IENG 450
INDUSTRIAL MANAGEMENT

CHAPTER 4
DECISION MAKING

31.03.2021

Introduction

- This chapter presents information on decision making and how it relates to the first management function of planning.
- A discussion of the origins of management science leads into one on modeling, the five-step process of management science, and the process of engineering problem solving.
- Different types of decisions are examined in this chapter. They are classified under conditions of **certainty**, using linear programming; **risk**, using expected value and decision trees; or **uncertainty**, depending on the degree with which the future environment determining the outcomes of these decisions is known.

Decision Making

- If planning is truly "deciding in advance what to do, how to do it, when to do it, and who is to do it", then decision making is an essential part of planning.

- Decision making is also required in designing and staffing an organization, developing methods of motivating subordinates, and identifying corrective actions in the control process.

Decision Making

- ***Decision*** is a choice among alternatives in order to select the one providing the most benefit.

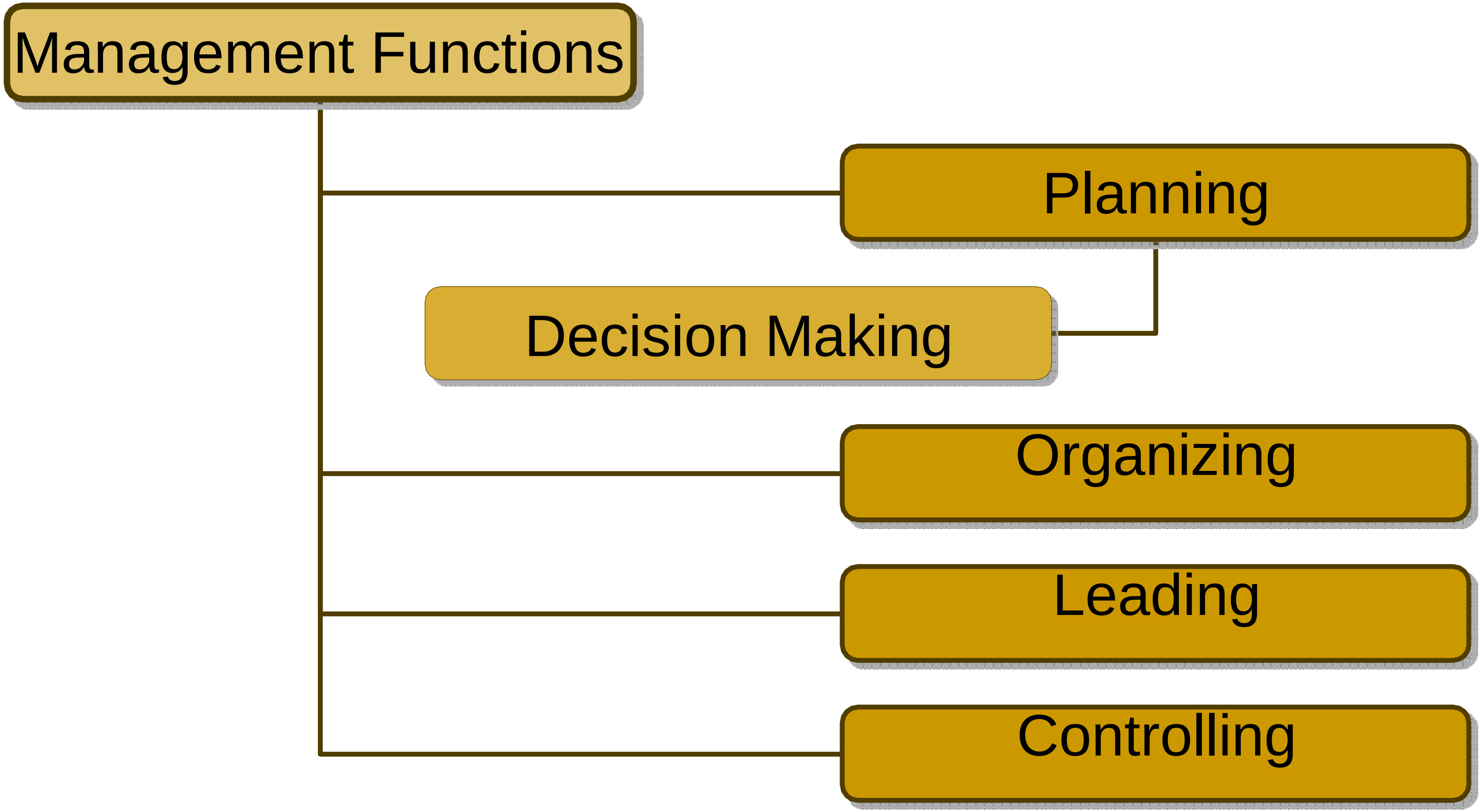
- It assumes the existence of a superior authority.

