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

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

$$\begin{array}{lr} \max Z = 10x_A + 6x_B + 4x_C & \textit{objective} \end{array}$$

$$\left.\begin{array}{lr}
x_A + x_B + x_C \leq 100 & \textit{labor} \\
10x_A + 4x_B + 5x_C \leq 600 & \textit{material} \\
2x_A + 2x_B + 6x_C \leq 300 & \textit{A \& G} \\
x_A , x_B , x_C \geq 0 & \textit{reality check}
\end{array}\right\} \textit{constraints}$$

PRODUCT MIX OPTIMIZATION PROBLEM

- ☐ The optimal solution is

$$x_A^* = 33.33 \qquad x_B^* = 66.67 \qquad x_C^* = 0$$

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:

$$labor : \$\ 3.33 \qquad material : \$\ 0.67 \qquad A\&G : \$\ 0$$

PRODUCT MIX OPTIMIZATION PROBLEM

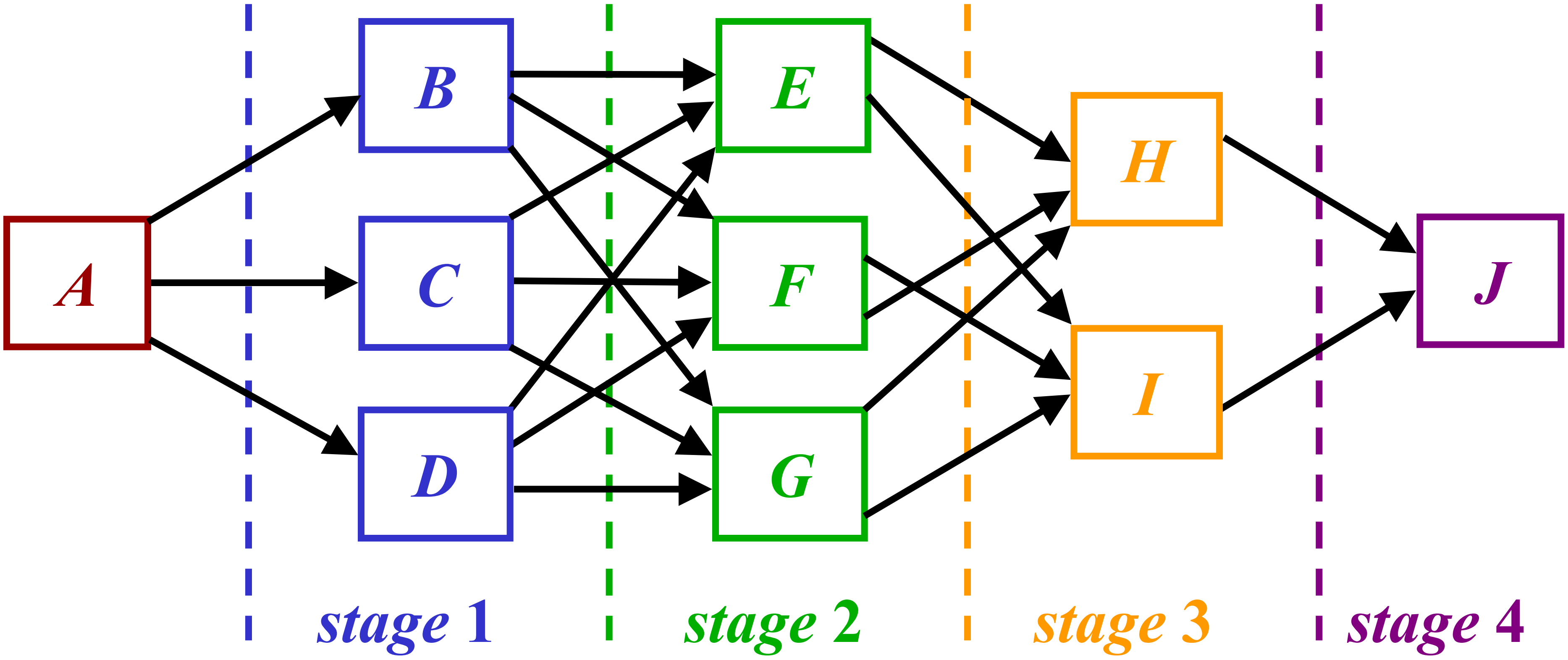
- We next examine a simple *what if sensitivity case* related to the use of overtime labor
- We are interested to determine the number of overtime hours that is profitable to schedule without any impact on the optimal product mix

