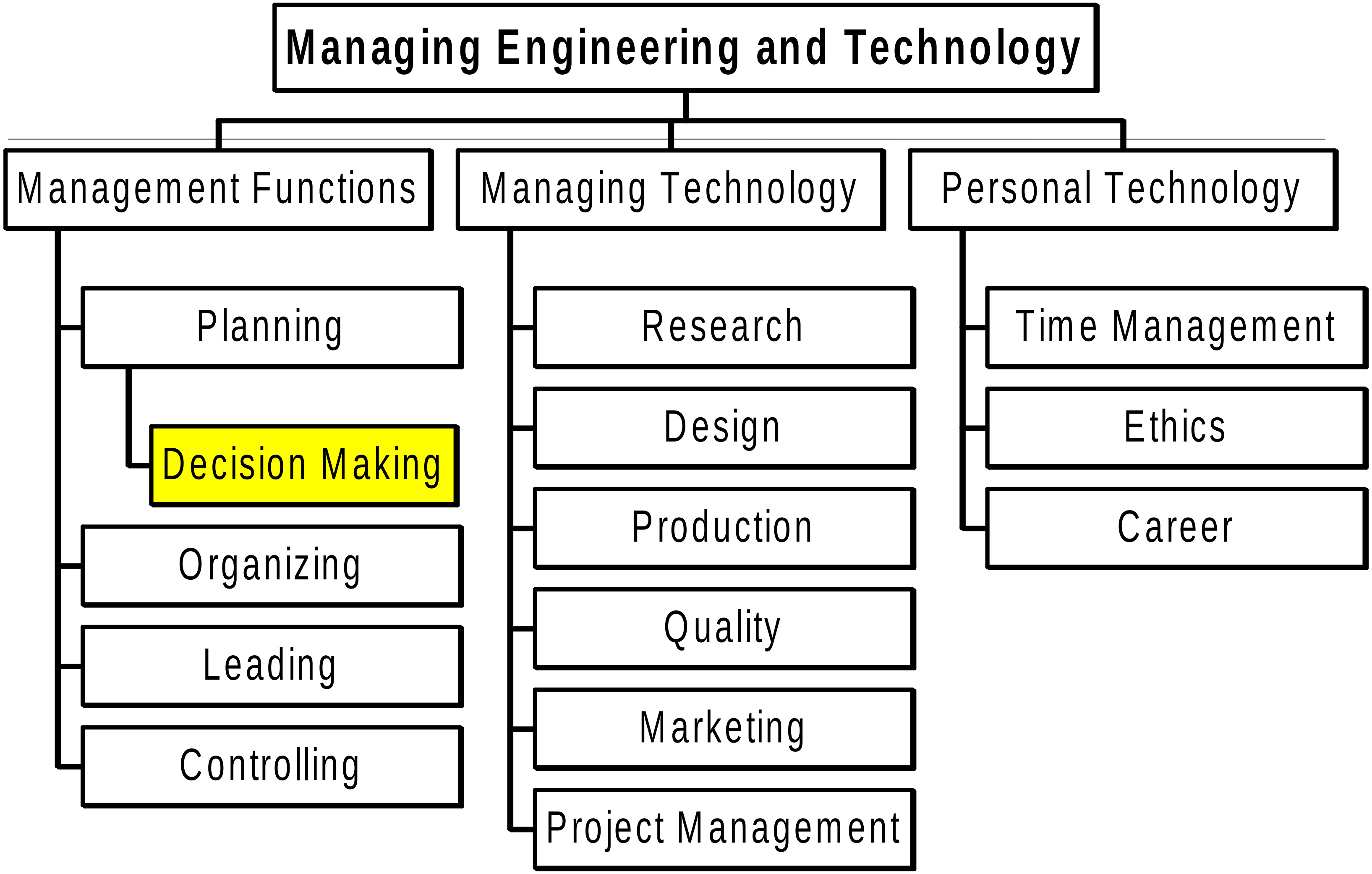
Functions of Technology Management

Decision Making


Managing Engineering and Technology
Management Functions
Managing Technology
Personal Technology
Planning
Decision Making
Organizing
Leading
Controlling
Research
Design
Production
Quality
Marketing
Project Management
Time Management
Ethics
Career

Chapter Objectives

Explain the process of management science.

Solve problems using three types of decision making tools

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.

Decision making is an essential part of planning as planning is “deciding in advance what to do, how to do it, when to do it, and who is to do it.”

Types of Decisions

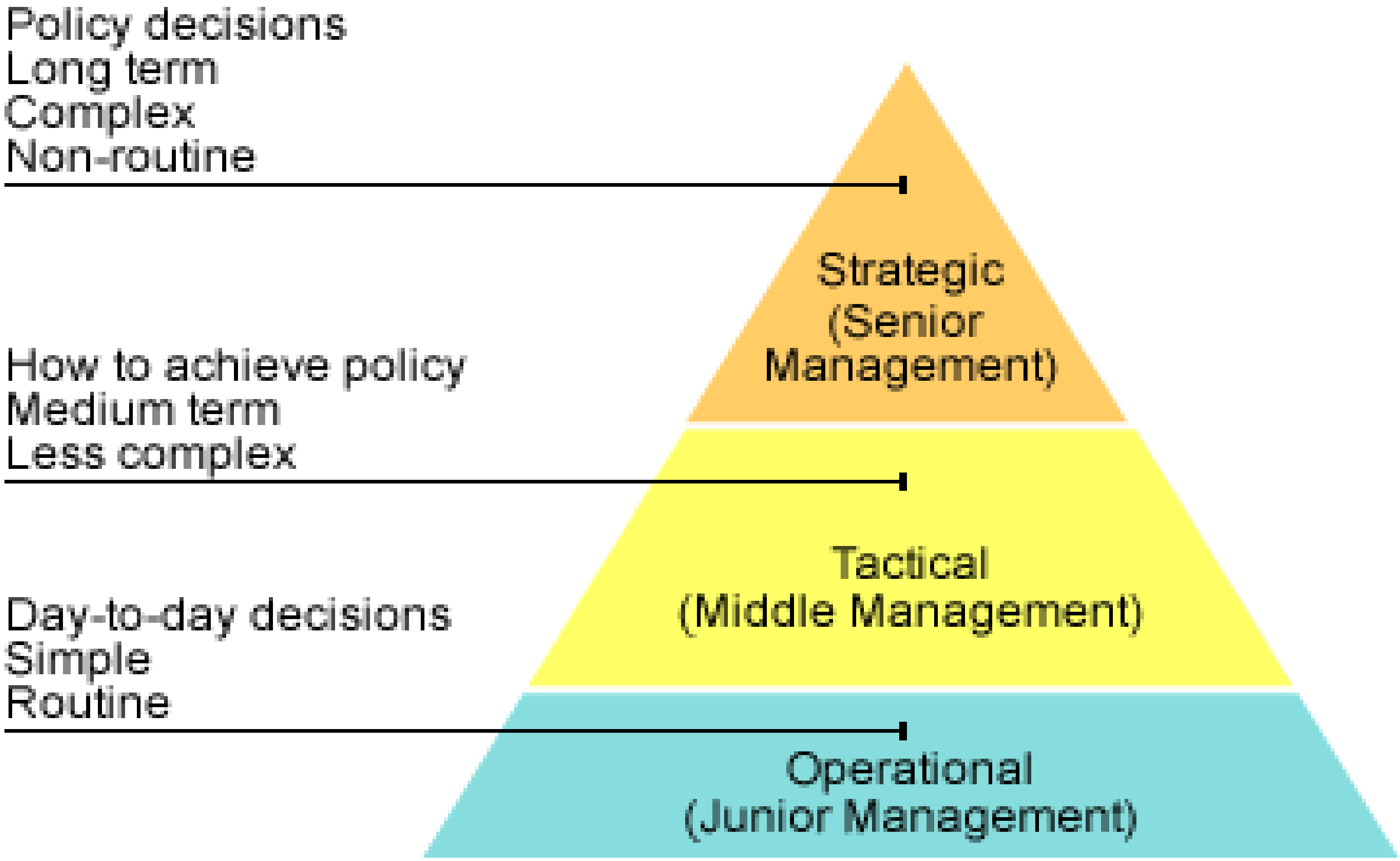
- Programmed Decision
  - A decision that is repetitive and routine and can be made by using a definite, systematic procedure.
- Nonprogrammed Decision
  - A decision that is unique and novel.

