) in the neighborhood met their criteria and due to some prior “casing” of the homes, Harry and Marv knew approximately how much loot they could steal from each of the homes: House 1 = $20,000, House 2 = $10,000, and House 3 = $8,000.
4. Using this information, Harry and Marv started to construct a decision tree. First, they drew a **decision node** (rectangle) associated with their strategic decision - which home will they rob. From this node, they drew three branches, one for each alternative.
5. Then the two would be robbers brainstormed to come up with the risks and uncertainties associated with robbing the three homes. As it turned out they did not anticipate any risks or uncertainties that were unique to either home B or C: pick the lock, locate the valuables, and steal the valuables. Nice and easy work. However, they discovered that in home A there was the possibility that a little boy was inside, definitely an uncertainty. So, Harry and Marv drew a circle

representing **<u>uncertainty or chance node</u>** on the decision tree. They estimated the chance that boy was inside at 80%.

6. However, just because the house was inhabited didn't mean they couldn't rob it. Harry and Marv believed that if the boy was present, he would be too frightened to stop them. Therefore, Harry and Marv drew another circle with two branches representing the chance that boy would be scared or not scared.
7. They closed each branch with a triangular **<u>end node.</u>** Harry and Marv attached a value to each end node. If the boy was home and not scared, the value would be zero as it would be difficult to get anything out of the home without the boy raising an alarm. For all of the other end nodes, Boy home and scared, Boy not Home, House 2, and House 3 the values would be the estimated amount of loot in the home.
8. Now that they had set up their decision tree, it was ready to calculate. The calculation started calculating values from right to left. For each uncertainty node, Harry and Marv needed to calculate an expected value. The expected value for the "Boy is at home" branch equals: (Boy is scared) + (Boy is not scared). Mathematically, it looks like this:
   ($20,000 *0.8) + ($0,000 * 0.2) = $16,000.
   As we calculate to the left, we can see that the expected value for "House A" equals: (Boy is home) + (Boy is not home), or
   $16,000*0.8 + $20,000*0.2 = $16,800.
9. Using expected value as their criteria, the decision for Harry and Marv is now easy to see. House 1 has highest expected value even taking into account the uncertainty associated with the possibility of the boy staying at the house.

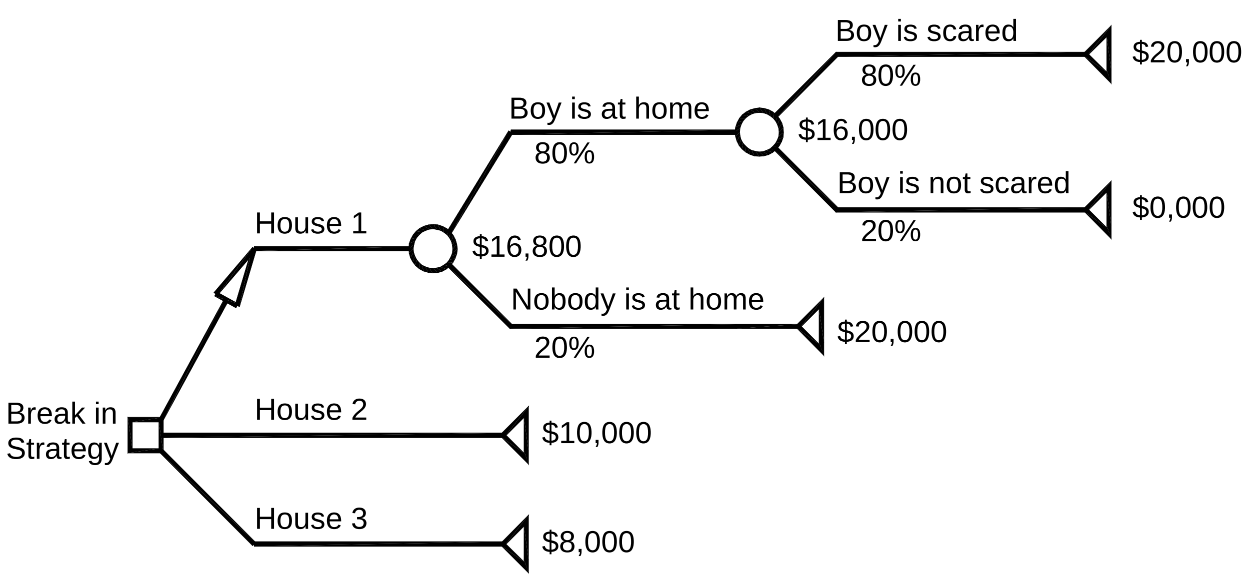

Figure 1. Analysis of break-in strategy using decision tree.

