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SIMON KUZNETS KHARKIV NATIONAL UNIVERSITY OF ECONOMICS

T. Borova
O. Milov

ENGLISH FOR BUSINESS ANALYSTS

Textbook
In 3 parts

PART 2. MODELS AND METHODS

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Рецензенти: проректор з НДР та міжнародної діяльності Харківської державної академії дизайну і мистецтв, д-р пед. наук, канд. філол. наук, пофесор *О. В. Гончар*; завідувач кафедри загального та прикладного мовознавства Харківського національного університету імені В. Н. Каразіна, канд. філол. наук, доцент *В. О. Гуторов*.

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The material for mastering the English language for business analysts is offered. The second part of the textbook is focused on the disciplines of the mathematical cycle of economic education that make the basis of business analysis, in particular, system analysis, modelling, operations research, econometrics, simulation, and game theory. These disciplines provide insight into various economic and mathematical aspects of business analysis. The textbook can be used for both training in groups and independent learning.

For students of speciality "Economics", lecturers, as well as people who learn and use English in the professional activity connected with the application of mathematical methods in economics.

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Introduction

Fluency in English is an indisputable condition for success in all areas of life, including business. This textbook aims to provide an opportunity for future specialists in business analytics to master English of the economic and mathematical area of focus and develop communicative competences (linguistic and pragmatic) for general and professional purposes to ensure effective communication in the academic and professional environment. Step by step, students learn the basics of analytical activities in the area of business in English while simultaneously improving communicative and language skills.

The second part is focused on the disciplines of mathematical fields of economics that are the basis of business analysis. In particular, the topics related to system analysis, models, operations research, econometrics, simulation, and game theory are considered. These topics provide insight into different economic and mathematical aspects of business analysis.

This part is addressed to students studying systems analysis and design, who are thinking about making a career in business analytics, or who are already working in systems teams. The textbook gives an introductory overview of words and phrases used in game theory, simulation, econometrics, operations research.

Students specializing in various social and natural sciences, where business analysis is part of the curriculum, should therefore find this textbook useful. It will be particularly helpful for students who sometimes feel daunted by mathematical language and vocabulary.

All units are identical in structure and consist of the basic text with comprehension exercises, including semantization of new lexical items and improving the grammatical competence of students, and speaking tasks promoting more efficient assimilation of new material. The textbook is based on the gradual complication of professional material.

The content of the authentic texts selected for the textbook meets the academic and professional purposes. Language skills that are necessary to perform the communicative tasks are connected with learning economic and mathematical methods used in business analytics. The vocabulary selected according to the requirements to the educational level of graduates is topically introduced and drilled in various tasks. Communicative integrated skills promote English study efficiency. The textbook materials aim to develop students' professional communicative competence, particularly involving videos and cases.

The structure of the textbook meets the modern requirements of learning English, the syllabus of English for professional purposes and the Common European Framework of Reference for Languages.

The publication contains different materials for self-study and development of language and communicative skills.

The textbook can be recommended to students studying economics with the focus on economic and mathematical methods; lecturers, postgraduate students, and all English language learners who use it for business and analytics purposes.

Unit 1. System

Task 1. Answer the questions.

1. What is systems analysis for you? Give five associations with this notion.
2. What do you know about systems division?
3. How does a system correlate with a mathematical model?

Task 2. Match the words with the definitions and then find and underline them in the text (Task 3).

1) assistance	a) to cut into pieces
2) reductionism (adj. reductionistic)	b) (of a compound) having its component elements present in the exact proportions indicated by its formula
3) spawn	c) to give (support, money, etc.) for a common purpose or fund
4) biodiversity	d) of or relating to a doctrine of holism (any doctrine that a system may have properties over and above those of its parts and their organization)
5) contribute	e) to produce or generate, esp. in large numbers
6) transcend	f) the transference of heat energy in a horizontal stream of gas, esp. of air
7) holistic	g) the existence of a wide variety of plant and animal species in their natural environments, which is the aim of conservationists concerned about the indiscriminate destruction of rainforests and other habitats
8) margin	h) to communicate (to conduct, transmit, or transfer)
9) depict	i) a mathematical statement that two expressions are equal
10) dissect	j) help; support
11) convey	k) a bound or limit
12) equation	l) to represent in words; describe
13) stoichiometric	m) the analysis of complex things, data, etc., into less complex constituents
14) diffusion	n) to inquire or research deeply or intensively (for information, etc.)

15) advection	o) the transfer of atoms or molecules by their random motion from one part of a medium to another
16) delve	p) to be superior to

Task 3. Read the text and answer the questions.

1. What ability has a system?
2. What is the main principle of systems analysis?
3. What is the main idea of the reductionistic principle? Give examples.
4. What core ideas of a mathematical model were discussed in the text?
5. What is the main idea of using a mathematical model in systems analysis?

Systems Analysis

Everything flows, nothing remains constant. Science sees our world as a dynamic system. To describe and analyze this world, science has developed the remarkable ability to divide systems into ever smaller pieces, into subsystems which are again subdivided into sub-subsystems and so forth. The resulting entities are dynamic systems themselves, but they are brought down to a level of complexity understandable for the human mind. In most cases, the analysis of these systems is performed with the assistance of mathematical methods.

The principle underlying all of this is called reductionism. The reductionistic principle is not without its critics, and sometimes it is given responsibility for spawning a sort of technological progress which is blind to its negative consequences (environmental impacts such as biodiversity loss, climate change, as well as other effects such as the growing division between rich and poor).

We do not claim to be able to contribute to this important discussion. We do argue, however, that to criticize, improve or even transcend an idea, one must first understand it. On closer inspection, we discover that characterizing a scientific approach as reductionistic or on the contrary as holistic is always a question of one's point of view. A cell biologist would probably call a molecular biologist's work reductionistic. Cell biology, however, will appear as a holistic field to her. On the other hand, from a population ecologist's viewpoint, cell biology would itself appear reductionistic.

The division of science into different areas of expertise thus not only takes place by putting different disciplines into different drawers of a chest (see illustration in the margin), but each drawer is again subdivided into further drawers. The chest of drawers depicted is therefore only one layer of reductionistic subdivision. In reality, many such chests would have to be drawn and each of their drawers would be subdivided further and further. Of course, this nested mass of drawers is not only a feature of biology – the reductionistic approach is used in every scientific field.

There are few concepts with which we could comprehend the world in a holistic way (whatever that may mean), without falling back to the method of subdividing it into smaller and more understandable parts. Even if we should develop such methods in the future, analyzing a system by dissecting its individual parts will always remain an important part of science. In any case, we want to think critically about our use of a reductionistic approach, and not lose track of the bigger picture.

Let us consider the core ideas of a mathematical model to convey how to model and analyze real-world systems. The underlying core principle is to construct simplified representations of such complex systems. These representations, called models, can often be expressed mathematically (e.g. through a system of equations). The construction of a mathematical model can be reduced to a few core ideas, in particular:

- the balancing of mass, energy or the number of objects (e.g. individuals of a biological species);
- the description of chemical or simple biological transformations through stoichiometric reaction equations;
- the description of populations through equations describing growth, death and interaction between individuals;
- the description of transport processes through exchange rates and processes of diffusion or advection;
- the application of statistical methods to describe systems with many degrees of freedom.

You should gain the ability to analyze real systems and make quantitative statements about their behavior. This requires the ability to translate empirically identified properties of these systems into a mathematical form, and to discuss the resulting equations (in particular, differential equations), in some cases even to solve them analytically. We will also delve into the behavior of more complex models, without specifically discussing how to solve them. Finally, we also want to demonstrate the limits of simulation and the emergence of mathematical artifacts.

(Adapted from [9])

Task 4. Work in pairs and discuss the examples of core ideas of a mathematical model.

Useful phrases

My view is …, because …

Surely the main point is …

The fact is …

On the one hand … , on the other hand …

Another idea is that …

I think that / In my opinion …

As far as I'm concerned / In my experience / In my view / From my experience / From my perspective / Personally speaking ...

Focus on Reading

Task 5. Match the words with the definitions. Use a dictionary for help [17].

1) lug	a) the small hard seedlike fruit of a grass, esp. a cereal plant
2) spruce	b) having no limits or boundaries in time, space, extent, or magnitude
3) indignantly	c) forming part of a whole; component
4) pile	d) so small, unimportant, etc., as to be not worth considering; insignificant
5) cease	e) to bring or come to an end; stop
6) constituent	f) feeling or showing scornful anger or a sense of injured innocence
7) heap	g) expressing much in few words; brief and to the point
8) grain	h) to carry or drag (something heavy) with great effort
9) pore	i) the wood of any of these trees
10) sediment	j) to make impure, esp. by touching or mixing; pollute
11) assume	k) to keep or close within bounds; limit; restrict
12) robust	l) the resolution or separation into component parts
13) infinite	m) to make a close intent examination or study
14) negligible	n) a collection of objects laid on top of one another or of other material stacked vertically; heap; mound
15) confine	o) accept without proof; suppose

16) dissolution	p) strong in constitution; hardy
17) contaminate	q) matter that settles to the bottom of a liquid
18) concise	r) a large number or quantity

Task 6. Some of the key terms given above are used in the text (Task 8). Look through the text and underline them (Task 8).

Task 7. Read the text below (Task 8) and choose the best heading to each of its parts.

A. The Earth in the Solar System.

B. A Lake as a System.

C. The Ant and the Dung Beetle.

D. Sand Heap.

Task 8. Read the text carefully. Say whether the statements below are true or false.

1. An ant's work is part of building a system.
2. A system is a set of objects between which relations are not present.
3. Simply through interior relations can the component parts become a system.
4. The system boundary does not form the border between the system and its environment.
5. The environment is influenced by the system.
6. The earth has insignificant influence on the sun.
7. An irrational system boundary between the earth and the surrounding solar system would thus be drawn in the upper stratosphere.
8. Our system is already a very complex entity with limit influences.
9. In order to create a summarizing model, we would likely have to complicate many of influences.
10. There is no completely valid way to define a system's boundary.

What Is a System?

1. …

A dung beetle watches an ant, desperately trying to lug a spruce needle onto a vast anthill. "Why waste your strength?" the beetle asks, "one needle more or less won't make a difference. What's the point?" "My work is part of building a system", the ant replies indignantly, and thinks to itself, "You'll see that this is more than a pile of needles soon enough, when we carry you inside the anthill's vast tunnels after paralyzing you with our poison!"

The word "system" originates from Greek and means configuration or composition. The New Oxford American Dictionary gives the following definition: "a set of connected things or parts forming a complex whole". In a more abstract way, one could also say that a system is a set of objects between which relations exist.

What does this mean? A system is composed of different parts, the objects or system components. They are connected with each other through mutual interactions which we call internal relations.

A pile of metal parts is therefore not yet a system. The parts have to be connected in a meaningful manner. They might be connected to form the system clockwork. If one cog is removed from that system, it will entirely cease to function. This fact is reflected in the saying "A system is more than the sum of its parts".

Only through internal relations can the constituent parts become a system. This is not always as straightforward as in the clockwork example.

2. ...

Is a sand heap a system? Many will say that it is not. One can easily remove a grain of sand and what we call the *sand heap* remains nevertheless. Furthermore, from a mineralogical point of view one learns essentially the same whether looking at a couple of grains or at the whole heap. Others, however, will contend that a sand heap is indeed a system. Between the individual grains of sand, small gaps called *pore space* exist. These pores provide space for various organisms, they can store water, or in the case of sediments, provide information about the sand heap's formation through their structure.

Whether a number of objects constitute a system can therefore not be decided in a general way without taking into account the particulars of the specific question to be answered. For a construction firm a sand heap is a source of raw material, whereas for a geologist it is a system containing valuable information.

Part of a system's definition is the system boundary, which forms the (often virtual) border between the system and its environment. This does not mean, of course, that there are no interactions between a system and the larger environment. On the contrary, it is these interactions across the boundary that make a system interesting. We assume here, however, that it is a one-way relationship: the system is influenced by the environment through what we call the external relations, but the environment is not influenced by the system. In other words, we assume that the environment is infinitely large and infinitely robust in comparison to the system we are looking at, therefore, any influence the system might have on the environment is so small that we can neglect it (Fig. 1.1).

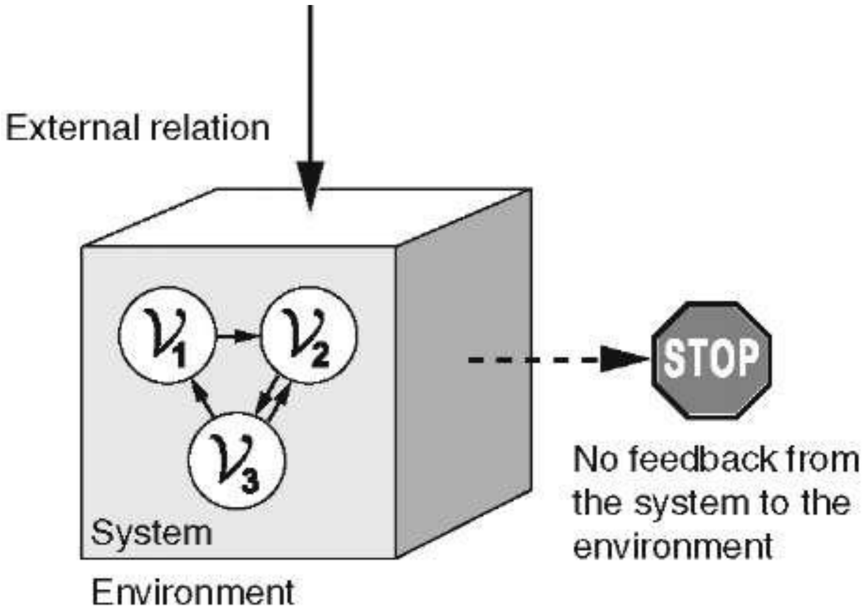


Fig. 1.1. **The schematic depiction of a system with three system variables V_1, V_2 and V_3**

The system boundary is the border between the system and the environment. The environment acts on the system (or rather, the system variables) through the external relation. The system variables are coupled through the internal relations. The feedback from the system to the environment is neglected.

The next example illustrates the hierarchy of interactions described above.

3. ...

The earth is a subsystem of the solar system. It is influenced in particular by the energy reaching it from the sun, therefore, we can say it is driven by that external relation. On the other hand, we can assume that the earth has negligible influence on the sun. A sensible system boundary between the earth and the surrounding solar system would thus be drawn in the upper stratosphere (or maybe somewhat higher).

But setting the system boundary is not always as simple, as the next example demonstrates.

4. ...

Let's look at a lake. Our goal is to describe the concentration of phosphorus in this lake. The lake's body of water is confined by the water surface and by the sediment. However, we will quickly realize that this system boundary makes little sense: the amount of phosphorus in the lake is also influenced by the dissolution of phosphorus from the sediment. As a result of prior phosphorus contaminations, a large amount of phosphorus is stored in the sediment body. So we choose as the system the body of water and the sediments combined. But then we further note that predicting the phosphorus concentration in the lake is impossible without knowing what happens in its upstream catchment area (population growth, construction of sewage treatment plants, agricultural policy, draining of wetlands, etc.). Therefore we choose as a system: the body of water, the sediment, as well as the catchment basin. By now, of course, our system is already a very complex entity with countless influences. In order to create a concise model, we would likely have to simplify or even neglect many of these influences.

Summing up, we can say that systems are theoretical constructs that help us in understanding a part of the world. There is no absolutely valid way to define a system's boundary. In fact, the exact choice of boundary depends on the question we are asking.

(Adapted from [9])

Task 9. Read the text (Task 8) again and answer the questions.

1. Why should an anthill be considered as a system?
2. What is the definition of the word "system"?
3. How should we describe a sand heap as a system?
4. What are the subsystems of the solar system and why?
5. What components can be chosen as a system in a lake? (Explain your answer).

Task 10. Give your arguments in favour of the statement that a system is more than the sum of its parts.

Focus on Vocabulary

Task 11. Match the words with similar meaning.

1) form	a) insignificant
2) mutual	b) diverse
3) entirely	c) particular
4) essentially	d) all of two or more parties
5) various	e) fundamentally
6) negligible	f) brief
7) concise	g) structure
8) specific	h) completely

Task 12. Match the words with opposite meaning.

1) vast	a) insignificant
2) internal	b) tiny
3) meaningful	c) complex
4) simplify	d) external

Focus on *Reading*

Task 13. Match the words with the definitions. Use a dictionary for help [17].

1) imposing	a) a part that is allocated; share
2) reduce	b) to differ or diverge
3) enhance	c) cooperating
4) bog down	d) to make or become smaller in size, number, extent, degree, intensity, etc.
5) rigid	e) to give rise
6) elapse	f) to adapt, as to a new environment, etc.
7) acute	g) to attempt to persuade or entice to do something
8) tempt	h) having a sharp end or point
9) deviate	i) to enclose within a circle; surround
10) trigger	j) not flexible
11) allocation	k) impressive
12) encompass	l) to impede or be impeded physically or mentally
13) concurrent	m) to assign an initial value to (a variable or storage location) in a computer program

14) adjust	n) to pass by
15) initialize	o) to intensify or increase in quality, value, power, etc.; improve

Task 14. Some of the key terms given above are used in the text (Task 16). Look through the text and underline them.

Task 15. Read the text below (Task 16) and choose the best heading to each of its parts.

A. Inputs and Related Ideas.
B. Methodologies.
C. Strengths, Weaknesses, and Limitations.
D. The System Life Cycle.
E. The Waterfall Method.
F. Purpose.
G. Concepts.
H. Information Systems.

Task 16. Read the text carefully. Say whether the statements below are true or false.

1. The purpose of a methodology is to indicate a set of well-defined steps or phases, coupled with a set of clear, measurable exit criteria, for solving a complex problem.
2. The tools associated with a good methodology make it more difficult to solve the problem.
3. The elapsed time between the initial proposal and system completion can be quite short.
4. The system development life cycle implies a phased approach, with complex tasks decomposed into smaller phases (stages, steps) that are more complicated to achieve, control, and manage.
5. A system is a set of interrelated components that function together in any way.
6. A process is an activity that changes the system in some way.
7. An information system is a set of hardware, software, data, human, and procedural components intended to provide the right data and information to the right person at the right time.
8. An information system "dies" when a problem is recognized.

9. A key purpose of a methodology is ensuring that nothing is overlooked in the process of solving a complex problem.

10. It is sometimes called the waterfall method because the model visually suggests work cascading from step to step like a series of waterfalls (problem definition, analysis, design, development, testing, implementation, maintenance).

The Systems Development Life Cycle

1. ...

The purpose of a methodology is to specify a set of well-defined steps or phases, coupled with a set of clear, measurable exit criteria, for solving a complex problem (such as developing an information system). The systems development life cycle (SDLC) is a set of steps that serves as the basis for most systems analysis and design methodologies.

2. ...

A methodology (such as the systems development life cycle) acts as a memory aid by imposing discipline, thus reducing the risk that key details will be overlooked. Communication is enhanced because the methodology imposes a consistent set of documentation standards. The steps in the methodology enhance management control, providing a framework for scheduling, budgeting, and project management. The tools associated with a good methodology make it easier to solve the problem. Finally, a good methodology increases the likelihood that significant errors are detected early.

There are dangers associated with using a methodology, however. Some people become so bogged down in the mechanics of following the steps and completing the exit criteria that they fail to solve the real problem. (There is a fine line between discipline and rigidity.) Additionally, no matter what methodology is chosen, there will be problems for which that methodology is (at best) inappropriate, and it is a mistake to try to force the application to fit the tool.

There is always a concern that the system developed may not accurately reflect the current business environment. The elapsed time between the initial proposal and system completion can be quite lengthy (often one or more years). Many methodologies require that specifications be "frozen" as work progresses from one step to the next, and user requirements do change over time. Given the fast pace of technology, this problem is particularly acute with hardware and/or software selected early in the process.

The traditional methodologies are not optimal for developing some types of information systems, such as expert systems and real-time processing systems. Additionally, fourth-generation, fifth-generation, and objected-oriented languages require modifications to the traditional approach.

Sometimes management is tempted to believe (or hope) that technology can replace technical experts. A good methodology makes a competent analyst more productive, but no methodology can convert an unskilled, untrained person into a competent analyst.

3. ...

The systems development life cycle provides a framework or structure for virtually all the tools and techniques discussed in this text.

The system development life cycle implies a phased approach, with complex tasks decomposed into smaller phases (stages, steps) that are easier to achieve, control, and manage. Many traditional methodologies, such as Martin's information engineering and Orr's structured requirements definition, emphasize the phased approach, with clearly defined entrance and exit criteria for each individual phase. Practicing analysts often deviate from the rigidly phased approach defined by the methodology, however.

The project management life cycle is similar to the systems development life cycle, with stages or phases defining a schedule and triggering resource allocations. Note, however, that a given project might encompass several related systems, and a given system might be divided into several sequential or concurrent projects.

4. ...

A system (Fig. 1.2) is a set of interrelated components that function together in a meaningful way. A system is delimited from its environment (its suprasystem) by a boundary. A system accepts inputs at its boundaries. Outputs flow back across the boundaries. A process is an activity that changes the system in some way. Of particular interest are the interfaces, the points at which the various system components communicate or interact. As a general rule, the more interfaces a system contains, the more complex the system.

In addition to inputs, processes, interfaces, and outputs, the system also includes control and feedback mechanisms that together allow the system to determine if it is achieving its purpose. Feedback is the return of a portion of the system's output to its input. If the feedback suggests a deviation from the expected value (the control), the system reacts by attempting to adjust itself.