Routine Decisions – *delegation/rules based*

- Payroll processing
- Reordering standard inventory
- Paying suppliers

Non-Routine Decisions

- Unstructured situations
- Usually more at higher level of management
- Based on statistical decision making
- Based on subjective decisions


Policy decisions
Long term
Complex
Non-routine
How to achieve policy
Medium term
Less complex
Day-to-day decisions
Simple
Routine
Strategic
(Senior
Management)
Tactical
(Middle Management)
Operational
(Junior Management)

	Programmed Decisions	Non-programmed Decisions
1. Nature of Problem	Structured/Routine/Well-defined	Unstructured/Novel/Ill defined
2. Recurrence of Problem	Repetitive	Non-repetitive
3. Method of solving	Policies/Standards/Rules	Managerial Initiative
4. Judgment	Objective	Subjective
5. Probability of outcome	Some degree of certainty is involved	Uncertain
6. Level of management	Middle/Lower-level	Top-level
7. Types	Organisational/Operational/ Research/Opportunity	Personal/Strategic/Crisis Intuitive/Problem-solving

Engineers often find themselves unable to rise in management unless they can develop the “tolerance for ambiguity” that is needed to tackle unstructured problems.

Objective versus Bounded Rationality

Objective Rationality

- Viewing all behavior alternatives
- All consequences of choosing an alternative
- Values assigned for singling out the alternative

Bounded Rationality

- Take only known factors
- Time and resource constraint
- Choose action that is satisfactory or "good enough"
- Solution that "*satisfices*" rather than the best one

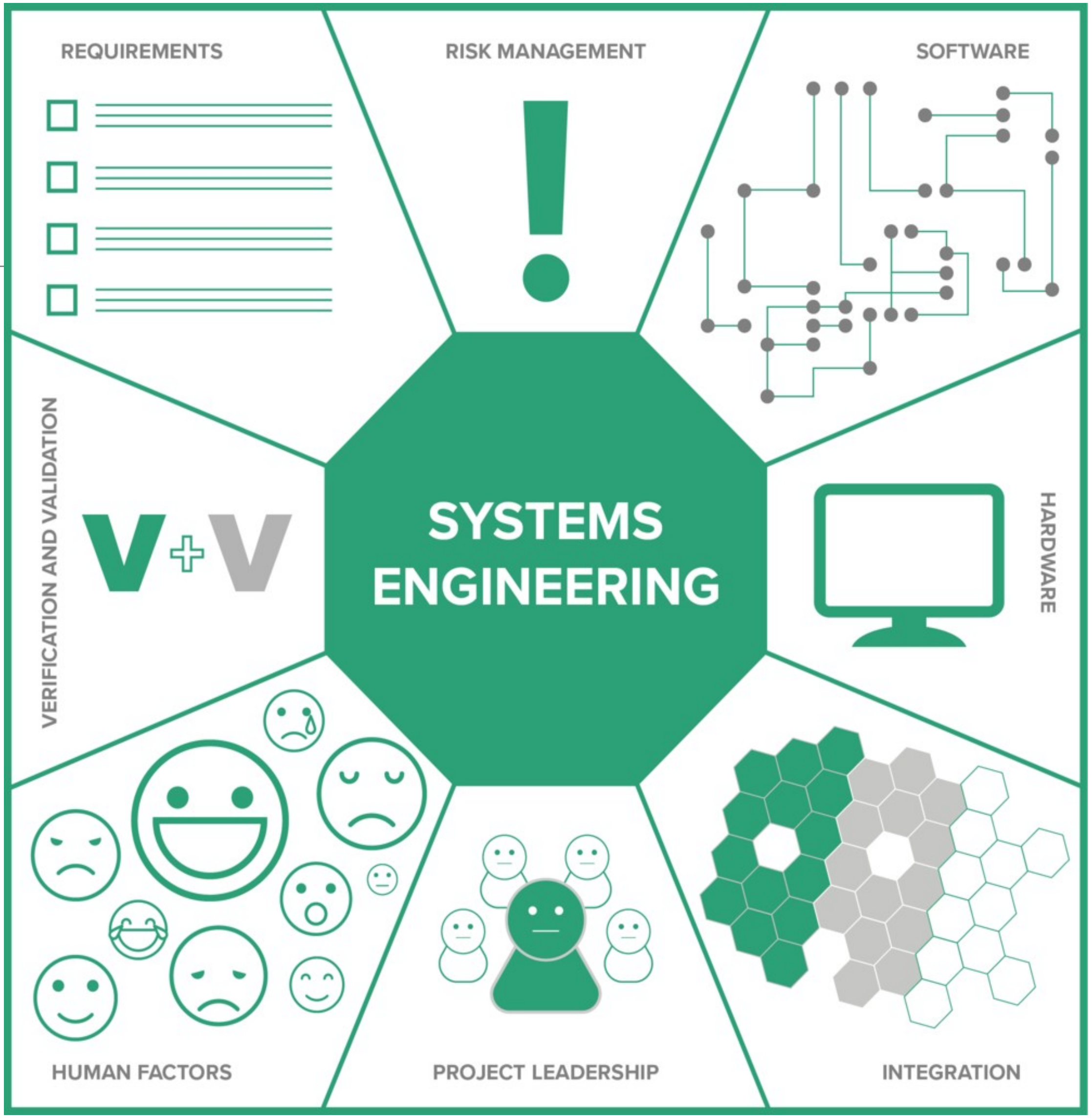
Management Science Characteristics

Management science has been defined as having the following “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.

