DECISION MAKING TECHNIQUES IN MANAGEMENT INFORMATION SYSTEMS (MIS)

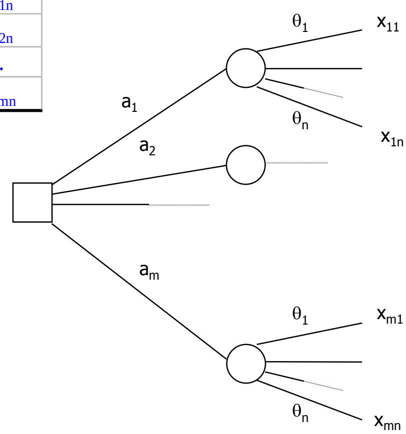
LECTURE -3-
(Decision trees, Utility Theory)

DECISION TREES

- A *decision tree* is a diagram consisting of
  - decision nodes (squares)
  - chance nodes (circles)
  - decision branches (alternatives)
  - chance branches (state of natures)
  - terminal nodes (payoffs or utilities)

Representing decision table as decision tree

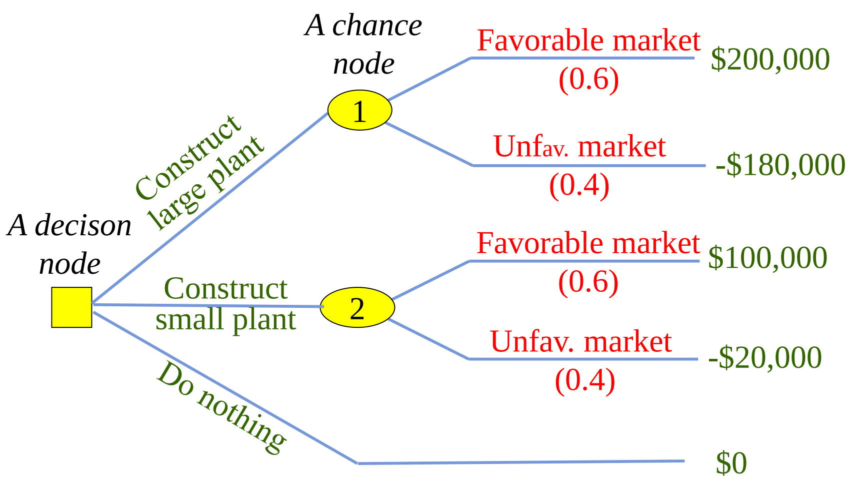
	STATES OF NATURE			
ALTERNATIVES	θ_1	θ_2	...	θ_n
a_1	x_{11}	x_{12}	...	x_{1n}
a_2	x_{21}	x_{22}	...	x_{2n}
.	.	.	...	.
a_m	x_{m1}	x_{m2}	...	x_{mn}

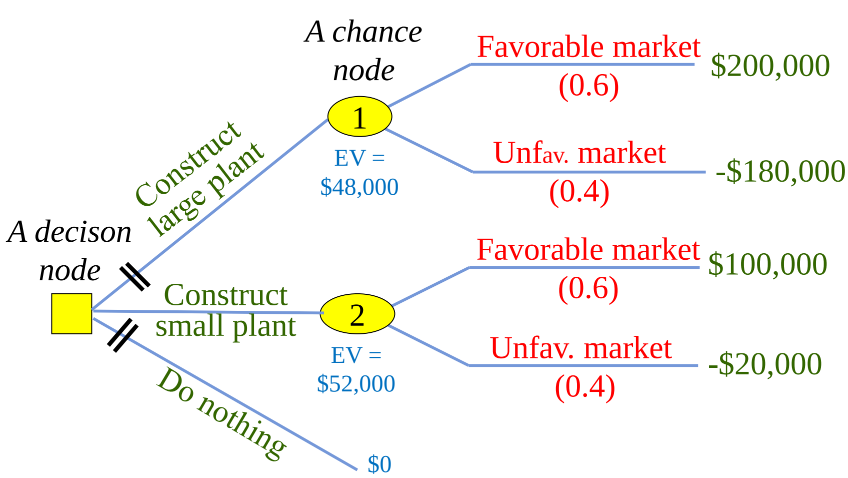


Decision Tree Method

1. Define the problem
2. Structure / draw the decision tree
3. Assign probabilities to the states of nature
4. Calculate expected payoff (or utility) for the corresponding chance node – backward, computation
5. Assign expected payoff (or utility) for the corresponding decision node – backward, comparison
6. Represent the recommendation

