
ECE 307 – Techniques for Engineering Decisions

Lecture 1. Course Overview

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SCOPE OF COURSE

- ❑ The course covers *techniques* that are useful when combined with the appropriate technical knowledge, to make *engineering/economic decisions*
- ❑ Such decisions are typical of those made by business firms, government–owned enterprises and agencies and individuals
- ❑ Our focus is on the *systematic evaluation* of the set of alternatives before we make a decision on a given problem

SOME EXAMPLES OF DECISION MAKING PROBLEMS

- ☐ Introduction of a new product**
- ☐ Expansion of production facilities/warehousing**
- ☐ Adoption of new technology**
- ☐ Implementation of a new production schedule**
- ☐ Changes in the production mix**
- ☐ Risk management in purchase/sale activities**
- ☐ Optimal scheduling of processes/projects**

ECE 307: TWO BASIC THRUSTS

- ❑ Development of the **analytical framework** for decision making based on a sound foundation with the goals to enable the decision maker to
 - undertake an appropriate analysis; and
 - systematically evaluate various alternatives
- ❑ Provision of **training for engineers** to play an increasingly more prominent role in the decision making processes in their work environment

THE UNDERLYING BASIS

- ❑ Decisions are made by selecting from possible alternatives with reference to the future, which is inherently *uncertain*
- ❑ We can set up a useful basis by the formulation of the decisions in *economic* terms
- ❑ A key consideration is the nature of the introduced *assumptions* to enable us to undertake the systematic analysis and the evaluation of alternatives

PRODUCT MIX OPTIMIZATION PROBLEM

- ❑ A factory manufactures three different products that require various levels of resources and result in different benefits (profits)
- ❑ The constraints on each resource are given
- ❑ Problem is to **determine the optimal daily mix**, *i.e.*, the production schedule that maximizes profits without the violation of any constraints

PRODUCT MIX OPTIMIZATION PROBLEM

<i>product</i>		<i>A</i>	<i>B</i>	<i>C</i>	<i>limit</i>
<i>resources required per unit of product</i>	<i>labor (h)</i>	1	1	1	100
	<i>material (lb)</i>	10	4	5	600
	<i>A&G (h)</i>	2	2	6	300
<i>profits per unit of product (\$)</i>		10	6	4	—

PRODUCT MIX OPTIMIZATION PROBLEM

- We formulate the decision problem by defining the decision variables:

x_i = daily production level of product i , $i = A, B, C$

- We construct a programming problem for the schedule by expressing

- the **objective function**;
- the **constraints**; and,
- the **common sense requirements**

in *mathematical* terms

PRODUCT MIX OPTIMIZATION PROBLEM

$$\max Z = 10x_A + 6x_B + 4x_C \quad \text{objective}$$

$$x_A + x_B + x_C \leq 100 \quad \text{labor}$$

$$10x_A + 4x_B + 5x_C \leq 600 \quad \text{materials}$$

$$2x_A + 2x_B + 6x_C \leq 300 \quad \text{A \& G}$$

$$x_A, x_B, x_C \geq 0 \quad \text{reality check}$$

constraints

PRODUCT MIX OPTIMIZATION PROBLEM

□ The optimal solution is

$$x_A^* = 33.33$$

$$x_B^* = 66.67$$

$$x_C^* = 0$$

and correspond to maximum profits

$$Z^* = \$ 733.33$$

□ The **shadow prices that** correspond to the constraints state the change in profits for each unit of an additional resource have values:

$$\text{labor} : \$ 3.33$$

$$\text{material} : \$ 0.67$$

$$A\&G : \$ 0$$

PRODUCT MIX OPTIMIZATION PROBLEM

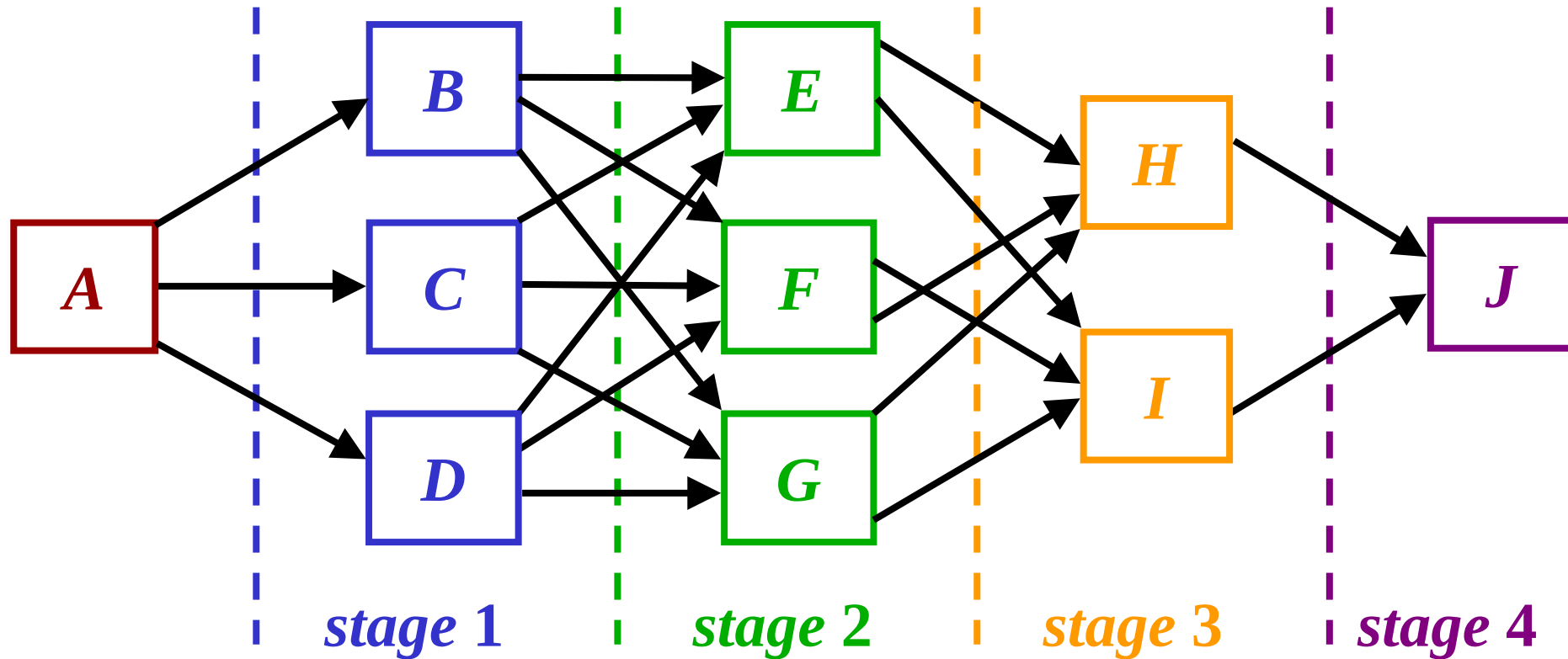
- ❑ We next examine a simple *what if sensitivity case* related to the use of overtime labor
- ❑ We are interested to determine the number of overtime hours that is profitable to schedule without any impact on the *optimal product mix*

PRODUCT MIX OPTIMIZATION PROBLEM

- 20 hours of labor overtime increase profits by
 $(20)(3.33) = \$ 66.6$
- as long as the cost of overtime labor does not exceed \$ 66.6 it is worthwhile to use it
- the optimal product mix remains **unchanged**,
as we produce only products *A* and *B* and no
product *C*

OPTIMAL TRAJECTORY PLANNING

- Mr. Jones has to travel from a fixed starting point **A** to a fixed destination point **J** with the choice in the intermediate points he goes through:



OPTIMAL TRAJECTORY PLANNING

- The relative “costs” for the various possible paths are given by

	<i>B</i>	<i>C</i>	<i>D</i>
<i>A</i>	2	4	3

	<i>E</i>	<i>F</i>	<i>G</i>
<i>B</i>	7	4	6
<i>C</i>	3	2	4
<i>D</i>	4	1	5

	<i>H</i>	<i>I</i>
<i>E</i>	1	4
<i>F</i>	6	3
<i>G</i>	3	3

	<i>J</i>
<i>H</i>	3
<i>I</i>	4

- The problem is to select the **trajectory** that **minimizes** the total costs of the trip

OPTIMAL TRAJECTORY PLANNING

❑ Solution approaches:

- enumerate all possibilities: this is, in general, too time consuming since we need to consider

$$3 \times 3 \times 2 = 18$$

different routes for this simple case

- select the best for each successive stage:
myopic decision making solution leads to the path

A → *B* → *F* → *I* → *J*

with costs of 13

OPTIMAL TRAJECTORY PLANNING

- use some *heuristic* approach which allows to sacrifice a little at one stage in the hope of attaining savings thereafter: for example, the path $A \rightarrow D \rightarrow F$ costs 4 which is less than the path $A \rightarrow B \rightarrow F$, whose costs are 6

□ The *optimal trajectory* is

$A \rightarrow C \rightarrow E \rightarrow H \rightarrow J$

whose costs are 11

OPTIMAL TRAJECTORY PLANNING

- There are two additional routes, which cost 11:

A → *D* → *E* → *H* → *J*

A → *D* → *F* → *I* → *J*

- Thus, this is a problem that does not have a

unique optimum for the given data

BUSING PROBLEM

- Three school districts in *Busville* have a distribution of *Caucasians* (C) and *African Americans* (A) as shown in the table

<i>district</i>	<i>number of students</i>	
	C	A
1	210	120
2	210	30
3	180	150

BUSING PROBLEM

- ❑ Implementation of the *Supreme Court* ruling on racial balance requires that each of the three districts have exactly 300 students with identical racial make-up, *i.e.*, that

$$\left(\frac{A}{C}\right)_1 = \left(\frac{A}{C}\right)_2 = \left(\frac{A}{C}\right)_3$$

and the only means to attain the racial balance goal is through busing

BUSING PROBLEM

- Given the distances between the districts,
determine the total minimum distance that
students must be bussed to satisfy the racial
balance requirements

<i>district</i>	<i>number of students</i>		<i>distance to district</i>	
	<i>C</i>	<i>A</i>	2	3
1	210	120	3	5
2	210	30	—	4
3	180	150	4	—

THE ENVELOPE QUESTION

- ❑ On a television game show, the host subjects contestants to unusual tests of mental skill
- ❑ On one, a contestant may choose one of two identical envelopes – labeled A and B – each of which contains an unknown amount of money
- ❑ The host reveals, however, that one envelope contains twice as much money as the other

THE ENVELOPE QUESTION

- ❑ After choosing A , the host suggests that the contestant might want to switch. The host states:
“Switching is clearly advantageous. Suppose you have amount x in your envelope A . Then B must contain either $x/2$ or $2x$ – each with the probability 0.5. In fact, now that I think about it, I’ll only let you switch if you pay me

THE ENVELOPE QUESTION

10 % of your winnings. What do you say?

You'll still be ahead."

☐ The contestant replies:

"No deal. But I'll be happy to switch for free.