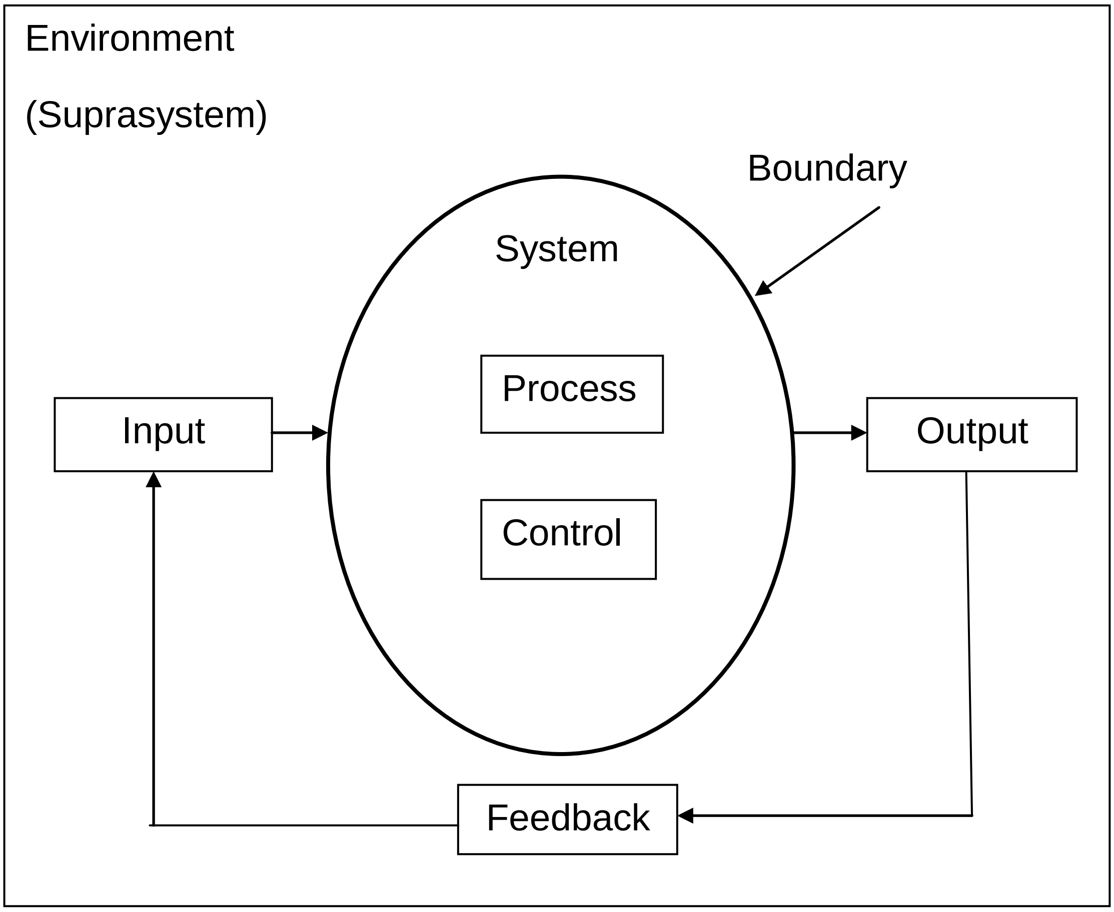


Fig. 1.2. **A system**

5. ...

This text is concerned with the analysis and design of information systems. An information system is a set of hardware, software, data, human, and procedural components intended to provide the right data and information to the right person at the right time.

6. ...

Every system has a life cycle (Fig. 1.3). An information system is "born" when a problem is recognized. After the system is developed, it grows until it reaches maturity. Eventually, a change in the nature of the problem or increasing maintenance costs degrade the value of the system, so it "dies" and a new or replacement system is born to take its place.

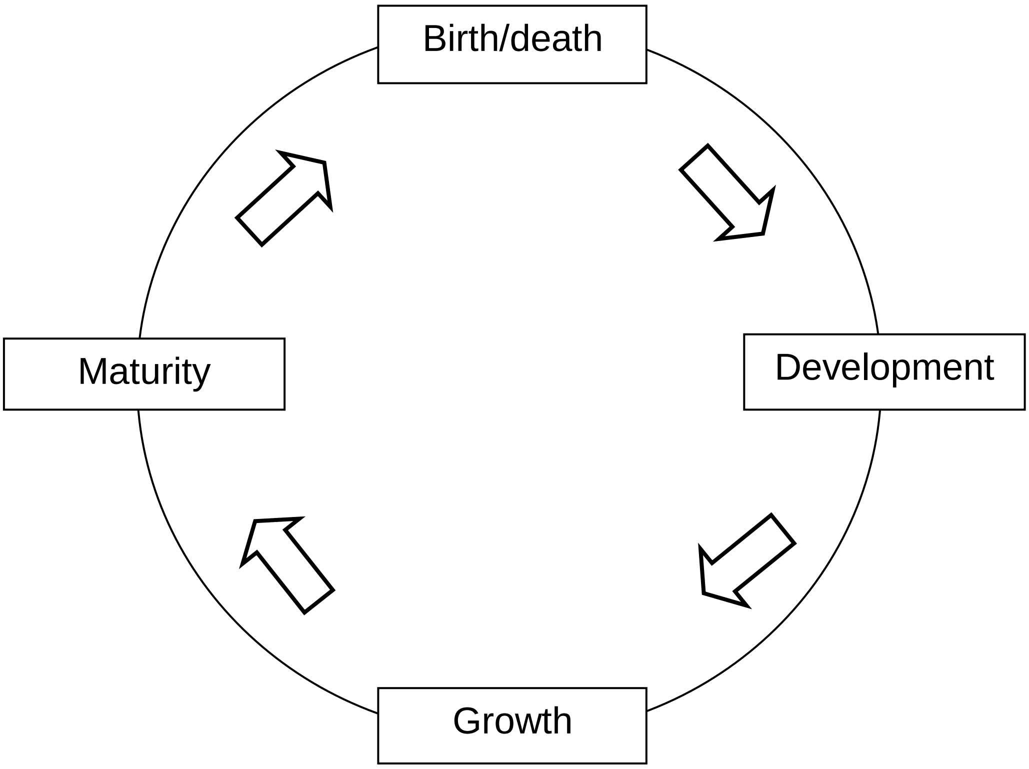


Fig. 1.3. **The system life cycle**

7. ...

A methodology is a body of practices, procedures, and rules used by those who work in a discipline or engage in an inquiry. Often, a methodology is implemented as a set of well-defined steps or phases, each of which ends with a clear, measurable set of exit criteria. A key purpose of a methodology is ensuring that nothing is overlooked in the process of solving a complex problem (such as developing a complex information system).

8. ...

The basis for most systems analysis and design methodologies is the system development life cycle or SDLC (Fig. 1.4). It is sometimes called the waterfall method because the model visually suggests work cascading from step to step like a series of waterfalls. (*Note* In reality, there is considerable feedback between the various steps or phases.)

The first step is problem definition. The intent is to identify the problem, determine its cause, and outline a strategy for solving it.

Given a clear problem definition, analysis begins. The objective of analysis is to determine exactly *what* must be done to solve the problem. Typically, the system's *logical* elements (its boundaries, processes, and data) are defined during analysis.

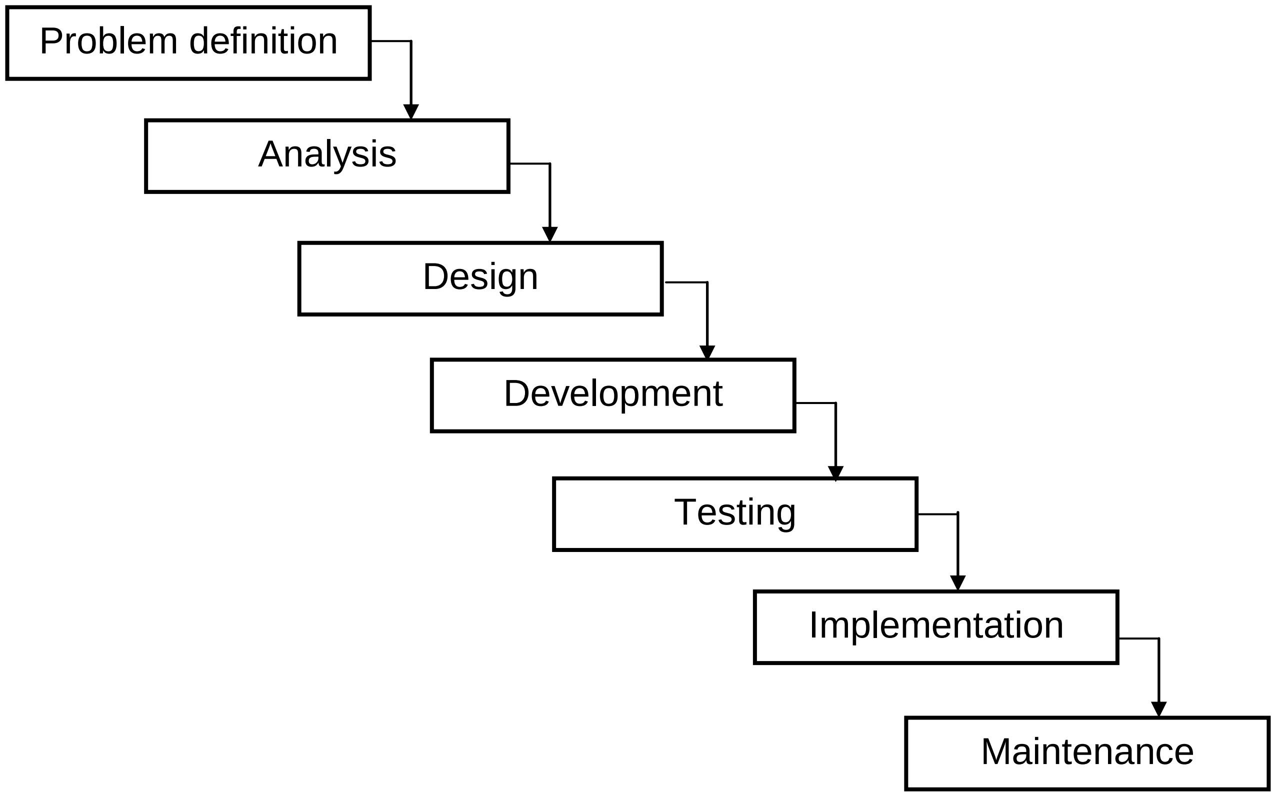


Fig. 1.4. **The system development life cycle is sometimes called the waterfall method**

The objective of design is to determine *how* the problem will be solved. During design the analyst's focus shifts from the logical to the *physical.* Processes are converted to manual procedures or computer programs. Data elements are grouped to form physical data structures, screens, reports, files, and databases. The hardware components that support the programs and the data are defined.

The system is created during development. (*Note.* Because the entire process is called the system *development* life cycle, some experts prefer to use other labels, such as system creation, for this stage.) Programs are coded, debugged, documented, and tested. New hardware is selected and ordered. Procedures are written and tested. End-user documentation is prepared. Databases and files are initialized. Users are trained.

Once the system is developed, it is tested to ensure that it does what it was designed to do. After the system passes its final test and any remaining problems are corrected, the system is implemented and released to the user. After the system is released, maintenance begins. The objective of maintenance is to keep the system functioning at an acceptable level.

(Adapted from [5])

Task 17. Read the text (Task 16) again and answer the questions.

1. What is the purpose of a methodology?
2. How does a methodology (such as the system development life cycle) act?
3. What does the systems development life cycle provide?
4. What are the interrelated components of a system?
5. What has every system? (Describe the elements).
6. What are the components of the waterfall method?

Task 18. Describe the methods of the systems development life cycle. Discuss their advantages.

Focus on Vocabulary

Task 19. Match the key terms with their definitions.

1) analysis	a) the third step in the system development life cycle (following analysis and preceding development) during which the responsible people determine how the problem will be solved by specifying the system's physical components
2) boundary	b) the fourth step in the system development life cycle (following design and preceding testing) during which the system is created
3) control	c) the sixth step in the system development life cycle (following testing and preceding maintenance) during which the system is installed and released to the user
4) design	d) attacking a problem by breaking it into sub-problems. The second step in the system development life cycle (following problem definition) during which the responsible people determine exactly what must be done to solve the problem
5) development	e) an entity that serves to delimit or separate a system from its environment
6) feedback	f) a mechanism or point of interaction between two or more system components

7) implementation	g) an expected value that can be compared with feedback. If the feedback suggests a deviation from the expected value (the control), the system reacts by attempting to adjust itself
8) information system	h) the first step in the system development lifecycle during which the problem is identified, its cause is determined, and a strategy for solving it is developed
9) interface	i) a body of practices, procedures, and rules used by those who work in a discipline or engage in an inquiry. It is often implemented as a set of well-defined steps or phases, each of which ends with a clear, measurable set of exit criteria
10) maintenance	j) a set of steps for solving information system problems; the basis for most systems analysis and design methodologies
11) methodology	k) the return of a portion of the system's output to its input
12) problem definition	l) a set of hardware, software, data, human, and procedural components intended to provide the right data and information to the right person at the right time
13) process	m) a model that stresses the stages of system usefulness. The stages are birth, development, growth, maturity, and death
14) suprasystem	n) the final step in the system development life cycle (following implementation) intended to keep the system functioning at an acceptable level
15) system	o) the fifth step in the system development life cycle (following development and preceding implementation) intended to ensure that the system does what it was designed to do
16) systems development life cycle (SDLC)	p) a system's environment
17) system life cycle	q) an activity that changes a system in some way
18) testing	r) a set of interrelated components that function together in a meaningful way

Task 20. Complete the text with the following words and phrases.

Body, communication, development, complex, process, problem definition, methodology, feedback, life cycle, environment.

1. The system development … (SDLC) is a set of steps that serves as the basis for most systems analysis and design methodologies.
2. … is enhanced because the methodology imposes a consistent set of documentation standards.
3. A good … makes a competent analyst more productive.
4. The system development life cycle implies a phased approach, with … tasks decomposed into smaller phases (stages, steps) that are easier to achieve, control, and manage.
5. A system is delimited from its … (its suprasystem) by a boundary.
6. A … is an activity that changes the system in some way.
7. … is the return of a portion of the system's output to its input.
8. A methodology is a … of practices, procedures, and rules used by those who work in a discipline or engage in an inquiry.
9. The first step is ... .
10. The system is created during ... .

Focus on Listening

Task 21. Discuss with your partner why students should study System Dynamics.

Task 22. Watch Video 1. "Why should students study System Dynamics? System Dynamics Society" and compare your answers. Do they have the same ideas? [https://www.youtube.com/watch?v=iveX64eYnbk].

Task 23. Complete the sentences, then watch Video 1 (Task 22) again and check them.

1. You should be interested in a system dynamics if you want to have … .
2. You also got to be able to live … .
3. It will take an unusual person who … .
4. That's how I got into system dynamics being willing to move into unknown territory … .
5. Professor Forrester founded the field of … .
6. His research focused on … .

Task 24. Give the main idea of the text (Task 23).

Focus on Speaking

Task 25. Work in pairs and complete each sentence.

1. The word system is a set of … .
2. A system is a set of objects between … .
3. The parts have to be connected in … .
4. The system boundary is the border between … .
5. Our system is already a very complex … .
6. The systems development life cycle (SDLC) is a set of steps that … .
7. A good methodology makes a competent analyst more … .
8. A system is a set of interrelated components that function … .
9. An information system is a set of hardware, software, data, human, and procedural components intended to provide … .
10. Every system has a … .
11. The waterfall method includes such components as: … .

Task 26. Describe the systems development life cycle.

Focus on Questions and Problems

Task 27. Read the text and answer the questions.

The alternative frameworks are prototyping, joint application design (JAD), rapid application development (RAD), participatory design (PD), and Agile Methodologies. Using prototyping, analysts build a working model of the system. In JAD, analysts and users meet to solve problems and design systems. RAD decreases the time needed to design and implement information systems. In PD, the emphasis is on the user community. Agile Methodologies focus on adaptive rather than predictive methodologies, on people rather than roles. Computer Aided Software Engineering (CASE) tools represent the use of information technology to assist in the systems development process. They include diagramming tools, screen and report design tools, and other special-purpose tools. CASE tools help programmers and analysts do their jobs efficiently and effectively by automating routine tasks.

(Adapted from [16])

1. What is information systems analysis and design?
2. What is systems thinking? How is it useful for thinking about computer-based information systems?
3. What is decomposition? Coupling? Cohesion?
4. List and explain the different phases in the systems development life cycle.
5. What is prototyping?
6. What is RAD? How does it compare to the typical SDLC?
7. What are Agile Methodologies?

Task 28. Discuss the problems and suggest your solutions.

1. Why is it important to use systems analysis and design methodologies when building a system? Why not just build the system in whatever way which seems to be "quick and easy?" What value is provided by using an "engineering" approach?
2. Describe your university or college as a system. What is the input? The output? The boundary? The components? Their interrelationships? The constraints? The purpose? The interfaces? The environment? Draw a diagram of this system.
3. A car is a system with several subsystems, including the braking subsystem, the electrical subsystem, the engine, the fuel subsystem, the climate-control subsystem, and the passenger subsystem. Draw a diagram of a car as a system and label all of its system characteristics.
4. Your personal computer is a system. Draw and label a personal computer as a system as you did for a car in Problem 3.
5. How is the joint application design (JAD) approach different from the participatory design (PD) approach developed in Europe? (You may have to do some digging at the library to answer this question adequately.) What are the benefits in using these types of approaches in building information systems? What are the barriers?
6. How would you organize a project team of students to work with a small business client? How would you organize a project team if you were working for a professional consulting organization?
7. How might prototyping be used as part of the SDLC?
8. Describe the difference in the role of a systems analyst in the SDLC versus prototyping.

9. Compare Figures 1.5 and 1.6. What similarities and differences do you see?

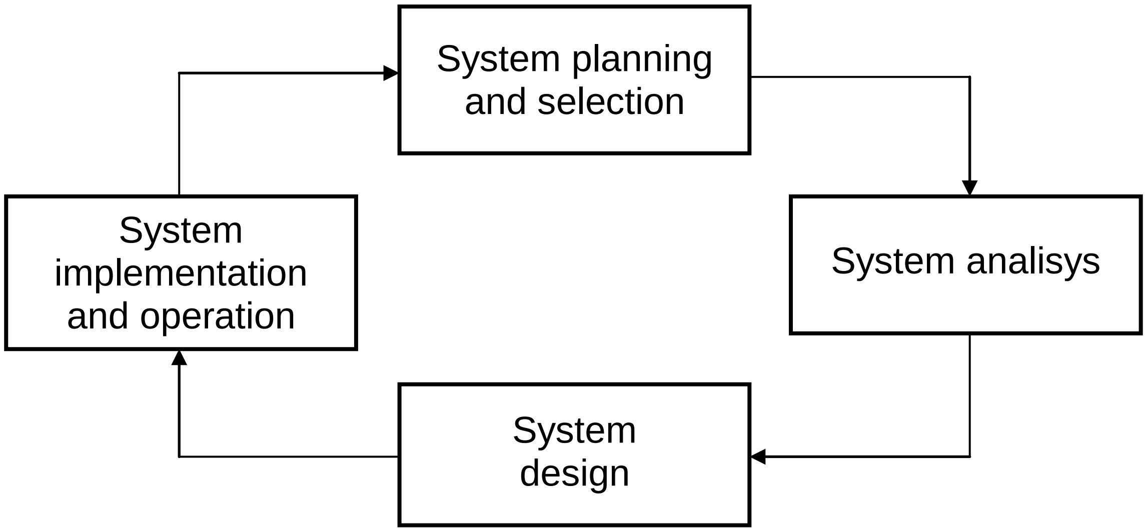


Fig. 1.5. **The systems development lifecycle (SDLC)**

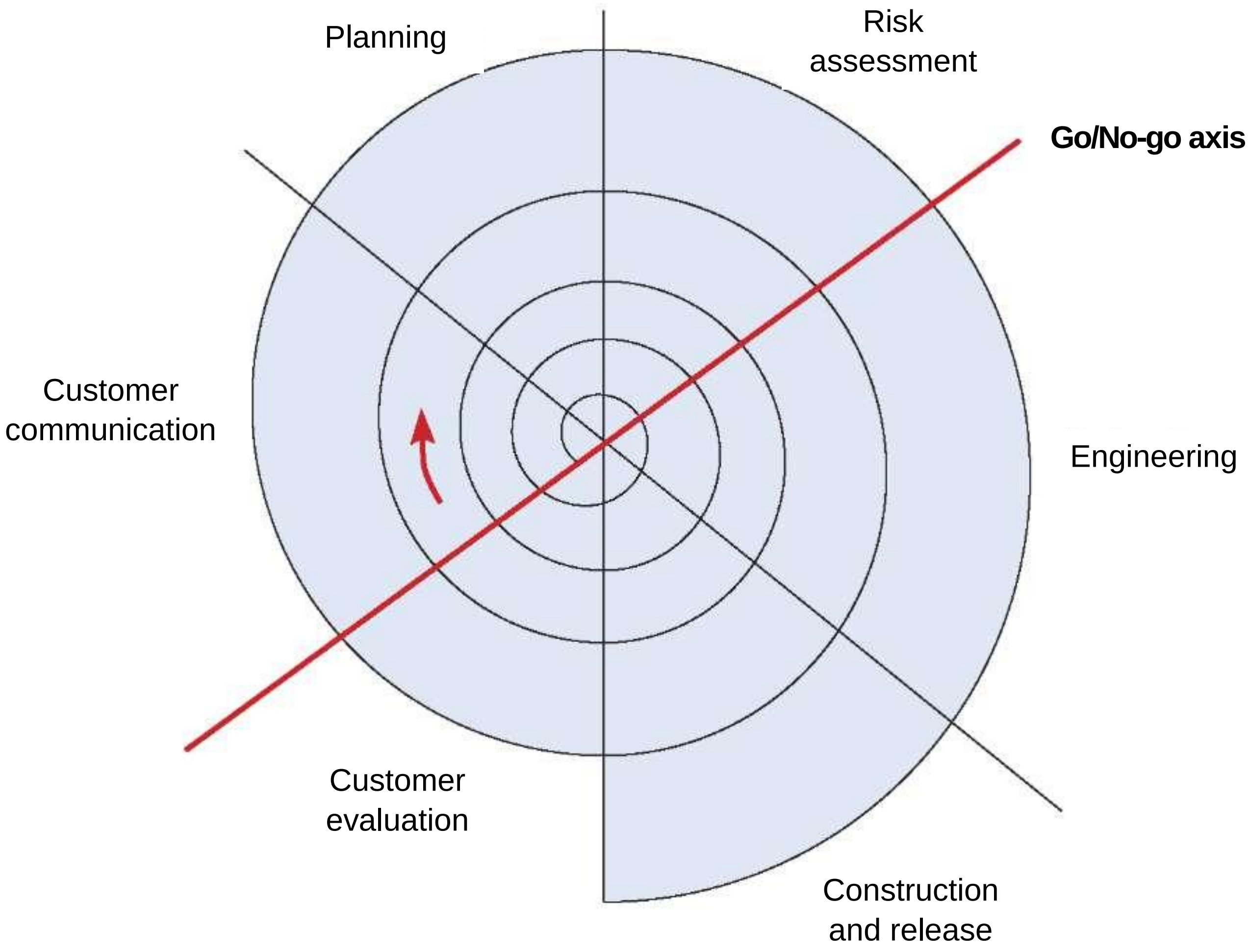


Fig. 1.6. **The evolutionary model SDLC**

10. If someone at a party asked you what a systems analyst was and why anyone would want to be one, what would you say?

11. Explain how a computer-based information system designed to process payroll is a specific example of a system. Be sure to account for all nine components of any system in your explanation.