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

	B	*C*	*D*
A	2	4	3

	E	*F*	*G*
B	7	4	6
C	3	2	4
D	4	1	5

	H	*I*
E	1	4
F	6	3
G	3	3

	J
H	3
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**

    $$A \rightarrow B \rightarrow F \rightarrow I \rightarrow J$$

    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:

$$A \rightarrow D \rightarrow E \rightarrow H \rightarrow J$$

$$A \rightarrow D \rightarrow F \rightarrow I \rightarrow J$$

- 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**

district	*number of students*	
	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**

district	*number of students*		*distance to district*	
	C	*A*	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.

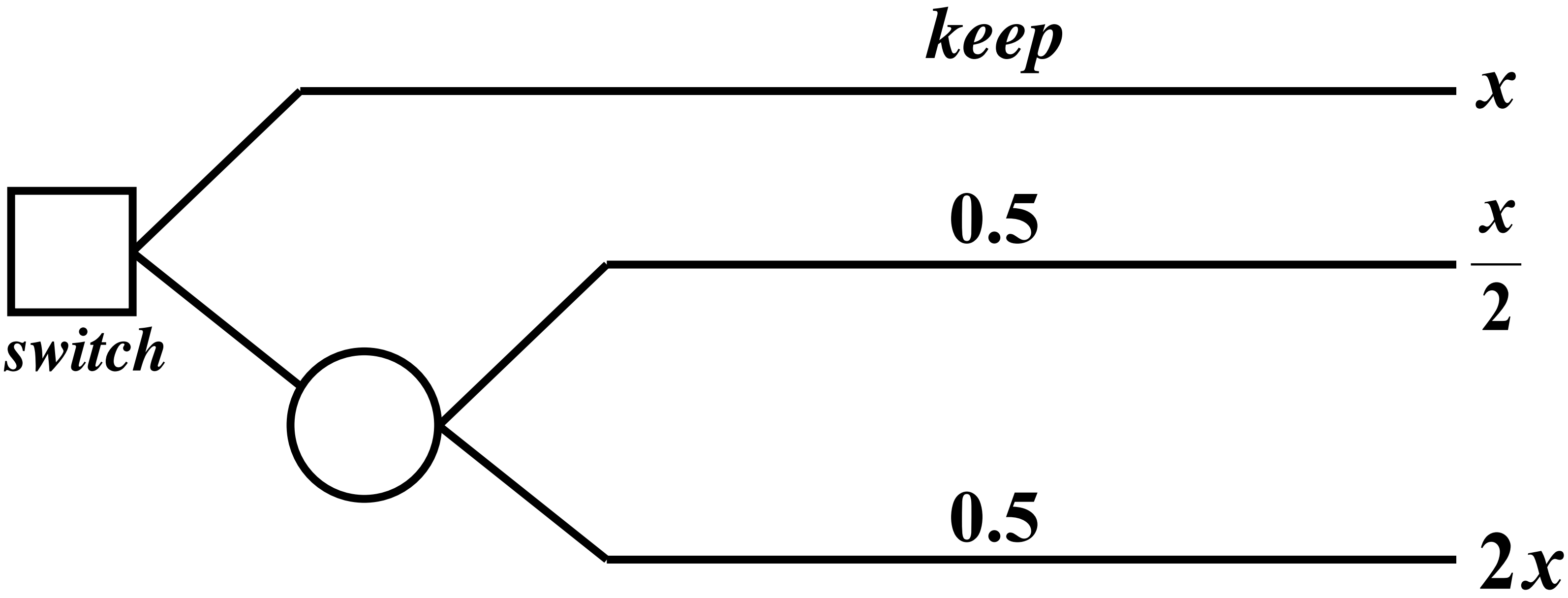
In fact, I'll even let you choose which envelope

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

- ☐ Who is correct?