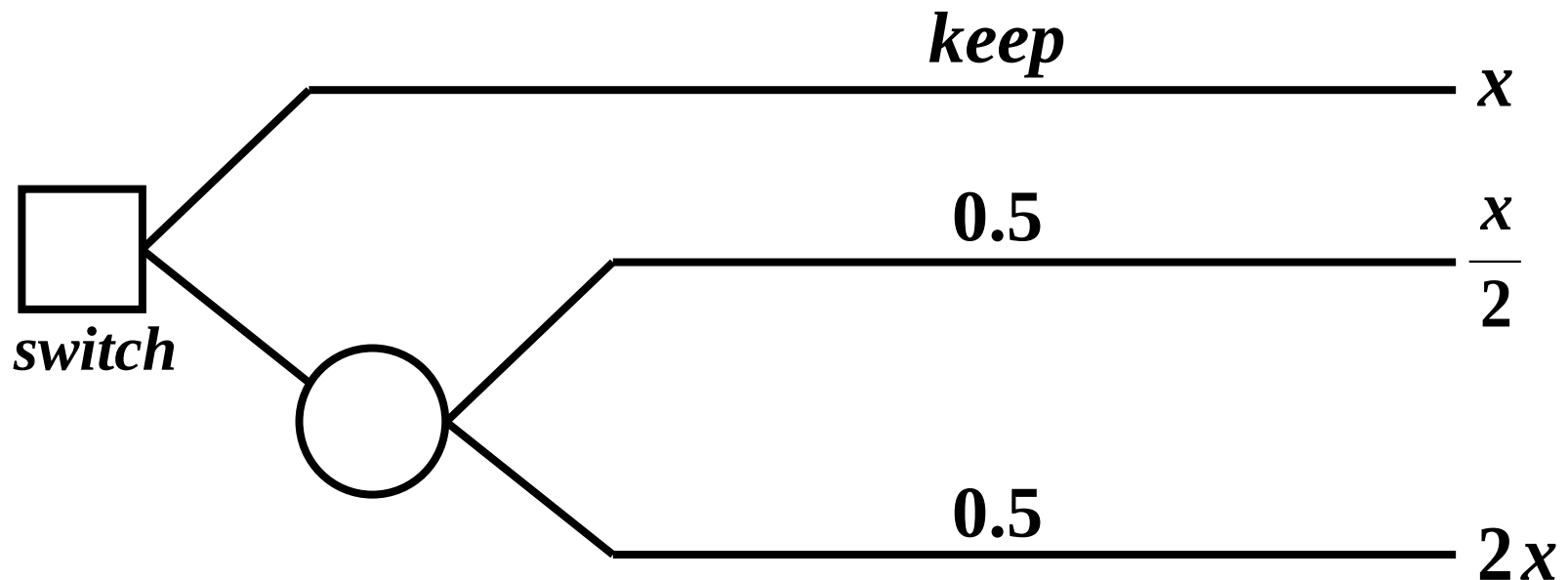
In fact, I'll even let you choose which envelope

I get. I won't even charge you anything!"

☐ Who is correct?