12. What do you think systems analysis and design will look like in the next decade? A computer programmer suddenly transported from the 1950s to the 2000s would have trouble recognizing the computing environment that had evolved just fifty years later. What dramatic changes might occur in the next ten years?

Task 29. Dilemma. Study the examples then answer the questions and fulfil the tasks.

1. Pine Valley Furniture

Alex Schuster began Pine Valley Furniture (PVF) as a hobby. Initially, Alex would build custom furniture in his garage for friends and family. As word spread about his quality craftsmanship, he began taking orders. The hobby has since evolved in to a medium-sized business, employing more than fifty workers.

Over the years, increased demand has forced Alex to relocate several times, increase his sales force, expand his product line, and renovate Pine Valley Furniture's information systems. As the company began to grow, Alex organized the company into functional areas – manufacturing, sales, orders, accounting, and purchasing. Originally, manual information systems were used; however, as the business began to expand rapidly, a mini-computer was installed to automate applications. In the beginning, a process-oriented approach was utilized. Each separate application had its own datafiles. The applications automated the manual systems on which they were modeled. In an effort to improve its information systems, PVF recently renovated its information systems, resulting in a company-wide database and applications that work with this database. Pine Valley Furniture's computer-based applications are primarily in the accounting and financial areas. All applications have been builtin-house, and when necessary, new information systems staff is hired to support Pine Valley Furniture's expanding information systems.

a. How did PVF go about developing its information systems? Why do you think the company chose this option? What other options were available?

b. One option available to PVF was an enterprise-wide system. What features does an enterprise-wide system, such as SAP, provide? What is the primary advantage of an enterprise-wide system?

c. PVF will be hiring two systems analysts next month. Your task is to develop a job advertisement for these positions. Locate several Web sites or newspapers that have job advertisements for systems analysts. What skills are required?

d. What types of information systems are currently utilized at PVF? Provide an example of each.

2. Hoosier Burger

As college students in the 1970s, Bob and Thelma Mellankamp often dreamed of starting their own business. While on their way to an economics class, Bob and Thelma drove by Myrtle's Family Restaurant and noticed a "for sale" sign in the window. Bob and Thelma quickly made arrangements to purchase the business, and Hoosier Burger Restaurant was born. The restaurant is moderately sized, consisting of a kitchen, dining room, counter, storage area, and office. Currently, all paper work is done by hand. Thelma and Bob have discussed the benefits of purchasing a computer system; however, Bob wants to investigate alternatives and hire a consultant to help them.

Perishable food items, such as beef patties, buns, and vegetables are delivered daily to the restaurant. Other items, such as napkins, straws, and cups, are ordered and delivered as needed. Bob Mellankamp receives deliveries at the restaurant's back door and then updates a stock log form. The stock log form helps Bob track inventory items. The stock log form is updated when deliveries are received and also nightly after daily sales have been tallied. Customers place their orders at the counter and are called when their orders are ready. The orders are written on an order ticket, totaled on the cash register, and then passed to the kitchen where the orders are prepared. The cash register is not capable of capturing point-of-sale information. Once an order is prepared and delivered, the order ticket is placed in the order ticket box. Bob reviews these order tickets nightly and makes adjustments to inventory.

In the past several months, Bob has noticed several problems with Hoosier Burger's current information systems, especially with the inventory control, customer ordering, and management reporting systems. Because the inventory control and customer ordering systems are paper-based, errors occur frequently. These errors often affect delivery orders received from suppliers as well as customer orders. Bob has often wanted to have electronic access to forecasting information, inventory usage, and basic sales information. This access is impossible because of the paper-based system.

a. Apply the SDLC approach to Hoosier Burger.

b. Using the Hoosier Burger scenario, identify an example of each system characteristic.

c. Decompose Hoosier Burger into its major subsystems.

d. Briefly summarize the approaches to systems development. Which approach do you feel should be used by Hoosier Burger?

3. Natural Best Health Food Stores

Natural Best Health Food Stores is a chain of health food stores serving Oklahoma, Arkansas, and Texas. Garrett Davis opened his first Natural Best Health Food Store in 1975 and has since opened fifteen stores in three states. Initially, he sold only herbal supplements, gourmet coffees and teas, and household products. In 1990, he expanded his product line to include personal care, pet care, and grocery items.

In the past several months, many of Mr. Davis's customers have requested the ability to purchase prepackaged meals, such as chicken, turkey, fish, and vegetarian, and have these prepackaged meals automatically delivered to their homes weekly, biweekly, or monthly. Mr. Davis feels that this option is viable because Natural Best has an automatic delivery system in place for its existing product lines.

With the current system, a customer can subscribe to the Natural Best Delivery Service (NBDS) and have personal care, petcare, gourmet products, and grocery items delivered on a weekly, biweekly, or monthly basis. The entire subscription process takes approximately five minutes. The sales clerk obtains the customer's name, mailing address, credit card number, desired delivery items and quantity, delivery frequency, and phone number. After the customer's subscription has been processed, delivery usually begins within a week. As customer orders are placed, inventory is automatically updated. The NBDS system is a client/server system. Each store is equipped with a client computer that accesses a centralized data-base housed on a central server. The server tracks inventory, customer activity, delivery schedules, and individual store sales. Each week the NBDS generates sales summary reports, low-in-stock reports, and delivery schedule reports for each store. The information contained on each of these individual reports is then consolidated into master sales summary, low-in-stock, and forecasting reports. Information contained on these reports facilitates restocking, product delivery, and forecasting decisions. Mr. Davis has an Excel worksheet that he uses to consolidate sales information from each store. He then uses this worksheet to make forecasting decisions for each store.

a. Identify the different types of information systems used at Natural Best Health Food Stores. Provide an example of each. Is an expert system currently used? If not, how could Natural Best benefit from the use of such a system?

b. Figure 1.7 identifies seven characteristics of a system. Using the Natural Best Health Food Stores scenario, provide an example of each system characteristic.

c. What type of computing environment does Natural Best Health Food Stores have?

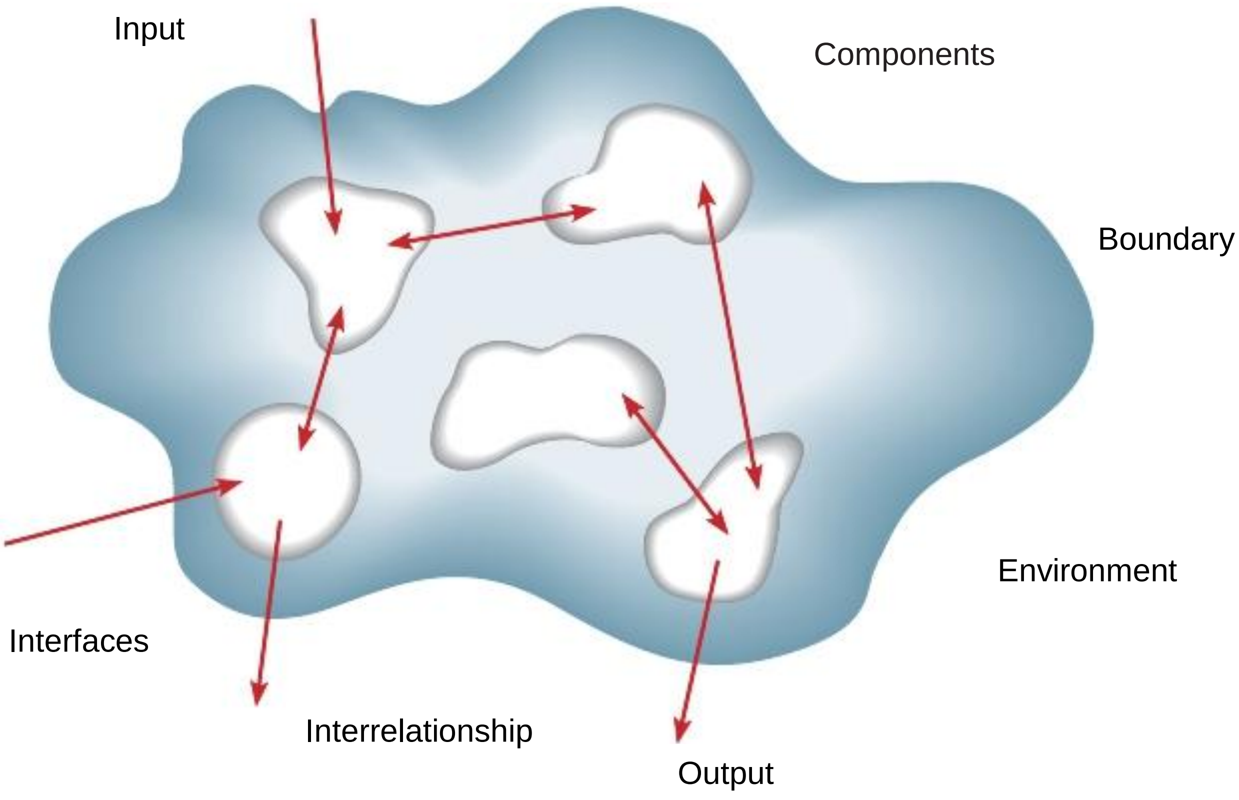


Fig. 1.7. **Seven characteristics of a system**

Unit 2. Models and Modeling

Task 1. Answer the questions.

1. What is the difference between a system and a model? Give your examples.
2. What do you know about model formation?
3. What do you know about the model's variables?

Task 2. Match the words with the definitions and then find and underline them in the text (Task 3).

1) variables	a) a measurement of the size of something in a particular direction, such as the length, width, height, or diameter
2) arrows	b) the tangible matter of which a thing consists
3) substance	c) feeding a larger stream
4) tributary	d) any of various things that resemble an arrow in shape, function, or speed, such as a sign indicating direction or position
5) dimension	e) a range of possible values

Task 3. Read the text and answer the questions.

1. What question helps us define the system?
2. What tools do you use for this first step of model formation?
3. What are the external relations called?
4. How many variables has the model according to the text?
5. What is the number of system variables called?

From System to Model

Before forming a model, we should think carefully about what we need the model for. What questions do we want to examine with it? Our research question helps us define the system, then select the system boundary and the relevant system variables.

For this first step of model formation, we can use some very simple tools. We draw our system as a box diagram. The boundary of the box corresponds to the system boundary. Inside the box we draw the system variables V_i. From outside the box, the external relations R_i influence the system. In many cases, these external relations consist of mass flows from the environment into the system. Therefore, the external relations are also called input variables or mass input. But there could also be other kinds of external relations, for instance, solar radiation, atmospheric temperature, or a bank's interest rate. We connect the system variables with arrows that indicate the relations between them. These are the internal relations of the system. They could, for instance, be mass flows between the system variables.

One natural system that we will use as an example is a lake. Fig. 2.1 shows a first simple model to describe a chemical substance in a lake.

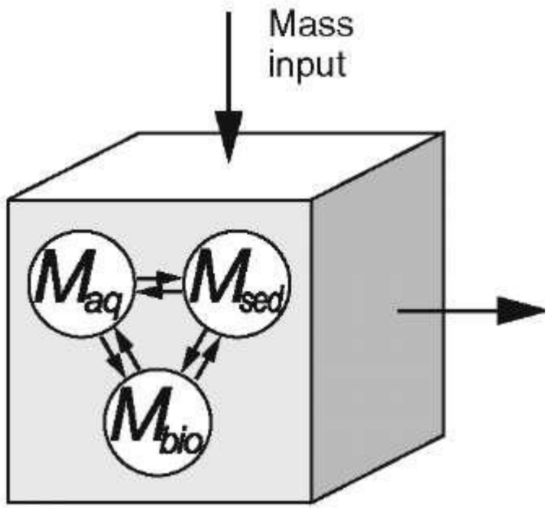


Fig. 2.1. **A lake as a box diagram with three variables**

Example: A lake as a black box.

The model has three variables: the amount or mass of a chemical substance in the lake water M_{aq}, in the lake's sediment M_{sed} and in its living organisms M_{bio} (for instance in fish). The substance to be modelled reaches the lake by a tributary river. This mass input represents the system's external relation. The loss of substance through the lake's outflow is symbolized by an arrow pointing out from the box. The exchange of substance between lake water, sediment and biomass is also symbolized by arrows connecting the three variables. These are the internal relations.

The number of system variables is called the dimension of a model. The dimension of a model equals the number of system variables. The example above represents a three-dimensional model with the three system variables M_{aq}, M_{sed} and M_{bio}. In order to formulate the model mathematically, we must describe the internal relations (the mass flows between the three system variables) and the external relations. By doing so, we arrive at the system or model equations. They usually contain additional quantities: the model parameters.

(Adapted from [9])

Task 4. Describe Fig. 2.1 (Task 3).

Focus on Reading

Task 5. Match the words with the definitions. Use a dictionary for help [17].

1) trace	a) smell left in passing, by which a person or animal may be traced
2) replica	b) to represent in a drawing or painting, etc.
3) lens	c) to prevent
4) depict	d) unusually large; huge; vast
5) explicit	e) to perceive or grasp mentally; understand
6) scent	f) the system around which something is built up
7) apprehend	g) precisely and clearly expressed, leaving nothing to implication; fully stated
8) framing	h) to observe, discover, or find vestiges or signs of by investigation
9) hinder	i) to judge or consider
10) immense	j) a copy or model, esp. on a smaller scale
11) deem	k) a piece of glass or other transparent material, used to converge or diverge transmitted light and form optical images

Task 6. Some of the key terms given above are used in the text (Task 7). Look through the text and underline them.

Task 7. Read the text carefully. Say whether the statements below are true or false.

1. A model is sometimes a simplified image of a real system.
2. A model necessarily has anything to do with maths at the outset.
3. A model is the lens through which we look at the real system – it is not an exact copy of that system.
4. One model is superior to another because it is more complex.

5. Good models allow us, through certain simplifications, to arrive at a readily comprehensible representation of the real world that can be described mathematically.

6. An important motivation to construct a model is to make predictions about a system's future behavior.

7. Mathematical models do not allow us to develop consistent theories about our physical surroundings.

8. To date, the field beyond natural science in which mathematical modeling has seen the most success is economics.

9. The models themselves would have been beyond reach of mathematical analysis if not for the enormous progress in information technology.

10. A model serves to describe the insignificant features of a system and to leave aside the important ones.

What is a Model?

We can trace the origin of our word *model* to ancient Rome, where small replicas of buildings were called modulus (Latin for "small-scale replica of a building"). Just as Roman architects needed replicas to assist them in designing large and complex buildings, if we want to analyze a natural system, we must first describe it in simplified terms. Whether this is as a drawing, a functional diagram, a mathematical equation or a verbal account, we can call such a description a model. So we can say that a model is always a simplified image of a real system.

A model, therefore, does not necessarily have anything to do with maths at the outset. It is simply a concept with which we can describe a complex system in simplified terms. Models are used in architecture to plan buildings, or in chemistry to describe atoms as spheres and the molecular bonds as little rods between them (Fig. 2.2). Models are in use everywhere, whether they are physical models or purely mental constructs.

A model is the lens through which we look at the real system – it is not an exact copy of that system. For the same system, there can be completely different models. We could depict a landscape as a topographical map, or as an impressionistic painting. In both cases, the simplification of the system "landscape" is our explicit intention. It is impossible to say a priori which model is better. One model is not superior to another because it is more complex. Depending on the point of view that we want to emphasize and the question we intend to answer, we include certain properties of the system in the model while excluding others. You can think of it like a dog taken for a walk in a forest. The dog's model of the forest will be different than that of its owner; it might predominantly consist of scents, for instance. But he will be able to navigate the forest just as well or even better than his owner.

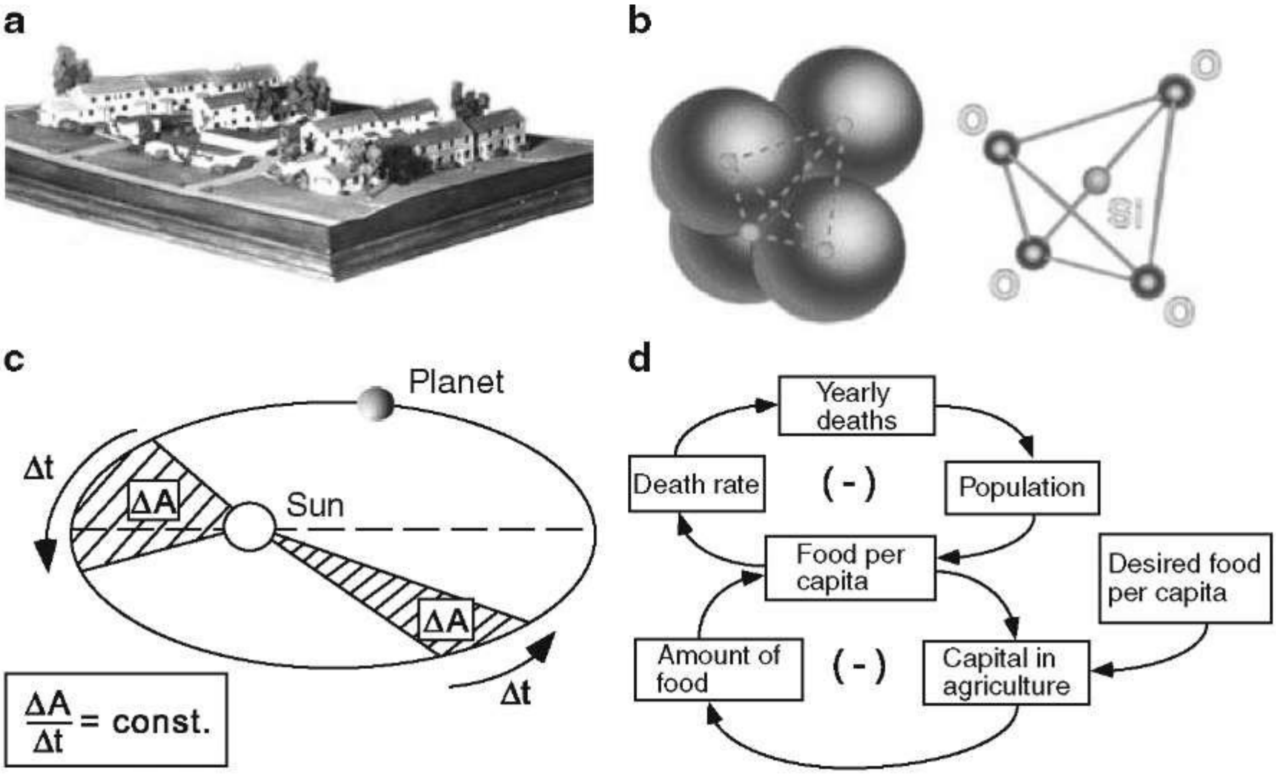


Fig. 2.2. **Examples of models: (a) an architectural model: scaled-down execution of a planned or existing building; (b) a physical model: a model of chemical molecules; (c) a mathematical model: Kepler's second law of planetary motion; (d) a conceptional model: a world dynamics model**

Good models allow us, through certain simplifications, to arrive at a readily comprehensible representation of the real world that can be described mathematically. Such models have a long tradition in science and engineering. The only way to apprehend and analyze a real system is with a model, that is, by framing it in terms that hold relevance for us. Often, an important motivation to construct a model is to make predictions about a system's future behavior. As we will see, however, making predictions is not the only role that models play.