THE ENVELOPE QUESTION

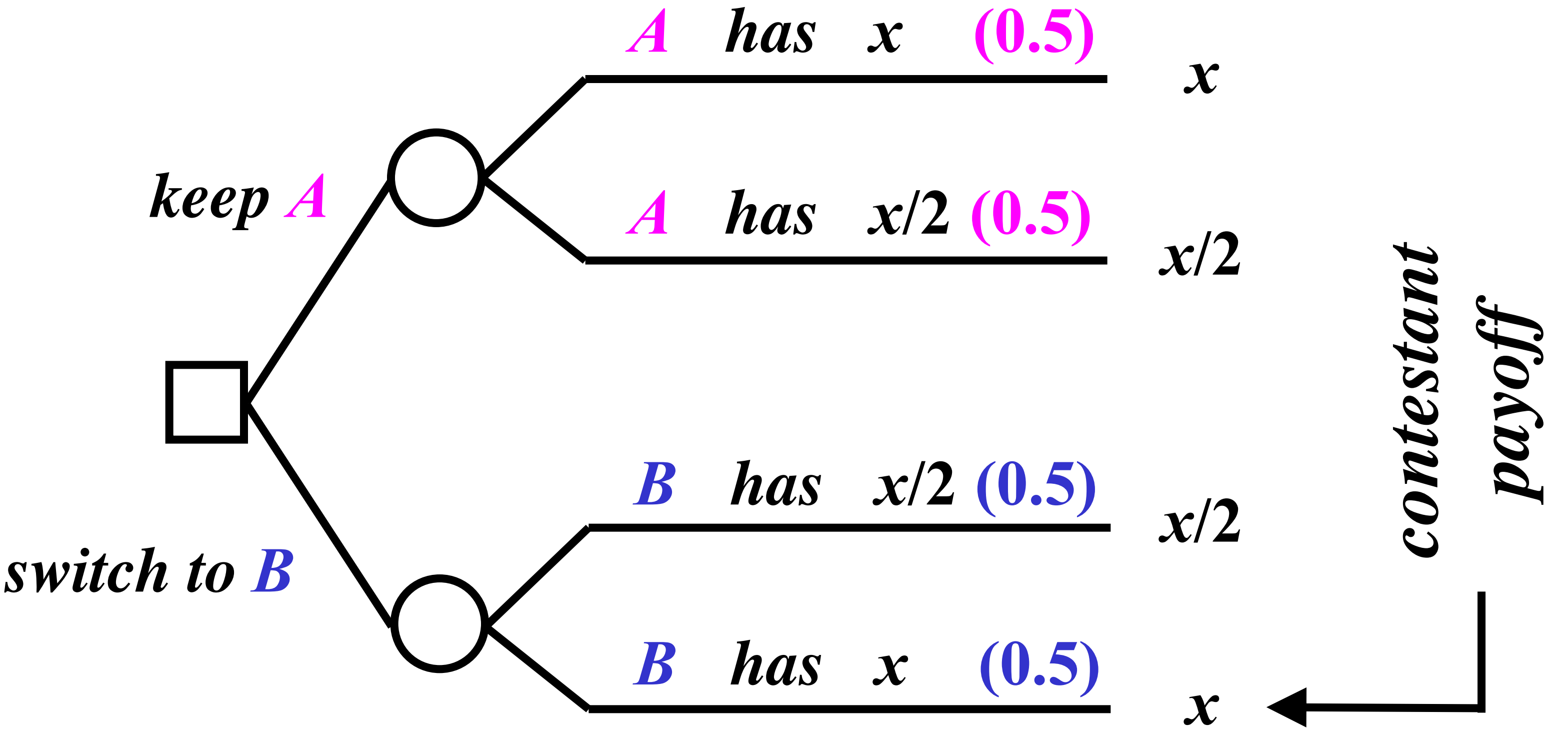
- ☐ **The host is proposing a decision tree that looks like this:**



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

decision alternative	*payoff ($)*	
	land has oil	*land is dry*
drill for oil	700,000	(100,000)
sell the land	90,000	90,000
probability	0.25	0.75

DECISION ANALYSIS PROTOTYPE EXAMPLE

☐ **Evaluation of the two alternative actions**

action	*expected payoff (k$)*
drill	$0.25\,(700) + 0.75\,(-100) = 100$
sell	$0.25\,(90) + 0.75\,(90) = 90$