THE ENVELOPE QUESTION

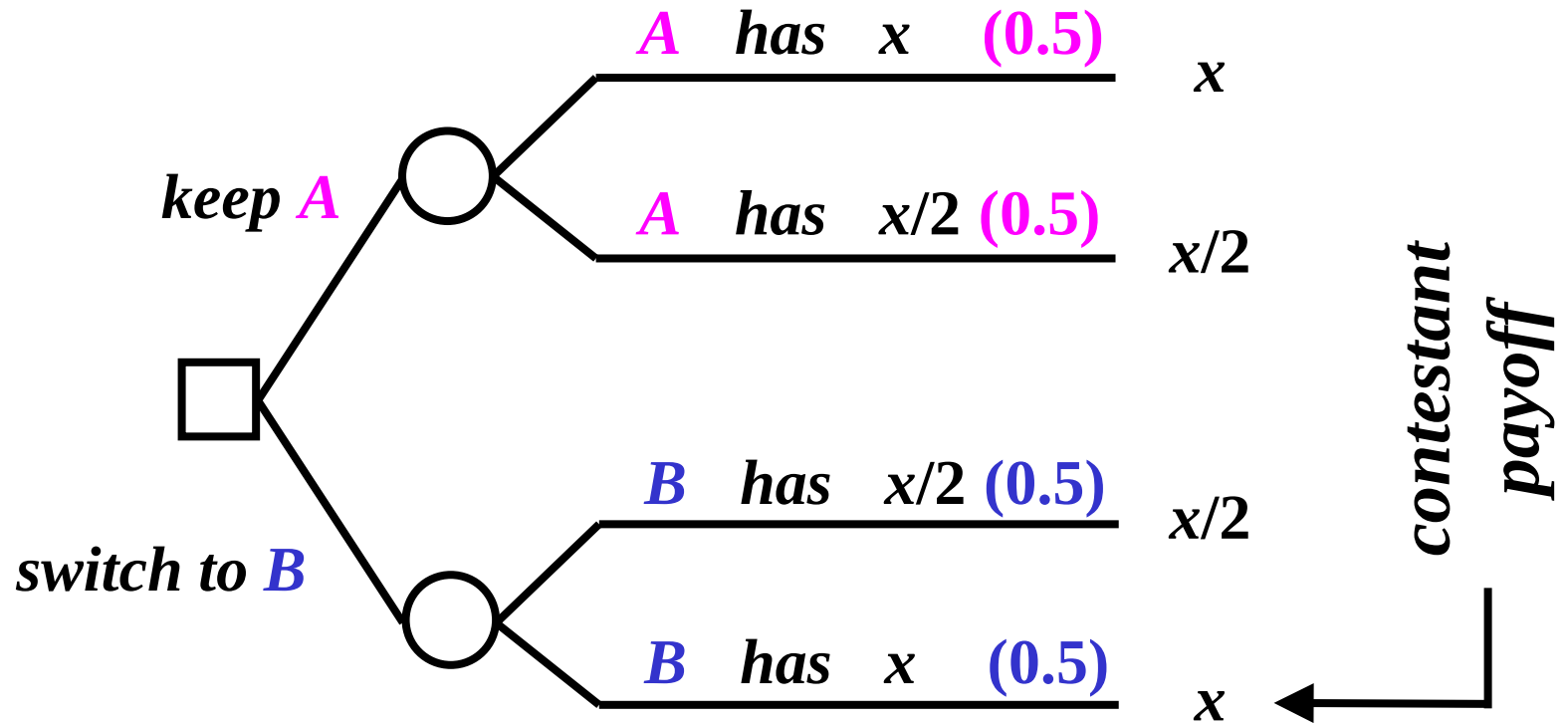
- ❑ The host is proposing a decision tree that looks like this:



which does not correctly represent the situation

THE ENVELOPE QUESTION

- Rather, we have for the two envelopes **A** and **B**



- The two decision branches are identical from the view of the decision maker – the contestant

DECISION ANALYSIS PROTOTYPE EXAMPLE

- ❑ The *Greazy Company* owns a tract of land that may contain oil; the report of a consulting geologist indicates that there is 1 chance in 4 that oil exists
- ❑ Because of this prospect, another oil company has offered to purchase the land for \$90,000 but *Greazy* assesses the option to hold the land so as to drill for oil itself: if oil is found, the profits are expected to be \$700,000 but if the land is dry, the losses are expected to be \$100,000

DECISION ANALYSIS PROTOTYPE EXAMPLE

<i>decision alternative</i>	<i>payoff (\$)</i>	
	<i>land has oil</i>	<i>land is dry</i>
<i>drill for oil</i>	700,000	(100,000)
<i>sell the land</i>	90,000	90,000
<i>probability</i>	0.25	0.75

DECISION ANALYSIS PROTOTYPE EXAMPLE

- Evaluation of the two alternative actions

<i>action</i>	<i>expected payoff (k\$)</i>
<i>drill</i>	$0.25 (700) + 0.75 (- 100) = 100$
<i>sell</i>	$0.25 (90) + 0.75 (90) = 90$

