Economic Risk and Decision Analysis for Oil and Gas Industry
CE81.9008

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Structuring Decisions using Decision Tree

Introduction

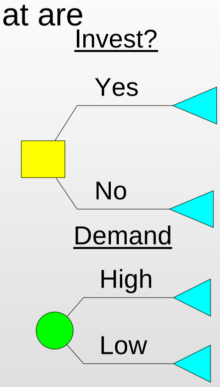
- **Decision Tree Analysis** is one of the tools available to aid in the decision making process.
- Decision Tree is **diagrammatic representation of decision situation** that chronologically displays all the **decisions and uncertainties**.
- It also provides a **probability based solution**, and its main appeal is its intuitive aproach and ease of use.

Decision Trees Described

- Decision trees
  - Help decision maker develop clear understanding of **structure of problem**
  - Make it easier to **determine possible scenarios** that can result if particular course of action chosen
  - Help decision maker judge nature of **information needed** for solving given problem
  - Help decision maker **identify alternatives** that maximize EMV
  - Serve as excellent **communication medium**

Decision Trees

- Decision trees are composed of **nodes** that are connected by **branches**.
- The **nodes** represent points in time.
  - A **decision node** is a time when a decision is made.
  - A **chance node** is a time when the result of an uncertain event becomes known.
  - An **end node** indicates that the problem is completed - all decisions have been made, all uncertainty have been resolved and all payoffs received



Decision Trees

- Time proceeds from ***left to right***
  - This means that **branches leading** into a node (from the left) have **already occurred**.
  - Any branches leading out of a node (to the right) have not yet occurred.
- Branches leading out of a **decision node** represent the **possible decisions**; the decision maker can **choose** the preferred branch.
- Branches leading out of **probability nodes** represent the **possible outcomes** of uncertain events; the decision maker has **no control** over which of these will occur.

Decision Trees

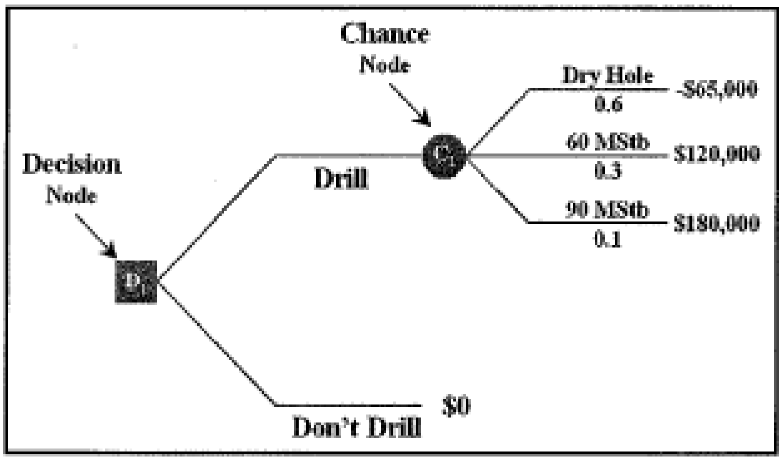
- **Probabilities** are listed in the **chance nodes**.
- These **probabilities are *conditional*** on the events that have already been observed (those to the left).
- The probabilities on branches leading out of any particular probability node must add to 1.
- Cash flows are shown below the branches where they occur, and cumulative values are shown to above the branches.

Decision Making Elements

- Although there is a wide variety of contexts in decision making, all decision making problems have three elements:
  - The **set of decisions** (or strategies) available to the decision maker
  - The **set of possible outcomes** and the probabilities of these outcome
  - A **value model** that prescribes results, usually monetary values, for the various combinations of decisions and outcomes.
- Once these elements are known, the decision maker can find an "optimal" decision.