What Is Systems Engineering?

Systems engineering is an interdisciplinary approach and means to enable the realization 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**



Models and Their Analysis

A **model** is an abstraction or simplification of reality, designed to include only the essential features that determine the behavior of a real system.

A simple equation (model) to represent the financial operations of a company:

$$\boxed{\textit{net income} = \textit{revenue} - \textit{expenses} - \textit{taxes}}$$

Management science uses a *five-step* process that begins in the real world, moves into the model world to solve the problem, then returns to the real world for implementation.

Real World

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

Simulated (Model) World

2. Construct a mathematical model (a simplified yet realistic representation of the system).
3. Test the model's ability to predict the present from the past, and revise until you are satisfied.
4. Derive a solution from the model.

Real World

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

The **scientific method** or scientific process is fundamental to scientific investigation and to the acquisition of new knowledge based upon physical evidence by the scientific community.

Scientists use observations and reasoning to propose tentative explanations for natural phenomena, termed *hypotheses*. **Engineering problem solving** is more applied and is different to some extent from the scientific method.

Scientific Method **Engineering Problem Solving Approach**

- Define the problem. Define the problem.
- Collect data. • Collect and analyze the data.
- Develop hypotheses. • Search for solutions.
- Test hypotheses. • Evaluate alternatives.
- Analyze results. • Select solution and evaluate the impact.
- Draw conclusion.

Tools for Decision Making

Categories of Decision Making

Decision Making under Certainty
- Only one state of nature exists.
- Linear Programming

Decision Making under Risk
- Probabilities for states of natures are known.
- Expected value, Decision trees, Queuing theory, and Simulation

Decision Making under Uncertainty
- Probabilities for states of natures are unknown.
- Game theory

Pay-off Table

State of Nature/Probability

	N1	N2	…	Nj	…	Nn
Alternative	P1	P2	…	Pj	…	Pn
A1	O11	O12		O1j		O1n
A2	O21	O22		O2j		O2n
…	…	…	…	…	…	…
Ai	Oi1	Oi2		Oij		Oin
…	…	…	…	…	…	…
Am	Om1	Om2		Omj		Omn

Decision Making under Certainty

- Linear programming
  - Graphical solution
  - Simplex method
  - Computer software
- Non-linear programming
- Engineering Economic Analysis

	N_1	N_2	....	N_j	....	N_n
Alt.	1.0	(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}

Steps in solving Linear Programming

1. State the problem
2. Identify decision variables
3. Objective function
4. Constraints

Example

Consider a factory producing two products, product *X* and product *Y*. The problem is this: If you can realize \$10.00 profit per unit of product *X* and \$14.00 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 *P* each day? Your production, and therefore your profit, is subject to resource limitations, or *constraints*. Assume in this example that you employ five workers—three machinists and two assemblers—and that each works only 40 hours a week.

- 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.

State the problem: How many of product *X* and product *Y* to produce to maximize profit?

Example

Consider a factory producing two products, product X and product Y. The problem is this: If you can realize \$10.00 profit per unit of product X and \$14.00 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 P each day? Your production, and therefore your profit, is subject to resource limitations, or *constraints*. Assume in this example that you employ five workers—three machinists and two assemblers—and that each works only 40 hours a week.

- 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.

State the problem: How many of product X and product Y to produce to maximize profit?

Decision variables: Let x = number of product X to produce per day
Let y = number of product Y to produce per day

Objective function: maximize $P = 10x + 14y$

Constraints: $3x + 2y \leq 120$ (hours of machining time)
$x + 2y \leq 80$ (hours of assembly time)