Here are a few more thoughts regarding Harry and Marv's decision tree:

- A number of decisions, which can rely one on another, sometimes can be made upfront. In this case decision nodes are not confined to the beginning (on the left) of the tree, but can be placed throughout decision trees wherever a decision must be made. For example, Harry and Marv might have wanted to see the effect of scaring the boy out of the house had on the expected value.
- You can incorporate risk profiles by applying a utility function to the decision tree analysis. Apparently Harry and Marv, like most criminals, are risk takers and this risk profile could affect their choices.
- In reality, in most situations the value associated with the end node can be calculated using a valuation model. For example, Harry and Marv's valuation model could include a number of parameters: house type, habitation status, etc. It would be possible to set these parameters and the valuation model would return a value for each node.
- Influence diagrams can be used to construct a decision tree representing the same problem.

Why project managers avoid decision trees (and why they shouldn't)

It is not only burglars that use decision trees, but by some honest people use them as well. Trial lawyers routinely use decision trees when they try to determine their strategies - to sue or not to sue (with apologizes to Shakespeare). If they sue, should they accept an out of court settlement or go to trial? If they go to trial, what is the chance that they will win? If they win, what it is chance that the other side will appeal? This analysis all depends on the potential payout at each decision and can make for a very complex decision tree. What product has the most chance of success given the market uncertainties? What movie should the studio produce given the wide range of ideas and scripts on which they have options? What mineral deposits should a company explore and develop first? Many companies use decision trees to make their strategic decisions. How can organizations use them for project management?

The PMBOK® Guide (Project Management Institute, 2004) recommends using decision trees as one of the quantitative risk tools for the analysis of different project alternatives. PMBOK® Guide (Chapter 11) includes an example of a simple decision tree with explanations how to calculate the expected value of the project. However, with all this information about decision trees available, the actual use of this tool in project management remains very limited. We think there are a number of reasons:

- If a project is relatively small, most project managers believe that they can make a choice intuitively and they don't need to use sophisticated analysis tools like a decision tree. In these cases, project managers have made an assumption that is not necessarily true: that the size of projects and number of potential choices in a project are positively related. In reality, a small project may have many alternatives that require a more sophisticated analysis.

- If project is large and complex like the construction of a large highway, project managers prefer to delegate the decision analysis to a business analyst from their strategic planning department or hire a consultant.

It is important to remember that as soon you have to make a decision that depends upon other decisions, it is not trivial and a purely intuitive solution may lead to mistakes. In these cases decision trees will help you to make the right decision.

Here is another observation related to the use of decision trees in organizations. As with all quantitative methods in project decision analysis, decision trees rely on the valuation model of the project. In most cases, project managers do not create a valuation model specifically for a decision tree analysis; they already have too many other issues to worry about. But if they already have this model, which in many cases is the project schedule, it is easy to convert the model into a decision tree using available software tools (see Appendix A). With this in mind, project managers should not have any reason, excuses maybe, not to use decision tree analysis for small and medium size projects as it provides a lot of value for a little additional effort. Now, let's see how this conversion works.

Converting project schedules into decision trees

For most problems in project management, you can generate decision tree from the project schedule.

Let's assume that your project schedule includes different alternatives (Figure 2). If one project scenario depends on another scenario, the number of potential alternatives can be substantial. It is always easier to use one project schedule for multiple alternatives than creating separate schedules. Value measures for a project schedule can be project cost or duration.