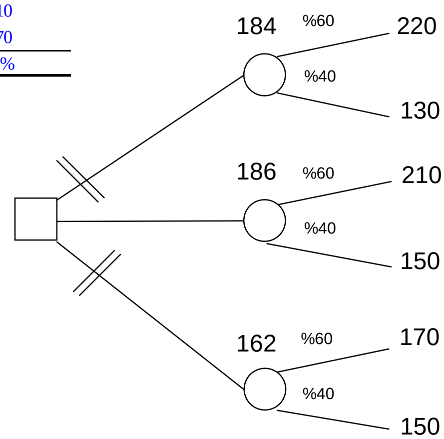
Example 1


A chance node
Favorable market (0.6)
$200,000
1
Unfav. market (0.4)
-$180,000
Construct large plant
A decison node
Favorable market (0.6)
$100,000
Construct small plant
2
Unfav. market (0.4)
-$20,000
Do nothing
$0


A chance node
Favorable market (0.6)
$200,000
1
EV = $48,000
Unfav. market (0.4)
-$180,000
Construct large plant
A decison node
Favorable market (0.6)
$100,000
Construct small plant
2
EV = $52,000
Unfav. market (0.4)
-$20,000
Do nothing
$0

EXAMPLE 2

STRATEGIES	STATES OF NATURES	
	Decrease	Increase
New equipment (S_1)	130	220
Overtime labor (S_2)	150	210
Do nothing (S_3)	150	170
PROBABILITIES	40%	60%



SEQUENTIAL DECISION TREE

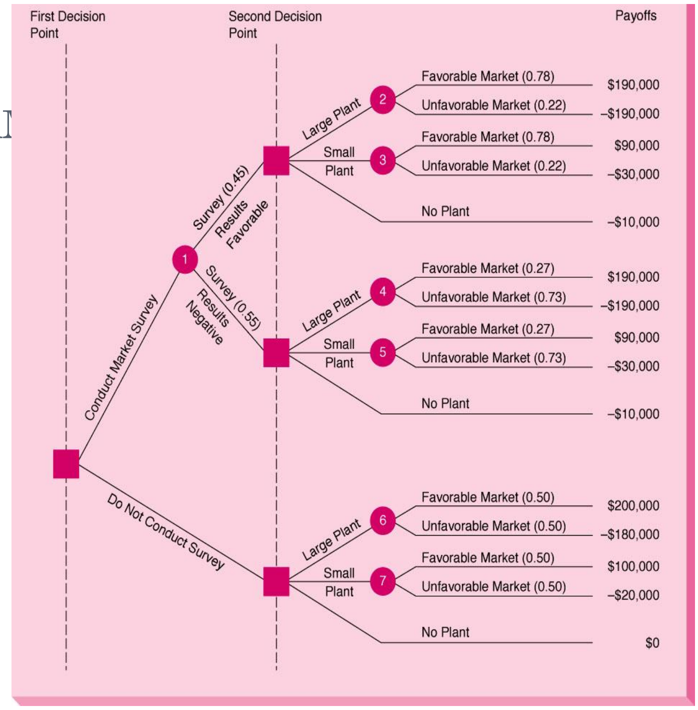
- A sequential decision tree is used to illustrate a situation requiring a series of decisions (multi-stage decision making) and it is used where a payoff matrix (limited to a single-stage decision) cannot be used.

EXAMPLE 3

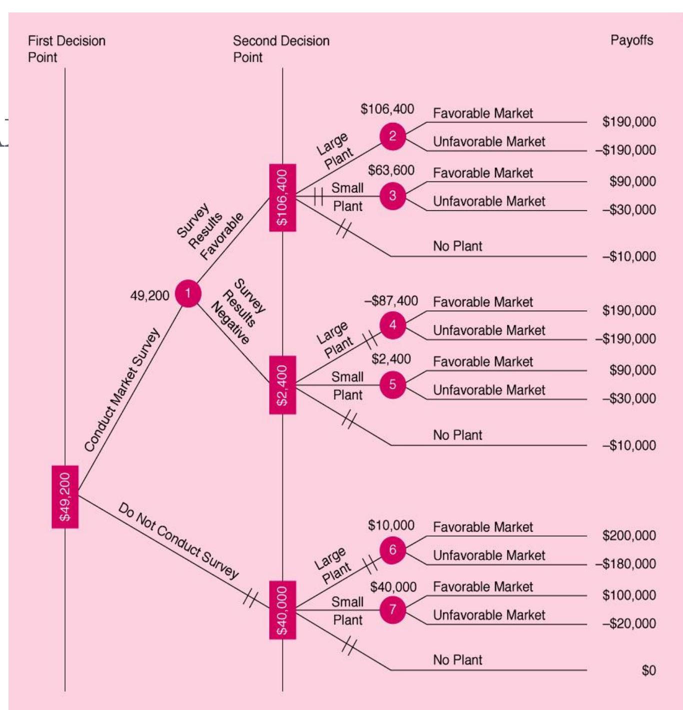
- Let's say that DM has two decisions to make, with the second decision dependent on the outcome of the first.
- Before deciding about building a new plant, DM has the option of conducting his own marketing research survey, at a cost of $10,000.
- The information from his survey could help him decide whether to construct a large plant, a small plant, or not to build at all.

