Chapter 4: Decision Analysis

Lecture 12

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14 July 2023

Chapter 15

Decision Analysis

Spreadsheet Modeling & Decision Analysis:

A Practical Introduction to Management Science, 3e
by Cliff Ragsdale

Introduction to Decision Analysis

- We have learnt many techniques in this course that can help managers and engineers gain insight and understanding about decision problems. But models do not make decisions – **people have to do.**

- Models help managers gain insight and understanding, but they can't make decisions.

- Decision making often remains a difficult task due to:
  - uncertainty regarding the future
  - conflicting values or objectives

Deciding Between Job Offers

Consider the following example..., after your graduation, you are offered a job in

- Company A
  - In a new industry that could boom or bust.
  - Low starting salary, but could increase rapidly.
  - Located near friends, family and favorite sports team.

- Company B
  - Established firm with financial strength and commitment to employees.
  - Higher starting salary but slower advancement opportunity.
  - Distant location, offering few cultural or sporting activities.

- ***What job would you like to join? A difficult decision to take***

Decision Analysis

- Making Good decisions involve defining alternatives, determining the preferences or values by which the decision will be based, and evaluating the alternatives. Managers with gut feeling will not be able to make good decisions all the time.

- ***Decision Analysis** is the formal study of how people make decisions, particularly when faced with uncertain information, as well as a collection of techniques to support the analysis of decision problems.*

Decision Analysis

- Main characteristics of decision situations
  - **They must be important**. Decision analysis techniques should not be used for small decisions.
  - **They are probably unique**. Usual decisions which happen regularly can be done with proper programming and delegation.
  - **They allow some time for study**. Decision analysis techniques will not be useful when decisions have to be taken urgently.

Decision Analysis

- Main characteristics of decision situations
  - **They are complex**. They may have multiple objectives, requiring trade-offs between alternatives.
  - **They involve uncertainty and risk**. Uncertainty is not knowing what will happen tomorrow. Risk is the uncertainty associated with an undesirable consequence, such as financial or physical loss.

Application of Decision Analysis

- Environmental Impact Assessment
- Capital –budgeting or investment
- Research and development activities
- Sports

Elements of Decision Problems

- There are essentially three types of components to any decision problem.
  - Decisions
  - Uncertain events or outcomes
  - Consequences or payoffs

Structuring Decision Problems

- Structuring decision problems involves defining alternative decision that can be made, uncertain outcomes that may result, and criteria by which to evaluate the value of the various combinations decisions and outcomes.

Structuring Decision Problems

- **Generating alternatives**
  - A set of decisions should be there so that a decision maker can select the optimal. Managers must ensure that they have considered all possible options so that the 'best' one will be included in the list.
    - Alternatives - different courses of action intended to solve a problem.
      - Work for company A
      - Work for company B
      - Reject both offers and keep looking

Structuring Decision Problems

- **Defining outcomes**
  - The second task in structuring decision problems is defining the outcomes, or events. These events occur once a decision is made and the decision maker has no control over them. Outcomes may be quantitative or qualitative.

    - States of Nature - future events not under the decision makers control.
      - Company A grows
      - Company A goes bust
      - etc

Structuring Decision Problems

- **Decision Criteria**
  - Decision makers must have well-defined criteria on which to evaluate potential options. These criteria might be to maximize the net profit or social benefits, or to minimize the costs, or some measure of loss.
  - The value of making a decision ***D*** and having event ***S*** occur is called the payoff and expressed as ***V(D,S).***
    - Criteria - factors that are important to the decision maker and influenced by the alternatives.
      - Salary
      - Career potential
      - Location

Payoff Matrix

- A ***payoff matrix*** is a table that summarizes the final outcome or payoff for each decision alternative under each possible state of nature.

Decision Strategy (Rule)

- **Non-probabilistic methods**
  - Average Payoff Strategy (Average payoff rule)
  - Aggressive Strategy (Maximax decision rule)
  - Conservative Strategy (Maximin Decision rule)
  - Opportunity Loss Strategy (The Minimax regret decision rule)

An Example: Magnolia Inns

- Hartsfield International Airport in Atlanta, Georgia, is one of the busiest airports in the world.
- It has expanded numerous times to accommodate increasing air traffic.
- Commercial development around the airport prevents it from building additional runways to handle the future air traffic demands.
- Plans are being developed to build another airport outside the city limits.

An Example: Magnolia Inns (con't)

- Two possible locations for the new airport have been identified, but a final decision is not expected to be made for another year.

- The Magnolia Inns hotel chain intends to build a new facility near the new airport once its site is determined.

- Land values around the two possible sites for the new airport are increasing as investors speculate that property values will increase greatly in the vicinity of the new airport.

- See data in file Fig15-1.xls

The Decision Alternatives

1) Buy the parcel of land at location A.

2) Buy the parcel of land at location B.

3) Buy both parcels.

4) Buy nothing.

The Possible States of Nature

1) The new airport is built at location A.

2) The new airport is built at location B.

Constructina a Pavoff Matrix

ee file Fig15-1.xls

	Parcel of Land Near Location A	B
Current purchase price	$18	$12
Present value of future cash flows if hotel and airport are built at this location	$31	$23
Present value of future sales price of parcel if the airport is not built at this location	$6	$4

(Note: All values are in millions of dollars.)

Payoff Matrix

Land Purchased at Location(s)	Airport is Built at Location A	B
A	$13	($12)
B	($8)	$11
A&B	$5	($1)
None	$0	$0

Decision Rules

- If the future state of nature (airport location) were known, it would be easy to make a decision.
- Failing this, a variety of non-probabilistic decision rules can be applied to this problem:
    - Maximax
    - Maximin
    - Minimax regret
- No decision rule is always best and each has its own weaknesses.