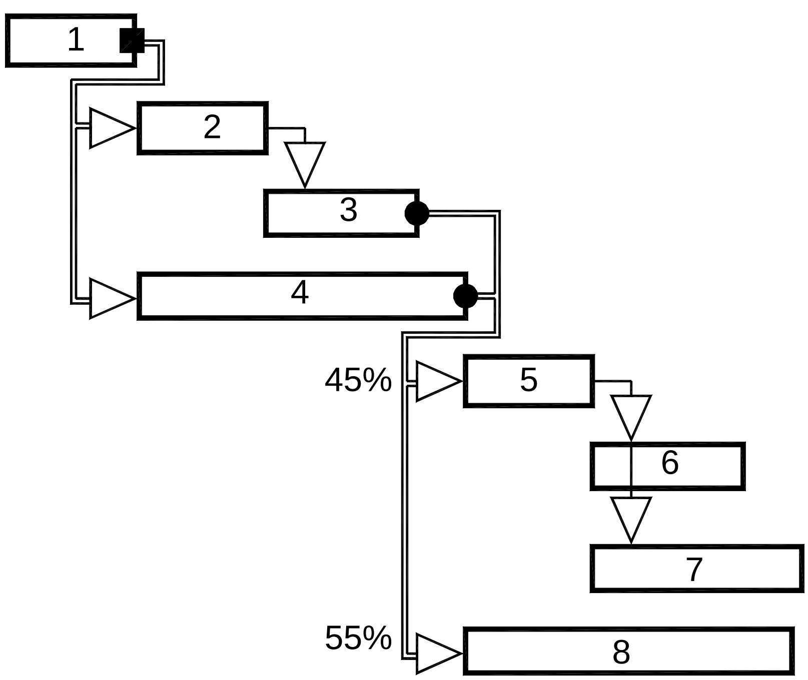

Figure 2: Project schedule to be converted to a decision tree

Here is how the **schedule-to-decision-tree conversion** works:

Create a project schedule that contains alternative scenarios. Alternative scenarios can be represented by different parallel paths through the schedule. Different paths of a project schedule are the result of branching when a predecessor activity has more than one successor activity.

There are two types of parallel paths:

a. Some activities are performed in parallel (Harry is looking for cash in the bedroom, while Marv is collecting electronics from the family room);

b. Different scenarios (either both Harry and Marv start with family room, or they go to the bedrooms).

To distinguish between the types of paths, they need to be visualized differently on a **Gantt chart**. We recommend using double lines and horizontal arrows for alternative paths versus single lines and vertical arrows for parallel activities. In our example, a double line connects Task 1 with Task 2 and Task 4. This represents that Task 2 and 4 with all their successors are alternative scenarios.

1. Activities can have alternative successors for the following reasons:
2. A decision must be made. The triangle at the end of the predecessor indicates that a decision is being made (see Task 1 on Figure 2).

The activity has uncertainties associated with it. The circle at the end of an activity indicates that there is an uncertainty (see Task 3 and Task 4) and the need to specify a probability associated with each branch (in our example, we have assigned probabilities of 45% and 55% for the branches after tasks 3 and 4).

When you have entered all of the information to construct a decision tree, perform separate network calculations (forward path for the critical path method) for each alternative. The end nodes of decision tree will represent cost or duration of each alternative, branches represent tasks or group of tasks.

In practice, project schedules can be very large and complex. To avoid situations where the decision tree becomes too large and unmanageable a **schedule consolidation** algorithm can be applied. With this algorithm, the cost and duration of all activities between the decision and uncertainties nodes are calculated separately and represented as one branch of the tree.

Figure 3 shows the results of a schedule-to-decision-tree conversion. Even if you don't go as far as converting your schedule to a decision tree, this approach can be beneficial in that it allows you to visualize decisions and uncertainties on any Gantt chart. This provides a useful tool for discussions regarding different project scenarios and the probabilities of their occurrence.