Example Decision Tree: Drill or Don't Drill

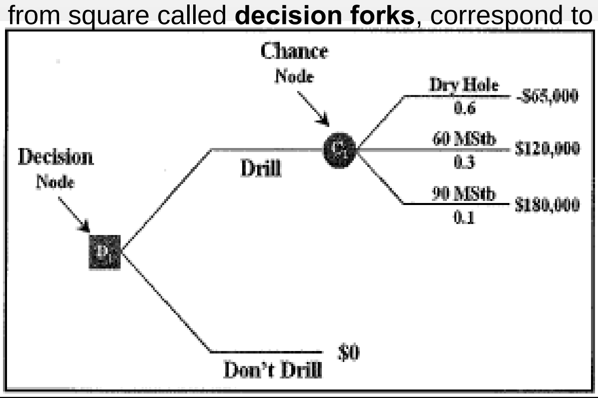
From left to right
- •Typically start with a decision to be made
- •Proceed to other decisions or chance events in chronological order



Conventions on Decision Tree

Decision Nodes

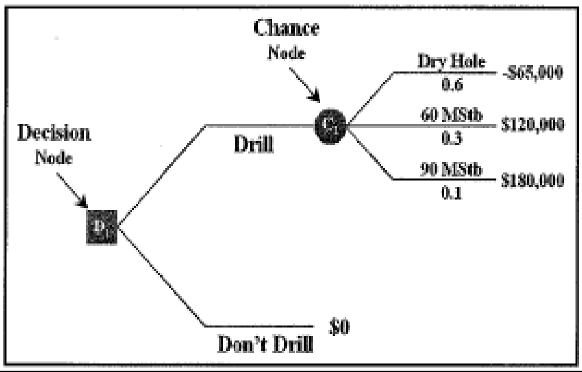
- •Represented by **square** ☐
- •Point at which we have control and **must make a choice**
- •Assigned sequential numbers (D_1 here)
- •May be followed by another decision node or chance node
- •Branches emanating from square called **decision forks**, correspond to **choices available**



Conventions on Decision Tree

Chance Nodes

•Represented by **circle O**, numbered sequentially (C_1 in example)
•Point at which we have **no control**, chance determines outcome
•Chance event probabilistic
•May be followed by series of decision nodes or chance nodes
•Branches emanating from circle called **chance forks**, represent **possible outcomes**



Conventions on Decision Tree

- **Probability** or **chance**
  - Likelihood of possible outcomes happening
- **End**, **terminal**, or **payoff node**
  - Payoff deterministic **financial outcome of decision**
  - Node represented by **triangle** (not on example)
  - Has no branches following, returns payoff and probability for associated path

Guidelines for Designing Trees

- Tree construction is iterative – we can change our minds as we learn more
- We should keep trees **as simple as possible**
- Define decision nodes so we can choose only one option (but we should describe every option)

Guidelines for Designing Trees

- We should design **chance nodes** so they are **mutually exclusive** and **collectively exhaustive**
- Tree should proceed chronologically from left to right
- Sum of probabilities should equal one at each chance node
- Remember that often we can draw a tree in number of different ways that **look different** but that are structurally equivalent

Solving Decision Trees

- Decision analysis on tree can produce **expected value** of model, **standard deviation**, and **risk profile** of optimum strategy
- Method of calculating optimum path called *folding back* or *rolling back* tree
- Solve from right to left – consider later decisions first