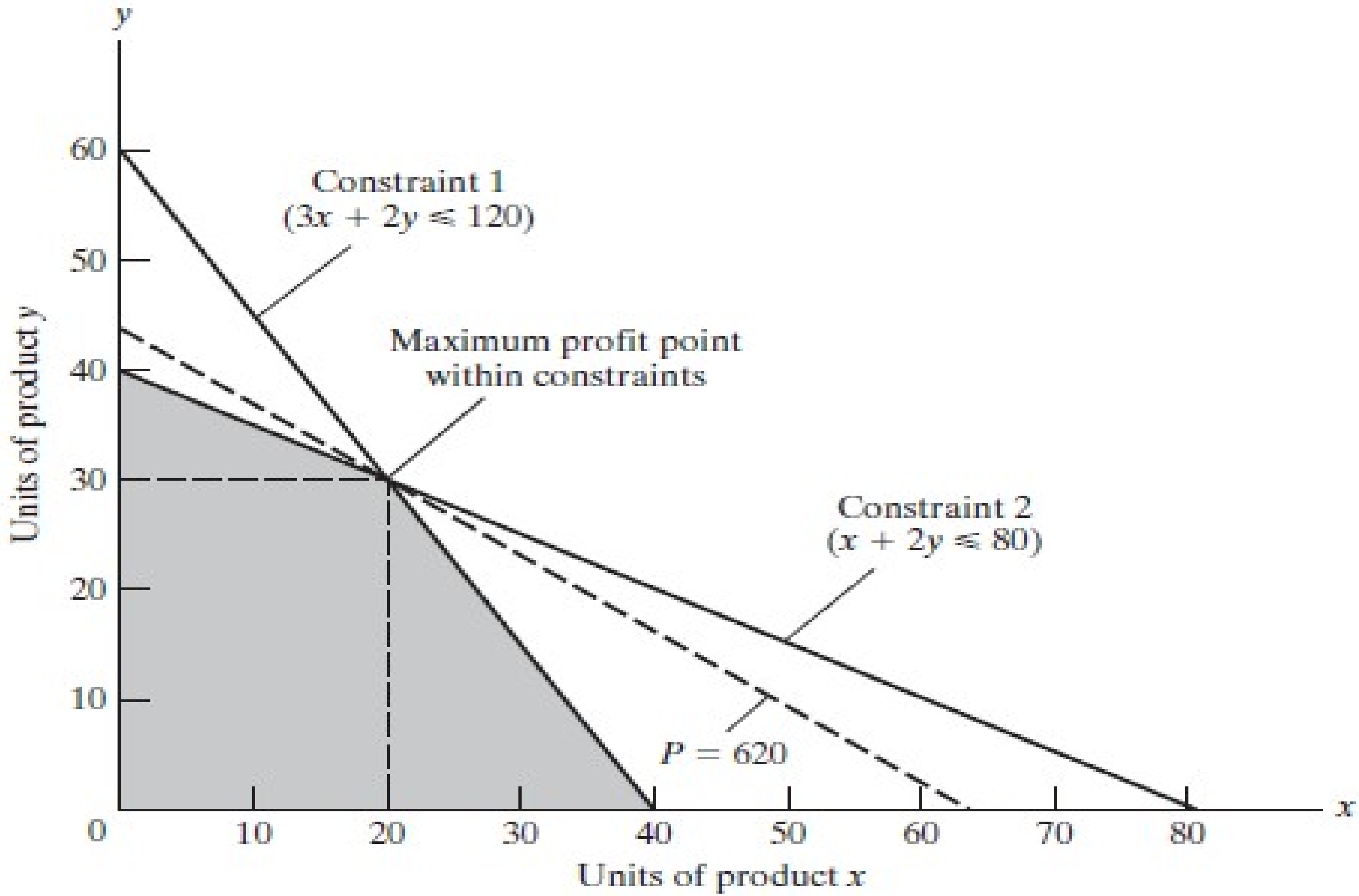


Figure 5-2 Linear program example: constraints and solution.

Engineering Economic Analysis

- Time Value of Money
- Minimum Acceptable Rate of Return
- Decision Criteria
  - Net Present Worth
  - Equivalent Annual Worth
  - Internal Rate of Return
  - Benefit / Cost Ratio

Decision Making under Risk

- Expected Value / Decision Trees
- Queuing (Waiting-Line Theory)
- Simulation

Expected Value

Given the future states of nature and their probabilities, the solution in decision making under risk is the alternative A_i that provides the hi [illegible] value E_i

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

	N_1 $p_1 = 0.999$	N_2 $p_2 = 0.001$
A_1	\$ −200	\$ −200
A_2	0	\$ −100,000

Expected value of Alternative A_1

$E(A_1)=(-\$200) * 0.999+(-\$200)*0.001$

$= - \$199.8 – \$ 0.2$

$= -\$200$

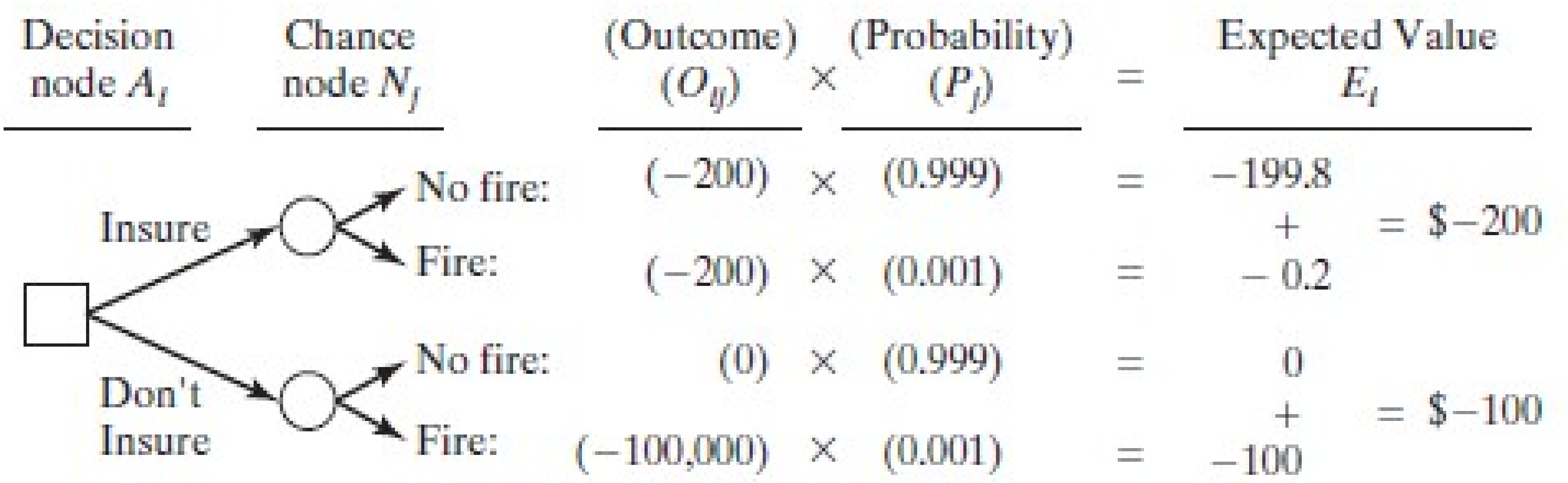
Expected value of Alternative A_2

$E (A_2) =0 * 0.999 – 100,000* 0.001= -\$100$

	N_1 (No Accident) $P_1=0.999$	N_2 (Fire) $P_2=0.001$	Expected Value
A_1=Buy Ins.	-\$200	-\$200	-\$200
A_2=Self-Ins.	0	-\$100,000	-\$100

Decision trees provide another technique used in finding expected value.

- provide a very visible solution procedure, especially when a sequence of decisions, chance nodes, new decisions, and new chance nodes exist.



Queuing Theory

Organization	Activity	Arrivals	Servers
Airport	Landing	Airplanes	Runway
College	Registration	Students	Registrars
Court system	Trials	Cases	Judges
Hospital	Medical service	Patients	Rooms/doctors
Personnel office	Job interviews	Applicants	Interviewers
Supermarket	Checkout	Customers	Checkout clerks
Toll bridge	Taking tolls	Vehicles	Toll takers
Tool room	Tool issue	Machinists	Tool room clerks

The essence of the typical queuing problem is identifying the optimum number of servers needed to reduce overall cost.

Mathematical expressions for mean queue length and delay as a function of mean arrival and service rates have been developed for a number of probability distributions (in particular, exponential and Poisson) of arrival and of service times.

Simulation

- In case real-world system is too complex to express in simple equations, construct a model that simulates operation of a real system by mathematically describing behavior of individual interrelated parts.
- For instance, time between arrivals and services can be represented by probability distributions.
- Develop a computer program for one cycle of operation, and Run it for many cycles.

Simulation modeling seeks to:

- Describe the behavior of a system
- Use the model to predict future behavior, i.e. the effects that will be produced by changes in the system or in its method of operation.