If a model is formulated with mathematical equations, it becomes a mathematical model. Mathematical models were developed primarily in the exact natural sciences and in engineering, above all in physics. They allow us to develop consistent theories about our physical surroundings. Under the influence of the phenomenal success these scientific disciplines had, more and more additional disciplines started using mathematical models throughout the twentieth century. This development did not stop short of the social sciences and humanities, although it was hindered there until the recent availability of immense amounts of data and with it the emergent "digital" social science and humanities. To date, the field beyond natural science in which mathematical modeling has seen the most success is economics.

The development of systems-oriented branches of science (such as ecology and environmental science) would not have been possible without models. More importantly, the models themselves would soon have been beyond reach of mathematical analysis if not for the enormous progress in information technology. The development of powerful computers now allows us to simulate models numerically which even in the 1990s were deemed to be unsolvable. On the other hand, some of the most influential ecological models, such as the famous predator-prey equations by Lotka and Volterra, were formulated more than 90 years ago, when computers did not yet exist.

To summarize: A model is a concept for the simplified description of a complex system. It serves to characterize the important features of a system and to leave aside the peripheral ones. If the model is a mathematical one, the interactions between the system variables (internal relations) and the ones between the system and its environment (external relations) are formulated mathematically. This way, the model can be analyzed by mathematical simulation.

(Adapted from [9])

Task 8. Read the text (Task 7) again and answer the questions.

1. What should we do if we want to analyze a natural system?
2. Which spheres are models used in?
3. What kind of models are described in the text?
4. Is it possible to say a priori which model is better?
5. Which models have a long tradition in science and engineering?
6. What roles do models play?
7. What does the development of powerful computers allow us to do?
8. What is a model?
9. What is the main idea of a model?
10. What is the purpose of mathematical models?

Task 9. Discuss with your partner what a model is.

Focus on Vocabulary

Task 10. Match the models with their characteristics.

Characteristics of Mathematical Models

A good model should be as simple as possible. A model helps one to go beyond the surface of a phenomenon to an understanding of the mechanisms and relationships.

The characteristics and requirements of mathematical models include the following.

1) realism of models	a) If a single model is applicable to many fields, then the model is very useful and this is known as the transferability of the model. For example, the Laplace equation model is used in many fields such as irrotational flows, electrostatic potential, gravitational potential, and so on
2) robustness of models	b) A successful model (a) gives good agreement between observations and predictions, and (b) has simplicity in the model equations
3) nonuniqueness of models	c) A mathematical model should represent the reality as closely as possible, but at the same time it should be mathematically tractable
4) hierarchy of models	d) A mathematical model is said to be robust if small changes in the parameters lead to small changes in the behavior of the model. Any dynamical behavior is considered to be robust when it is detected in a dense set formed by key parameters of model systems. The decision is made by using sensitivity analysis of the models
5) self-consistency of models	e) No model is complete in all respects. There is always a chance for improvement. However, there is an inherent cost involved for each improvement

6) estimation of parameters	f) A particular situation need not have only one mathematical model. We can search for better and different models
7) generality and applicability of models	g) A mathematical model that involves equations and inequations should be self-consistent
8) imperfections of models and the cost of modeling	h) Some models are used in a large number of situations and there are others which are applicable to some specific situations only. For example, logistic maps and the Laplace equation are used in a wide variety of situations
9) transferability of mathematical models	i) Every mathematical model contains some parameters which control the dynamics of the model system, and these need to be estimated. Optimal control theory is one of the methods for estimating these vital parameters. For example, it is desirable to estimate the proportion of a population of voters who will vote for a particular candidate. That proportion is the unobservable parameter; the estimate is based on a small random sample of voters
10) criteria for successful models	j) For every situation, we can obtain a hierarchy of models. Models obtained at each stage should be more realistic and better than the previous one

(Adapted from [15])

Task 11. Complete the text with the following words and phrases.

Appropriate model, provide, data, refine, underlying phenomenon, mathematical modeling, the problem, variables and predictors, reflected, real-world situations, testing, gain insight.

Introduction to Mathematical Modeling

Over the last several decades, **1** … has been playing a major role in understanding and solving many real-life problems, under certain conditions. Most mathematical models have been like individual works of art that **2** … the scientific views and personal characteristics of the modeler. However, many attempts are being made to unify the mathematical models in order to **3** … a standardized and reliable method of investigation accessible for every scientist. Modeling is a multistep process involving the following:

1. Identifying **4** … .
2. Constructing or selecting the **5** … .
3. Figuring out what **6** … need to be collected.
4. Deciding the number of **7** … to be chosen for greater accuracy.
5. Analytically or numerically computing the solution and **8** … the validity of models.
6. Implementing the models in **9** … .

Usually, modeling is an iterative process in which we start from a crude model and gradually refine it until it is suitable for solving the problem, and modeling enables us to **10 ...** into the original situation. The purpose of the model is to understand the **11** … and perhaps to make predictions about future behavior. If the predictions do not compare well with reality, we need to **12** … our model or formulate a new model and start the cycle again.

Task 12. Complete the text with the following words and phrases.

Guidelines, results, implementing, complex, mathematical solution, model.

Limitations Associated with Mathematical Modeling

Some of the limitations/problems associated with mathematical modeling include:

1. Sometimes, the model may not address the situation you want to describe. The model may be too simple to mirror adequately or too … to aid in the understanding of the situation.
2. A … may be very sensitive to the initial conditions or to the parameter values.
3. Successful … may not be available for choosing the number of parameters and for estimating the values of these parameters.
4. The model may create a mathematical problem that does not lend itself to a … .
5. The … may be too technical in nature or may not be in a form that can be implemented.
6. Funds may be inadequate for … a suggested solution.

Focus on Reading

Task 13. Read the text carefully. Say whether the statements below are true or false.

1. Mathematical modeling is a discipline that attempts to describe real-world phenomena in mathematical terms and then solves them.
2. The methodology consists of carefully formulating the definitions of the concepts to be discussed and explicitly stating the assumptions that shall be the basis for the reasoning employed.
3. Mathematical modeling is a process involving transformation of a physical situation into mathematical analogies with appropriate conditions and the solving and study of the problem in almost every aspect of its development.
4. A model is not supposed to be a prototype of the system under investigation.
5. New mathematical techniques are being proposed and are being successfully applied to explore an interesting topic.
6. The process of mathematical modeling can be divided into two major steps.
7. A mathematical model can be defined as a group of logical connections, formalized dependences, and formulas that makes possible the study of real-world problems without its experimental analysis.
8. Testing is preparing a mathematical model.
9. A mathematical model is an idealization and always gives a completely accurate representation of a physical situation.
10. The purpose of the model is to understand the phenomenon and perhaps make predictions about past behavior.

What is Mathematical Modeling?

Mathematical modeling is a discipline that attempts to describe real-world phenomena in mathematical terms and then solves them. Mathematical models were constructed and analyzed by different people for different reasons. The foremost reason is that direct experimental evidence cannot be obtained by simulating a real-life situation. For example, the spread of a communicable disease or the outcome of a space program (e.g., trajectory planning, flight simulation, and shuttle re-entry) cannot be decided based on experiments or field studies alone. There may be situations where certain conclusions have to be drawn before the problem itself can be completely formulated.

A real-world problem is modeled using mathematical equations to describe the process with the help of a suitable number of variables, parameters, and so on. The methodology consists of carefully formulating the definitions of the concepts to be discussed and explicitly stating the assumptions that shall be the basis for the reasoning employed. The actual problem is formulated by using these definitions and assumptions, whereas the conclusions are drawn by employing rigorous logic, based upon observations derived from the mathematical analysis. Thus, mathematical modeling is a process involving transformation of a physical situation into mathematical analogies with appropriate conditions and the solving and study of the problem in almost every aspect of its development. Modeling primarily deals with the study of the characteristics governing the observable and operating features. A model is supposed to be a prototype of the system under investigation. In mathematical modeling, we neither perform any practical activity nor interact with the actual situation directly. For example, we do not take any sample of blood from the body to know about the physiology. The rapid development of high-speed computers with the increasing desire to find some answers to everyday life problems has led to the enhanced demand for modeling in almost every area.

It is now a well-accepted fact that the flow of knowledge in science and technology depends, to a great extent, on the development of advanced mathematical tools. New mathematical techniques are being proposed and are being successfully applied to explore a variety of interesting topics in many application areas. A few of these topics and some application areas include: computer science (image processing and computer graphics), engineering (microchip analysis, power supply network optimization, planning of production units, stability of high-rise buildings, bridges and airplanes, and crash simulation), medicine (radiation therapy planning, blood circulation models, and computer-aided tomography), meteorology (weather prediction and climate prediction), biology (protein folding and human genome project), psychology (formalizing diaries of therapy sessions), chemistry (chemical reaction dynamics and molecular modeling), physics (laser dynamics and quantum field theory predictions), economics (data analysis), finance (risk analysis and value estimation of options), social sciences (election voting patterns), and so on.

Most real-world problems are highly nonlinear and a large number of them can be modeled in the form of a system of nonlinear ordinary or partial differential equations. Computer simulations of such mathematical models are being used extensively to solve such problems.

The process of mathematical modeling can be divided into three major steps:

1. Obtain a clear idea of the various types of laws governing the problem.
2. Idealize or simplify the problem by introducing certain assumptions and convert the problem into mathematical equations.
3. Solve the mathematical equations and interpret the results; this requires knowledge of analytical, numerical, and graphical tools.

A mathematical model can be defined as a group of logical connections, formalized dependences, and formulas that enables us to study real-world problems without its experimental analysis. As mentioned earlier, it is preparing a mathematical model and then testing it is an iterative process. We start with a simple model and then gradually refine it by looking back at the assumptions and simplifications so that the results match the real-world situation or experiment. Mathematical modeling is like diving into a mathematical ocean and emerging with a solution for the real life problem. If the solution is not acceptable, we make modifications to the model and may also make the solution procedure more rigorous. We repeat the procedure until a satisfactory solution is obtained. A mathematical model is an idealization and never gives a completely accurate representation of a physical situation. The purpose of the model is to understand the phenomenon and perhaps make predictions about future behavior. A good model simplifies reality so as to permit mathematical calculations but is accurate enough to provide valuable conclusions. It is important to realize the limitations of a model.

(Adapted from [12])

Task 14. Read the text (Task 13) again and answer the questions.

1. What is mathematical modeling?
2. What is the foremost reason?
3. How is a real-world problem modeled?
4. What does a mathematical modeling process involve?

5. What does modeling primarily deal with?
6. What is the aim of new mathematical techniques?
7. Which topics and application areas include mathematical modeling?
8. What steps can the process of mathematical modeling be divided into?
9. What is the purpose of the model?
10. What does a good model simplify?

Task 15. Discuss with your partner what mathematical modeling is.

Focus on Vocabulary

Task 16. Complete the text with the following words and phrases.

Traffic flow, video games, global warming, human system, social insects, fluid flow, planning, diseases, nature of the ground surface, endocrine system.

Examples of the interesting real-life problems for which mathematical models are available or are being constructed include:

1. Mathematical models to show how … (such as swine flu and anthrax) might spread in humans in the event of an epidemic/bioterrorism.
2. Mathematical modeling of … such as honeybees, termites, and so on to find out how they use local information to generate a complex and functional pattern of communication.
3. Mathematical modeling of urban city … .
4. Mathematical modeling of the … on highways or the stock market options.
5. Mathematical models to understand the working of heart, brain, lungs, kidneys, and the … .
6. Mathematical models to study the spread of forest/mine fire depending on the types of tree/coal, weather, and … .
7. Mathematical models to understand the … in drains, lakes, rivers, spillways, and so on.
8. Mathematical models for … .
9. Mathematical models to demonstrate the action of medicine in the … .
10. Mathematical models for developing … .

Focus on Reading

Task 17. Match the words with the definitions. Use a dictionary for help [17].

1) empirical	a) a line representing data, esp. statistical data, on a graph
2) obtain	b) having a probability distribution, usually with finite variance
3) procedure	c) a method for determining the best value of an unknown quantity relating one or more sets of observations or measurements, esp. to find a curve that best fits a set of data
4) approximation	d) to find out or establish precisely (have to determine the extent of the problem)
5) least-squares	e) a series of actions conducted in a certain order or manner
6) curve	f) to take for granted; accept without proof; suppose
7) inspire	g) to form an approximate idea of (distance, size, cost, etc.); calculate roughly; gauge
8) stochastic	h) to gain possession of; acquire; get
9) estimate	i) to stimulate or arouse (a person) to esp. creative activity
10) determine	j) separate or distinct in form or concept
11) assume	k) based on practical experience rather than scientific proof
12) discrete	l) the process or result of making a rough calculation, estimate, or guess

Task 18. Some of the key terms given above are used in the text (Task 20). Look through the the text and underline them.

Task 19. Read the text below (Task 20) and choose the best heading to each of its parts.

A. Deterministic Approach.
B. Discrete and Continuous Approaches.
C. Empirical Approach.
D. Simulation Approach.
E. Statistical Approach.

F. Stochastic or Probabilistic Approach.
G. Theoretical Approach.

Task 20. Read the text carefully. Say whether the statements below are true or false.

1. The advantage of this approach is that we cannot be confident that the fitted curve can be used outside the range of data considered.
2. We use the basic laws of nature to construct the mathematical models.
3. This approach should not be used when there is a high degree of variability in the problem.
4. This approach is broadly used and can produce accurate results providing valuable insights into the problem.
5. The statistical approach is not used in psychology, paleontology, and biological sciences.
6. The best models are usually those which are complex, yet they provide results which are useful.
7. In the discrete approach, the time variable is treated as a continuous variable rather than as a discrete variable.

Modeling Approaches

We present different approaches for modeling real-world situations, each approach providing an insight into a different aspect. A combination of seven approaches may provide the best understanding of the situation.

1. ...

Empirical models are based on an experimental hypothesis. When the problem-solving process is data driven, we call the approach an empirical approach. Empirical models lead to *laws of nature,* which represent the fundamental characteristics of nature. Many empirical models were formulated by Newton, Einstein, and others. When data are collected from an experiment or field, empirical relations between the data may be obtained through various procedures. One such method is the least-squares approximation. We fit a least-squares curve for the data and then use this curve to predict the outcomes where there are no data. However, the empirical approach is least useful. The disadvantage of this approach is that we cannot be confident that the fitted curve can be used outside the range of data considered. This approach is often used to create a continuous dataset to be used as the input for another model.

2. ...

Theoretical models are inspired by empirical models. We use the basic laws of nature to construct the mathematical models. The modeling process is based more on theory.

3. ...

Using the stochastic or probabilistic approach, we try to estimate the probability of a certain outcome based on the available data. This approach should ideally be used when there is a high degree of variability in the problem. Examples include: (1) modeling a small population when reproduction rates need to be predicted over a time interval; (2) modeling the economic fluctuations or economic growths; (3) modeling the insurance, telecommunications, and traffic theory problems; and (4) biological models.

4. ...

In the deterministic approach, the chance factors are not taken into account. We ignore the random variations and formulate the mathematical equations that describe the relationship between the variables of the problem. This approach is widely used and can produce accurate results providing valuable insights into the problem. An example is the modeling of (predicting) satellite orbits. In a population model, we aim to obtain an equation relating birth rates and death rates which themselves are related to the population size at any given time. The exponential and logistic models of population growth can be formulated in terms of differential equations as $dP/dt = (b - d)P$ and $dP/dt = rP(1 - P/P_{max})$, respectively.

5. ...

The statistical approach concerns testing of the hypothesis, that is, finding out from which category the data have been obtained. The datasets are assumed to have some particular type of distribution (with the associated means, variances, or standard deviations). This distribution can be used to predict the outcome of further trials. The statistical approach is widely used in psychology, paleontology, and biological sciences.

6. ...

The simulation approach is used when the problem under investigation cannot be easily modeled analytically or the relevant data required for modeling the system cannot be collected. In this approach, a computer program simulates (produces) a set of data that mimics a real outcome. It provides a useful means by which datasets can be generated. The computer program can be run many times and the necessary information gained in the process. The simulation approach provides realistic but not the best models. The best models are usually those which are simple, yet they provide results which are useful. For example, in designing an aircraft, the design engineer investigates the air flow around the aircraft. This can be done by using the theory of fluid mechanics and dynamical system theory. It is easier to simulate the study by building a scale model of the aircraft and by investigating the behavior of the model in a wind tunnel. Another example of simulation modeling is a hospital scenario, where the hospital administration would like to know the optimal number of doctors required to manage the patients in various shifts. A simulation of the model can be carried out by using suitable data on a computer.

7. ...

In the discrete approach, the time variable is treated as a discrete variable rather than as a continuous variable. This may mean, for example, that it is sufficient or meaningful to measure certain physical variables after finite intervals of time, say an hour, a week, a month, and so on rather than on a continuous basis. Examples of a discrete approach are the following: population of an insect species in a forest, radioactive decay, rainfall and temperature of a metropolitan city, and so forth. These systems are represented by difference equations/recursion relations/iterated maps.

In the continuous approach, time is always treated as a continuous (flow) variable and the models appear to be easier to handle than the discrete approach due to the development of calculus and differential equations. The continuous models are simpler only when analytical solutions are available, otherwise we have to approximate it so that we can handle it numerically. Some examples of the continuous approach are the Rössler model, Lorenz model, Helmholtz oscillator, Duffing oscillator, and others.

(Adapted from [12])

Task 21. Read the text (Task 20) again and answer the questions.

1. What are empirical models based on?
2. What is the modeling process based on?
3. What do we try to estimate using the stochastic or probabilistic approach?
4. What can the deterministic approach produce?
5. What does the statistical approach concern?
6. How can a simulation of the model be carried out?
7. When are the continuous models simpler?

Focus on Vocabulary

Task 22. Complete the text with the following words and phrases.

Equations, refine, attempt, complex, predictions.

Modeling/Cyclic Processes

A mathematical model is a representation of a **1** … real-world problem. Some mathematical **2** … describe the processes involved in the problem. A model is an **3** … at mimicking the real-world situation and cannot describe it completely. The purpose of the model is to understand the phenomenon and maybe to make **4** … about future behavior. If the predictions do not compare well with reality, we need to **5** … our model or formulate a new model and start the cycle again.

Focus on Listening

Task 23. Give your association with this formula:

solution = problem / variables.

Task 24. Discuss with your partner what mathematical modeling is and why we use it.

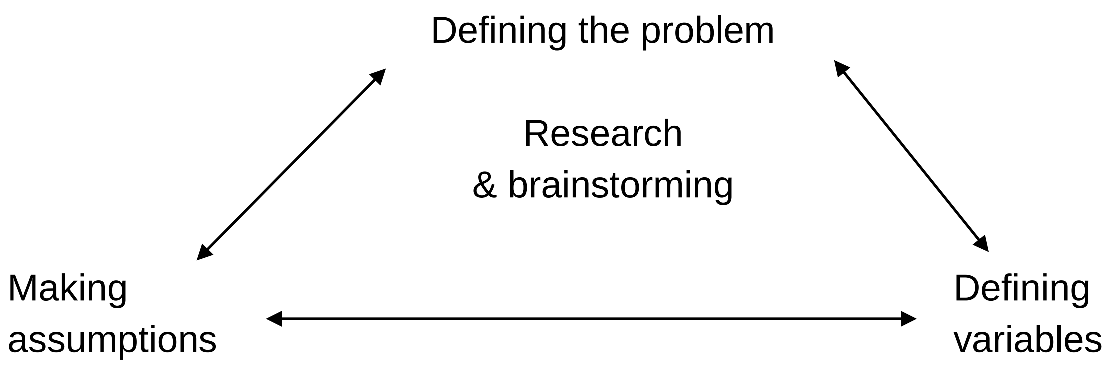
Task 25. Watch Video 2 "Math Modeling Video Series Part 1. What is Mathematical Modeling" and compare your answers. Do they have the same ideas? [https://www.youtube.com/watch?v=xHtsuOB-TPw]

Task 26. Complete the sentences then watch Video 2 (Task 25) again and check them.

1. These are real world scenarios for which math modeling can provide … .
2. Modeling is a process that uses math to …, … or otherwise … .
3. In my opinion, anything in our life …, so we can always find a pattern in our life.
4. To simplify the scope of the problem you'll need … .
5. If you are trying to make a mathematical model, you can … .
6. You will analyze your model to make sure it works, ask yourself "…?", "Does it answer the original question?", "…?"
7. … is your results. A model is more than just math.
8. It's …, how we came up with those assumptions of the justification is extremely important.
9. … can help us answer big messy questions.

Task 27. Give the main idea of the text (Task 23).

Task 28. Describe the model below.



Focus on Speaking

Task 29. Work in pairs and complete each sentence.

1. The number of system variables is called … .
2. A model is always a simplified image of … .
3. A model is the lens through which we look at … .
4. Good models allow us to arrive at a readily comprehensible representation of the real world that … .
5. If a model is formulated with mathematical equations, it becomes … .
6. A model is a concept for … .

7. A model serves to characterize … .
8. The purpose of the model is to understand … .
9. Mathematical modeling is a discipline that … .
10. A model is supposed to be a prototype of … .
11. The process of mathematical modeling can be divided into three major steps, such as: … .
12. We present different approaches to modeling real-world situations, each approach providing … .

Task 30. Describe the mathematical model below (Fig. 2.3).