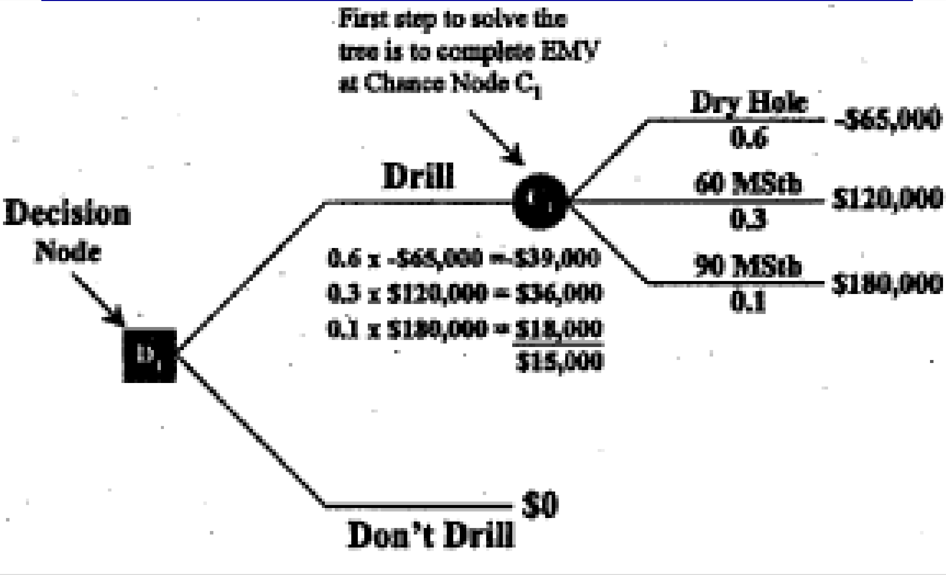
Solving Decision Trees

- **Chance node reduction**
  - Calculate **expected value** of rightmost chance nodes and **reduce to single event**
- **Decision node reduction**
  - **Choose optimal path** of rightmost decision nodes and **reduce to single event** (choose maximum $E\{C_i\}$ at decision node)
- **Repeat**
  - Repeat procedure until you arrive at final, leftmost, decision node

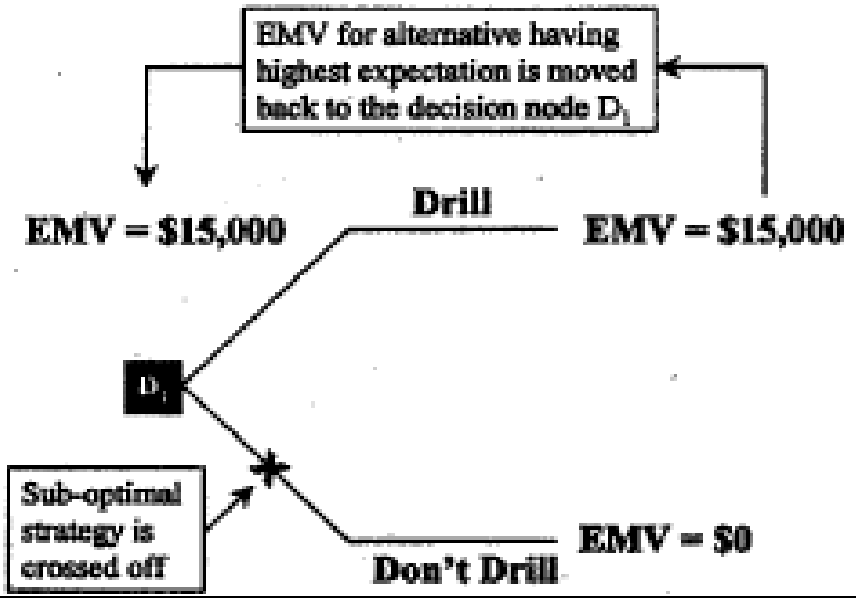
Example Decision Tree

- Lucky Oil Company wants to decide whether to drill new prospect
- Geologists and engineers expect
  - Probability of dry hole 60%, NPV -$65M
  - Probability of 60M STB 30%, NPV $120M
  - Probability of 90M STB 10%, NPV $180M