The Maximax Decision Rule

- Identify the maximum payoff for each alternative.
- Choose the alternative with the largest maximum payoff.

See file Fig15-1.xls

	Payoff Matrix &			
Land Purchased	Airport is Built at Location			
at Location(s)	A	B	MAX	
A	$13	($12)	$13	<--maximum
B	($8)	$11	$11	
A&B	$5	($1)	$5	
None	$0	$0	$0	

The Maximin Decision Rule

- Identify the minimum payoff for each alternative.
- Choose the alternative with the largest minimum payoff.

See file Fig15-1.xls

Payoff Matrix &				
Land Purchased	Airport is Built at Location			
at Location(s)	A	B	MIN	
A	$13	($12)	($12)	
B	($8)	$11	($8)	
A&B	$5	($1)	($1)	
None	$0	$0	$0	<--maximum

The Minimax Regret Decision Rule

- Compute the possible regret for each alternative under each state of nature.
- Identify the maximum possible regret for each alternative.
- Choose the alternative with the smallest maximum regret.

See file Fig15-1.xls

Regret Matrix &

Land Purchased	Airport is Built at Location			
at Location(s)	A	B	Max	
A	$0	$23	$23	
B	$21	$0	$21	
A&B	$8	$12	$12	<--minimum
None	$13	$11	$13	

=MAX(Payoffs!B$5:B$8)-Payoffs!B5

Anomalies with the Minimax Regret Rule

- Consider the following payoff matrix

	State of Nature	
Decision	1	2
A	9	2
B	4	6

- The regret matrix is:

	State of Nature			
Decision	1	2	MAX	
A	0	4	4	<--minimum
B	5	0	5	

- Note that we prefer A to B.
- Now let's add an alternative...

Adding an Alternative

- Consider the following payoff matrix

	State of Nature	
Decision	1	2
A	9	2
B	4	6
C	3	9

- The regret matrix is:

	State of Nature			
Decision	1	2	MAX	
A	0	7	7	
B	5	3	5	<--minimum
C	6	0	6	

- Now we prefer B to A?

Decision Strategy (Rule)

Probabilistic Methods

Decision Strategy (Rule)

- **Probabilistic Methods**
  - Probabilistic decision strategy (decision rule) can be used if the states of nature in a decision problem can be assigned probabilities that represent their likelihood of occurrence.
  - For decision problems that occur more than once, it might be possible to estimate these probabilities from historical data.

Probabilistic Methods

- Other decision problems (such as the Magnolia Inns problem) represent one-time decisions where historical data for estimating probabilities don’t exist.
- In these cases, probabilities are often assigned subjectively based on interviews with one or more domain experts.
- Highly structured interviewing techniques exist for soliciting probability estimates that are reasonably accurate and free of the unconscious biases that may impact an expert’s opinions.
- We will focus on techniques that can be used once appropriate probability estimates have been obtained.

Expected Monetary Value (EMV)

- The expected monetary value method selects the decision alternative with the largest EMV. The EMV of alternative i is given by

$$\text{EMV}_i = \sum_j r_{ij} p_j$$

$$r_{ij} = \text{payoff for alternative } i \text{ under the } j\text{th state of nature}$$

$$p_j = \text{the probability of the } j\text{th state of nature}$$

Expected Monetary Value

- The EMV for a given decision alternative indicates the average payoff we would receive if we encounter the identical decision problem repeatedly and always select this alternative.

- This decision rule can be very risky in decision problem encountered only once.

See file Fig15-1.xls

	A	B	C	D	E
1		Payoff Matrix &			
2					
3	Land Purchased	Airport is Built at Location			
4	at Location(s)	A	B	EMV	
5	A	$13	($12)	($2.0)	
6	B	($8)	$11	$3.4	<--maximum
7	A&B	$5	($1)	$1.4	
8	None	$0	$0	$0.0	
9					
10	Probability	0.4	0.6		

=SUMPRODUCT($B$10:$C$10, B5:C5)

Expected Regret or Opportunity Loss

- Selects alternative with the smallest expected regret or opportunity loss (EOL)

$$\mathrm{EOL}_i = \sum_j g_{ij} p_j$$

$$g_{ij} = \text{regret for alternative } i \text{ under the } j\text{th state of nature}$$

$$p_j = \text{the probability of the } j\text{th state of nature}$$

- The decision with the largest EMV will also have the smallest EOL.
- See file Fig15-1.xls

Regret Matrix &

Land Purchased at Location(s)	Airport is Built at Location A	B	EOL	
A	$0	$23	$13.8	
B	$21	$0	$8.4	<--minimum
A&B	$8	$12	$10.4	
None	$13	$11	$11.8	
Probability	0.4	0.6		

=MAX(Payoffs!B$5:B$8)-Payoffs!B5

The Expected Value of Perfect Information (EVPI)

- One of the main difficulties in decision making is that we usually do not know which state of nature will occur.
- Suppose, we could hire a consultant who could tell us in advance and with 100% accuracy which state of nature will occur, 40% of the time the consultant tells that the airport will be built at site A, and 60% of the time at site B.

The Expected Value of Perfect Information

- With such perfect information, Magnolia Inns' average payoff would be:

  EV with PI = 0.4*$13 + 0.6*$11 = $11.8 (in millions)

- Without perfect information, the EMV was $3.4 million.