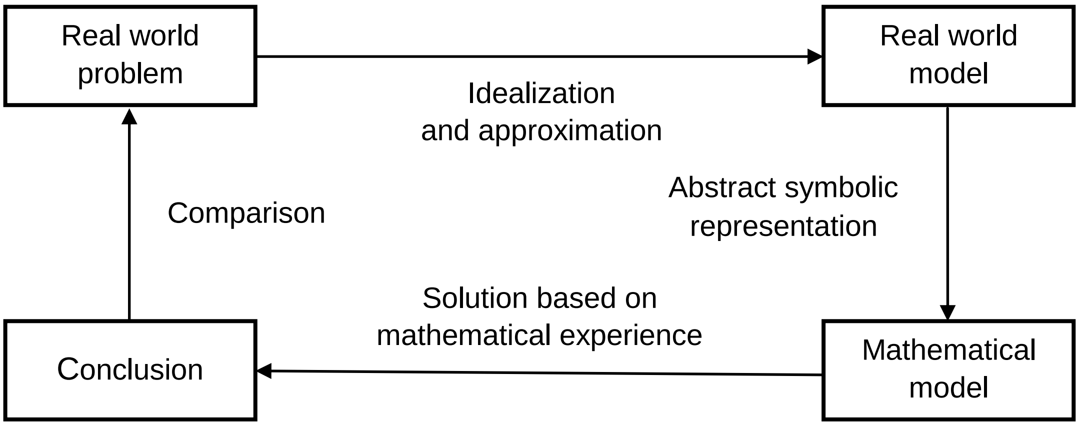


Fig. 2.3. **A symbolic representation of a mathematical model**

Task 31. Describe the stages of a mathematical model.

The important stages of construction of a mathematical model as given by Barnes and Fulford are presented in Fig. 2.4. If the model does not produce results consistent with observations, then we return to step (2) (assumptions) and modify the assumptions. Berry and Houston have also given a schematic diagram of a modeling cycle.

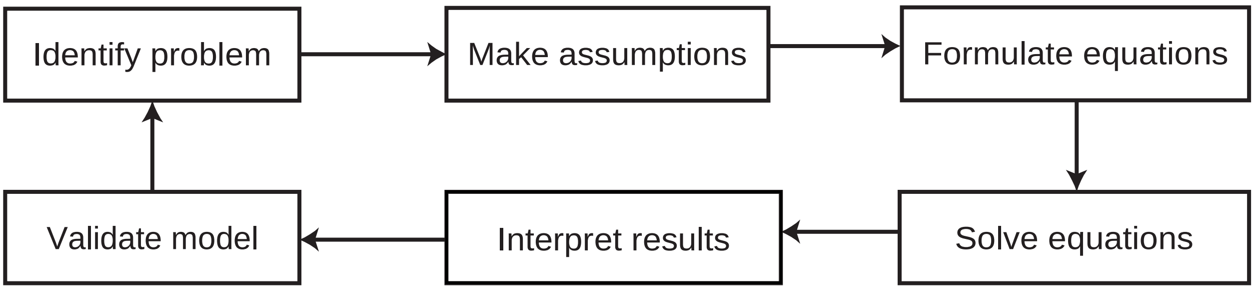


Fig. 2.4. **A schematic diagram of a modeling cycle**

Task 32. Describe the modeling diagram.

A Modeling Diagram

Here, we present the modeling diagram as suggested by Arnold Neumaier (Fig. 2.5). The nodes of the diagram represent information to be collected, sorted, evaluated, and organized. The edges of the diagram represent activities of two-way communication between the nodes and the corresponding source of information.

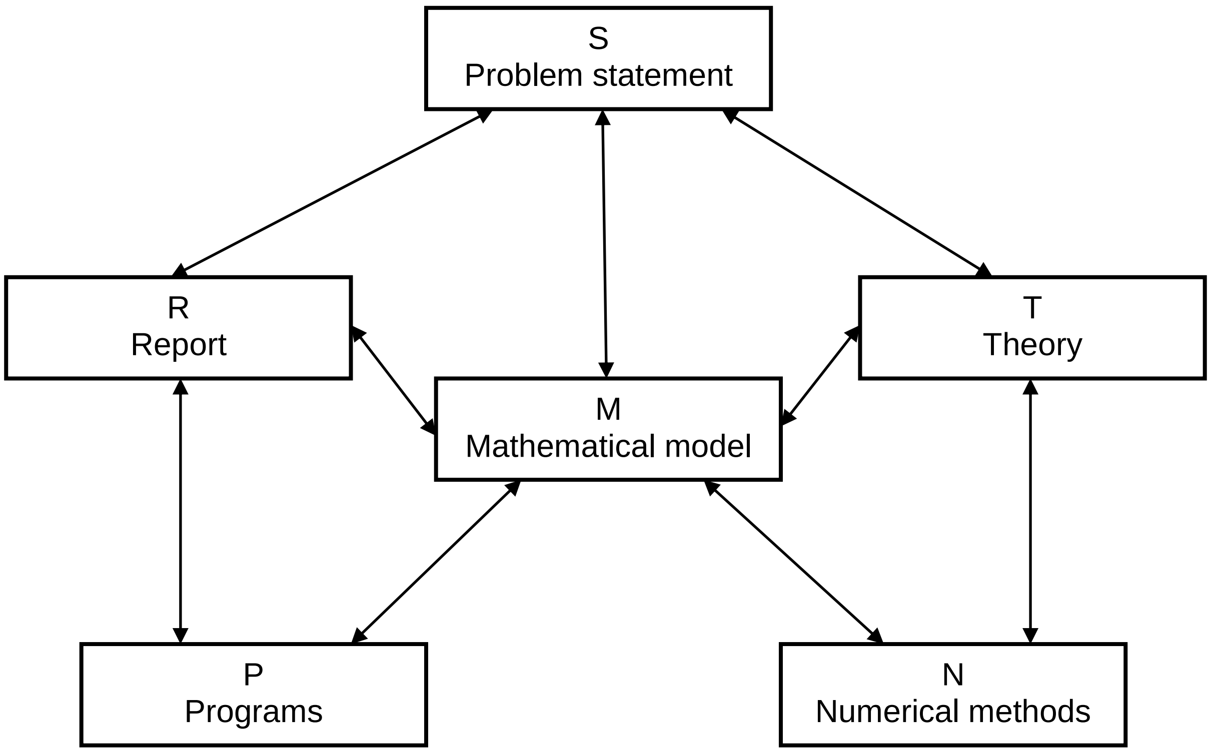


Fig. 2.5. **A modeling diagram**

S: Problem statement (arising out of real-world situations).

M: Mathematical model (uses concepts/variables, relations, restrictions, defines a goal and decides priorities/quality assignments).

T: Theory (of application, of mathematics, literature search).

N: Numerical methods (software).

P: Programs (flow diagrams, implementation, user interface, and documentation).

R: Report (analysis of results, validation, visualization, limitations, and recommendations).

Focus on Questions and Problems

Task 33. Answer the questions.

1. Why is there no simple and unambiguous definition to differentiate between a reductionistic and a holistic description of a system?

2. What is implied with the statement "The relation between a system and its environment is asymmetrical"?

3. Give a short definition for each of the following terms: *system*, *model*, *mathematical model*.

4. What distinguishes a model from reality?

5. Give some of the most important decisions that have to be made when constructing a model.

6. Which functions do models have in science?

7. What does model validation mean?

Task 34. Dilemma. Study the problems then answer the questions and fulfil the tasks.

Problem 1. Model formation.

Look at the following three systems and try to formulate a model. Consider what system variables and external relations are important for the models. What can be neglected? Where is the system boundary?

1. Population growth (nationally, i.e. in a specific country).
2. Population growth (globally, i.e. for the entire planet).
3. Lead (a heavy metal) in a lake's sediment.

Problem 2. The solar system.

For a simplified description of the solar system, we choose the following variables: the location and speed of the sun and the eight planets.

4. What are the internal relations?
5. What external relations does the system have?
6. How does our system deviate from the real solar system as part of the cosmos? Do our simplifications relate to the internal relations, the external relations, or both of them?

Problem 3. A mathematical model of happiness. [http://feelhappiness.com/mathematical-model-of-happiness/]

How can you maximize the amount of happiness you experience over a life time? There is no single, correct answer to this question that would take into account all the variables that go into happiness, including aspects that are unique to you. But I am a math nerd. And as a math nerd, I feel obliged to create a model for any thing that I see.

By definition, models are imperfect. They are not reality. They are just approximations of reality. Models are useful because they take something that is incredibly complex and then make it simple and understandable. Then you can manipulate the variables in your model to achieve some desired effect.

This model may seem a bit technical, but bear with me.

The Model is following:

Total Happiness = T × [G × (PEF × PEI + SPF × SPI) – NEF × NEI].

In this model, T = time alive, G = gratitude factor, PEF = peak experience frequency, PEI = peak experience intensity, SPF = simple pleasure frequency, SPI = simple pleasure intensity, NEF = negative experience frequency, and NEI = negative experience intensity.

For our purposes here, a peak experience is any experience that was particularly awesome. No need to get too scientific.

Before going over the positive aspects of the model, it's important to explain its limitations.

To reiterate what I said in the introduction: models are imperfect. This model by no means captures every thing that goes into making you a happier person (although it does capture a lot).

So, what are the problems?

First of all, this model measures total lifetime happiness, which might not ultimately be what you care about. You might prefer having a greater concentration of happiness over a shorter period of time, for example.

Secondly, the model is linear. Another unit of peak experience will increase happiness by the same amount. In reality, there are diminishing returns here. In other words, as you have more and more peak experiences, the happiness you gain from them will decrease.

This can be mentally accounted for by saying that the PEI value goes down as PEF goes up, but a more complex model is needed to really deal with this problem.

The model also assumes that all the variables are stable overtime, which is of course not true.

You can feel more gratitude for some experiences than others. Think of the numbers here as averages for now, and may be one day I will come up with a dynamic model that takes these changes into account.

Finally, the variables are very broad and not well defined. This makes it almost impossible to use a model like this for actual measurements. That being said, the model is still useful.

1. What does the model do right?
2. What can you learn from the model?
3. What are the weights of the happiness components (PE, SP, NE)?
4. How does diminishing marginal returns work?
5. Is the gratitude quotient different for SP and PE?

Unit 3. Econometrics

Task 1. Answer the questions.

1. What is econometrics? Give your examples.
2. What is econometrics based upon?
3. Has econometrics evolved as a separate discipline?

Task 2. Match the words with the definitions and then find and underline them in the text (Task 3).

1) enrollment	a) contradictory; inconsistent or incompatible
2) subsequent	b) causing fear or discouragement; intimidating
3) treasury bill	c) to work out, contrive, or plan (something) in one's mind
4) comply	d) not clearly perceptible or discernible; indistinct
5) daunting	e) following a specified event, etc. in time, esp. as a consequence
6) vague	f) to develop or cause to develop gradually
7) evolve	g) to act in accordance with rules, wishes, etc.; be obedient (to)
8) repugnant	h) the number of persons enrolled, esp. at a school or college
9) devise	i) a short-term noninterest-bearing obligation issued by the Treasury, payable to bearer and maturing usually in three months, within which it is tradable on a discount basis on the open market

Task 3. Read the text and answer the questions.

1. What does the program teach us?
2. What is econometrics based upon?
3. What is the most common application of econometrics?
4. Why has econometrics evolved as a separate discipline from mathematical statistics?
5. What have econometricians borrowed from mathematical statisticians?

Imagine that you are hired by your state government to evaluate the effectiveness of a publicly funded job training program. Suppose this program teaches workers various ways to use computers in the manufacturing process. The twenty-week program offers courses during nonworking hours. Any hourly manufacturing worker may participate, and enrollment in all or part of the program is voluntary. You are to determine what, if any, effect the training program has on each worker's subsequent hourly wage.

Now suppose you work for an investment bank. You are to study the returns on different investment strategies involving short-term U.S. treasury bills to decide whether they comply with implied economic theories.

The task of answering such questions may seem daunting at first. At this point, you may only have a vague idea of the kind of data you would need to collect. By the end of this introductory econometrics course, you should know how to use econometric methods to formally evaluate a job training program or to test a simple economic theory.

Econometrics is based upon the development of statistical methods for estimating economic relationships, testing economic theories, and evaluating and implementing government and business policy. The most common application of econometrics is the forecasting of such important macroeconomic variables as interest rates, inflation rates, and gross domestic product. While forecasts of economic indicators are highly visible and are often widely published, econometric methods can be used in economic areas that have nothing to do with macroeconomic forecasting. For example, we will study the effects of political campaign expenditures on voting outcomes. We will consider the effect of school spending on student performance in the field of education. In addition, we will learn how to use econometric methods for forecasting economic time series.

Econometrics has evolved as a separate discipline from mathematical statistics because the former focuses on the problems inherent in collecting and analyzing nonexperimental economic data. Nonexperimental data are not accumulated through controlled experiments on individuals, firms, or segments of the economy. (Nonexperimental data are sometimes called observational data to emphasize the fact that the researcher is a passive collector of the data.) Experimental data are often collected in laboratory environments in the natural sciences, but they are much more difficult to obtain in the social sciences. While some social experiments can be devised, it is often impossible, prohibitively expensive, or morally repugnant to conduct the kinds of controlled experiments that would be needed to address economic issues.

Naturally, econometricians have borrowed from mathematical statisticians whenever possible. The method of multiple regression analysis is the mainstay in both fields, but its focus and interpretation can differ markedly. In addition, economists have devised new techniques to deal with the complexities of economic data and to test the predictions of economic theories.

(Adapted from [18])

Task 4. Describe the main idea of the text (Task 3).

Focus on Reading

Task 5. Match the words with the definitions. Use a dictionary for help [17].

1) erratic	a) a (esp. measurable or quantifiable) characteristic or feature
2) estimation	b) to make by fitting parts together; build, form (something physical or abstract)
3) precisely	c) irregular in performance, behaviour, or attitude; inconsistent and unpredictable
4) parameter	d) exactly
5) construct	e) a considered opinion; judgment

Task 6. Some of the key terms given above are used in the text (Task 7). Look through the text and underline them.

Task 7. Read the text carefully. Say whether the statements below are true or false.

1. The economic issues can concern macroeconomics, international economics, and microeconomics, but also finance, marketing, and accounting.
2. Anyone who either invents new econometric techniques, or applies old or new techniques, is called an "econometrician".
3. An econometrician is a statistician who investigates the properties particular to economic data.
4. Econometric theory sometimes involves the development of new methods and the study of their properties.
5. Data on individual behavior are easy and usually are cheap to obtain, and often one has to survey individuals oneself.

6. An econometric model usually amounts to one or more equations.

7. An econometrician needs to translate a practical question like, for example, "what can explain today's stock market returns in Amsterdam?" into a model.

8. The second key activity of an econometrician concerns the match of the model with the data.

9. A third key activity concerns the application of the model outcomes.

What is Econometrics?

Econometric techniques are usually developed and employed for answering practical questions. As the first five letters of the word "econometrics" indicate, these questions tend to deal with economic issues, although applications to other disciplines are widespread. The economic issues can concern macroeconomics, international economics, and microeconomics, but also finance, marketing, and accounting. The questions usually aim at a better understanding of an actually observed phenomenon and sometimes also at providing forecasts for future situations. Often it is hoped that these insights can be used to modify current policies or to put forward new strategies.

The whole range of econometric methods is usually simply called "econometrics". And anyone who either invents new econometric techniques, or applies old or new techniques, is called an "econometrician". One might also think of an econometrician as being a statistician who investigates the properties particular to economic data. Econometrics can be divided into *econometric theory* and *applied econometrics*. Econometric theory usually involves the development of new methods and the study of their properties. Applied econometrics concerns the development and application of tools to solve relevant practical questions.

In order to answer practical questions, econometric techniques are applied to actually observed data. These data can concern: (1) observations over time, like a country's GDP when measured annually, (2) observations across individuals, like donations to charity, or (3) observations over time and over individuals. Perhaps "individuals" would be better phrased as "individual cases", to indicate that these observations can also concern countries, firms, or households, to mention just a few. Additionally, when one thinks about observations over time, these can concern seconds, days, or years.

Sometimes the relevant data are easy to access. Financial data concerning, for example, stock markets, can be found in daily newspapers or on the internet. Macroeconomic data on imports, exports, consumption, and income are often available on a monthly basis. In both cases one may need to pay a statistical agency in order to be able to download macroeconomic and financial indicators. Data in marketing are less easy to obtain, and this can be owing to issues of confidentiality. In general, data on individual behavior are not easy and usually are costly to obtain, and often one has to survey individuals oneself.

The econometrician uses an *econometric model*. This model usually amounts to one or more equations. In words, these equations can be like "the probability that an individual donates to charity is 0.6 when the same individual donated last time and 0.2 when s/he did not", or "on average, today's stock market return on the Amsterdam Exchange is equal to yesterday's return on the New York Stock Exchange", or "the upward trend in Nigeria's *per capita* GDP is half the size of that of Kenya". Even though these three examples are hypothetical, the verbal expressions come close to the outcomes of actual econometric models.

The key activities of econometricians can now be illustrated. First, an econometrician needs to *translate a practical question* like, for example, "what can explain today's stock market returns in Amsterdam?" *into a model*. This usually amounts to thinking about the economic issue at stake, and also about the availability and quality of the data. Fluctuations in the Dow Jones may lead to similar fluctuations in Amsterdam, and this is perhaps not much of a surprise. However, it is by no means certain that this is best observed for daily data. Indeed, perhaps one should focus only on the first few minutes of a trading day, or perhaps even look at monthly data to get rid of erratic and irrelevant fluctuations, thereby obtaining a better overall picture. In sum, a key activity is to translate a practical question into an econometric model, where this model also somehow matches with the available data. For this translation, econometricians tend to rely on mathematics, as a sort of language. Econometricians are by no means mathematicians, but mathematical tools usually serve to condense notation and simplify certain technical matters. First, it comes in handy to know a little bit about matrix algebra before taking econometrics courses. Second, it is relevant to know some of the basics of calculus, in particular, differential and integral calculus. To become an econometrician, one needs to have some knowledge of these tools.

The second key activity of an econometrician concerns the *match of the model with the data*. In the examples above, one could note numerical statements such as "equal" or "half the size". How does one get these numbers?

There are various methods to get them, and these are collected under the header "estimation" More precisely, these numbers are often associated with unknown parameters. The notion "parameter estimation" already indicates that econometricians are never certain about these numbers. However, what econometricians can do is to provide a certain degree of confidence around these numbers. For example, one could say that "it is very likely that growth in *per capita* GDP in Nigeria is smaller than that of Kenya" or that "it is unlikely that an individual donates to charity again if s/he did last time". To make such statements, econometricians use statistical techniques.

Finally, a third key activity concerns the *implementation of the model outcomes*. This may mean the construction of *forecasts*. It can also be possible to simulate the properties of the model and thereby examine the effects of various policy rules.

To summarize, econometricians use economic insights and mathematical language to construct their econometric model, and they use statistical techniques to analyze its properties. This combination of three input disciplines ensures that courses in econometrics are not the easiest ones to study.

(Adapted from [7])

Task 8. Read the text (Task 7) again and answer the questions.

1. What are the components of econometrics?
2. What is the purpose of applied econometrics?
3. What can observed data include?
4. Does the term "econometricians" mean the same as "mathematicians"?
5. What is the difference between the econometric and mathematical language?

Task 9. Discuss with your partner what econometrics is.

Focus on Vocabulary

Task 10. Match the words with similar meaning.

1) concern	a) implement
2) modify	b) engage
3) apply	c) explore
4) investigate	d) be relevant

5) involve	e) make easier
6) simplify	f) give
7) provide	g) gain
8) obtain	h) change

Task 11. Complete the text with the following words and phrases.

Testing, applied, depends, model, tools, empirical, formulation, equations, predictions, assumption.

Steps in Empirical Economic Analysis

Econometric methods are relevant in virtually every branch of **1** … economics. They come into play either when we have an economic theory to test or when we have a relationship in mind that has some importance for business decisions or policy analysis. An **2** … analysis uses data to test a theory or to estimate a relationship.

How does one go about structuring an empirical economic analysis? It may seem obvious, but it is worth emphasizing that the first step in any empirical analysis is the careful **3** … of the question of interest. The question might deal with **4** … a certain aspect of an economic theory, or it might pertain to testing the effects of a government policy. In principle, econometric methods can be used to answer a wide range of questions.

In some cases, especially those that involve the testing of economic theories, a formal economic **5** … is constructed. An economic model consists of mathematical **6** … that describe various relationships. Economists are well-known for their building of models to describe a vast array of behaviors. For example, in intermediate microeconomics, individual consumption decisions, subject to a budget constraint, are described by mathematical models. The basic premise underlying these models is utility maximization. The **7** … that individuals make choices to maximize their well-being, subject to resource constraints, gives us a very powerful framework for creating tractable economic models and making clear **8** … . In the context of consumption decisions, utility maximization leads to a set of demand equations. In a demand equation, the quantity demanded of each commodity **9** … on the price of the goods, the price of substitute and complementary goods, the consumer's income, and the individual's characteristics that affect taste. These equations can form the basis of an econometric analysis of consumer demand.

Economists have used basic economic **10** ..., such as the utility maximization framework, to explain behaviors that at first glance may appear to be noneconomic in nature. A classic example is Becker's (1968) economic model of criminal behavior.

Focus on Reading

Task 12. Read the text carefully. Say whether the statements below are true or false.