Example Decision Tree



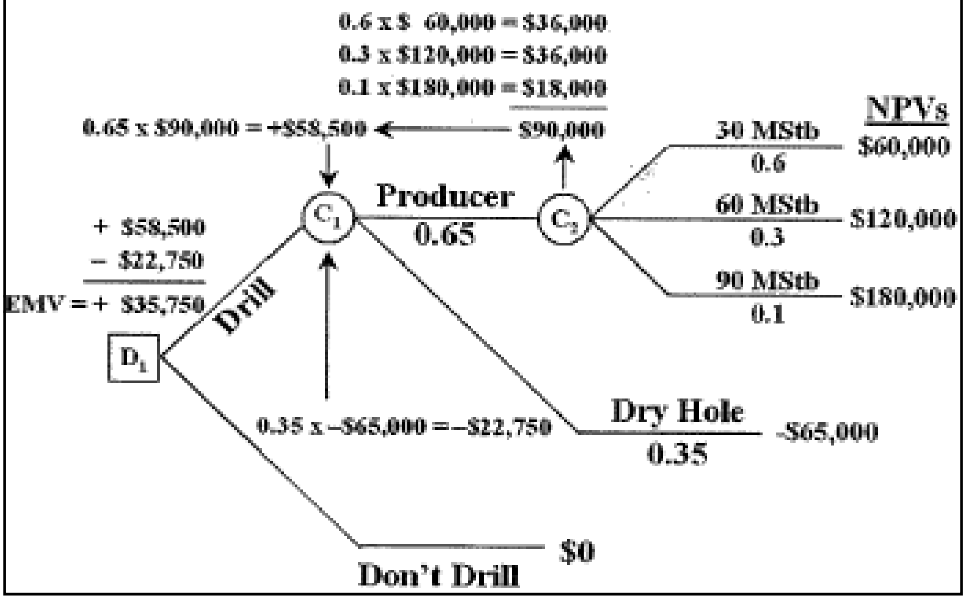
Example Decision Tree



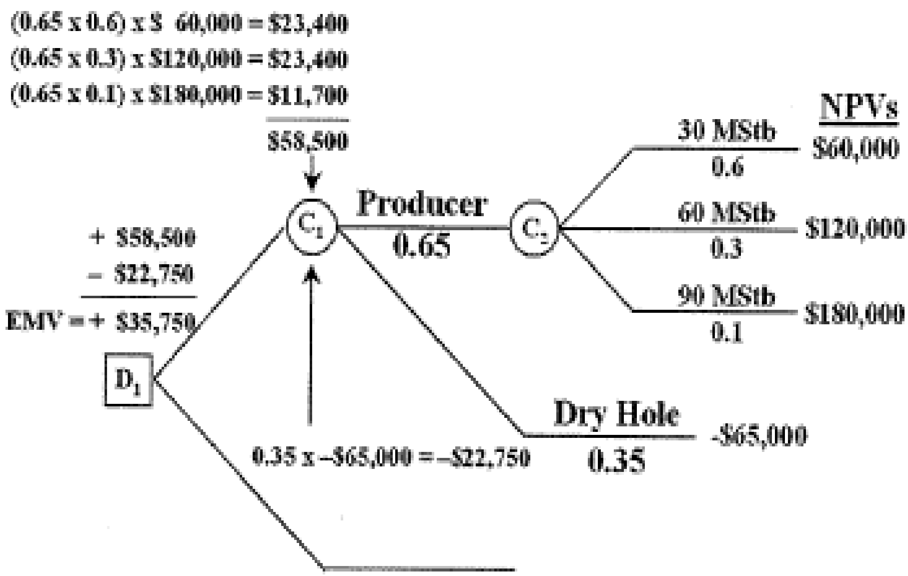
Another Example Decision Tree

- Lucky Oil Company plans to drill a well, wants to determine EMV of drilling
- 35% chance of dry hole, NPV -$65M
- 65% chance of producer – if successful
  - 60% chance of 30M STB, NPV $60M
  - 30% chance of 60M STB, NPV $120M
  - 10% chance of 90M STB, NPV $180M

Another Example Decision Tree

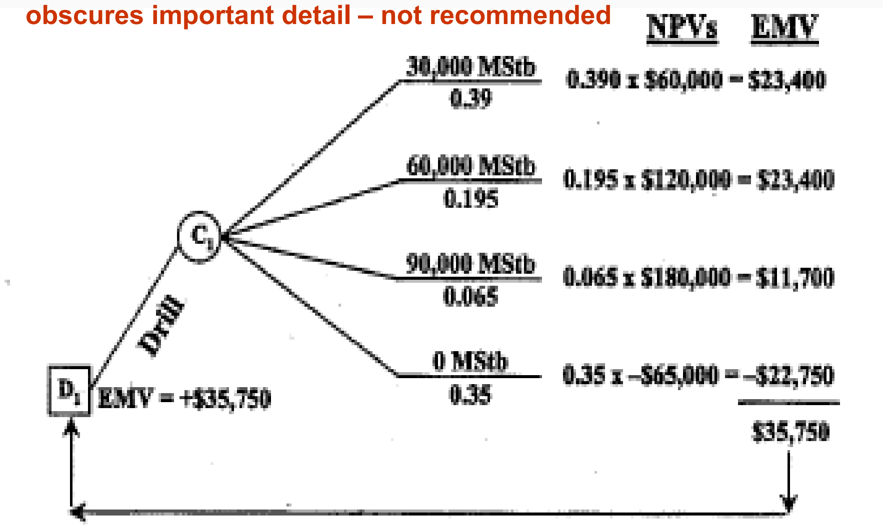


Alternative Approach – Collapse Tree



Alternative Approach – Collapse Tree

Too much collapsing
obscures important detail – not recommended



Constructing Risk Profiles

- **Risk profile** is **distribution function** describing chance associated with every possible outcome of decision model