- The expected value of perfect information is therefore,
  - EV of PI = $11.8 - $3.4 = $8.4 (in millions)

- In general, **EV of PI = EV with PI - maximum EMV**

- It will always be the case that, EV of PI = minimum EOL

Payoff Matrix &

	A	B	C	D	E
1					
2					
3	**Land Purchased**	**Airport is Built at Location**			
4	**at Location(s)**	**A**	**B**	**EMV**	
5	**A**	$13	($12)	($2.0)	
6	**B**	($8)	$11	$3.4	**<--maximum**
7	**A&B**	$5	($1)	$1.4	
8	**None**	$0	$0	$0.0	
9					
10	**Probability**	0.4	0.6		
11					
12	**Payoff of decision made with perfect information**	$13	$11	$11.8	
13					
14			**EVPI**	$8.4	

=MAX(B5:B8)

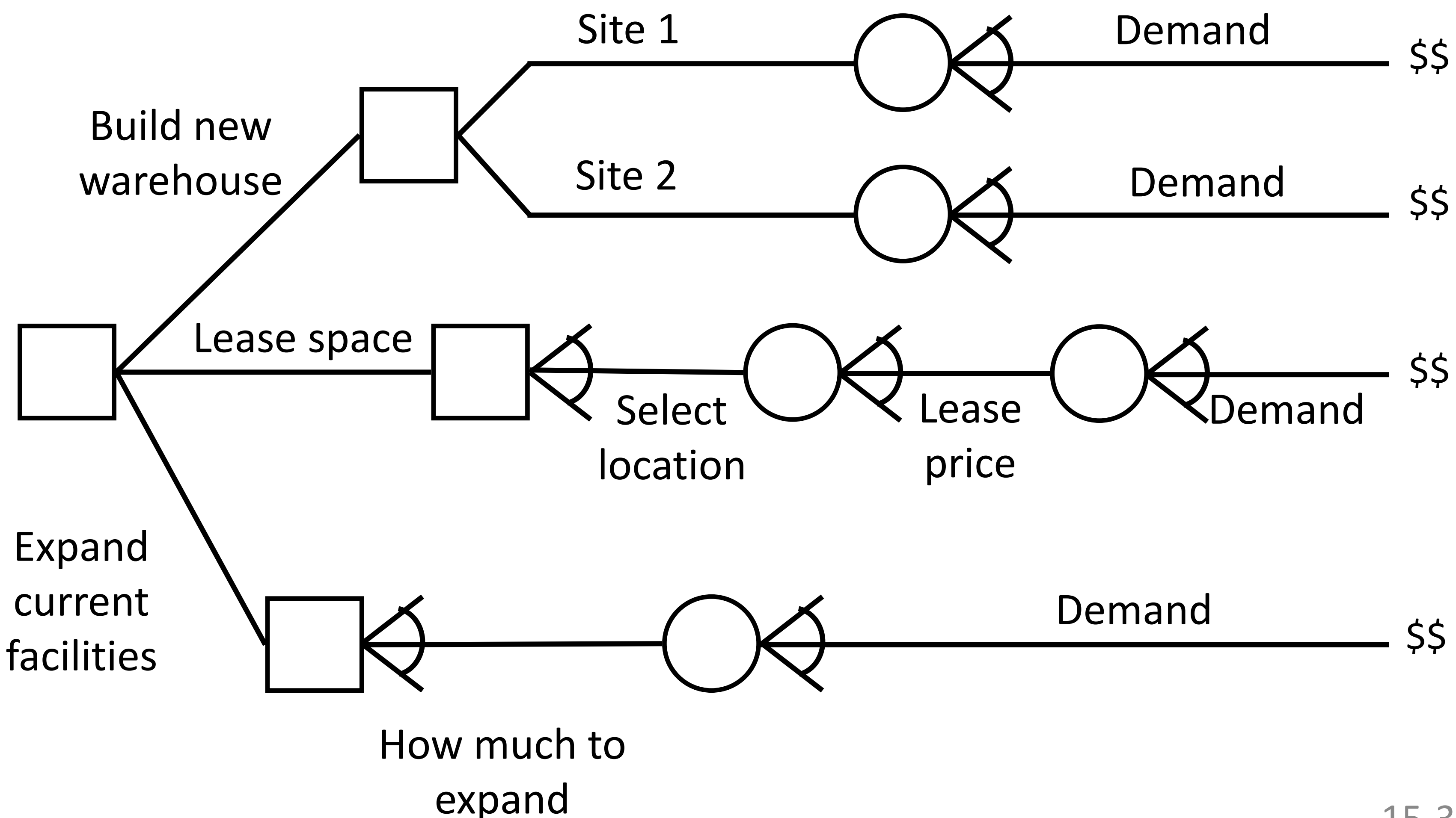
=SUMPRODUCT(B12:C12, $B$10:$C$10)

D12-MAX(D5:D8)

Decision/Event Trees

- ***Synopsis:*** A decision/event tree is a graphical model showing the sequence of events in a problem.
- ***Strength:*** Fairly simple to understand and construct, and able to show a high level of detail. Solution algorithm is simple.
- ***Weakness:*** The size of the tree grows quite rapidly when there are many choices or possibilities.

Example of a Decision/Event Tree



Common Problems in Making Decision Trees

- Determining the sequence of events
- Confusion in determining the probabilities

Influence Diagrams vs. Decision Trees

Decision Trees

- Better at showing details
- Becomes messy quite quickly
- Good for showing sequence and steps
- Straightforward solution algorithm

Influence Diagrams

- Better at showing structure
- Compact display of structure
- Good for structuring phase
- Complicated solution algorithm

Solving Decision Trees

- Start with a structure to record sequence of events
- Complete tree by adding probabilities for random events and determining payoffs for different scenarios
- Can solve decision tree to determine optimal strategy to maximize (minimize) expected payoff

Oil Wildcatting

An oil wildcatter must decide whether or not to drill at a given site before his option expires. He must decide whether to drill (action a_1) or not to drill (action a_2). He is uncertain as to whether the hole is dry (state s_1), wet (state s_2), or soaking (state s_3).