1. The two variables may be independent (unrelated). For instance, one might result from laboratory data taken last week, the other might come from old trade statistics.
2. At the other extreme, the two variables may be different, in that each is completely informative about the other.
3. We are left with the typical and important case: two-dimensional data, (x_1, y_1), ..., (x_n, y_n) say, where each of the x and y variables is completely informative about the other.
4. The prediction will be an uncertain one, to be sure, but better than nothing: there is information content in x about y, and we want to use this information.
5. The only name for x is the regressor, or regressor variable.
6. Our job is to fit a line through the data – that is, to estimate the systematic linear component.
7. When electric current is passed through a conducting wire, the current (in amps) is not proportional to the applied potential difference or voltage (in volts), the constant of proportionality being the inverse of the resistance of the wire (in ohms).
8. We note in passing that, as no current flows when no voltage is applied, one may restrict to lines through the origin (that is, lines with zero intercept) – by no means the typical case.

Linear Regression

When we first meet Statistics, we encounter random quantities (random variables, in probability language, or variates, in statistical language) one at a time. This suffices for a first course. Soon however we need to handle more than one random quantity at a time. Already we have to think about how they are related to each other.

Let us take the simplest case first, of two variables. Consider first the two extreme cases.

At one extreme, the two variables may be independent (unrelated). For instance, one might result from laboratory data taken last week, the other might come from old trade statistics. The two are unrelated. Each is uninformative about the other. They are best looked at separately. What we have here are really two one-dimensional problems, rather than one two-dimensional problem, and it is best to consider matters in these terms.

At the other extreme, the two variables may be essentially the same, in that each is completely informative about the other. For example, on the Centigrade (Celsius) temperature scale, the freezing point of water is 0^{o} and the boiling point is 100^{o}, while on the Fahrenheit scale, the freezing point is 32^{o} and the boiling point is 212^{o} (these bizarre choices are a result of Fahrenheit choosing as his origin of temperature the lowest temperature he could achieve in the laboratory, and recognising that the body is so sensitive to temperature that a hundredth of the freezing-boiling range as a unit is inconveniently large for everyday, non-scientific use, unless one resorts to decimals). The transformation formulae are accordingly $C = (F - 32) \times 5/9$, $F = C \times 9/5 + 32$.

While both scales remain in use, this is purely for convenience. To look at temperature in both Centigrade and Fahrenheit together for scientific purposes would be silly. Each is completely informative about the other. A plot of one against the other would lie exactly on a straight line. While apparently a two-dimensional problem, this would really be only one one-dimensional problem, and so best considered as such.

We are left with the typical and important case: two-dimensional data, (x_1, y_1), ..., (x_n, y_n) say, where each of the x and y variables is partially but not completely informative about the other.

Usually, our interest is on one variable, y say, and we are interested in what knowledge of the other – x – tells us about y. We then call y the response variable, and x the explanatory variable. We know more about y knowing x than not knowing x; thus knowledge of x explains, or accounts for, part but not all of the variability we see in y. Another name for x is the predictor variable: we may wish to use x to predict y (the prediction will be an uncertain one, to be sure, but better than nothing: there is information content in x about y, and we want to use this information). A third name for x is the *regressor*, or *regressor variable*; we will turn to the reason for this name below. It accounts for why the whole subject is called *regression*.

The first thing to do with any data set is to look at it. We subject it to exploratory data analysis (EDA); in particular, we plot the graph of the *n* data points (x_i, y_i).

Suppose that what we observe is a scatter plot that seems roughly linear. That is, there seems to be a systematic component, which is linear (or roughly so – linear to a first approximation, say) and an error component, which we think of as perturbing this in a random or unpredictable way. Our job is to fit a line through the data – that is, to estimate the systematic linear component.

For illustration, we recall the first case in which most of us meet such a task – experimental verification of Ohm's Law (G. S. Ohm (1787 – 1854), in 1826). When electric current is passed through a conducting wire, the current (in amps) is proportional to the applied potential difference or voltage (in volts), the constant of proportionality being the inverse of the resistance of the wire (in ohms). One measures the current observed for a variety of voltages (the more the better).

One then attempts to fit a line through the data, observing with dismay that, because of experimental error, no three of the data points are exactly collinear. A typical schoolboy solution is to use a perspex ruler and fit by eye. Clearly a more systematic procedure is needed. We note in passing that, as no current flows when no voltage is applied, one may restrict to lines through the origin (that is, lines with zero intercept) – by no means the typical case.

(Adapted from [1])

Task 13. Read the text (Task 12) again and answer the questions.

1. What kind of variables can there be at one extreme?
2. What is the difference between the one-dimensional problem and the two-dimensional problem?
3. What happens when two variables may be essentially the same?
4. What is the typical and important case?
5. What is another name for *x*?
6. What is a third name for *x?*
7. What is the first thing to do with any data set?

Task 14. Discuss with your partner what linear regression is.

Focus on Vocabulary

Task 15. Complete the text with the following words and phrases.

Regressor, two-variable, linear, confront, limitations, empirical, variables, functional, equation, regress and multiple.

The Simple Regression Model

The simple regression model can be used to study the relationship between two variables. For reasons we will see, the simple regression model has **1** … as a general tool for empirical analysis. Nevertheless, it is sometimes appropriate as an **2** … tool. Learning how to interpret the simple regression model is good practice for studying **3** … regression.

Much of applied econometric analysis begins with the following premise: *y* and *x* are two **4** …, representing some population, and we are interested in "explaining *y* in terms of *x*", or in "studying how *y* varies with changes in *x*".

We discussed some examples including: *y* is soybean crop yield and *x* is the amount of fertilizer; *y* is hourly wage and *x* is years of education; *y* is a community crime rate and *x* is the number of police officers.

In writing down a model that will "explain *y* in terms of *x*", we must **5** … three issues. First, since there is never an exact relationship between two variables, how do we allow for other factors to affect *y*? Second, what is the **6** … relationship between *y* and *x*? And third, how can we be sure we are capturing a ceteris paribus relationship between *y* and *x* (if that is a desired goal)?

We can resolve these ambiguities by writing down an **7** … relating *y* to *x*. A simple equation is

$$y = \beta_0 + \beta_1 x + u \qquad (3.1)$$

Equation (3.1), which is assumed to hold in the population of interest, defines the simple linear regression model. It is also called the **8** … regression model or bivariate linear regression model because it relates the two variables *x* and *y*. We now discuss the meaning of each of the quantities in (3.1).

When related by (3.1), the variables *y* and *x* have several different names used interchangeably, as follows. *y* is called the dependent variable, the explained variable, the response variable, the predicted variable, or the

9 … . *x* is called the independent variable, the explanatory variable, the control variable, the predictor variable, or the **10** … . (The term "covariate" is also used for *x*.) The terms "dependent variable" and "independent variable" are frequently used in econometrics.

Task 16. Match the terms for simple regression.

The terminology for simple regression

Y	X
Dependent variable	Control variable
Explained variable	Predictor variable
Response variable	Independent
Predicted variable	Regressor
Regressand	Explanatory variable

Focus on Reading

Task 17. Match the words with the definitions. Use a dictionary for help [17].

1) plot	a) absurd or ridiculous; laughable
2) scattered	b) one of two or three reference lines used in coordinate geometry to locate a point in a plane or in space
3) gradient	c) the state or quality of being mediocre (average or ordinary in quality)
4) wary	d) not clustered together; wide apart; sporadic
5) ludicrous	e) to locate and mark (one or more points) on a graph by means of coordinates
6) diminish	f) the rate at which this increases with distance, etc.
7) mediocrity	g) the rate of rise or fall of temperature, pressure, etc., in passing from one region to another
8) slope	h) to make or become smaller, fewer, or less
9) axis	i) on one's guard; given to caution; circumspect

Task 18. Some of the key terms given above are used in the text (Task 20). Look through the text and underline them.

Task 19. Read the text below (Task 20) and choose the best heading to each of its part.

Cause and Correlation.

Pearson's Correlation.

Regression Lines.

Spearman's Correlation.

Task 20. Read the text carefully. Say whether the statements below are true or false.

1. Correlation and regression go together like a horse and carriage and they are similar and have their own jobs to do.
2. Regression can be used to predict the values of one property (say weight) from the other (in this case, height).
3. The term "correlation" was introduced by Francis Galton in the 1890s.
4. The Pearson correlation coefficient, named after Galton's biographer and protégé Karl Pearson, is measured on a scale between minus one and plus one.
5. The correlation coefficient measures the tendency for data to lie along a straight line.
6. The value of the Pearson correlation coefficient would be around +0.9 indicating a small correlation.
7. Finding a strong correlation between two variables is sufficient to claim that one causes the other.
8. With correlation there may be a hidden intermediary variable at work.
9. There is no danger in using correlation.
10. The correlation coefficient can be adopted to treat ordered data – data where we want to know first, second, third, and so on, but not necessarily other numerical values.
11. The formula for this correlation coefficient was developed in 1908 by the psychologist Charles Spearman who, like Pearson, was influenced by Francis Galton.
12. Francis Galton conducted experiments in the 1890s in which he compared the heights of mature young adults with the heights of their parents.
13. Regression is not a powerful technique and is rarely applicable.
14. It is the number of customers that explains the number of staff needed and not the other way around.

Connecting Data

How are two sets of data connected? Statisticians of a hundred years ago thought they had the answer. Correlation and regression go together like a horse and carriage, but like this pairing, they are different and have their own jobs to do. Correlation measures how well two quantities such as weight and height are related to each other. Regression can be used to predict the values of one property (say weight) from the other (in this case, height).

1. ...

The term correlation was introduced by Francis Galton in the 1880s. He originally termed it "co-relation", a better word for explaining its meaning. Galton, a Victorian gentleman of science, had a desire to measure everything and applied correlation to his investigations into pairs of variables: the wing length and tail length of birds, for instance. The Pearson correlation coefficient, named after Galton's biographer and protégé Karl Pearson, is measured on a scale between minus one and plus one. If its numerical value is high, say +0.9, there is said to be a strong correlation between the variables. The correlation coefficient measures the tendency for data to lie along a straight line. If it is near to zero, the correlation is practically non-existent.

We frequently wish to work out the correlation between two variables to see how strongly they are connected. Let's take the example of the sales of sunglasses and see how this relates to the sales of ice creams (Fig. 3.1). San Francisco would be a good place in which to conduct our study and we shall gather data each month in that city. If we plot points on a graph where the x (horizontal) coordinate represents sales of sunglasses and the y (vertical) coordinate gives the sales of ice creams, each month we will have a data point (x, y) representing both pieces of data. For example, the point (3, 4) could mean the May sales of sunglasses were \$30,000 while sales of ice creams in the city were \$40,000 in that same month. We can plot the monthly data points (x, y) for a whole year on a scatter diagram. For this example, the value of the Pearson correlation coefficient would be around +0.9 indicating a strong correlation. The data has a tendency to follow a straight line. It is positive because the straight line has a positive gradient – it is pointing in a northeasterly direction.

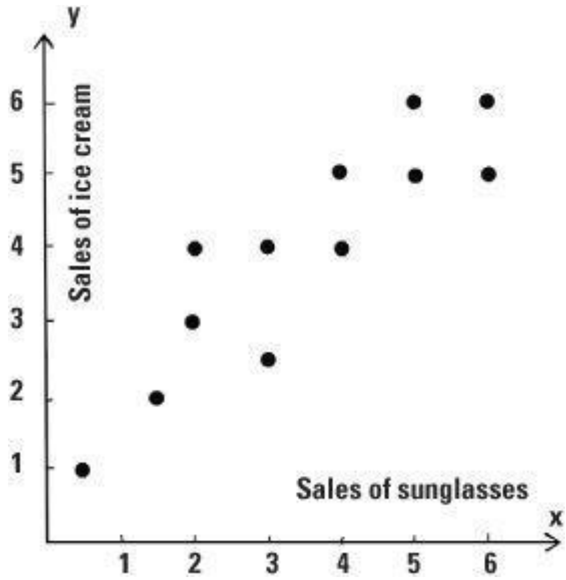


Fig. 3.1. **The scatter diagram**

2. ...

Finding a strong correlation between two variables is not sufficient to claim that one causes the other. There may be a cause and effect relation between the two variables but this cannot be claimed on the basis of numerical evidence alone. On the cause/correlation issue it is customary to use the word "association" and wise to be wary of claiming more than this.

In the sunglasses and ice cream example, there is a strong correlation between the sales of sunglasses and that of ice cream. As the sales of sunglasses increase, the number of ice creams sold tends to increase. It would be ludicrous to claim that the expenditure on sunglasses *caused* more ice creams to be sold. With correlation there may be a hidden intermediary variable at work. For example, the expenditure on sunglasses and on ice creams is linked together as a result of seasonal effects (hot weather in the summer months, cool weather in the winter). There is another danger in using correlation. There may be a high correlation between variables but no logical or scientific connection at all. There could be a high correlation between house numbers and the combined ages of the house's occupants but reading any significance into this would be unfortunate.

3. ...

Correlation can be put to other uses. The correlation coefficient can be adopted to treat ordered data – data where we want to know first, second, third, and so on, but not necessarily other numerical values.

Occasionally we have only the ranks as data. Let's look at Albert and Zac, two strong-minded ice skating judges at a competition who have to evaluate skaters on artistic merit. It will be a subjective evaluation. Albert and Zac have both won Olympic medals and are called on to judge the final group which has been narrowed down to five competitors: Ann, Beth, Charlotte, Dorothy and Ellie. If Albert and Zac ranked them in exactly the same way, that would be fine but life is not like that. On the other hand we would not expect Albert to rank them in one way and Zac to rank them in the very reverse order. The reality is that the rankings would be in between these two extremes. Albert ranked them 1 to 5 with Ann (the best) followed by Ellie, Beth, Charlotte and finally Dorothy in 5th position. Zac rated Ellie the best, followed by Beth, Ann, Dorothy and Charlotte. These rankings can be summarized in a table.

Skater	Albert's rankings	Zac's ranking	Differewnce in rank, *d*	d^2
Ann	1	3	-2	4
Ellie	2	1	1	1
Beth	3	2	1	1
Charlotte	4	5	-1	1
Dorothy	5	4	1	1
$n = 5$			Sum	8

Spearman's formula

$$p = 1\frac{6 \times \text{Sum}}{n \times (n^2 - 1)} \tag{3.2}$$

How can we measure the level of agreement between the judges? Spearman's correlation coefficient is the instrument mathematicians use to do this for ordered data. Its value here is +0.6 which indicates a limited measure of agreement between Albert and Zac. If we treat the pairs of ranks as points, we can plot them on a graph to obtain a visual representation of how closely the two judges agree (Fig. 3.2).

The formula for this correlation coefficient was developed in 1904 by the psychologist Charles Spearman who, like Pearson, was influenced by Francis Galton.

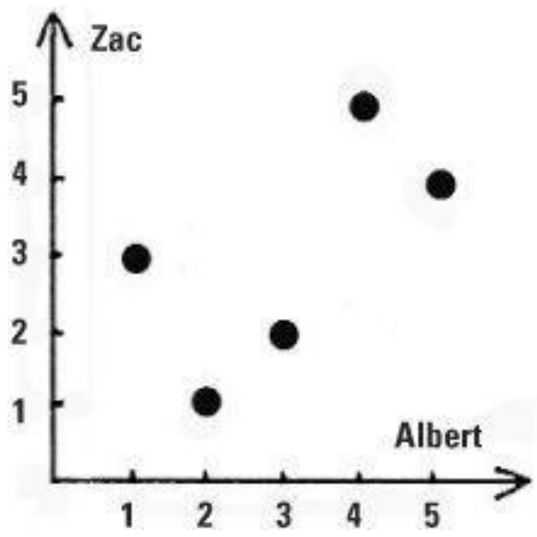


Fig. 3.2. **Measuring the agreement between two judges**

4. ...

Are you shorter or taller than both your parents or do you fall between their heights? If we were all taller than our parents, and this happened at each generation, then one day the population might be composed of ten-footers and upwards, and surely this cannot be. If we were all shorter than our parents then the population would gradually diminish in height and this is equally unlikely. The truth lies elsewhere.

Francis Galton conducted experiments in the 1880s in which he compared the heights of mature young adults with the heights of their parents. For each value of the *x* variable measuring parents' height (actually combining height of mother and father into a "mid-parent" height) he observed the heights of their offspring. We are talking about a practical scientist here, so out came the pencils and sheets of paper divided into squares on which he plotted the data. For 205 mid-parents and 928 offspring he found the average height of both sets to be 68¼ inches or 5 feet 8¼ inches (173.4 cm) which value he called the mediocrity. He found that children of very tall mid-parents were generally taller than this mediocrity but not as tall as their mid-parents, while shorter children were taller than their mid-parents but shorter than the mediocrity. In other words, the children's heights regressed towards the mediocrity.

Regression is a powerful technique and is widely applicable. Let's suppose that, for a survey, the operational research team of a popular retail chain chooses five of its stores, from small outlets (with 1000 customers a month) through to mega-stores (with 10,000 customers a month). The research team observes the number of staff employed in each. They plan to use regression to estimate how many staff they will need for their other stores.

Number of customers (1000s)	1	4	6	9	10
Number of staff	24	30	46	47	53

Let's plot this on a graph (Fig. 3.3), where we'll make the x coordinate the number of customers (we call this the explanatory variable) while the number of staff is plotted as the y coordinate (called the response variable). It is the number of customers that explains the number of staff needed and not the other way around. The average number of customers in the stores is plotted as 6 (i.e. 6000 customers) and the average number of staff in the stores is 40. The regression line always passes through the "average point", here (6, 40). There are formulae for calculating the regression line, the line which best fits the data (also known as the line of least squares). In our case the line is $\hat{y} = 20.8 + 3.2x$ so the slope is 3.2 and is positive (going up from left to right). The line crosses the vertical y axis at the point 20.8. The term $\hat{y}$ is the estimate of the y value obtained from the line. So if we want to know how many staff should be employed in a store that receives 5000 customers a month, we could substitute the value $x = 5$ into the regression equation and obtain the estimate $\hat{y} = 37$ staff showing how regression has a very practical purpose.

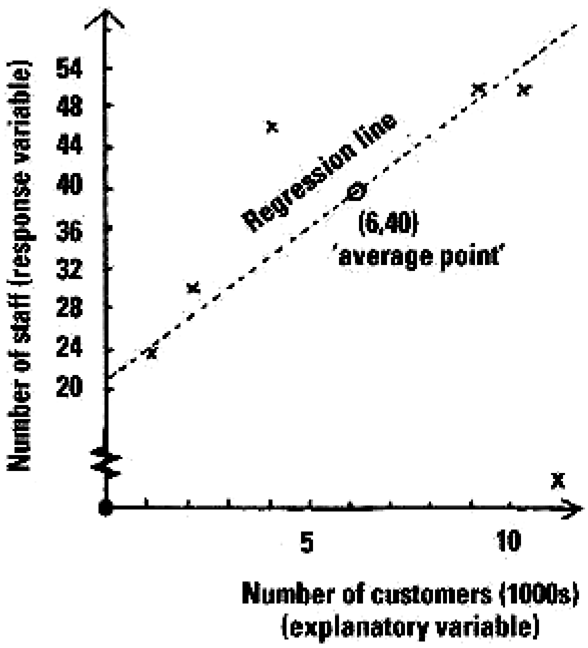


Fig.3.3. **Relations between explanatory and response variables**

(Adapted from [4])

Task 21. Read the text (Task 20) again and answer the questions.

1. Does correlation measures how well two quantities such as weight and height are related to each other?
2. How is the Pearson correlation coefficient measured?
3. What does the Pearson correlation coefficient of +0.9 show?
4. What does the correlation coefficient measure? Give an example of the sales.
5. How can skaters be evaluated?
6. How can we measure the level of agreement between the judges?
7. What experiments did Francis Galton conduct in the 1880s?
8. What kind of technique is Regression? Give an example of outlets.

Focus on Vocabulary

Task 22. Complete the text with the following words and phrases.

Fundamental, two-dimensional, variables, bivariate, mathematical.

Relationships Between Two Variables

The economics literature contains innumerable discussions of relationships between **1** … in pairs: quantity and price; consumption and income; demand for money and the interest rate; trade balance and the exchange rate; education and income; unemployment and the inflation rate; and many more. This is not to say that economists believe that the world can be analyzed adequately in terms of a collection of **2** … relations. When they leave the **3** … diagrams of the textbooks behind and take on the analysis of real problems, multivariate relationships abound. Nonetheless, some bivariate relationships are significant in themselves; more importantly for our purposes, the **4** … and statistical tools developed for two-variable relationships are **5** … building blocks for the analysis of more complicated situations.

Focus on Listening

Task 23. Discuss with your partner the concepts of econometrics and operations research and why we use them.

Task 24. Watch Video 3 "Econometrics and Operations Research" and compare your answers. Do they have the same ideas? [https://www.youtube.com/watch?v=xc9gD1D5gGc]

Task 25. Complete the sentences, then watch Video 3 (Task 24) again and check them.

1. An econometrician is someone who … .
2. He likes to solve … .
3. Countries and the European Union faced many serious challenges … .
4. An econometrician on the other hand will try to predict … .
5. Econometrics and operation techniques are used to … .
6. Econometricians know why the electronic ticket … .

Task 26. Give the main idea of the text (Task 24).

Focus on Speaking

Task 27. Work in pairs and complete each sentence.

1. The economic issues can concern macroeconomics … .
2. Anyone who either invents … is called an "econometrician".
3. An econometrician is a statistician who … .
4. Econometrics can be divided into *… .*
5. Econometric theory usually involves the development of … .
6. Applied econometrics concerns the development and application of … .
7. Observed data can concern (1) …, (2) …, or (3) … .
8. Data on individual behavior are not easy and are usually … .
9. An econometric model usually amounts … .
10. An econometrician needs to … into a model.
11. Econometricians are by no means mathematicians, but mathematical tools usually serve … .
12. The second key activity of an econometrician concerns the match of … .
13. A third key activity concerns the implementation of … .
14. Econometricians use economic insights and mathematical language to construct … .