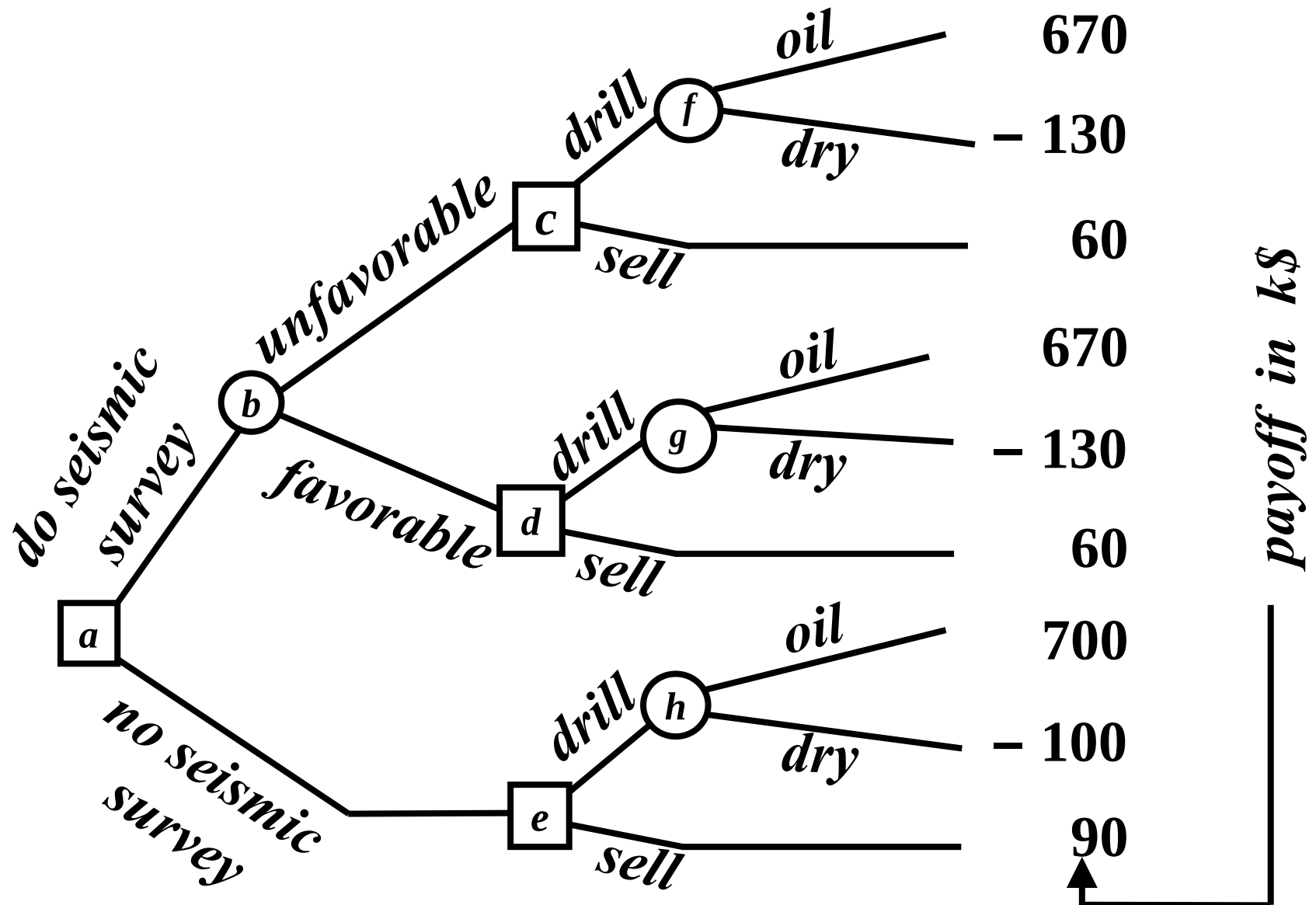
and the *better* alternative is to drill for oil

- The decision is *strongly dependent* on how good is the knowledge of the probabilities

DECISION ANALYSIS PROTOTYPE EXAMPLE

- ❑ Sometimes it is possible to undertake further work before a decision is taken; e.g., an available option before making a decision is to conduct a detailed seismic survey, with costs of \$30,000, to obtain a better estimate of the probability of oil
- ❑ We construct a **decision tree** to
 - visually display the problem
 - organize systematically the computation