Decision Making

- Decision making is an essential part of planning.

- Decision making and problem solving are used in all management functions, although they are considered a part of the planning phase.

Function of Management (by Fayol)



Nature of Decision Making

- Relation to Planning
  - Managerial decision making is the process of making a conscious choice between two or more rational alternatives in order to select the one that will produce the most desirable consequences (benefits) relative to unwanted consequences (costs).

Nature of Decision Making

- Types of Decisions

  - Routine Decisions
    - Well-structured situations that recur frequently, involve standard decision procedures and involve a minimum of uncertainty.
    - Ex: payroll processing, reordering standard inventory items, paying suppliers, etc...
    - Probably 90% of management decisions are largely routine.

Nature of Decision Making

- Types of Decisions
  - Nonroutine Decisions
    - Deal with unstructured situations of a novel, nonrecurring nature, often involving
      - incomplete knowledge,
      - high uncertainty, and
      - use of subjective judgement or even intuition, where no alternative can be proved to be the best solution to the particular problem.

Nature of Decision Making

- **Issues of rationality.**
  - Economists like to think that the behavior of human beings is rational.
  - E.g. always the same basket of commodities is the best one for a customer if his/her income and the prices are unchanged. Further on if basket A is better than basket B, and B is better than basket C then A is better than C.
  - In decision making the complete/objective rationality would be to explore all the alternatives with pros and cons.

Nature of Decision Making

- **Issues of rationality.**
  - Even bounded rationality means that a model is built. A model takes into consideration at least a limited set of alternatives with their consequences.
  - A simple *one-step-solution* does not satisfy the requirements bounded rationality.
  - E.g. the <u>first step</u> is a raise in prices. Then the <u>second step</u> is customer's reaction, who chooses substitutes. Thus a measure to raise the prices must take into consideration of the whole market, otherwise profit and/or income may decrease.

Nature of Decision Making

- Level of Certainty
  - Certainty,
  - Risk,
  - Uncertainty.

Management Science

- Origin
  - At the beginning of World War II, a research group of scientists studied the optimum depth at which antisubmarine bombs to explode for the greatest effectiveness (20 to 25 feet) and the relative merits of large versus small convoys (large convoys led to fewer total ship losses).
  - Soon after the United States entered the war, similar activities were initiated by the U.S. Navy and the Army Air Force. With the immediacy of the military threat, these studies involved **research on the operations of existing systems**. After the war, these techniques were applied to longer-range military problems and to problems of industrial organizations. With the development of more and more powerful electronic computers, it became possible to model large systems as a part of the design process, and the terms systems engineering and management science came into use.

Management Science

- Definition:

  Management Science is the primary distinguishing characteristics:

  1. A systems view of the problem – a viewpoint is taken that includes all of the significant interrelated variables contained in the problem.
  2. The team approach – personnel with heterogeneous backgrounds and training work together on specific problems.
  3. An emphasis on the use of formal mathematical models and statistical and quantitative techniques.

Management Science

- Systems Engineering
  - is an interdisciplinary approach and means to enable the relaization of successful systems.
  - It focuses on defining customer needs and required functionality early in the development cycle, documenting requirements, then proceeding with design synthesis and system validation while considering the complete problem.

Management Science

- Models and their analysis
  - A model is an abstraction or simplification of relaity, designed to include only the essential features that determine the behavior of a real system.

  - Most of the models of management science are *mathematical* models.
    - Ex. *Net income = revenue – expenses- taxes*

Management Science

- Models and their analysis
  - Management science uses a five-step process:
    - Begins in the real world,
    - Moves into the model world to solve the problem,
    - Returns to the real world for implementation.

Management Science

Real World

1. Formulate the problem (define objectives, variables and constraints).

Simulated (Model) World

2. Construct a mathematival model.
3. Test the model's ability to predict the present from past, and revise until you are satisfied.
4. Derive a solution from the model.