Task 28. Give the main idea of econometrics.

Focus on Questions and Problems

Task 29. Answer the questions or complete the statements choosing from a – d.

1. Econometrics is the branch of economics that … .

a) studies the behavior of individual economic agents in making economic decisions;

b) develops and uses statistical methods for estimating economic relationships;

c) deals with the performance, structure, behavior, and decision-making of an economy as a whole;

d) applies mathematical methods to represent economic theories and solve economic problems.

2. Nonexperimental data is called ... .

a) cross-sectional data;

b) observational data;

c) time series data;

d) panel data.

3. Which of the following is true of experimental data?

a) experimental data are collected in laboratory environments in the natural sciences;

b) experimental data cannot be collected in a controlled environment;

c) experimental data is sometimes called observational data;

d) experimental data is sometimes called retrospective data.

4. An empirical analysis relies on ... to test a theory.

a) common sense;

b) ethical considerations;

c) data;

d) customs and conventions.

5. The term "u" in an econometric model is usually referred to as the ... .

a) error term;

b) parameter;

c) hypothesis;

d) dependent variable.

6. The constants of econometric models are referred to as ... .

a) parameters;

b) statistics;

c) error terms;

d) hypotheses.

7. The parameters of an econometric model ... .

a) include all unobserved factors affecting the variable being studied;

b) describe the strength of the relationship between the variable under study and the factors affecting it;

c) refer to the explanatory variables included in the model;

d) refer to the predictions that can be made using the model.

8. Which of the following is the first step in empirical economic analysis?

a) collection of data;

b) statement of hypotheses;

c) specification of an econometric model;

d) testing of hypotheses.

9. A data set that consists of a sample of individuals, households, firms, cities, states, countries, or a variety of other units, taken at a given point in time, is called a(n) ... .

a) cross-sectional data set;

b) longitudinal data set;

c) time series data set;

d) experimental data set.

10. Data on the income of law graduates collected at different times during the same year is ... .

a) panel data;

b) experimental data;

c) time series data;

d) cross-sectional data.

11. A data set that consists of observations on a variable or several variables over time is called a ... data set.

a) binary;

b) cross-sectional;

c) time series;

d) experimental.

12. Which of the following is an example of time series data?

a) data on the unemployment rates in different parts of a country during a year;

b) data on the consumption of wheat by 200 households during a year;

c) data on the gross domestic product of a country over a period of 10 years;

d) data on the number of vacancies in various departments of an organization on a particular month.

13. Which of the following refers to panel data?

a) data on the unemployment rate in a country over a 5-year period;

b) data on the birth rate, death rate and population growth rate in developing countries over a 10-year period;

c) data on the income of 5 members of a family on a particular year;

d) data on the price of a company's share during a year.

14. Which of the following is a difference between panel and pooled cross-sectional data?

a) a panel data set consists of data on different cross-sectional units over a given period of time while a pooled data set consists of data on the same cross-sectional units over a given period of time;

b) a panel data set consists of data on the same cross-sectional units over a given period of time while a pooled data set consists of data on different cross-sectional units over a given period of time;

c) a panel data consists of data on a single variable measured at a given point in time while a pooled data set consists of data on the same cross-sectional units over a given period of time;

d) a panel data set consists of data on a single variable measured at a given point in time while a pooled data set consists of data on more than one variable at a given point in time.

15. ... has a causal effect on ... .

a) Income; unemployment;

b) Height; health;

c) Income; consumption;

d) Age; wage.

16. Which of the following is true?

a) a variable has a causal effect on another variable if both variables increase or decrease simultaneously;

b) the notion of "ceteris paribus" plays an important role in causal analysis;

c) difficulty in inferring causality disappears when studying data at fairly high levels of aggregation;

d) the problem of inferring causality arises if experimental data is used for analysis.

17. Which of the following terms measures the association between two variables?

a) casual effect;

b) independence;

c) average;

d) correlation.

18. Experimental data are sometimes called retrospective data.

a) True.

b) False.

19. Experimental data are easy to obtain in the social sciences.

a) True.

b) False.

20. An economic model consists of mathematical equations that describe various relationships between economic variables.

a) True.

b) False.

21. Random sampling complicates the analysis of cross-sectional data.

a) True.

b) False.

22. A cross-sectional data set consists of observations on a variable or several variables over time.

a) True.

b) False.

23. A time series data is also called a longitudinal data set.

a) True.

b) False.

24. The notion of ceteris paribus means "other factors being equal".

a) True.

b) False.

Task 30. Dilemma. Study the examples and fulfil the tasks.

Gasoline is retailed on the West Coast of the United States by the "majors" (Arco, Shell, Texaco, etc.) and by "minors", or "independents". Traditionally the majors have offered a greater variety of products, differentiated in terms of grade of gasoline, method of payment, degree of service, and so forth; whereas the minors have sold for cash and offered a smaller range of products. In the spring of 1983 Arco abolished its credit cards and sold for cash only. By the fall of 1983 the other majors had responded by continuing their credit cards but introducing two prices, a credit price and a lower cash price. Subsequently one of the independents sued Arco under the antitrust laws. The essence of the plaintiff's case was that there were really two separate markets for gasoline, one in which the majors competed with each other, and a second in which the minors competed. They further alleged, though not in this precise language, that Arco was like a shark that had jumped out of the big pool into their little pool with the intention of gobbling them all up. No one questioned that there was competition *within* the majors and competition *within* the minors: the crucial question was whether there was competition between majors and minors.

The problem was a perfect candidate for the Stigler/Sherwin type of analysis. The Lundberg Survey reports detailed information twice a month on the prices of all types and grades of gasoline at a very large sample of stations. These data are also averaged for majors and minors. Twelve differentiated products were defined for the majors and four for the minors. This step allowed the calculation of 66 correlation coefficients for all pairs of products within the majors and 6 correlation coefficients within the minors. Each set of coefficients would be expected to consist of very high numbers, reflecting the intensity of competition inside each group. However, it was also possible to calculate 48 correlation coefficients for all cross-pairs of a major price and a minor price. If the plaintiff's argument were correct, these 48 coefficients would be of negligible size. On the other hand, if there were just a single large market for gasoline, the cross correlations should not be markedly less than correlations within each group. A nice feature of the problem was that the within-group correlations provided a standard of reference for the assessment of the cross correlations. In the cases discussed in the Stigler/Sherwin paper only subjective judgments could be made about the size of correlation coefficient required to establish that two goods were in the same market.

The preceding approach yielded a matrix of 120 correlation coefficients. In order to guard against possible spurious correlation, such a matrix was computed for levels, for first differences, for logs of levels, and for first differences of logs (which measure percent changes in price). In addition, regression analysis was used to adjust for possible common influences from the price of crude oil or from general inflation, and matrices were produced for correlations between the residuals from these regressions. In all cases the matrices showed "forests" of tall trees (that is, high correlation coefficients), and the trees were just as tall in the rectangle of cross correlations as in the triangles of within correlations. The simple correlation coefficients thus provided conclusive evidence for the existence of a single market for retail gasoline.

(Adapted from [10])

Unit 4. Operations Research

Task 1. Answer the questions.

1. What is operations research?
2. What do you know about model formation?
3. What do you know about the model's variables?

Task 2. Translate these words and phrases into your native language.

operations research	
linear programming	
solution procedures	
minimize	
simplex method	
practical significance	
variables	

Task 3. Read the text and answer the questions.

1. Who and when formulated the method for solving linear programming problems called the simplex method?
2. Who independently formulated the theory of linear programming?
3. Who and when was awarded the Nobel Prize in Economics for work on the allocation of resources, which included linear programming techniques?
4. When did the Indian mathematician Narendra Karmarkar derive a new algorithm of practical significance?
5. When was the basic linear programming model applied?

In 1947 the American mathematician George Dantzig, then working for the US Air Force, formulated a method for solving linear programming problems called the simplex method. It was so successful that Dantzig became known in the West as the father of linear programming. Leonid Kantorovich independently formulated a theory of linear programming. In 1975, Kantorovich and the Dutch mathematician Tjalling Koopmans were awarded the Nobel Prize in Economics for work on the allocation of resources, which included linear programming techniques.

When Dantzig found his method there were few computers but there was the Mathematical Tables Project – a decade-long job creation scheme which began in New York in 1938. It took a team of some ten human calculators working for 12 days with hand calculators to solve a diet problem in nine "vitamin" requirements and 77 variables.

While the simplex method and its variants have been phenomenally successful, other methods have also been tried. In 1984 the Indian mathematician Narendra Karmarkar derived a new algorithm of practical significance, and Leonid Khachiyan proposed one of chiefly theoretical importance.

The basic linear programming model has been applied to many situations other than choosing a diet. One type of problem, the transportation problem, concerns itself with transporting goods from factories to warehouses. It is of a special structure and has become a field in its own right. The objective in this case is to minimize the cost of transportation. In some linear programming problems the objective is to maximize (like maximizing profit). In other problems the variables only take integer values or just two values 0 or 1, but these problems are quite different and require their own solution procedures.

(Adapted from [4])

Task 4. Discuss with your partner who and when formulated the method for solving linear programming problems (Task 3).

Focus on Reading

Task 5. Match the words with the definitions. Use a dictionary for help [17].

1) attempt	a) something achieved or successfully completed
2) capabilities	b) to be devoted
3) trace	c) to gain or cause to gain entrance or access surreptitiously
4) identify	d) having no precedent; unparalleled
5) define	e) the quality of being capable; ability
6) pace	f) compulsion, force, or restraint
7) unprecedented	g) to take or receive (something offered)
8) accomplishment	h) to make an effort (to do something) or to achieve (something); try
9) infiltrate	i) to follow to its origins

10) accept	j) to recognize
11) adhere	k) to state precisely the meaning of (words, terms, etc.)
12) constraint	l) speed of movement

Task 6. Some of the key terms given above are used in the text (Task 7). Look through the text and underline them.

Task 7. Read the text carefully. Say whether the statements below are true or false.

1. Management science is characterized by a unscientific approach to managerial decision making.
2. Management science attempts to apply mathematical methods and the capabilities of modern computers to the difficult and unstructured problems confronting modern managers.
3. It is an old and traditional discipline.
4. It has grown at a slow pace, unprecedented for most scientific accomplishments; it is changing our attitudes toward decision making, and infiltrating every conceivable area of application, covering a wide variety of business, industrial, military, and public-sector problems.
5. Management science has been known by a variety of other names.
6. Some people tend to identify the scientific approach to managerial problem-solving under such other names as systems analysis, cost-benefit analysis, and cost-effectiveness analysis.
7. Mathematical programming, and especially linear programming, is not one of the best developed and most used branches of management science.
8. When the mathematical representation uses linear functions exclusively, we have a linear-programming model.

Mathematical Programming: an Overview

Management science is characterized by a scientific approach to managerial decision making. It attempts to apply mathematical methods and the capabilities of modern computers to the difficult and unstructured problems confronting modern managers. It is a young and novel discipline. Although its roots can be traced back to problems posed by early civilizations, it was not until World War II that it became identified as a respectable and well defined body of knowledge. Since then, it has grown at an impressive pace, unprecedented for most scientific accomplishments; it is changing our attitudes toward decision making, and infiltrating very conceivable area of application, covering a wide variety of business, industrial, military, and public-sector problems.

Management science has been known by a variety of other names. In the United States, operations research has served as a synonym and it is used widely today, while in Britain operational research seems to be the more accepted name. Some people tend to identify the scientific approach to managerial problem-solving under such other names as systems analysis, cost-benefit analysis, and cost-effectiveness analysis. We will adhere to management science throughout this textbook.

Mathematical programming, and especially linear programming, is one of the best developed and most used branches of management science. It concerns the optimum allocation of limited resources among competing activities, under a set of constraints imposed by the nature of the problem being studied. These constraints could reflect financial, technological, marketing, organizational, or many other considerations. In broad terms, mathematical programming can be defined as a mathematical representation aimed at programming or planning the best possible allocation of scarce resources. When the mathematical representation uses linear functions exclusively, we have a linear-programming model.

(Adapted from [2])

Task 8. Read the text (Task 7) again and answer the questions.

1. What is management science characterized by?
2. What problems can its roots be traced back to?
3. What is changing our attitudes toward decision making?
4. What other names has management science been known by?
5. What is one of the best developed and the most used branches of management science?
6. What branch of science concerns the optimum allocation of limited resources among competing activities, under a set of constraints imposed by the nature of the problem being studied?

Task 9. Discuss with your partner what mathematical programming is.

Focus on Vocabulary

Task 10. Complete the text with the following words and phrases.

Efficiency, implementation, assumptions, business environment, mathematical-programming approach, optimization method, simplex, high-speed digital, linear-programming.

In 1947, George B. Dantzig, then part of a research group of the U.S. Air Force known as Project SCOOP (Scientific Computation Of Optimum Programs), developed the **1** … method for solving the general **2** … problem. The extraordinary computational **3** … and robustness of the simplex method, together with the availability of **4** … computers, have made linear programming the most powerful **5** … ever designed and the most widely applied in the **6** … . Since then, many additional techniques have been developed, which relax the **7** … of the linear-programming model and broaden the applications of the **8** … . It is this spectrum of techniques and their effective **9** … in practice.

Focus on Reading

Task 11. Match the words with the definitions. Use a dictionary for help [17].

1) noncontroversial	a) to obtain by force or trickery
2) contribution	b) to establish as something to be obeyed or complied with; enforce
3) rigid	c) suitable to the circumstances; appropriate
4) seek	d) extremely difficult to defeat, overcome, manage, etc.
5) insufficient	e) completing; forming a complement
6) capture	f) not causing dispute, argument, debate, etc.
7) formidable	g) to try to find by searching; look for
8) expedient	h) not flexible; that cannot be bent (a rigid frame)
9) impose	i) something contributed, such as money or ideas
10) complementarily	j) not sufficient; inadequate or deficient

Task 12. Some of the key terms given above are used in the text (Task 13). Look through the text and underline them.

Task 13. Read the text carefully. Say whether the statements below are true or false.

1. Mathematical programming is not only a tool of the broad discipline known as management science.
2. Mathematical programming has benefited from contributions originating in the social and natural sciences, econometrics, and mathematics, much of which escape the rigidity of a definition.
3. Management science is characterized by the use of any models in providing guidelines to managers for making effective decisions within the state of the current information, or in seeking further information if current knowledge is insufficient to reach a proper decision.
4. The core of management science is the model-building approach – that is, an attempt to capture the most significant features of the decision under consideration by means of a mathematical abstraction.
5. Models are not simplified representations of the real world.
6. Models have to provide a nonrealistic representation of the decision environment by incorporating all the elements required to characterize the essence of the problem under study.
7. The chief will supply managers with a formidable tool to be used in complex decision situations.
8. Through this model-design effort, management science tries to provide guidelines to managers or to increase managers' understanding of the consequences of their actions.
9. Models cannot expediently and effectively account for many interrelationships.
10. Managers should formulate the basic questions to be addressed by the model, and then interpret the model's results in light of their own experience and intuition, recognizing the model's limitations.
11. Models have been criticized for creating reasonable requirements for information.

An Introduction To Management Science

Since mathematical programming is only a tool of the broad discipline known as management science, let us first attempt to understand the management-science approach and identify the role of mathematical programming within that approach.

It is hard to give a noncontroversial definition of management science. As we have indicated before, this is a rather new field that is renewing itself and changing constantly. It has benefited from contributions originating in the social and natural sciences, econometrics, and mathematics, much of which escape the rigidity of a definition. Nonetheless, it is possible to provide a general statement about the basic elements of the management-science approach.

Management science is characterized by the use of *mathematical models* in providing guidelines to managers for making effective decisions within the state of the current information, or in seeking further information if current knowledge is insufficient to reach a proper decision.

There are several elements of this statement that are deserving of emphasis. First, the essence of management science is the model-building approach – that is, an attempt to capture the most significant features of the decision under consideration by means of a mathematical abstraction. Models are simplified representations of the real world. In order for models to be useful in supporting management decisions, they have to be simple to understand and easy to use. At the same time, they have to provide a complete and realistic representation of the decision environment by incorporating all the elements required to characterize the essence of the problem under study. This is not an easy task but, if done properly, it will supply managers with a formidable tool to be used in complex decision situations.

Second, through this model-design effort, management science tries to provide guidelines to managers or, in other words, to increase managers' understanding of the consequences of their actions. There is never an attempt to replace or substitute for managers, but rather the aim is to *support* management actions. It is critical, then, to recognize the strong interaction required between managers and models. Models can expediently and effectively account for the many interrelationships that might be present among the alternatives being considered, and can explicitly evaluate the economic consequences of the actions available to managers within the constraints imposed by the existing resources and the demands placed upon the use of those resources. Managers, on the other hand, should formulate the basic questions to be addressed by the model, and then interpret the model's results in light of their own experience and intuition, recognizing the model's limitations. The complementarity between the superior computational capabilities provided by the model and the higher judgmental capabilities of the human decision-maker is the key to a successful management-science approach. Finally, it is the complexity of the decision under study, and not the tool being used to investigate the decision-making process, that should determine the amount of information needed to handle that decision effectively. Models have been criticized for creating unreasonable requirements for information. In fact, this is not necessary. Quite to the contrary, models can be constructed within the current state of available information and they can be used to evaluate whether or not it is economically desirable to gather additional information.

(Adapted from [2])

Task 14. Read the text (Task 13) again and answer the questions.

1. What is a tool of the broad discipline known as management science?
2. What has management science benefited from?
3. How is management science characterized by?
4. What are the elements of management science?
5. What is the aim of models in supporting management decisions?
6. What features should models possess to be useful in supporting management decisions?
7. What does the complexity of the decision under study determine?

Focus on Vocabulary

Task 15. Match the words with opposite meaning.

1) indicate	a) appropriate
2) benefit	b) necessity
3) effective	c) estimate
4) proper	d) signify
5) deserving	e) practical
6) realistic	f) worthy
7) requirement	g) advantage
8) evaluate	h) efficient

Focus on Reading

Task 16. Match the words with the definitions. Use a dictionary for help [17].

1) merely	a) leader
2) crude	b) existing in something, esp. as a permanent or characteristic attribute
3) refinery	c) obligatory; compulsory
4) mandatory	d) in a natural or unrefined state
5) accuracy	e) very; to a great extent
6) exceedingly	f) a factory for the purification of some crude material, such as ore, sugar, oil, etc.
7) acquisition	g) only; nothing more than
8) inherent	h) correctness; precision
9) duce	i) the act of acquiring or gaining possession

Task 17. Some of the key terms given above are used in the text (Task 19). Look through the text and underline them.

Task 18. Read the text below (Task 19) and choose the best heading to each of its parts.

A. Analytical Model.
B. Gaming.
C. Operational Exercise.
D. Simulation.

Task 19. Read the text carefully. Say whether the statements below are true or false.

1. An operational exercise approach operates directly with the nonreal environment in which the decision under study is going to take place.
2. The modeling effort does not only involve designing asset of experiments to be conducted in that environment, and measuring and interpreting the results of those experiments.
3. In order for this approach to operate successfully, it is optional to design experiments to be conducted carefully, to evaluate the experimental results in light of errors that can be introduced by measurement inaccuracies, and to draw inferences about the decisions reached, based upon the limited number of observations performed.

4. The essence of the operational exercise is an inductive learning process, characteristic of empirical research in the natural sciences, in which generalizations are drawn from particular observations of a given phenomenon.

5. Operational exercises contain the lowest degree of realism of any form of modeling approach.

6. Gaming is constructing a model that is an abstract and simplified representation of the existent environment.

7. This model provides a responsive mechanism to estimate the effectiveness of proposed alternatives, which the decision-maker must supply in an organized and sequential fashion.

8. The model should reflect, with an acceptable degree of inaccuracy, the relationships between the inputs and outputs of the refinery process.

9. Gaming is used mostly as a learning device for developing some appreciation for those complexities inherent in a decision-making process.

10. Simulation models are not similar to gaming models except that all human decision-makers are removed from the modeling process.

11. The model provides the means to evaluate the performance of a number of alternatives, supplied externally to the model by the decision-maker, with allowing for human interactions at intermediate stages of the model computation.

12. Like operational exercises and gaming, simulation models either generate alternatives or produce an optimum answer to the decision under study.

13. These types of models are inductive and empirical in nature; they are useful only to assess the performance of alternatives identified previously by the decision-maker.

14. Many simulation models take the form of computer programs, where logical arithmetic operations are performed in a prearranged sequence.

15. Analytical models are rarely represented in mathematical terms.

16. Analytical models are normally the most expensive and difficult models to develop.

17. Most of the work undertaken by management scientists has been oriented toward the development and implementation of analytical models.

Model Classification

The management-science literature includes several approaches to classifying models. We will begin with a categorization that identifies broad types of models according to the degree of realism that they achieve in representing a given problem.

1. ...

The first model type is an operational exercise. This modeling approach operates directly with the real environment in which the decision under study is going to take place. The modeling effort merely involves designing asset of experiments to be conducted in that environment, and measuring and interpreting the results of those experiments. Suppose, for instance, that we would like to determine what mix of several crude oils should be blended in a given oil refinery to satisfy, in the most effective way, the market requirements for final products to be delivered from that refinery. If we were to conduct an operational exercise to support that decision, we would try different quantities of several combinations of crude oil types directly in the actual refinery process, and observe the resulting revenues and costs associated with each alternative mix. After performing quite a few trials, we would begin to develop an understanding of the relationship between the crude oil input and the net revenue obtained from the refinery process, which would guide us in identifying an appropriate mix.