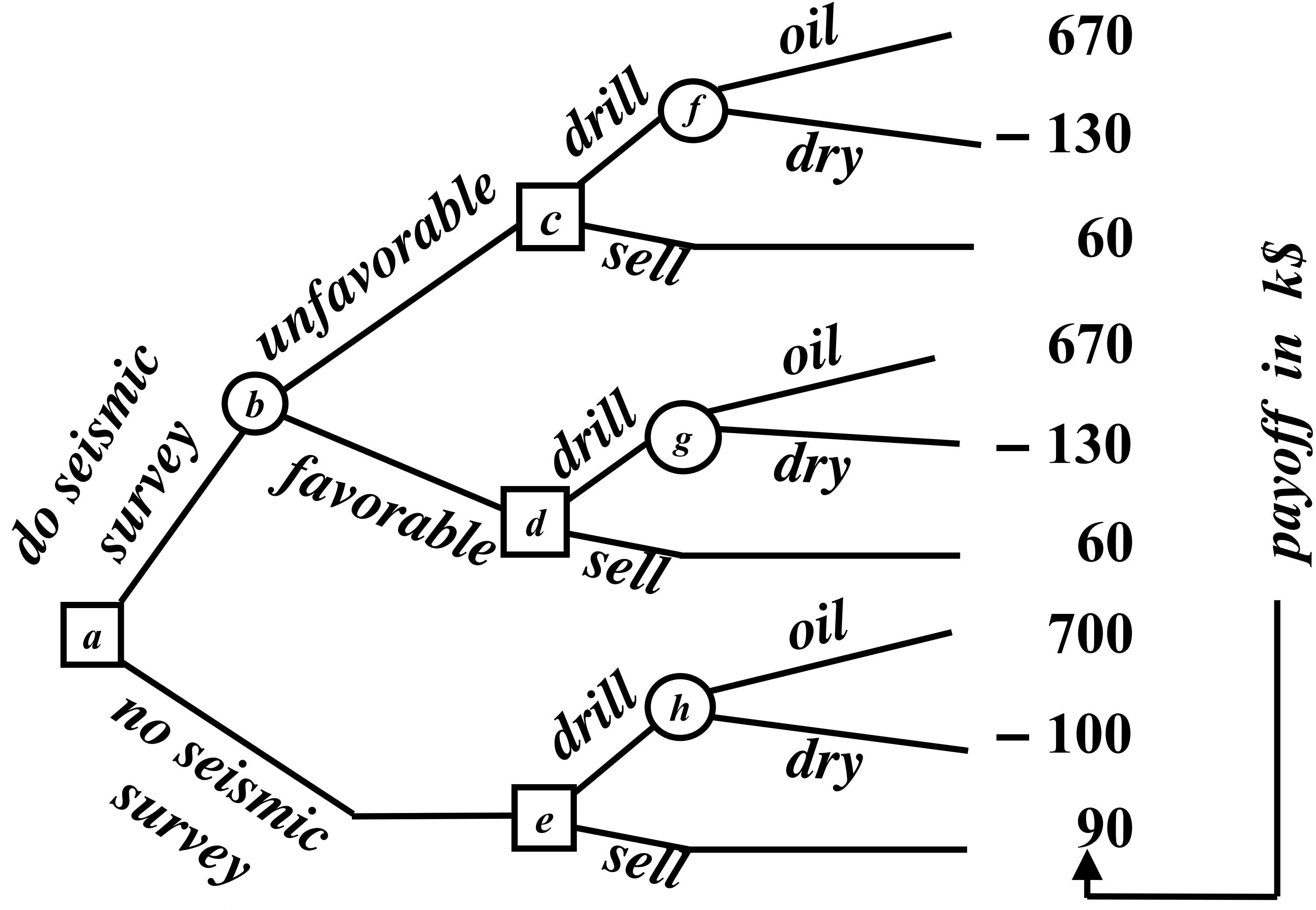
and the *better* alternative is to drill for oil

☐ **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

component	*percentage*
homework	**15**
team projects	**10**
midterm	**25**
final	**50**
total	**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