- Before survey, DM believes that the probability of a favorable market is exactly the same as the probability of an unfavorable market: each state of nature has a 50% probability
- There is a 45% chance that the survey results will indicate a favorable market
- Such a market survey will not provide DM with **perfect information**, but it may help quite a bit nevertheless by *conditional (posterior) probabilities*:
  - 78% is the probability of a favorable market given a favorable result from the market survey
  - 27% is the probability of a favorable market given a negative result from the market survey

EXA


First Decision Point
Second Decision Point
Payoffs
Conduct Market Survey
Survey (0.45) Results Favorable
Survey (0.55) Results Negative
Do Not Conduct Survey
Large Plant
Small Plant
No Plant
Favorable Market (0.78)
Unfavorable Market (0.22)
Favorable Market (0.78)
Unfavorable Market (0.22)
No Plant
Favorable Market (0.27)
Unfavorable Market (0.73)
Favorable Market (0.27)
Unfavorable Market (0.73)
No Plant
Favorable Market (0.50)
Unfavorable Market (0.50)
Favorable Market (0.50)
Unfavorable Market (0.50)
No Plant
$190,000
–$190,000
$90,000
–$30,000
–$10,000
$190,000
–$190,000
$90,000
–$30,000
–$10,000
$200,000
–$180,000
$100,000
–$20,000
$0

EXA


First Decision Point
Second Decision Point
Payoffs
$49,200
49,200
Conduct Market Survey
Survey Results Favorable
Survey Results Negative
Do Not Conduct Survey
$106,400
$2,400
$40,000
Large Plant
Small Plant
No Plant
$106,400
$63,600
−$87,400
$2,400
$10,000
$40,000
Favorable Market
Unfavorable Market
No Plant
$190,000
–$190,000
$90,000
–$30,000
–$10,000
$190,000
–$190,000
$90,000
–$30,000
–$10,000
$200,000
–$180,000
$100,000
–$20,000
$0

Expected Value of Sample Information

EVSI

If there is no cost of using sample information

= EV of best decision *with* sample information, assuming no cost to gather it

– EV of best decision *without* sample information

If there is the cost of using sample information

= EV with sample info. + cost – EV without sample info.

DM could pay up to EVSI for a survey.

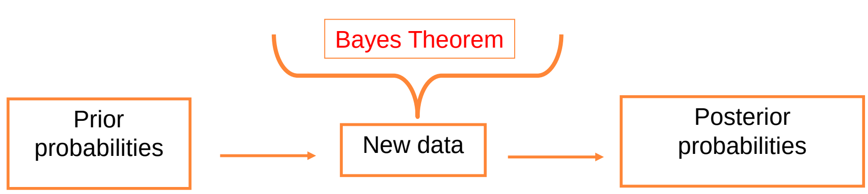
If the cost of the survey is less than EVSI, it is indeed worthwhile.

In the example:

EVSI = $49,200 + $10,000 – $40,000 = $19,200

Estimating Probability Values by Bayesian Analysis

- Management experience or intuition
- History
- Existing data
- Need to be able to *revise* probabilities based upon new data



Bayesian Analysis

Example:

- Market research specialists have told DM that, statistically, of all new products with a favorable market, market surveys were positive and predicted success correctly 70% of the time.

  P (positive / FM)= 0.70
- 30% of the time the surveys falsely predicted negative result

  P (negative / FM)= 0.30
- On the other hand, when there was actually an unfavorable market for a new product, 80% of the surveys correctly predicted the negative results.

  P (negative / UM)= 0.80
- The surveys incorrectly predicted positive results the remaining 20% of the time.