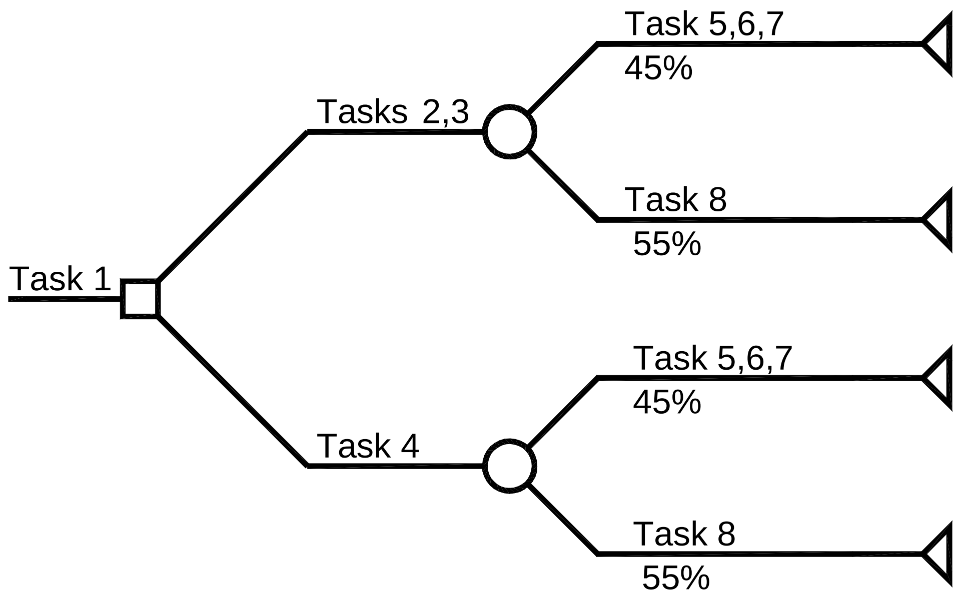

Figure 3. Result of schedule-to-decision-tree conversion

Value of Perfect Information

Here is a anecdotal story that we came across.

At a chemical plan,t a huge reactor had broken down and nobody knew the exact reason for the failure. To understand what went wrong, management had two choices: disassemble a major section of the reactor; or, examine many little sections of the reactor one at a time. In either scenario, it would cost millions of dollars due to the lengthy downtime. So before starting the investigation, the project management team invited a guru, hoping that he could pinpoint the cause of the breakdown faster. The guru walked around the reactor a couple of times, and soon became interested in a particular section of the reactor. He pulled out a small hammer and tapped it lightly on the reactor and listened intently. After a few more minutes of tapping and listening, the guru turned around and said: "Cut a small opening here and replace the pipe". A supervisor quickly put some workers on the task, though he was skeptical and thought the whole process a bit odd. Much to his astonishment and the rest of the management team, this almost miraculous fix had the reactor up and running at full capacity the very same day. The plant manager was extremely happy. "What is this going to cost me?" he asked the guru. "One million dollars", came the reply. "One million dollars for hitting the reactor with small hammer?", the manager protested. " "No, hitting the reactor only costs you $1, the $999,999 is for saving you at least triple the amount that you would have spent if you had gone ahead with your original plans", answered the guru.

The guru had calculated the value of the information he provided, which was the amount of money that was saved through his investigation. This concept of the value of information is very important in project management:

- Should you spend the time and money to create a prototype of a new device?

- Should you perform additional testing of a software or hardware component to ensure its reliability?
- Should you buy new software to perform a more detailed analysis?
- Should you hire a consultant to solve a complex problem?

Here is how the value of information is calculated. Harry and Marv want to break into a house, but do not know exactly how much money is there. It can be a “Loaded home” worth $20,000 (80% probability) or nothing (20% probability). For the other houses, Harry and Marv already know with 100% certainty that they have $10,000.

So, due to the uncertainty around the one home, Harry and Marv decided to get additional information. If you saw the movie, you will remember that Harry visited the homes before Christmas dressed as a police officer. But before he did this, they needed to estimate whether it made sense to get this information. First, Harry needed to procure a police uniform; in addition, visiting the homes impersonating a police officer could increase the chance that they would be discovered. So Harry and Marv constructed the decision tree shown in Figure 4.

They have three alternatives:

1. Break into House 1. Expected value will be $0,000*0.2 + $20,000*0.8 = $16,000
2. Break in to House 2. The know for sure that they can get $10,000
3. Get additional information about house 1.

If Harry goes to House 1 and acquires the additional information, he may find that the probabilities are 80% “loaded” and 20% nothing. If the house has nothing, it would be wise to break into second house instead and get a certain $10,000. So the expected value of “Get additional information” alternative is $10,000*0.2 + $20,000*0.8 = $18,000. As a result, the expected value of information is $18,000 - $16,000 = $2,000. Now, Harry may use this number to decide whether risks of procuring (buy or steal) a police uniform and visiting the houses is worth the additional $2000 in potential benefit.