- Steps to generate risk profile

1. Reduce chance nodes (collapse tree)
2. Reduce decision nodes – consider only optimal branches

Steps in Constructing Risk Profiles

3. Repeat steps 1 and 2 until tree is reduced to single chance node with set of values and corresponding probabilities

4. Generate risk profile
   - Final set of payoff and probability pairs defines **discrete probability distribution** used to generate risk profile
   - Can graph risk profile as **discrete cumulative density distribution** or **scatter diagram**

Steps in Constructing Risk Profile

5. Calculate expected value, variance, and standard deviation, as in example

Unconditional Probability, p_i	NPV, X_i, \$M	EMV, \$M	Variance,\$MM $p_i(X_i\text{-EMV})^2$
0.350	-65	-22.75	3,552.697
0.065	180	11.70	1,352.524
0.195	120	23.40	1,384.122
0.390	60	23.40	229.344
		35.75	6,518.687

$$s = \sqrt{6{,}518.687e6} = \$80.74M$$

Spreadsheet Applications

- **Excel built-in functions** simplify calculation of EMV, variance, standard deviation
- **Palisade's PrecisionTree** assists us in constructing and solving decision trees

Excel SUMPRODUCT Function

	B	C
3	Unconditional	NPV
4	Probability, p_i	X_i ($)
5	0.350	-$65,000
6	0.065	$180,000
7	0.195	$120,000
8	0.390	$60,000
9	1.000	
10	EMV	$35,750
11	Variance, s^2	$6,518,687,500
12	Standard Deviation	$80,738
	C10=SUMPRODUCT(B5:B8,C5:C8)	
	C11=SUMPRODUCT(B5:B8,C5:C8^2)-C10^2	
	C12=SQRT(C11)	

PrecisionTree

- Part of Palisades suite
- Add-in to Microsoft Excel
- Allows us to create and solve decision trees in Excel
- Also capable of performing sensitivity analysis, displaying results as spider graphs and tornado charts

Running Precision Tree

- Pages 212 to 226 of Mian, Vol. II, serve as a tutorial for using PrecisionTree to create and solve decision trees
- Be sure that you can reproduce Examples 3-10, 3-11, and 3-12

Example

Deciding the Installation of a Vapor Recovery Unit (VRU)

Vapor Recovery Unit (VRU)

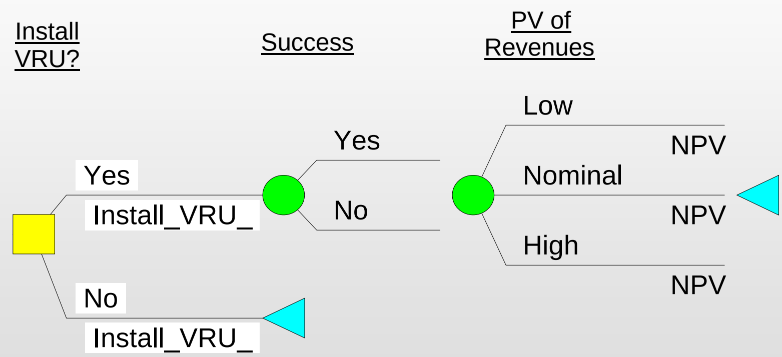
- Sometimes the output of an oil well can be enhanced by the installation of a **Vapor Recovery Unit (VRU).**
- Based on his experience with similar wells, the manager of this operation estimates that there is a 55% chance that the VRU installation on this well would be economically successful.
- If the project is successful, the economic life of the well is expected to be 10 years.

Vapor Recovery Unit (VRU)

- The VRU will cost $200,000 to install, and will have no salvage value after 10 years.
- If the project is not successful, the VRU will have a salvage value of $100,000.
- The estimates of the return for a successful project are as follows:

Probability	PV of Cash Flows
0.25	$600,000
0.35	$500,000
0.40	$400,000

VRU Decision: DPL model



Analysis of VRU Decision