State of the Oil Well

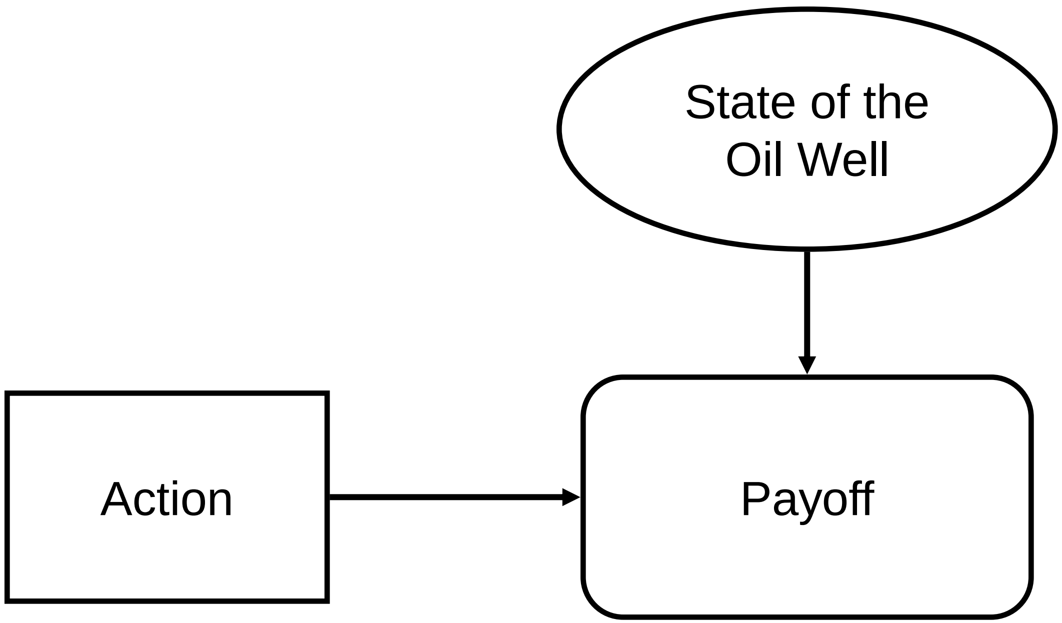
State	Prob
Dry (s_1)	50%
Wet (s_2)	30%
Soaking (s_3)	20%

Payoffs for the Problem

State	Act	
	a_1	a_2
Dry (s_1)	-$70,000	0
Wet (s_2)	$50,000	0
Soaking (s_3)	$200,000	0