There are three categories of computer simulations

1. Live simulations have real people and real equipment operating in a simulated environment.
   Example training exercises conducted by the military.
2. Virtual simulations have real people using simulated equipment.
   Example would be a driving simulator or computer games, such as a flight simulator.
3. Constructive simulations have simulated people and equipment,
   Example what might be found in a model of a factory production layout or airport screening operation.
   Live and virtual simulations are typically used where safety is an important consideration. Constructive simulations are typically used where cost, decision making, and prototyping limit implementing the real system.

Risk as Variance

Risk = Variability of Outcome

Measurement of variability: variance or standard deviation

Project X		Project Y	
Probability	Cash Flow	Probability	Cash Flow
0.10	$3,000	0.10	$2,000
0.20	3,500	0.25	3,000
0.40	4,000	0.30	4,000
0.20	4,500	0.25	5,000
0.10	5,000	0.10	6,000

Expected cash flows are calculated in the same way as expected value:

a. $E(X) = 0.10(3{,}000) + 0.20(3{,}500) + 0.40(4{,}000) + 0.20(4{,}500) + 0.10(5{,}000)$
$= \$4{,}000$

b. $E(Y) = 0.10(2{,}000) + 0.25(3{,}000) + 0.30(4{,}000) + 0.25(5{,}000) + 0.10(6{,}000)$
$= \$4{,}000$

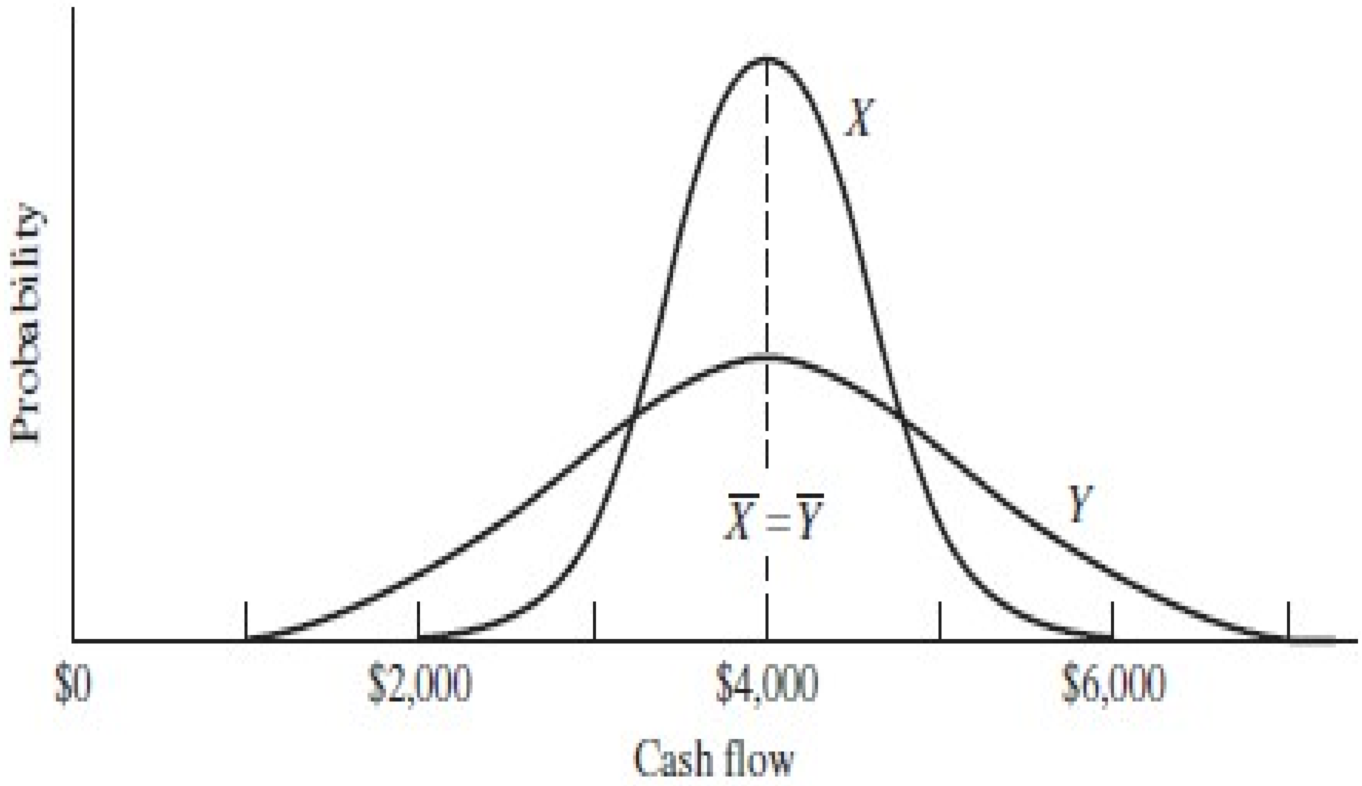
Although both projects have the same mean (expected) cash flows, the expected values of the variances (squares of the deviations from the mean) differ as follows (see also Figure 5-4):

$$V_X = 0.10(3{,}000 - 4{,}000)^2 + 0.20(3{,}500 - 4{,}000)^2 + \cdots + 0.10(5{,}000 - 4{,}000)^2$$
$$= 300{,}000$$
$$V_Y = 0.10(2{,}000 - 40{,}000)^2 + 0.25(3{,}000 - 4{,}000)^2 + \cdots + 0.10(6{,}000 - 4{,}000)^2$$
$$= 1{,}300{,}000$$

The standard deviations are the square roots of these values:

$$\sigma_X = \$548, \quad \sigma_Y = \$1{,}140$$

Since project Y has the greater variability (whether measured in variance or in standard deviation), it must be considered to offer greater *risk* than does project X.



Projects with the same expected value but different variances.

Decision Making under Uncertainty

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 know.

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

	N_1	N_2	....	N_j	....	N_n
Alt.	(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}

Decision Making Approaches under Uncertainty

- The optimistic decision maker may choose the alternative that offers the highest possible outcome(the “**maximax**” solution);
- The pessimist decision maker may choose the alternative whose worst outcome is “least bad”(the “**maximin**” solution);
- The third decision maker may choose a position somewhere between optimism and pessimism(“**Hurwicz**” approach);
- Another decision maker may simply assume that all states of nature are **equally likely** (the so-called “principle of insufficient reason”), set all p_j values equal to $1.0/n$, and maximize expected value based on that assumption.
- The fifth decision maker may choose the alternative that has the smallest difference between the best and worst outcomes (the “**minimax regret**” solution). Regret here is understood as proportional to the difference between what we actually get, and the better position that we could have received if a different course of action had been chosen. Regret is sometimes also called “opportunity loss.” The minimax regret rule captures the behavior of individuals who spend their post-decision time regretting their choices.