5. Apply the model's solution to the real system, document its effectiveness, and revise further as required.

Payoff Table (Decision Matrix)

	State of Nature/Probability					
	N_1	N_2	...	N_j	...	N_n
Alternative	p_1	p_2	...	p_j	...	p_n
A_1	O_{11}	O_{12}	...	O_{1j}	...	O_{1n}
A_2	O_{21}	O_{22}	...	O_{2j}	...	O_{2n}
...	...	...	...	...	...	...
A_i	O_{i1}	O_{i2}	...	O_{ij}	...	O_{in}
...	...	...	...	...	...	...
A_m	O_{m1}	O_{m2}	...	O_{mj}	...	O_{mn}

Tools for Decision Making

- **Categories of Decision Making**
  - Our decision will be made among some number of m alternatives (A_1, A_2, ..., A_m)
  - There may be more than one future "statae of nature" N (the model allows for n different futures).
  - These future states of nature may not be equally likely, but each state N_j will have some (known or unknown) probability of occurrence p_j.
  - Since the future must take on one of the n values of N_j, the sum of the n values of p_j must be 1.0.
  - The outcome (or payoff, benefit gained) will depend on both the alternative chosen and the future state of nature that occurs.
  - For example, if you choose alternative A_i and state of nature N_j takes place (as it will with probability p_j), the payoff will be O_{ij}.
  - A full payoff table will contain m times n possible outcomes.

Decision Making Under Certainty

- We are certain of the future state of nature (or we assume that we are).

- In our model, this means that the probability p_1 of the future N_1 is 1.0, and all other futures have zero probability.

- The solution is to choose the alternative A_i that gives the most favorable outcome O_{ij}.

Decision Making Under Certainty

- Linear Programming
  - A desired benefit (such as profit) can be expressed as a mathematical function (the value model or objective function) of several variables.
  - The solution set is the set of values for the independent variables (decision variables) that serves to maximize the benefit (or to minimize the cost) subject to certain limits (constraints).

Decision Making Under Certainty

- Ex: Consider a factory producing two products, product X and product Y. The problem is this: if you can realize \$10 profit per unit of product X and \$14 per unit of product Y, what is the production level of x units of product X and y units of product Y that maximizes the profit?