Influence Diagram for Problem

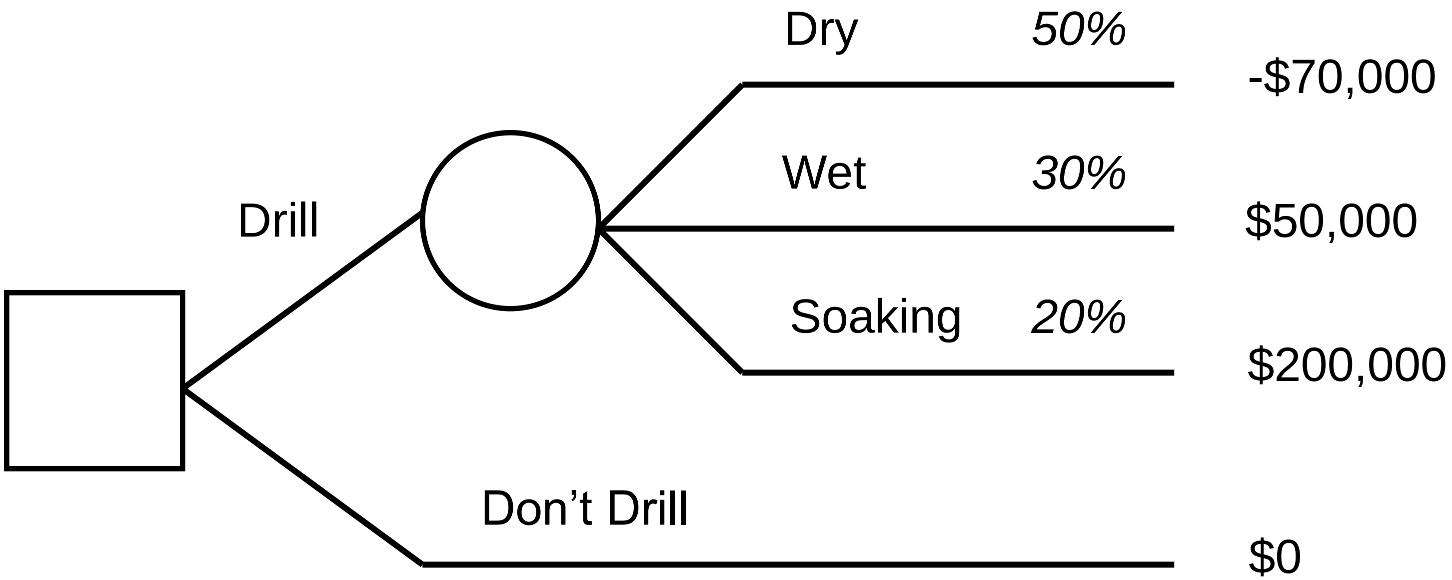
Dry
Wet
Soaking



Drill
Don’t Drill

	Drill	Don’t
Dry	-70	0
Wet	50	0
Soak.	200	0

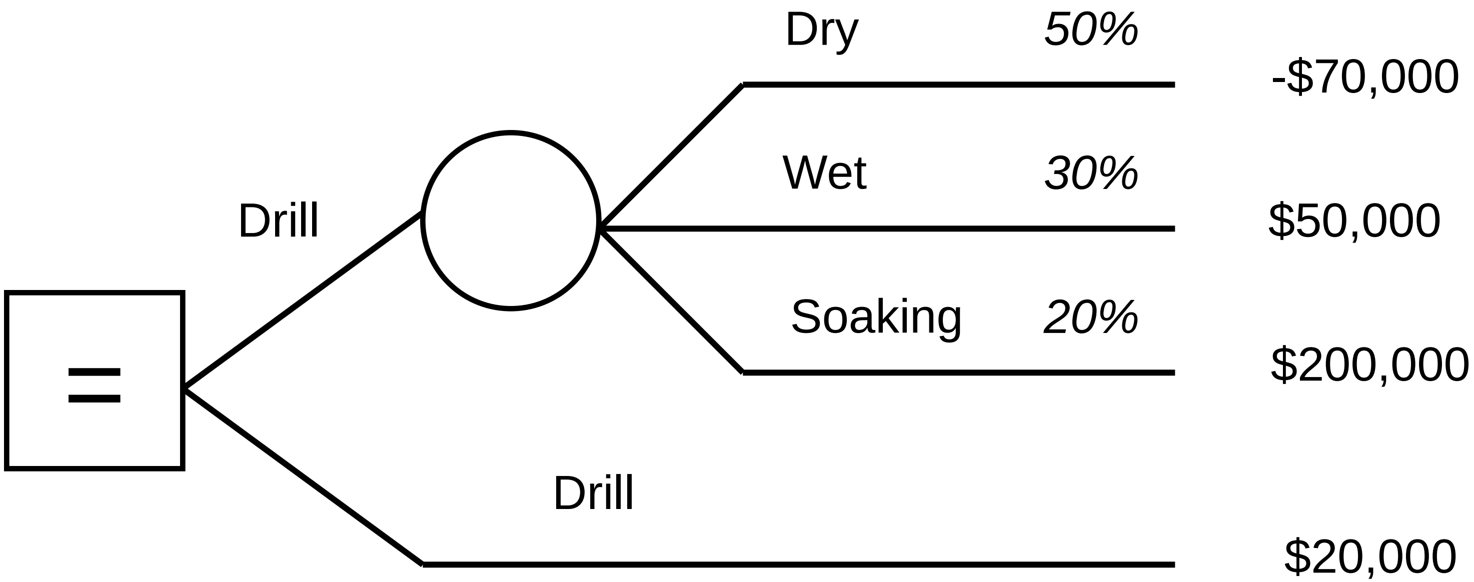
Decision Tree for the Problem



Solving the Decision Tree

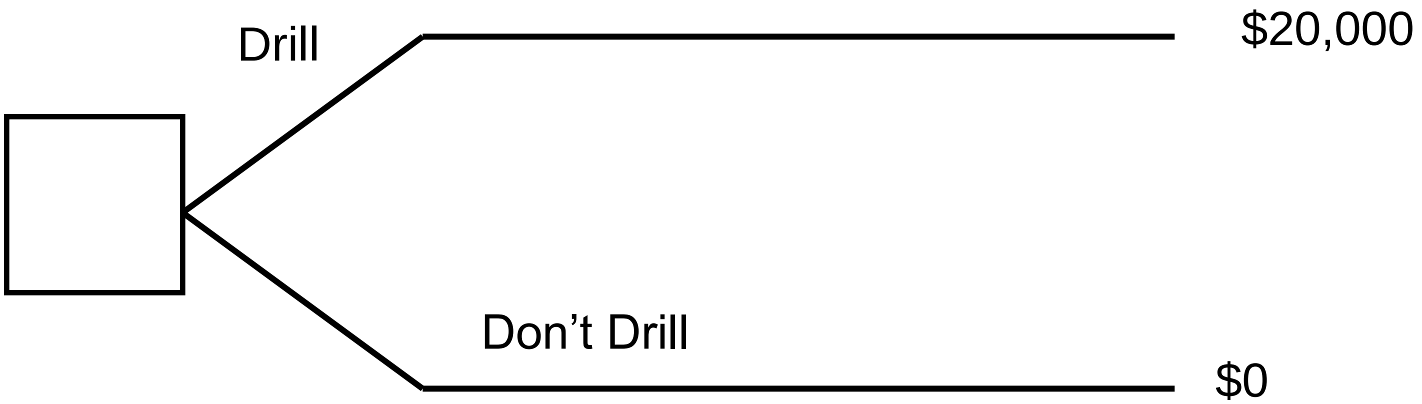
- Rolling-back
- At random event nodes
  - Record expected value of branches
- At decision nodes
  - Determine max (min) value of branches
  - Record branch giving max (min) value