Maximin, Maximax, and Minimax Regret Strategies to Evaluate Decision Alternatives

Maximin strategy selects the alternative that maximizes the minimum gain. It is a pessimistic or conservative strategy.

Maximax strategy selects the alternative that maximizes the maximum gain. It is an optimistic strategy.

Minimax regret strategy selects the alternative that minimizes the maximum regret (opportunity loss).

Maximax

	N_1 Dry Hole	N_2 Small Well	N_3 Big Well	Max.
A_1:Don't drill	$0	$0	$0	$0
A_2:Drill alone	-$500k	$300k	$9,300k	$9,300k
A_3:Farm out	$0	$125k	$1,250k	$1,250k

Maximin

	N_1 Dry Hole	N_2 Small Hole	N_3 Big Well	Min.
A_1:Don't drill	\$0	\$0	\$0	\$0
A_2:Drill alone	-\$500k	\$300k	\$9,300k	-\$500k
A_3:Farm out	\$0	\$125k	\$1,250k	\$0

Minimax

Alternatives	Events (Uncertain Demand)	
	Low	High
Small facility	200	270
Large facility	160	800
Do nothing	0	0

If you chose a small facility and demand is high, you forgo the higher payoff of 800, and thus have a regret of 530.

Regret Matrix

Alternatives	Events		Total Regrets
	Low	High	
Small facility	0	530	530
Large facility	40	0	40
Do nothing	200	800	1000

Building a large facility offers the least regret.

Maximin, Maximax, and Minimax Regret Strategies

Payoff Table

Purchase	Bull Market, S_1 (0.6)	Bear Market, S_2 (0.4)	Maximin	Maximax
Kayser Chemicals (A_1)	$2,400	$1,000	1,000	2,400
Rim Homes (A_2)	2,200	1,100	1,100	2,200
Texas Electronics (A_3)	1,900	1,150	1,150	1,900

Opportunity Loss Table

Opportunity Losses for Various Combinations of Stock Purchase and Market Movement

	Opportunity Loss		
Purchase	Market Rise	Market Decline	Minimax Regret
Kayser Chemicals	$ 0	$150	150
Rim Homes	200	50	200
Texas Electronics	500	0	500

Example:

Table 5-3 Well Drilling Example—Decision Making Under Risk

	State of Nature/Probability			
	N_1: Dry Hole	N_2: Small Well	N_3: Big Well	
Alternative	$p_1 = 0.6$	$p_2 = 0.3$	$p_3 = 0.1$	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

Table 5-6 Decision Making Under Uncertainty Example

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

*Preferred solution.

A decision maker who is neither a total optimist nor a total pessimist may be asked to express a "coefficient of optimism" as a fractional value α between 0 and 1 and then to use this formula:

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

The outcome using this "**Hurwicz**" approach and a coefficient of optimism of 0.2 is shown in the third column of Table 5-6; A_2 is again the winner.

If decision makers believe that the future states are "**equally likely**," they will seek the higher expected value and choose A_2 on that basis:

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

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

Game Theory

- The future states of nature and their probabilities are replaced by the decisions of a competitor.
  - Begley and Grant explain:

    In essence, game theory provides the model of a contest. The contest can be a war or an election, an auction or a children’s game, as long as it requires strategy, bargaining, threat, and reward.
- Leads to selecting a mixture of two or more strategies, alternated randomly with some specified probability.
  - Begley and Grant provide a simple example:

    In the children’s game called **Odds and Evens**, for instance, two players flash one or two fingers.
    If the total is 2 or 4, Even wins; if [it is] 3, Odd wins. A little analysis shows that the winning ploy is to randomly mix up the number of fingers flashed.
    For no matter what Odd does, Even can expect to come out the winner about half the time, and vice versa. If Even attempts anything trickier, such as alternating 1s and 2s, he can be beaten if Odd catches on to the strategy and alternates 2s and 1s

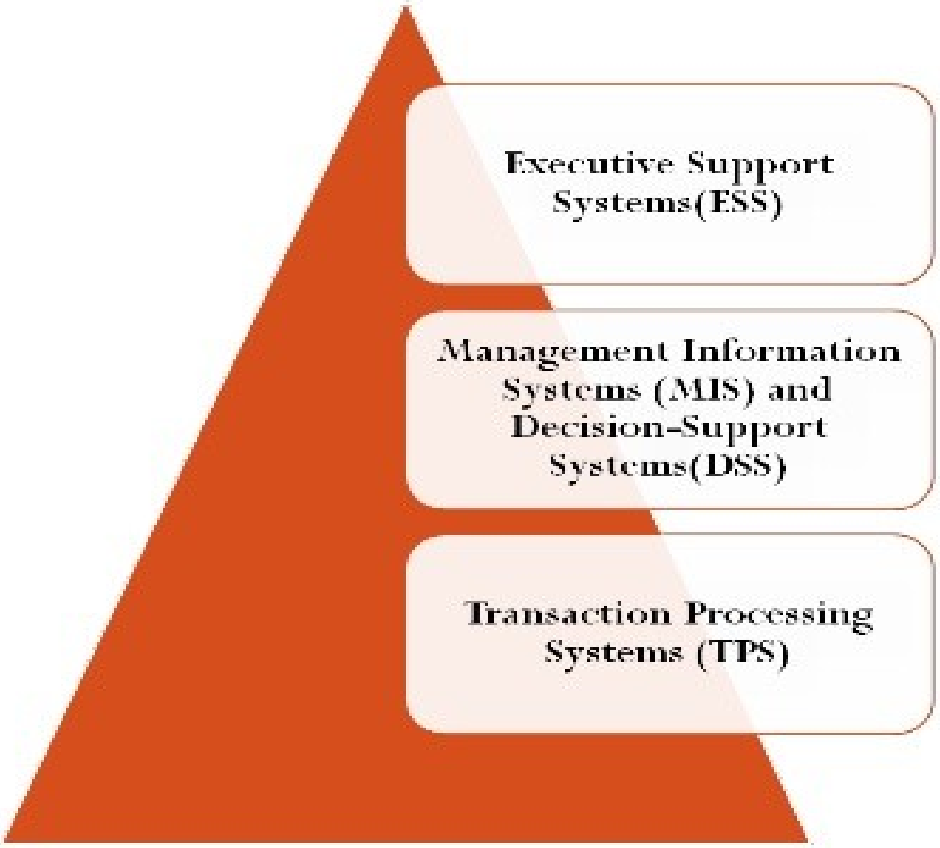
Computer-Based Information Systems

- Integrated Databases
  - Same data stored in various system over and over again has been now integrated in same system
  - Cost, Time,Space etc
- Management Information/Decision Support Systems
- Expert Systems