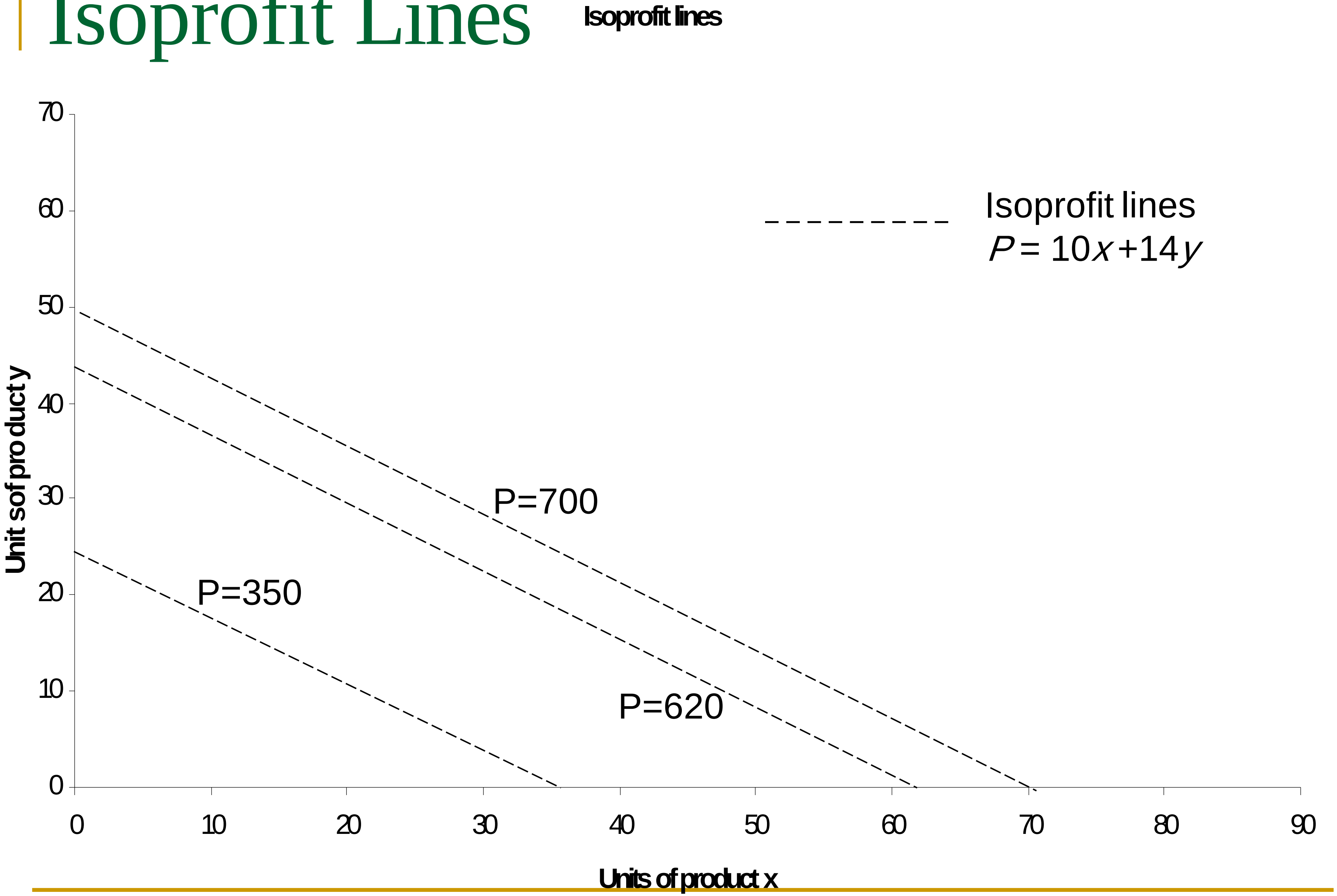
$$\text{maximize } P = 10x + 14y$$

Decision Making Under Certainty

- You can get a profit of
  - $350 by selling 35 units of X or 25 units of Y,
  - $700 by selling 70 units of X or 50 units of Y,
  - $620 by selling 62 units of X or 44.3 units of Y

  - Or any combination of X and Y on the isoprofit line connecting these points.

Isoprofit Lines



Decision Making Under Certainty

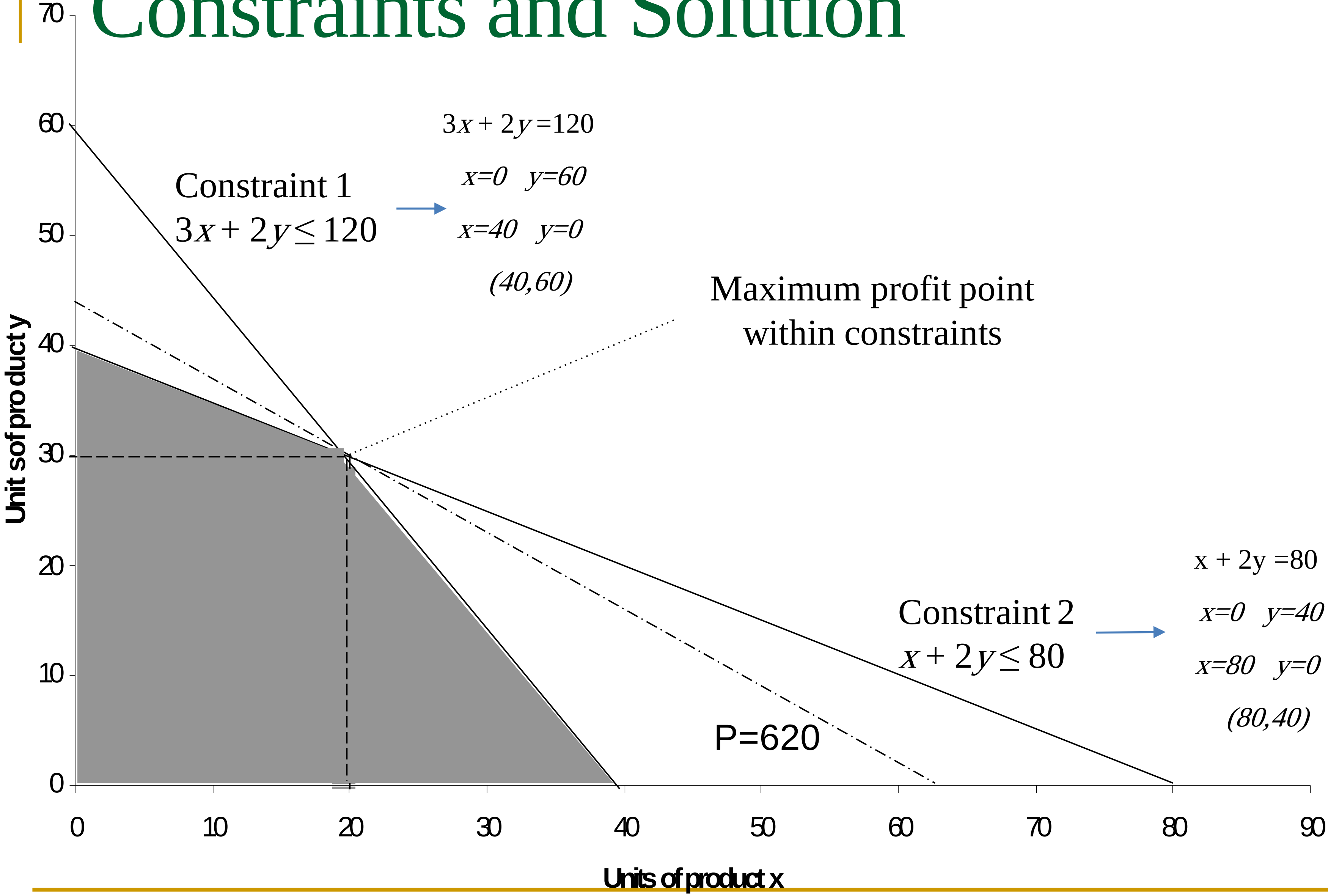
- Your production, and therefore your profit is subject to resource limitations, or *constraints*.
- Assume that you employ five workers – three machinists and two assemblers – and that each works only 40 hours a week.
- Products *X* and/or *Y* can be produced by these workers subject to the following constraints:
  - Product *X* requires three hours of machining and one hour of assembly per unit,
  - Product *Y* requires two hours of machining and two hours of assembly per unit.