  P (positive / UM)= 0.20

Market Survey Reliability

	Actual States of Nature	
Result of Survey	Favorable Market (FM)	Unfavorable Market (UM)
Positive (predicts favorable market for product)	*P*(survey positive|FM) = 0.70	*P*(survey positive|UM) = 0.20
Negative (predicts unfavorable market for product)	*P*(survey negative|FM) = 0.30	*P*(survey negative|UM) = 0.80

Calculating Posterior Probabilities

$$P(A|B) = \frac{P(B|A)\ P(A)}{P(B|A)\ P(A) + P(B|A')\ P(A')}$$

where A and B are any two events, A' is the complement of A

P(FM|survey positive) =
[P(survey positive|FM)×P(FM)] /
[P(survey positive|FM)×P(FM) + P(survey positive|UM)×P(UM)]

P(UM|survey positive) =
[P(survey positive|UM)×P(UM)] /
[P(survey positive|FM)×P(FM) + P(survey positive|UM)×P(UM)]

Probability Revisions Given a Positive Survey				
	Conditional Probability			
State of Nature	P(Survey positive|State of Nature	Prior Probability	Joint Probability	Posterior Probability
FM	0.70	* 0.50	0.35	$\frac{0.35}{0.45}$ = 0.78
UM	0.20	* 0.50	0.10	$\frac{0.10}{0.45}$ = 0.22
			0.45	1.00

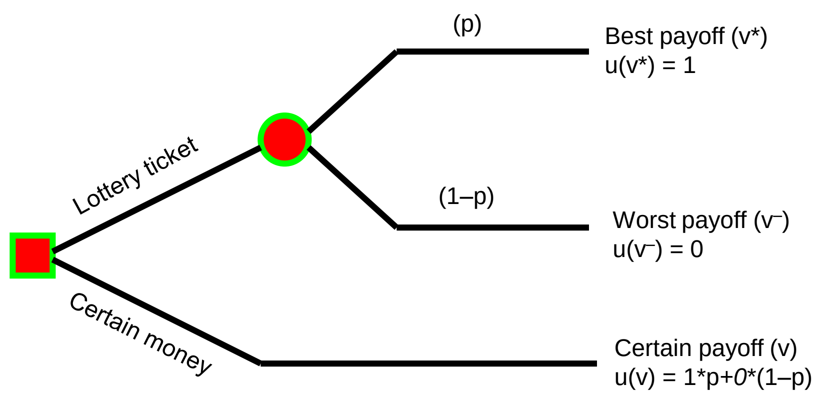
Probability Revisions Given a Negative Survey				
	Conditional Probability			
State of Nature	P(Survey negative|State of Nature)	Prior Probability	Joint Probability	Posterior Probability
FM	0.30	* 0.50	0.15	$\frac{0.15}{0.55} = 0.27$
UM	0.80	* 0.50	0.40	$\frac{0.40}{0.55} = 0.73$
			0.55	1.00

UTiLiTY THEORY

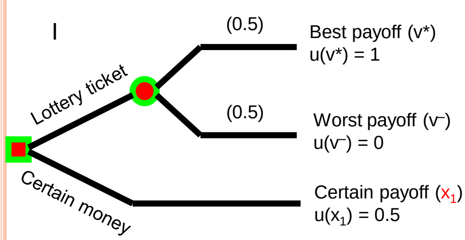
- Utility assessment may assign the *worst payoff* a utility of *0* and the *best payoff* a utility of *1*.
- A *standard gamble* is used to determine utility values: When DM is ***indifferent*** between two alternatives, the utility values of them are *equal*.
- Choose the alternative with the maximum *expected utility*

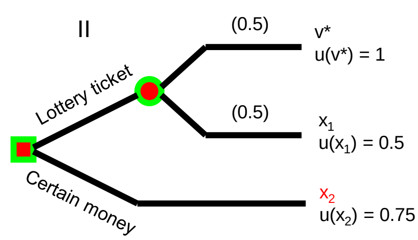
$$\mathrm{EU}(a_i) = \mathrm{u}(a_i) = \sum_j \mathrm{u}(v_{ij})\,\mathrm{P}(\mathrm{q}_j)$$

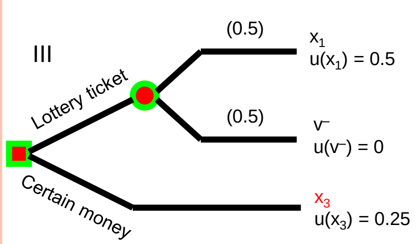
Standard Gamble for Utility Assessment



Utility Assessment (1st approach)