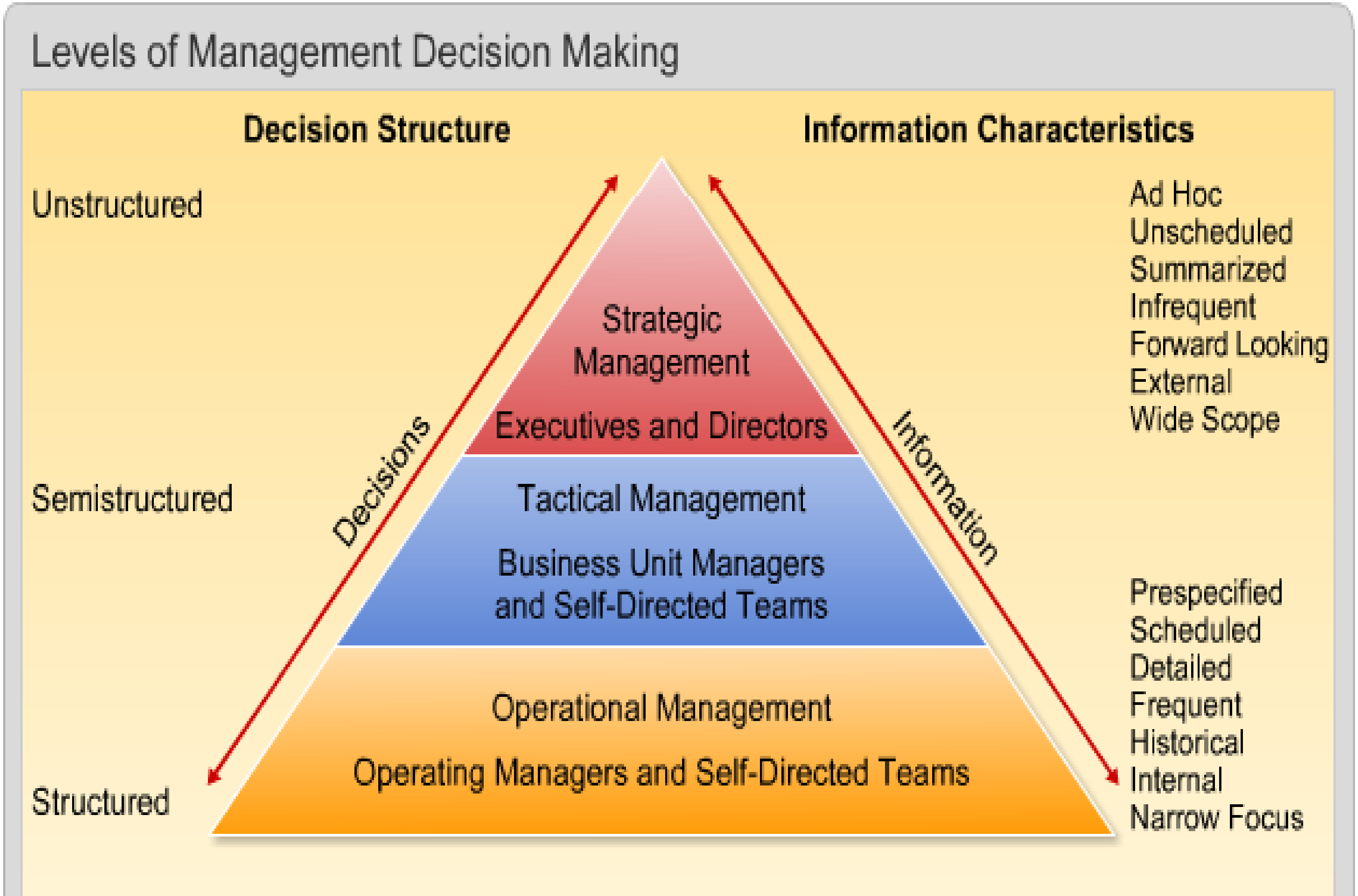
Management Information/Decision Support Systems

Management Level	Number of Decisions	Cost of Making Poor Decisions	Information Needs
Top	Least	Highest	Strategic
Middle	Intermediate	Intermediate	Implementation
First-line	Most	Lowest	Operational

Information Systems at Different Levels of Management



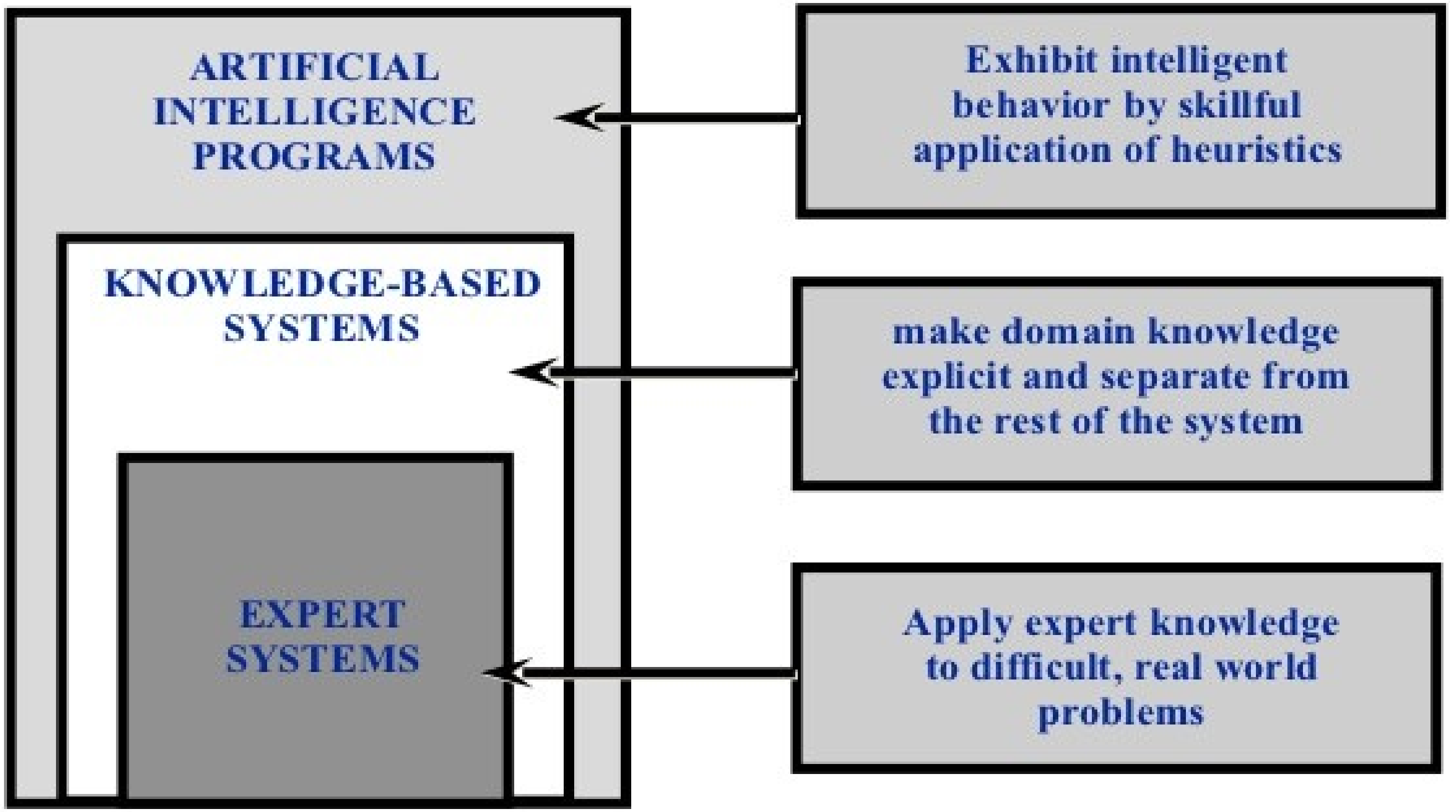
- **ESS:** Helps address strategic issues and long-term trends, both in firm and in external environment.
- **MIS & DSS:** Helps with monitoring, controlling, decision making, and administrative activities.
- **TPS:** Keeps track of basic activities and transactions of organization (e.g., sales, receipts, deposits, withdrawals, payroll, flow of materials in a factory).