DECISION ANALYSIS PROTOTYPE EXAMPLE



GENERAL FRAMEWORK FOR DECISION MAKING UNDER UNCERTAINTY

- ❑ The decision maker must select an alternative from a set of possible actions; we refer to them as the *set of feasible alternatives*
- ❑ The underlying premise is that the choice of action is made under *uncertainty* because the outcomes are affected by random factors *outside the control* of the decision maker; such a situation requires a *classification* of the possible *states of nature*

GENERAL FRAMEWORK FOR DECISION MAKING UNDER UNCERTAINTY

- ❑ For each action and state of nature, the value to the decision maker of the consequences of an outcome is determined and quantified in terms of the so-called *payoff*
- ❑ The *payoff* is defined as the measure of the value to the decision maker of the consequences of an outcome

GENERAL FRAMEWORK FOR DECISION MAKING UNDER UNCERTAINTY

- ❑ The *expected payoffs* are used to select the *optimal action* for the decision maker according to some selected criterion
- ❑ Example: *Bayes' decision rule* centers on the use of the best available estimates of the probabilities of the states of nature to calculate the expected value of the *payoffs* for each possible action and then to choose the action that obtains the *maximum expected payoffs*

DECISION ANALYSIS

- ❑ We study decision analysis since its application can lead to *better decisions*
- ❑ We need to differentiate between *good* decisions and *lucky* outcomes
- ❑ Every decision may have a *lucky* or an *unlucky* outcome
- ❑ A good decision is one that gives *the best outcome*
- ❑ The goal is to make effective decisions *more consistently*

ECE 307

- ❑ **Prerequisite: ECE 210**
- ❑ **Corequisite: ECE 313**
- ❑ **Required texts**
 - **A. Ravindran, D. T. Phillips and J. J. Solberg, "*Operations Research: Principles and Practice*," J. Wiley, New York, 1992.**
 - **R. T. Clemen, "*Making Hard Decisions: An Introduction to Decision Analysis*," Duxbury Press/Wadsworth Publishing Company, 1995.**
- ❑ **Course Website: courses.engr.illinois.edu/ece307/**

PROPOSED GRADING POLICY

- ❑ Two exams: midterm and final
- ❑ Two team project presentations
- ❑ Proposed grade allocation

<i>component</i>	<i>percentage</i>
<i>homework</i>	15
<i>team projects</i>	10
<i>midterm</i>	25
<i>final</i>	50
<i>total</i>	100

ECE 307 TOPICAL OUTLINE

- ❑ **Introduction:** nature of engineering decisions; structuring of decisions; role of models; interplay of economics and technical/engineering considerations; decision making under certainty and uncertainty; good decisions vs. “good” outcomes; tools
- ❑ **Resource allocation decision making using the *linear programming framework*:** problem formulation; basic approach; duality; economic interpretation;

ECE 307 TOPICAL OUTLINE

sensitivity analysis; meaningful interpretation of the results

- ❑ **Scheduling and assignment decisions using**
network flow concepts: transshipment problem
formulation and solution; application to matching
decisions; network optimization; scheduling
applications; project management

ECE 307 TOPICAL OUTLINE

- ❑ **Sequential decision making in a *dynamic programming* framework:** nature of the dynamic programming approach; problem formulation; solution procedures; key limitations
- ❑ **Probability theory:** random variables; probability distributions; expectation; conditional probability; moments; convolution
- ❑ **Statistical concepts:** data analysis; statistical measures; estimation

ECE 307 TOPICAL OUTLINE

- ❑ **Application of probabilistic concepts to *modeling of uncertainty* in decision making:** modeling of the impacts of uncertainty; applications to siting, investment and price volatility problems
- ❑ **Decision making *under uncertainty*:** decision trees; value of information; uses of data; sensitivity analysis and statistics
- ❑ **Case studies and presentations**