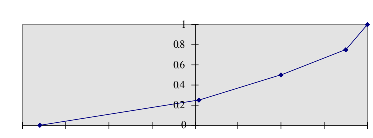
In the example:

u(-180) = 0 and u(200) = 1

x_1= 100 $\Rightarrow$ u(100) = 0.5

x_2 = 175 $\Rightarrow$ u(175) = 0.75

x_3 = 5 $\Rightarrow$ u(5) = 0.25



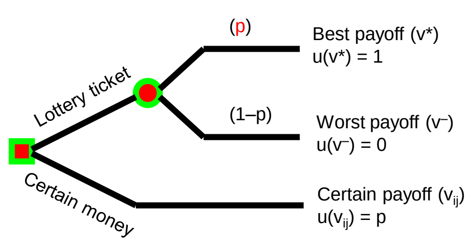
Expected Utility (Example 1)

v_{ij}	$u(v_{ij})$
200	1
175	0.75
100	0.5
5	0.25
0	
-20	
-180	0

v_{ij}	$u(v_{ij})$
5	0.25
0	**0.2432**
-20	**0.2162**
-180	0

Utilities	STATES OF NATURE		
ALTERNATIVES	Favorable market	Unfavorable market	Expected Utility
Construct large plant	1	0	**0.6**
Construct small plant	0.5	0.2162	0.3865
Do nothing	0.2432	0.2432	0.2432
PROBABILITIES	0.6	0.4	

Utility Assessment (2^{ND} approach)



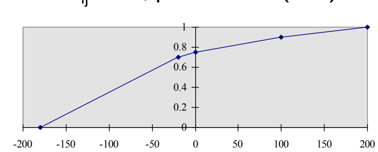
In the example:

u(-180) = 0 and u(200) = 1

For v_{ij}=–20, p=%70 ⇒ u(–20) = 0.7

For v_{ij}=0, p=%75 ⇒ u(0) = 0.75

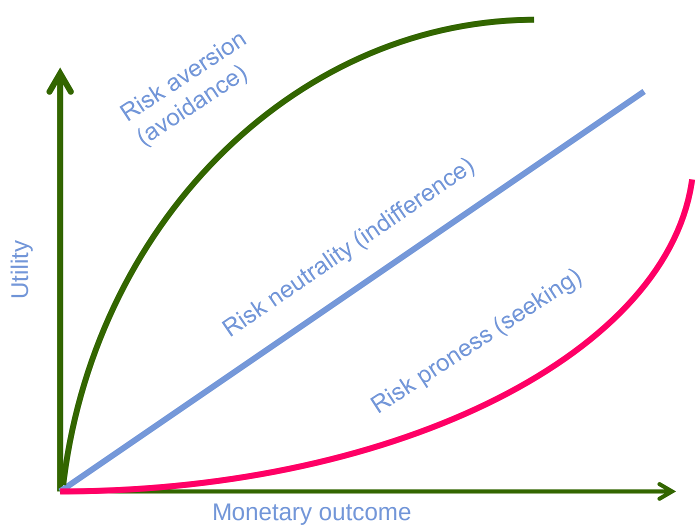
For v_{ij}=100, p=%90 ⇒ u(100) = 0.9



Expected Utility (Example 2)

Utilities	STATES OF NATURE		
ALTERNATIVES	Favorable market	Unfavorable market	Expected Utility
Construct large plant	1	0	0.6
Construct small plant	0.9	0.7	**0.82**
Do nothing	0.75	0.75	0.75
PROBABILITIES	0.6	0.4	

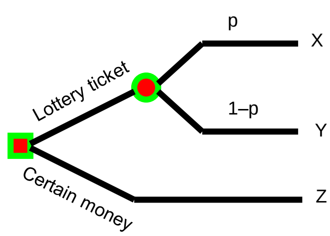
Preferences for Risk



Certainty Equivalence

- If a DM is indifferent between accepting a lottery ticket and accepting a sum of certain money, the monetary sum is the *Certainty Equivalent* (CE) of the lottery

- Z is CE of the lottery (Y≥Z≥X).