Decision Making Under Certainty

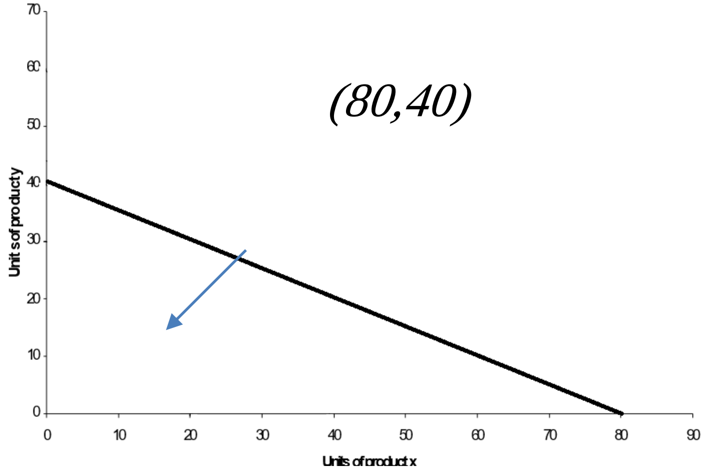
- Product *X* requires three hours of machining and one hour of assembly per unit,
- Product *Y* requires two hours of machining and two hours of assembly per unit.

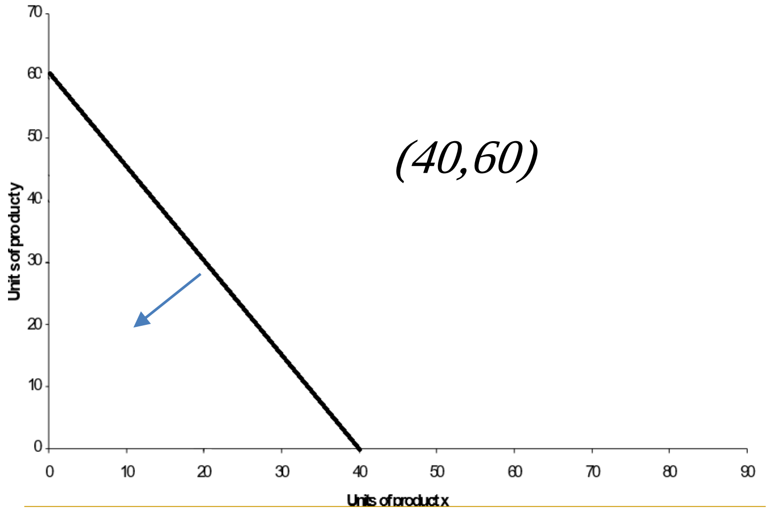
  - $3x + 2y \leq 120$ (hours of machining time)
    - (120 => 3 machinists × 40 hours)
  - $x + 2y \leq 80$ (hours of assembly time)
    - (80 => 2 assemblers × 40 hours)