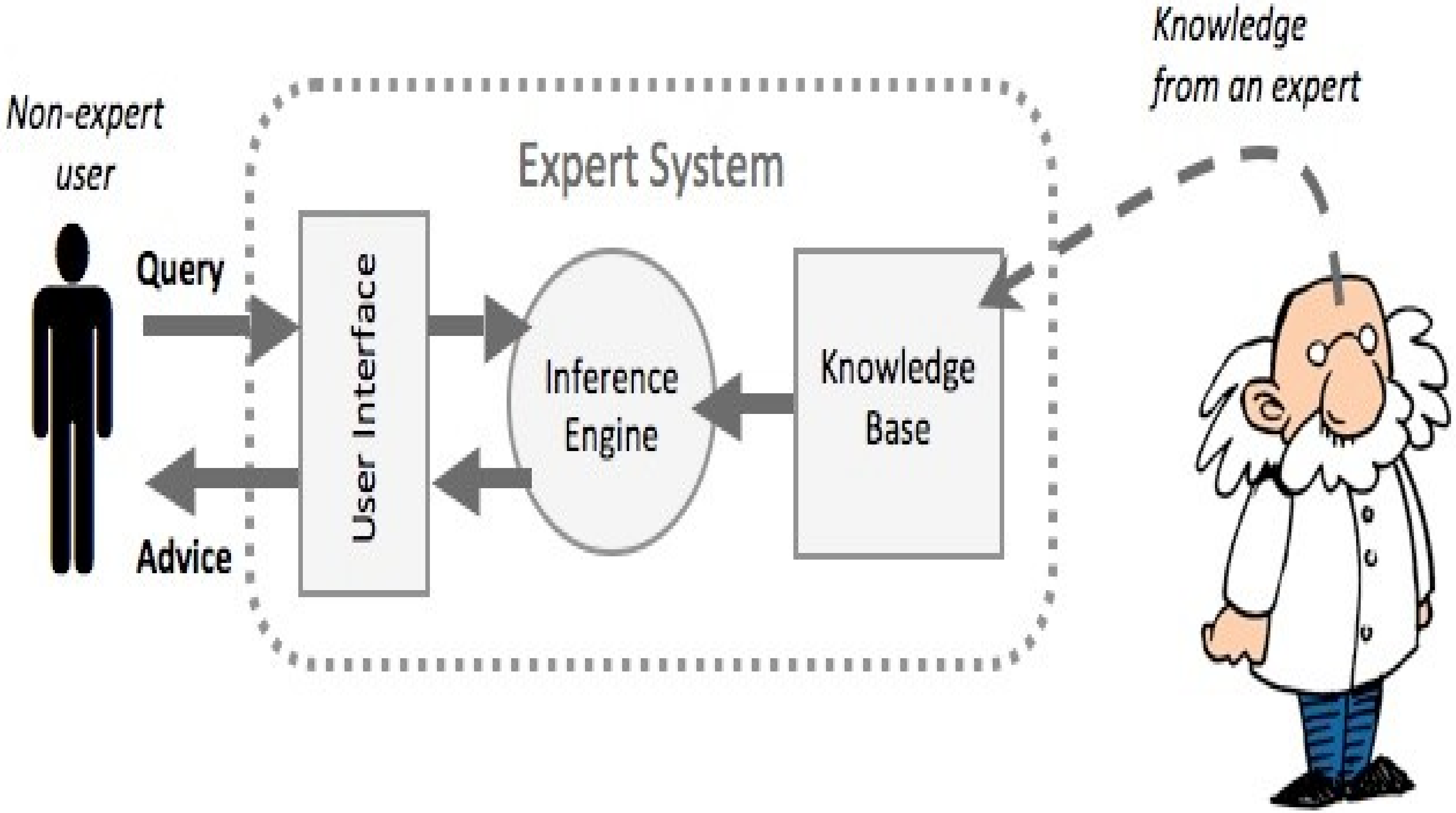


Source: Management Information Systems, James A. O'Brien and George M. Markus, 10th edition, McGraw Hill Irwin, 2011.

- Transaction Processing Systems (TPS)
  - Automate handling of data about business activities (transactions)
- Management Information Systems (MIS)
  - Converts raw data from transaction processing system into meaningful form
- Decision Support Systems (DSS)
  - Designed to help decision makers
  - Provides interactive environment for decision making
- Expert Systems (ES)
  - Replicates decision making process
  - Knowledge representation describes the way an expert would approach the problem

Expert Systems




Non-expert user
Knowledge from an expert
Expert System
Query
Advice
User Interface
Inference Engine
Knowledge Base

Implementation

Decisions, no matter how well conceived, are of little value until they are put to use—that is, until they are implemented.

Koestenbaum puts it well:

Leadership is to know that decisions are merely the start, not the end.

Next comes the higher level decision to sustain and to implement the original decision, and that requires courage. Courage is the willingness to submerge oneself in the loneliness, the anxiety, and the guilt of a decision maker. Courage is the decision, and a decision is, to have faith in the crisis of the soul that comes with every significant decision. The faith is that on the other end one findsin oneself character and the exhilaration of having become a strong, centered, and grounded human being.