Risk Premium

- *Risk Premium* (RP) of a lottery is the difference between the EV of the lottery and the CE of the lottery
  - If the DM is risk averse (avoids risk), RP > 0

    S/he prefers to receive a sum of money equal to expected value of a lottery than to enter the lottery itself
  - If the DM is risk prone (seeks risk), RP < 0

    S/he prefers to enter a lottery than to receive a sum of money equal to its expected value
  - If the DM is risk neutral, RP = 0

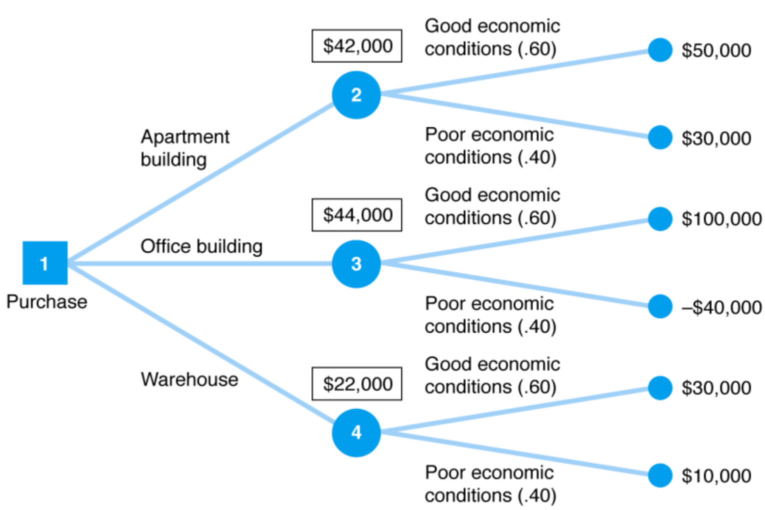
    S/he is indifferent between entering any lottery and receiving a sum of money equal to its expected value

APPLICATION 1

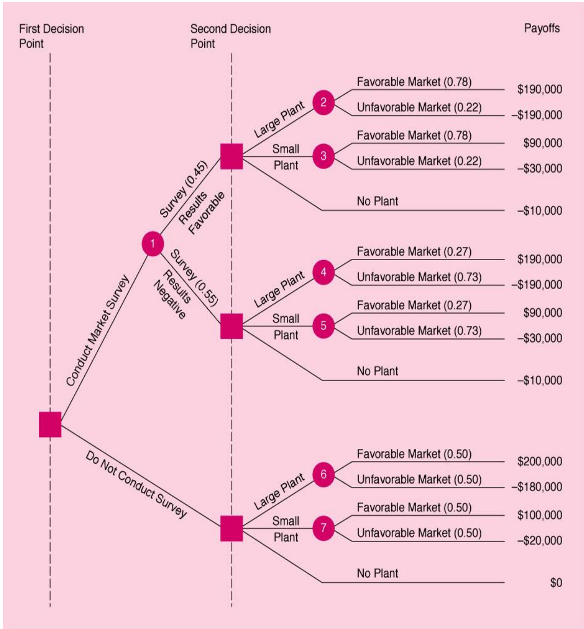
- Draw the decision tree and determine the best alternative regarding the expected value.

Decision (Purchase)	States of Nature: Good Economic Conditions .60	Poor Economic Conditions .40
Apartment building	$ 50,000	$ 30,000
Office building	100,000	–40,000
Warehouse	30,000	10,000

ANSWER TO APPLICATION 1

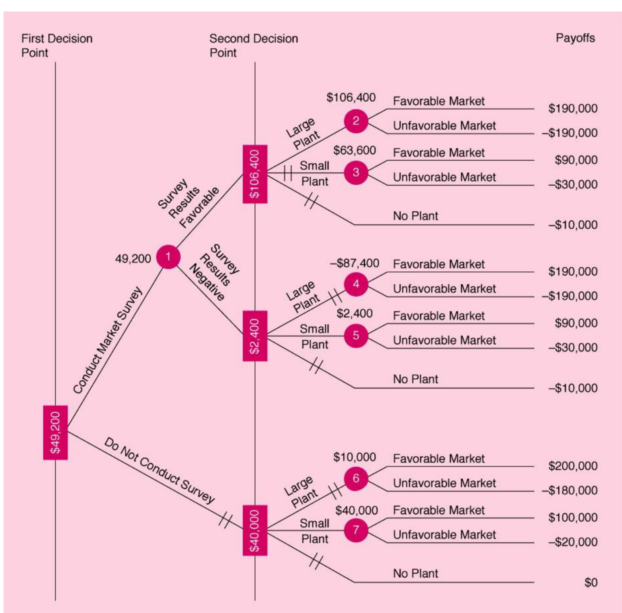


APPLICATION 2



- Draw the decision tree and determine the best alternative regarding the expected value.

ANSWER TO APPLICATION 2



REFERENCES

- Lecture notes of “Prof. Dr. Y. İlker Topçu”, http://web.itu.edu.tr/topcuil/