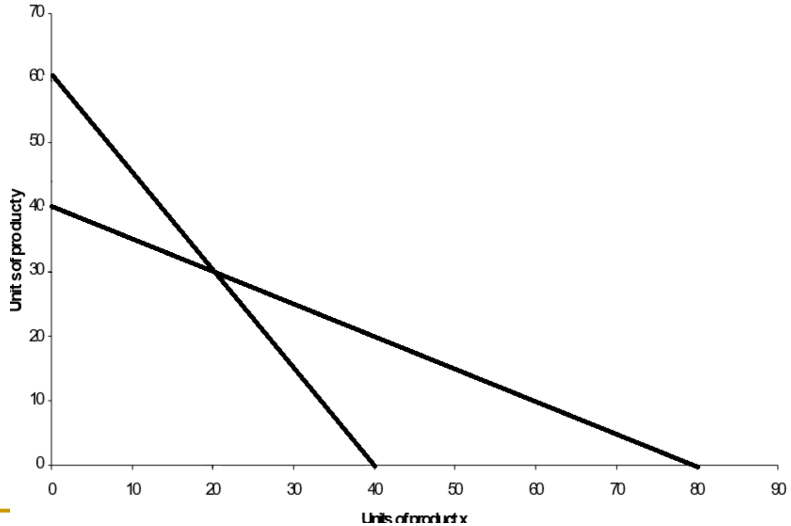
Constraints and Solution

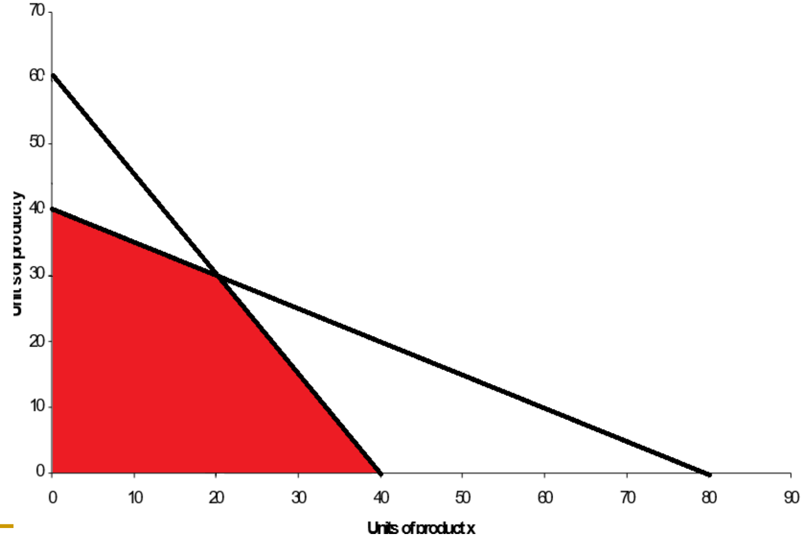


Constraints and Solution









Decision Making Under Certainty

- At point $(x, y) = (20, 30)$

- Profit $P = (20 \times \$10) + (30 \times \$14)$

  $P = \$620$

Decision Making Under Risk

- Nature of Risk
  - In decision making under risk one assumes that there exist a number of possible future states of nature N_j.
  - Each N_j has a known (or assumed) probability p_j of occurring, and there may not be one future state that results in the best outcome for all alternatives A_i.

- Expected Value
  - Given the future states of nature and their probabilities, the solution in decision making under risk is alternative A_i that provides the highest *expected value* E_i, which is defined as the sum of the products of each outcome O_{ij} times the probability p_j that the associated state of nature N_j occurs:

$$E_i = \sum_{j=1}^{n} (p_j O_{ij})$$

Decision Making Under Risk

- Simple Example

Alternative	N_1 $p_1 = 0.999$	N_2 $p_2 = 0.001$
A_1	$-200	$-200
A_2	0	-100,000

Decision Making Under Risk

- Solution:

	N_1	N_2
Alternative	$p_1 = 0.999$	$p_2 = 0.001$
A_1	$-200	$-200
A_2	0	-100,000

$$E(A_1) = 0.999\,(\$\text{-}200) + 0.001\,(\$\text{-}200) = \$\text{-}200$$

$$E(A_2) = 0.999\,(\$0) + 0.001\,(\$\text{-}100{,}000) = \$\text{-}100$$

As $E(A_2) > E(A_1)$, we should choose A_2

Decision Making Under Risk

- Example:

  Consider that you own rights to plot of land under which there may or may not be oil. You are considering three alternatives: doing nothing ("don't drill"), drilling at your own expense of $500,000 and "farming out" the opportunity to someone who drill the well and give you part of the profit if the well is successful. You see three possible states of nature: a dry hole, a midly interesting small well, and a very profitable gusher. You estimate the probabilities of the three states of nature p_j and the nine outcomes O_{ij} are shown in table below.