Folding Back at a Random Event Node

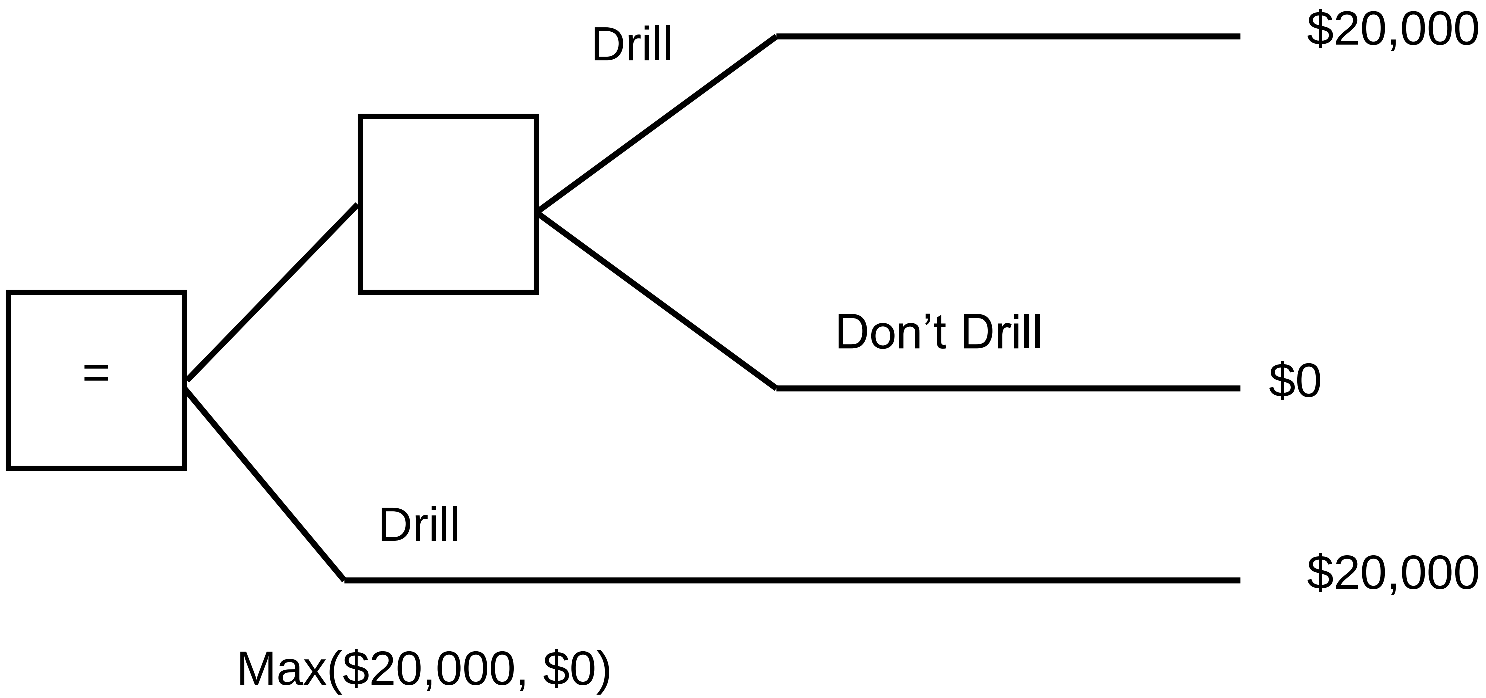


E[Drill] = -70(0.5) + 50(0.3) + 200(0.2) = 20

After Collapsing the Random Event Node



Folding Back at a Decision Node