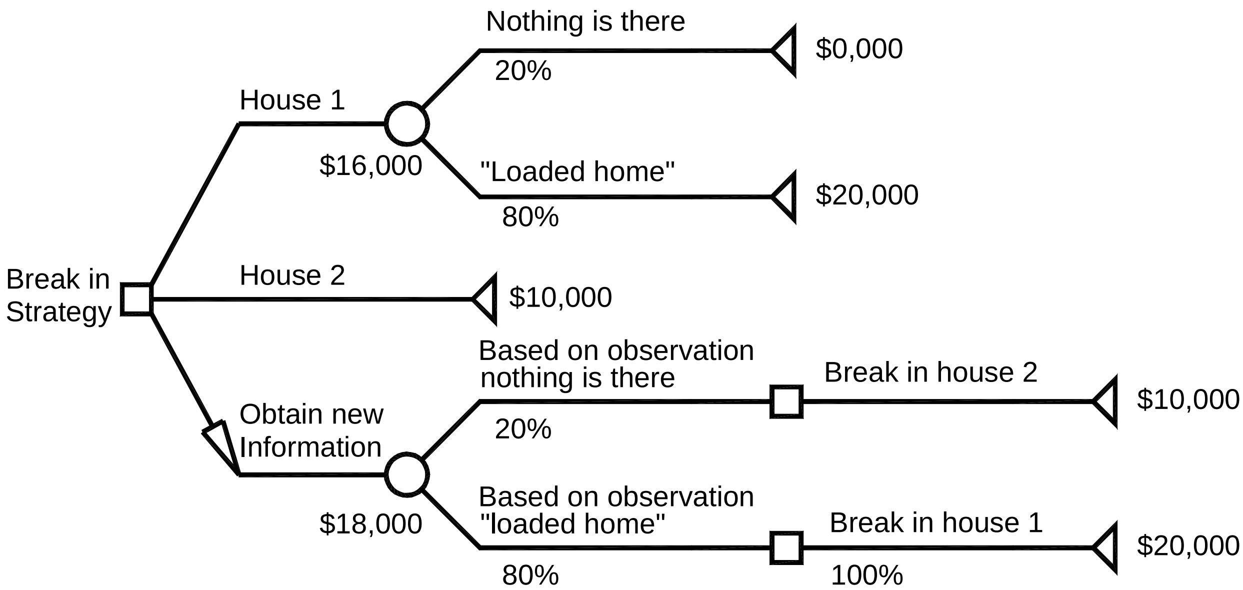

Figure 4. Analysis of value of perfect information for break-in strategy

Value of Imperfect Information

Value of information analysis which we just described has only one "if". The **information** Harry got **is perfect**. In other words, the burglars assume that Harry's observations are absolutely reliable.

> Analysis of the value of new imperfect information can be done using Bayes theorem. Bayes theorem is a formula, which revises probabilities based on new information.

In reality, Harry assessments will not be absolutely accurate. There will be some things he could not see, others that he will have difficulty evaluating. In other words, there is a probability that Harry's assessment could be inaccurate.

Decision theory offers methods to incorporate imperfect information into the analysis and calculate an expected value for it. This approach is based on Bayes' theorem and is calculated in the following manner. If the probability of event A is conditional on event B, it is generally different from the probability of event B when it is conditional on event A. The Bayes' theorem actually defines this relationship. The theorem is named after Thomas Bayes.

Be skeptical if an expert or consultant tells you that Bayes' theorem is a straight-forward concept. The formula itself is really very simple; however, the explanation and actual application of the formula has been known to cause some confusion. Therefore, we have not included the formula in this book. You may find the actual formula in most of the books on decision analysis mentioned in the Future Reading section. If you want to calculate the value of imperfect information for your project, you can find software tools that will do this for you in Appendix 1.

Summary

- ✓ Decision trees are tools that help to analyze and select different project alternatives.
- ✓ Decision trees can be easy generated using a project schedule; you may use diagrams representing the project schedule to visualize alternative scenarios with their probabilities
- ✓ Value of information determines whether the additional information such as tests, prototypes, and more detailed modeling techniques can save more than was spent