Decision Making Under Risk

	State of Nature/Probability			
	N_1: Dry Hole	N_2: Small Well	N_3: *Big Well*	*Expected*
Alternative	$p_1 = 0.6$	$p_2 = 0.3$	$p_3 = 0.1$	*Value*
A_1: *Don't drill*	$ 0	$ 0	$ 0	$ 0
A_2: *Drill alone*	-500,000	300,000	9,300,000	720,000
A_3: *Farm out*	0	125,000	1,250,000	162,500

Decision Making Under Risk

Alternative	State of Nature/Probability			Expected Value
	N_1: Dry Hole $p_1 = 0.6$	N_2: Small Well $p_2 = 0.3$	N_3: *Big Well* $p_3 = 0.1$	
A_1: *Don't drill*	$ 0	$ 0	$ 0	$ 0
A_2: *Drill alone*	-500,000	300,000	9,300,000	720,000
A_3: *Farm out*	0	125,000	1,250,000	162,500

$E_1 = \$\ 0$ (Doing nothing)

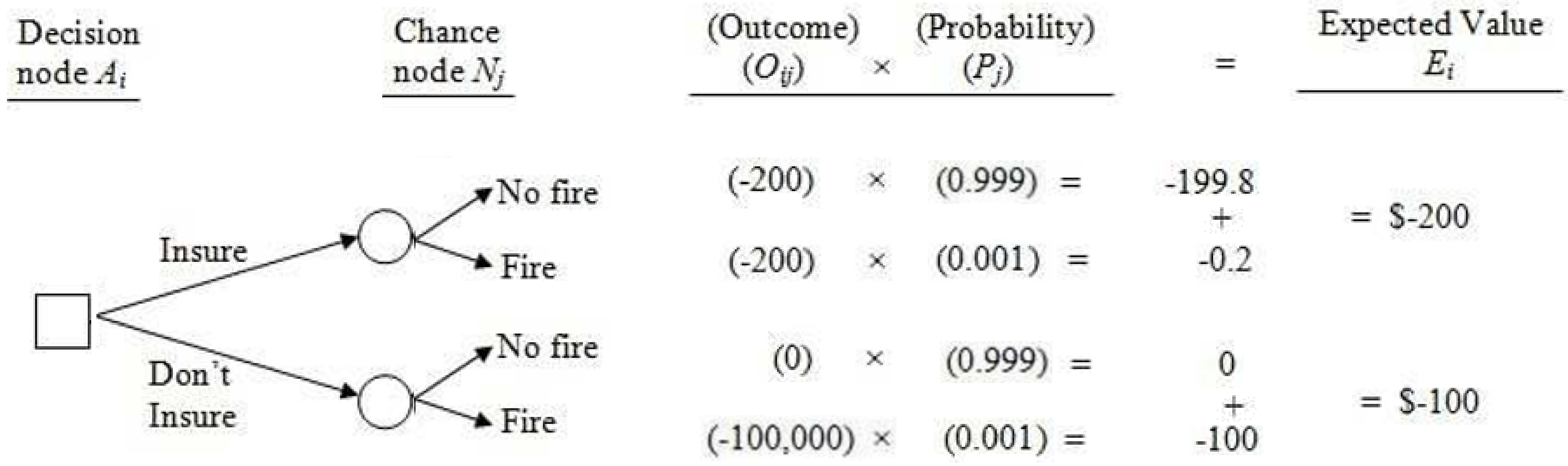
$E_2 = 0.6\,(-500{,}000) + 0.3\,(300{,}000) + 0.1\,(9{,}300{,}0) = \$\ 720{,}000$

$E_3 = 0.6\,(0) + 0.3\,(125{,}000) + 0.1\,(1{,}250{,}000) = \$\ 162{,}500$

- Choice: alternative A_2 (drill alone) if you are willing and able to risk losing $ 500,000.