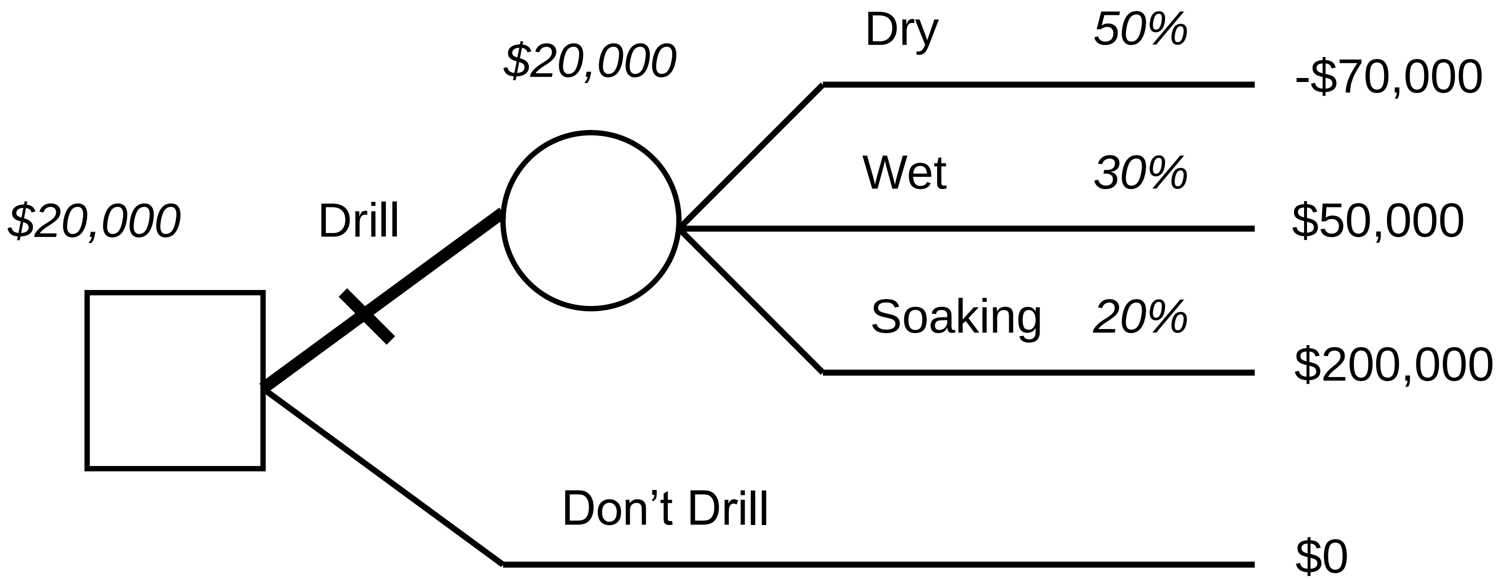


After Collapsing the Decision Node

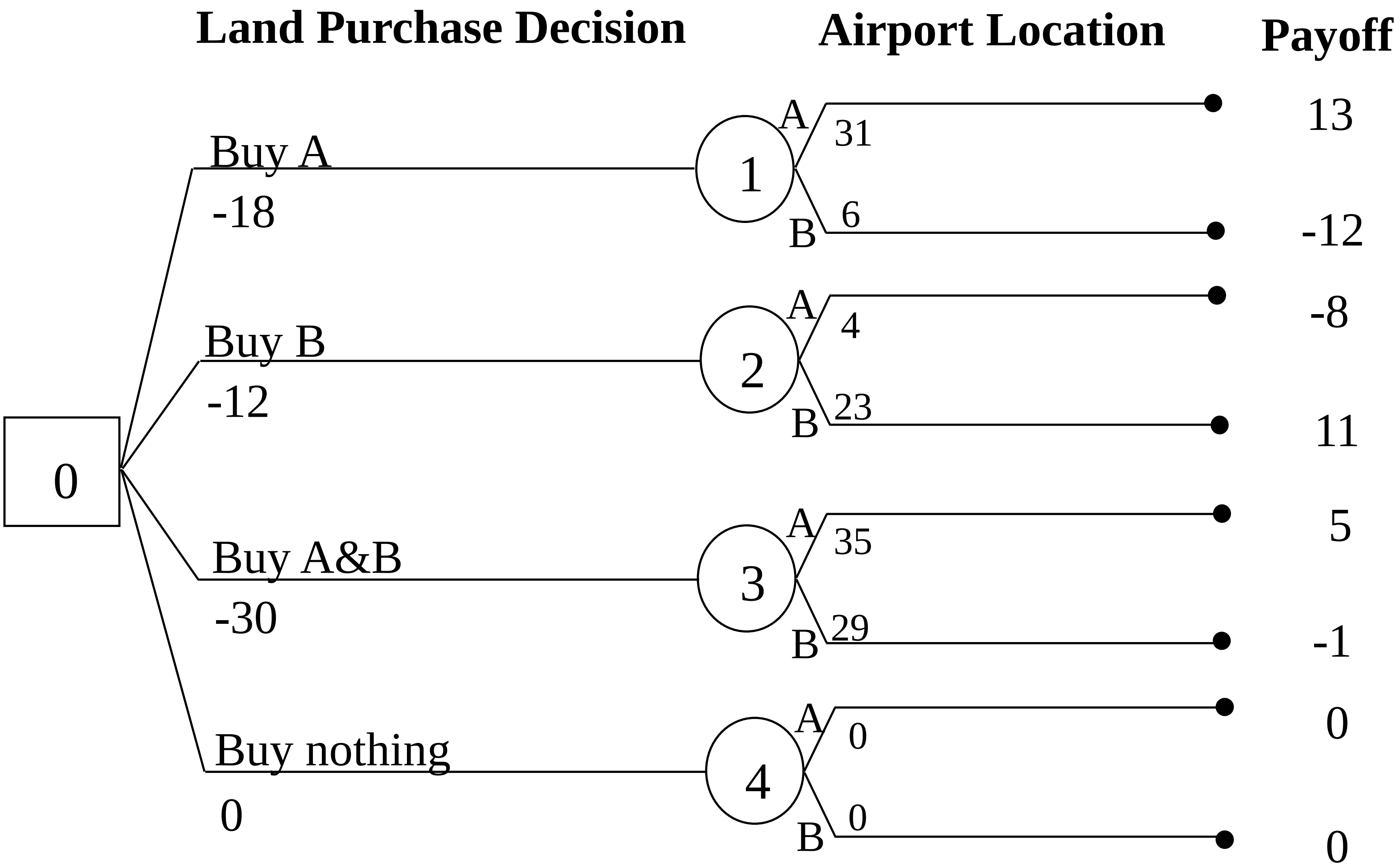
Drill

$20,000

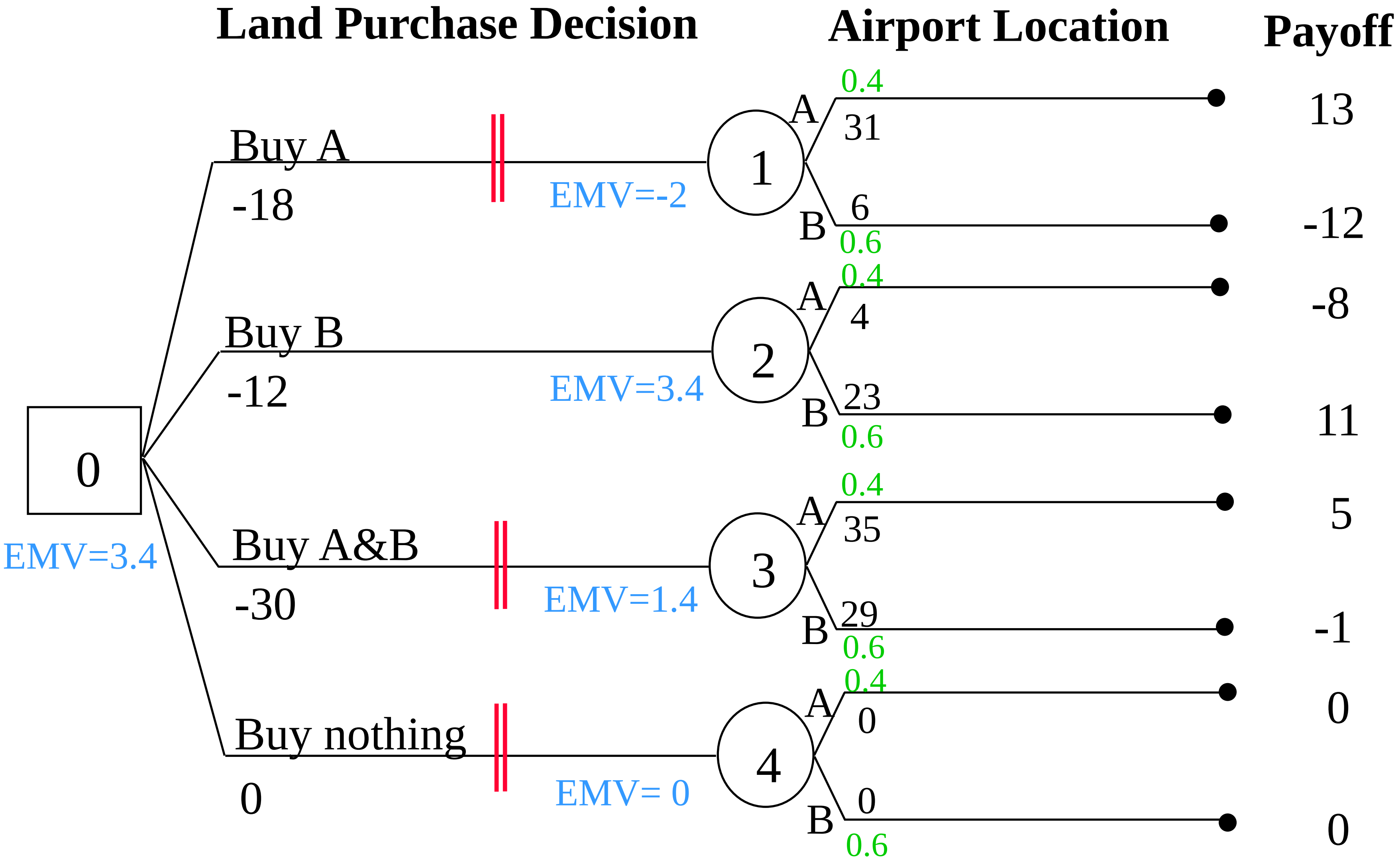
Solved Decision Tree



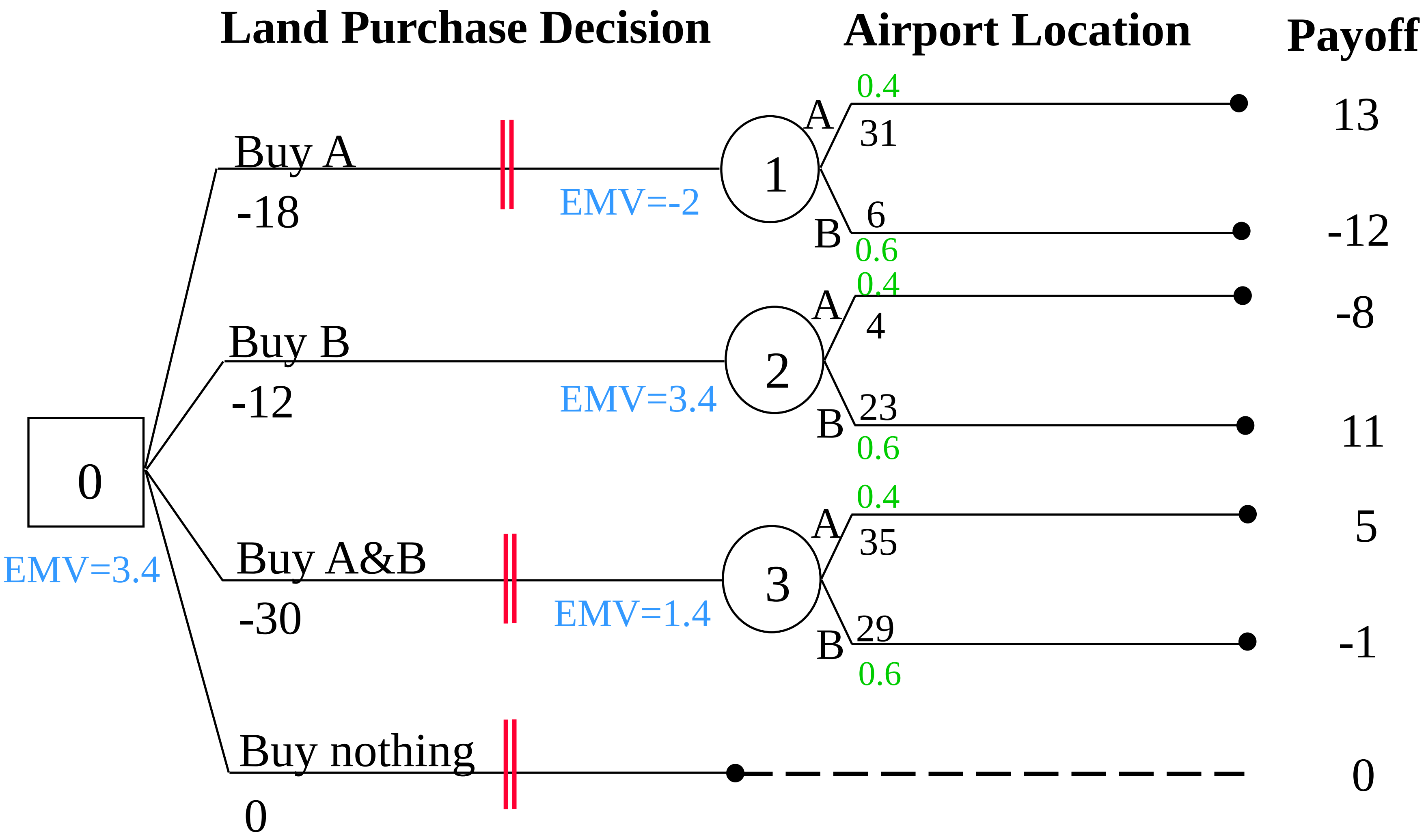
A Decision Tree for Magnolia Inns



Rolling Back A Decision Tree



Alternate Decision Tree



Assignment -7

Chapter 15
Question no.: 3,4,5, 7,8,10

Due date: 21 July 2023

End of Chapter 15