Decision Making Under Risk

- Decision Tree



Alternative	N_1 $p_1 = 0.999$	N_2 $p_2 = 0.001$
A_1	$-200	$-200
A_2	0	-100,000

Decision Making Under Risk

- Risk as Variance

Project X		Project Y	
Probability	Cash Flow	Probability	Cash Flow
0.10	$3000	0.10	$2000
0.20	3500	0.25	3000
0.40	4000	0.30	4000
0.20	4500	0.25	5000
0.10	5000	0.10	6000

a. $E(X) = 0.10(3000) + 0.20(3500) + 0.40(4000) + 0.20(4500) + 0.10(5000)$

$E(X) = \$\ 4000$

b. $E(Y) = 0.10(2000) + 0.25(3000) + 0.40(4000) + 0.25(5000) + 0.10(6000)$

$E(Y) = \$\ 4000$

Decision Making Under Risk

- Risk as Variance
  - Although boh projects have the samae mean (expected) cash flows, the expected values of the variances (squares of the deviations from the mean) differ as follows:

$V_X = 0.10(3000\text{-}4000)^2 + 0.20(3500\text{-}4000)^2 + \ldots + 0.10(5000\text{-}4000)^2$

$V_X = 300{,}000$

$V_Y = 0.10(2000\text{-}4000)^2 + 0.25(3000\text{-}4000)^2 + \ldots + 0.10(6000\text{-}4000)^2$

$V_Y = 1{,}300{,}000$

The standard deviations are the square roots of these values:

$\sigma_X = \$548, \qquad \sigma_Y = \$1140$

Since the project *Y* has greater variability, it must be considered to offer greater *risk* than does project *X*.

Decision Making Under Uncertainty

- At times a decision maker cannot assess the probability of occurrence for the various states of nature.

- Uncertainty occurs when there exist several (i.e., more than one) future states of nature N_j, but the probabilities p_j of each of these states occurring are not known.

- In such situations the decision maker can choose among several possible approaches for making the decision.

Decision Making Under Uncertainty

- The <u>optimistic</u> decision maker may choose the alternative that offers the highest possible outcome ("the maximax" solution).
- The <u>pessimist</u> may choose the alternative whose worst outcome is "least bad" ("the maximin" solution.
- A third decision maker may choose a poisition somewhat between optimism and pessimisim ("Hurwicz" approach).
- A fourth may simply assume that all states of nature are equally likely, set all p_j values equal to $1.0/n$.
- A fifth decision maker may choose the alternative that has the smallest difference between the best and worst outcomes (the "minimax regret" solution).

Decision Making Under Uncertainty

	State of Nature			
Alternative	N_1: Dry Hole	N_2: Small Well	N_3: *Big Well*	*Maximum Regret*
A_1: *Don't drill*	$ 0	$ 0	$ 0	$ 0
A_2: *Drill alone*	-500,000	300,000	9,300,000	9,300,000
A_3: *Farm out*	0	125,000	1,250,000	1,250,000

- "Hurwicz" approach :
  - A decision maker who is neither a total optimist nor a total pessimist maybe asked to express a "coefficient of optimism" as a fractional value α between 0 and 1 and then to

$$\text{maximize } [(\alpha \times \text{best outcome}) + (1-\alpha)(\text{worst outcome})]$$

Decision Making Under Uncertainty

Alternative	Maximum	Minimum	Hurwicz ($\alpha = 0.2$)	Equally Likely
A_2	\$9,300,000*	\$ -500,000	\$1,460,000*	\$3,033,333*
A_3	1,250,000	0*	250,000	458,333

- Equally Likely:

$$E_2 = \frac{-500{,}000 + 300{,}000 + 9{,}300{,}000}{3} = \$3{,}033{,}333$$

$$E_3 = \frac{0 + 125{,}000 + 1{,}250{,}000}{3} = \$458{,}333$$

Alternative	State of Nature/Probability: N_1: Dry Hole $p_1 = 0.6$	N_2: Small Well $p_2 = 0.3$	N_3: *Big Well* $p_3 = 0.1$	*Expected Value*
A_1: *Don't drill*	\$ 0	\$ 0	\$ 0	\$ 0
A_2: *Drill alone*	-500,000	300,000	9,300,000	720,000
A_3: *Farm out*	0	125,000	1,250,000	162,500

- Hurwicz:

A_2 = (0.2×9,300,000) + (1-0.2)(-500,000) = 1,460,000

A_3 = (0.2×1,250,000) + (1-0.2)(0) = 250,000