In order for this approach to operate successfully, it is mandatory to design experiments to be conducted carefully, to evaluate the experimental results in light of errors that can be introduced by measurement inaccuracies, and to draw inferences about the decisions reached, based upon the limited number of observations performed. Many statistical and optimization methods can be used to accomplish these tasks properly. The essence of the operational exercise is an inductive learning process, characteristic of empirical research in the natural sciences, in which generalizations are drawn from particular observations of a given phenomenon.

Operational exercises contain the highest degree of realism of any form of modeling approach, since hardly any external abstractions or oversimplifications are introduced other than those connected with the interpretation of the observed results and the generalizations to be drawn from them. However, the method is exceedingly, usually prohibitively, expensive to implement. Moreover, in most cases it is impossible to exhaustively analyze the alternatives available to the decision-maker. This can lead to severe suboptimization in the final conclusions. For these reasons, operational exercises are seldom used as a pure form of modeling practice. It is important to recognize, however, that direct observation of the actual environment underlies most model conceptualizations and also constitutes one of the most important sources of data. Consequently, even though they may not be used exclusively, operational exercises produce significant contributions to the improvement of managerial decision-making.

2. ...

The second type of model in this classification is gaming. In this case, a model is constructed that is an abstract and simplified representation of the real environment. This model provides a responsive mechanism to evaluate the effectiveness of proposed alternatives, which the decision-maker must supply in an organized and sequential fashion. The model is simply a device that allows the decision-maker to test the performance of the various alternatives that seem worthwhile to pursue. In addition, in a gaming situation, all the human interactions that affect the decision environment are allowed to participate actively by providing the inputs they are usually responsible for in the actual realization of their activities. If a gaming approach is used in our previous example, the refinery process would be represented by a computer or mathematical model, which could assume any kind of structure.

The model should reflect, with an acceptable degree of accuracy, the relationships between the inputs and outputs of the refinery process. Subsequently, all the personnel who participate in structuring the decision process in the management of the refinery would be allowed to interact with the model. The production manager would establish production plans, the marketing manager would secure contracts and develop marketing strategies, the purchasing manager would identify prices and sources of crude oil and develop acquisition programs, and so forth. As before, several combinations of quantities and types of crude oil would be tried, and the resulting revenues and cost figures derived from the model would be obtained, to guide us in formulating an optimal policy. Certainly, we have lost some degree of realism in our modeling approach with respect to the operational exercise, since we are operating with an abstract environment, but we have retained some of the human interactions of the real process. However, the cost of processing each alternative has been reduced, and the speed of measuring the performance of each alternative has been increased.

Gaming is used mostly as a learning device for developing some appreciation for those complexities inherent in a decision-making process. Several management games have been designed to illustrate how marketing, production, and financial decisions interact in a competitive economy.

3. ...

Simulation models are similar to gaming models except that all human decision-makers are removed from the modeling process. The model provides the means to evaluate the performance of a number of alternatives, supplied externally to the model by the decision-maker, without allowing for human interactions at intermediate stages of the model computation.

Like operational exercises and gaming, simulation models neither generate alternatives nor produce an optimum answer to the decision under study. These types of models are inductive and empirical in nature; they are useful only to assess the performance of alternatives identified previously by the decision-maker.

If we were to conduct a simulation model in our refinery example, we would program in advance a large number of combinations of quantities and types of crude oil to be used, and we would obtain the net revenues associated with each alternative without any external inputs of the decision-makers. Once the model results were produced, new runs could be conducted until we felt that we had reached a proper understanding of the problem on hand.

Many simulation models take the form of computer programs, where logical arithmetic operations are performed in a prearranged sequence. It is not necessary, therefore, to define the problem exclusively in analytic terms. This provides an added flexibility in model formulation and permits a high degree of realism to be achieved, which is particularly useful when uncertainties are an important aspect of the decision.

4. ...

Finally, the fourth model category proposed in this framework is the analytical model. In this type of model, the problem is represented completely in mathematical terms, normally by means of a criterion or objective, which we seek to maximize or minimize, subject to asset of mathematical constraints that portray the conditions under which the decisions have to be made. The model computes an optimal solution, that is, one that satisfies all the constraints and gives the best possible value of the objective function.

In the refinery example, the use of an analytical model implies setting up as an objective the maximization of the net revenues obtained from the refinery operation as a function of the types and quantities of the crude oil used. In addition, the technology of the refinery process, the final product requirements, and the crude oil availabilities must be represented in mathematical terms to define the constraints of our problem. The solution to the model will be the exact amount of each available crude-oil type to be processed that will maximize the net revenues within the proposed constraint set. Linear programming has been, in the last two decades, the indisputable analytical model to use for this kind of problem.

Analytical models are normally the least expensive and easiest models to develop. However, they introduce the highest degree of simplification in the model representation. As a rule of thumb, it is better to be as much to the right as possible in the model spectrum (no political implication intended!), provided that the resulting degree of realism is appropriate to characterize the decision under study.

Most of the work undertaken by management scientists has been oriented toward the development and implementation of analytical models. As a result of this effort, many different techniques and methodologies have been proposed to address specific kinds of problems. Table 4.1 presents a classification of the most important types of analytical and simulation models that have been developed.

Table 4.1

Classification of analytical and simulation models

	Strategy evaluation	Strategy generation
Certainty	• Deterministic simulation; • econometric models; • systems of simultaneous equations; • input-output models	• Linear programming; • network models; • integer and mixed-integer programming; • nonlinear programming; • control theory
Uncertainty	• Monte Carlo simulation; • econometric models; • stochastic processes; • queueing theory; • reliability theory	• Decision theory; • dynamic programming; • inventory theory; • stochastic programming; • stochastic control theory

Statistics and subjective assessment are used in all models to determine values for parameters of the models and limits on the alternatives.

The classification presented in Table 4.1 is not rigid, since strategy evaluation models are used for improving decisions by trying different alternatives until one is determined that appears "best". The important distinction of the proposed classification is that, for strategy evaluation models, the user must first choose and construct the alternative and then evaluate it with the aid of the model. For strategy generation models, the alternative is not completely determined by the user; rather, the class of alternatives is determined by establishing constraints on the decisions, and then an algorithmic procedure is used to automatically generate the "best" alternative within that class. The horizontal classification should be clear, and is introduced because the inclusion of uncertainty (or not) generally makes a substantial difference in the type and complexity of the techniques that are employed. Problems involving uncertainty are inherently more difficult to formulate well and to solve efficiently.

(Adapted from [2])

Task 20. Read the text (Task 19) again and answer the questions.

1. What approach is used in the operational exercise modeling?
2. What do operational exercises contain?
3. What kind of model provides a responsive mechanism?
4. What kind of model should reflect the relationships between the inputs and outputs of the refinery process?
5. What is gaming used for?
6. What do simulation models provide?
7. What types of models are inductive and empirical in nature?
8. What kind of models satisfies all the constraints and gives the best possible value of the objective function?
9. What does the classification include?

Focus on Vocabulary

Task 21. Complete the text with the following words and phrases.

Strategy, assumption, disciplines, mathematical programming, applications, control theory.

Mathematical programming is a part of management science that has a common base of theory and a large range of **1** … . Generally, mathematical programming includes all of the topics under the heading of **2** … generation except for decision theory and control theory. These two topics are entire **3** … in themselves, depending essentially on different underlying theories and techniques. Recently, though, the similarities between mathematical programming and **4** … are becoming better understood, and these disciplines are beginning to merge. In **5** …, the main body of material that has been developed, and more especially applied, is under the **6** … of certainty.

Task 22. Describe the model categories that can be illustrated as shown in Fig. 4.1.

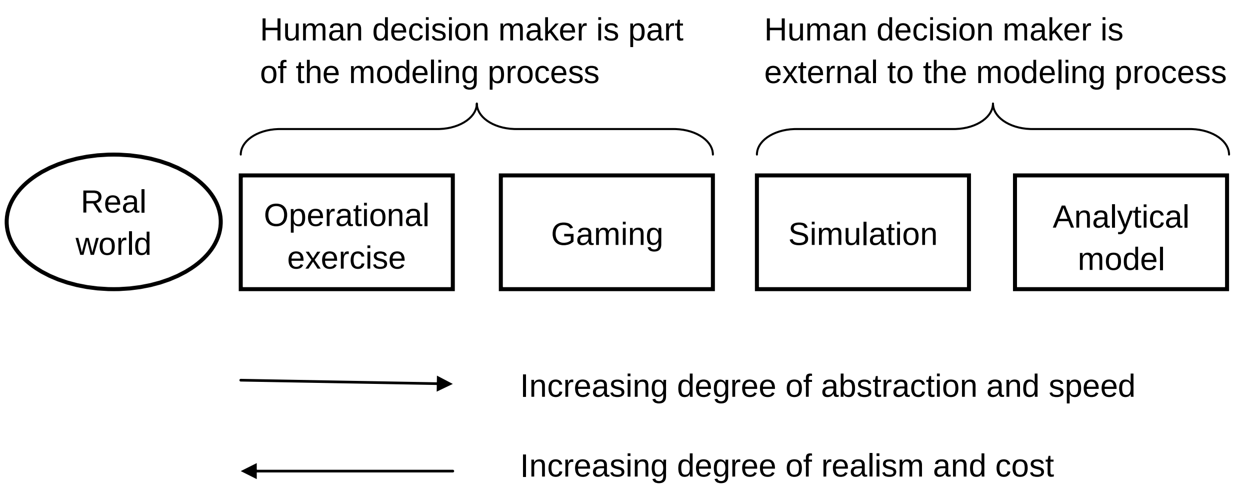


Fig. 4.1. **The types of model representation**

Focus on Listening

Task 23. Give your association with the phrase "operations research".

Task 24. Discuss with your partner the concept of operations research and say why we use it.

Task 25. Watch Video 4 "A New view of Analytics and Operations Research" and compare your answers. Do they have the same ideas? [https://www.youtube.com/watch?v=sFWrmpXPVJw]

Task 26. Complete the sentences then watch Video 4 (Task 25) again and check them.

1. How can management win in a world with so many variables? The answer is … .
2. Operations research has a broad reach, it offers … .

3. Operations research has improved management in business … .

4. Their operations research solution used cost-benefit trade-off analysis to create … .

5. Applying operations research means recognizing the value … .

6. The Netherlands' railways applied sophisticated analytics to optimize … .

7. As the world rapidly grows, more intricate, operations research and analytics offer … .

Task 27. Give the main idea of the text (Task 25).

Focus on Speaking

Task 28. Work in pairs and complete each sentence.

1. Mathematical programming is only a tool of the broad discipline known as … .
2. It has benefited from contributions originating in … .
3. Management science is characterized by … .
4. The essence of management science is the model-building approach … .
5. Models are simplified … .
6. They have to provide a complete and realistic representation of the decision environment by incorporating … .
7. It will supply managers with a difficult tool to be used in … .
8. Through this model-design effort, management science tries to provide … .
9. Managers should formulate the basic … .
10. Models have been criticized for creating … .
11. An operational exercise modeling approach operates directly with the real … .
12. The modeling effort merely involves designing asset of experiments to be conducted in that … .
13. The essence of the operational exercise is an inductive learning process, characteristic … .
14. The second type of model in this classification is gaming. In this case, a model is constructed that … .
15. This model provides a responsive mechanism to evaluate … .
16. Simulation models are similar to … .
17. The model provides the means to evaluate the performance of … .

18. Many simulation models take the form of computer programs, where … .
19. An analytical model is represented completely in … .
20. Analytical models are normally the least … .
21. Most of the work undertaken by management scientists has been oriented toward … . As a result of this effort, many different techniques and methodologies have been proposed … .

Task 29. Work in pairs and discuss the main purpose of operations research.

Focus on Problems and Questions

Task 30. Read the text and explain to your partner every step of operations research. Then study the example and do the task.

Seven steps of operations research (OR) study

An OR project can be split in the following seven steps:

Step 1. Formulate the problem The OR analyst first defines the organization's problem. This includes specifying the organization's objectives and the parts of the organization (or system) that must be studied before the problem can be solved.

Step 2. Observe the system. Next, the OR analyst collects data to estimate the values of the parameters that affect the organization's problem. These estimates are used to develop (in Step 3) and evaluate (in Step 4) a mathematical model of the organization's problem.

Step 3. Formulate a mathematical model of the problem. The OR analyst develops an idealized representation – i.e. a mathematical model – of the problem.

Step 4. Verify the model and use it for prediction. The OR analyst tries to determine if the mathematical model developed in Step 3 is an accurate representation of the reality. The verification typically includes observing the system to check if the parameters are correct. If the model does not represent the reality well enough, then the OR analyst goes back either to Step 3 or Step 2.

Step 5. Select a suitable alternative. Given a model and a set of alternatives, the analyst now chooses the alternative that best meets the organization's objectives. Sometimes there are many best alternatives, in which case the OR analyst should present them all to the organization's decision-makers, or ask for more objectives or restrictions.

Step 6. Present the results and conclusions. The OR analyst presents the model and recommendations from Step 5 to the organization's decision-makers. At this point the OR analyst may find that the decision-makers do not approve of the recommendations. This may result from incorrect definition of the organization's problems or decision-makers may disagree with the parameters or the mathematical model. The OR analyst goes back to Step 1, Step 2, or Step 3, depending on where the disagreement lies.

Step 7. Implement and evaluate the recommendations. Finally, when the organization has accepted the study, the OR analyst helps in implementing the recommendations. The system must be constantly monitored and updated dynamically as the environment changes. This means going back to Step 1, Step 2, or Step 3, from time to time.

Example of an OR Study

An example elaborates how the seven-step list can be applied to a queueing problem. The example is cursory: we do not investigate all the possible objectives or choices there may be, and we do not go into the details of modeling.

A bank manager wants to reduce expenditures on tellers' salaries while still maintaining an adequate level of customer service.

Step 1. The OR analyst describes bank's objectives. The manager's vaguely stated wish may mean, e.g.,

- the bank wants to minimize the weekly salary cost needed to ensure that the average waiting a customer waits in line is at most 3 minutes.
- the bank wants to minimize the weekly salary cost required to ensure that only 5 % of all customers wait in line more than 3 minutes.

The analyst must also identify the aspects of the bank's operations that affect the achievement of the bank's objectives, e.g.,

- On the average, how many customers arrive at the bank each hour?
- On the average, how many customers can a teller serve per hour?

Step 2. The OR analyst observes the bank and estimates, among others, the following parameters:

- On the average, how many customers arrive each hour? Does the arrival rate depend on the time of day?
- On the average, how many customers can a teller serve each hour? Does the service speed depend on the number of customers waiting in line?

Step 3. The OR analyst develops a mathematical model. In this example a queueing model is appropriate. Let

W_q = average time a customer waits in line;

λ = average number of customers arriving each hour;

μ = average number of customers a teller can serve each hour.

A certain mathematical queueing model yields a connection between these parameters:

$$W_q = \lambda / (\mu \times (\mu - \lambda)). \tag{4.1}$$

This model corresponds to the first objective stated in Step 1.

Step 4. The analyst tries to verify that the model (4.1) represents reality well enough. This means that the OR analyst will estimate the parameter W_q, λ, and μ statistically, and then s/he will check whether the equation (4.1) is valid, or close enough. If this is not the case, then the OR analyst goes either back to Step 2 or Step 3.

Step 5. The OR analyst will optimize the model (4.1). This could mean solving how many tellers there must be to make μ big enough to make W_q small enough, e.g. 3 minutes.

We leave it to the students to wonder what may happen in steps 6 and 7.

(Adapted from [14])

Unit 5. Simulation

Task 1. Answer the questions.
1. What is simulation?
2. What do you know about simulation?

Task 2. Translate these words and phrases into your native language.

managerial problems	
standard problem	
standard tools	
simulation models	
trial-and-error experimentation	
system's behavior	

Task 3. Read the text and answer the question.
1. What is the reason to apply simulation models?

When managerial problems become complex, they often no longer fit the standard problem classifications that are solved by the standard tools. Development of special optimization models to handle such problems may be too costly in terms of dollars and time or the task may even be impossible. For such cases, simulation models are useful. A simulation model involves trial-and-error experimentation with a mathematical model in order to describe and evaluate the system's behavior.

Task 4. Discuss with your partner when simulation models are useful (Task 3).

Focus on Reading

Task 5. Study this example and answer the questions.
1. Why was Sunny delighted?
2. Why was Sunny offered a new position?
3. What experience did Sunny have?
4. What was the new task for Sunny?

Sunny Goldman was delighted with her new job as director, Tourist Information Center, for the city of Miami Beach. She had completed her graduate work in the Hotel and Entertainment Services program of a highly rated college in New York and accepted the offer for the new position from her former internship employer, the city of Miami Beach.

The city manager, Cy Bushnell, had been impressed with Sunny's analytical skills during her summers as an intern working at the Senior Citizens Center. There she had been instrumental in instituting programs that raised the quality of the center's services while simultaneously cutting their costs. Cy had been straightforward in his expectations when offering Sunny the permanent position of director for this new center: the budget was severely underfunded, yet the city council had high expectations for the center. If the first year was successful, the center would be much better funded the second year. If not, the city council might well cancel the entire concept.

Sunny saw her first task as determining the needs for service at the center. This required statistics concerning the tourists' arrival rates, their waiting times, and the service times they required to meet their needs. Following this, Sunny would look into more detail concerning the variety of services the tourists required. Special brochures and posters might handle a significant portion of their information requirements, for example. Or perhaps some form of "express line" for commonly asked questions or senior citizens was desirable.

(Adapted from [15])

Task 6. Discuss with your partner what you would do if you were Sunny. Compare your answer with the information from the text (Task 7).

Task 7. Read the text carefully. Say whether the statements below are true or false.

1. The case can be solved by the formulas because the arrival rate does not follow the Poisson distribution.
2. Sunny's first approach to the data collection problem was to register tourist arrivals and services in the facility.
3. Based on this quick preliminary sample, Sunny concluded that the usual tourist waited 7/10 of a minute and the employee was busy during 41/50 minutes or 82 percent of the time.
4. Sunny cannot conduct all her experiments on a model of the Tourist Agency.

5. Sunny cannot get answers to all her questions by using the technique of simulation.

6. Simulation is limited to waiting line problems.

7. Simulation can be applied to many different types of problems and yields a great deal of information concerning the effectiveness of different operating policies under various conditions and assumptions.

The General Nature of Simulation

The example just presented is a simple case of one server (possibly more) in a waiting line situation. Unfortunately, the case cannot be solved by the formulas because the arrival rate does not follow the Poisson distribution, nor is the service time exponential.

Sunny's first approach to the data collection problem was to log tourist arrivals and services in the facility. Her results for the first 10 tourists are shown in Table 5.1.

Table 5.1

The tourist information center data

Tourist number	Arrival time	Start of service	End of service	Tourist waiting from – to	Employee idle from – to
1	9:02	9:02	9:08	–	9:08 – 9:10
2	9:10	9:10	9:14	–	–
3	9:12	9:14	9:17	9:12 – 9:14	–
4	9:13	9:17	9:20	9:13 – 9:17	–
5	9:20	9:20	9:23	–	–
6	9:22	9:23	9:28	9:22 – 9:23	9:28 – 9:31
7	9:31	9:31	9:34	–	9:34 – 9:35
8	9:35	9:35	9:40	–	–
9	9:40	9:40	9:45	–	9:45 – 9:48
10	9:48	9:48	9:50	–	–
Total				7 minutes	9 minutes

Based on this quick preliminary sample, Sunny concluded that the average tourist waited 7/10 of a minute and the employee was busy during 41/50 minutes or 82 percent of the time. Several questions came to Sunny's mind:

How long should she clock the operation of the information clerk? How do the employees feel about being clocked?

How do the tourists feel about being clocked? What other kinds of measurements should she take?

What Sunny did not know then was that she can conduct all her experiments on a model of the Tourist Agency, and that she can get answers to all her questions by using the technique of simulation.

Simulation is not limited to waiting line problems. Other familiar simulations are the mock war games that national armies regularly schedule, primarily for their reservists, and Monopoly, the real estate game. Other, not so familiar, simulations are:

- Simulation models of urban systems.
- Corporate organizational (policy) models.
- Business games used for training.
- Flights to the planets and the moon.
- Plant and warehouse location models.
- Determination of the proper size of repair crews.
- Econometric models of national economies.
- Network models of traffic intersections to determine the best sequencing of traffic lights.
- Queuing models of airport runway takeoffs and landings.
- Air basin models to determine pollution sources, concentrations, and dynamics.
- Dam and river basin models to determine the effect of weather and operating policies on the hydroelectric output and water supply.
- Financial models (short and long run).

From the above list, it can be seen that simulation is one of the most flexible techniques in the tool kit of management scientists. It can be applied to many different types of problems and yields a great deal of information concerning the effectiveness of different operating policies under various conditions and assumptions.

(Adapted from [15])

Task 8. Read the text (Task 7) again and answer the questions.

1. What was Sunny's first approach to the data collection problem?
2. What did Sunny conclude about the problem?

3. Can Sunny conduct all her experiments on a model of the Tourist Agency?
4. What simulations are familiar?
5. What simulations are not so familiar?

Task 9. Discuss with your partner what simulation is.

Focus on Vocabulary

Task 10. Complete the text with the following words and phrases.

Founder, business cycles, contributions, urban planners, systems scientist, interactions, complex, social problems, sustainability.

Jay Wright Forrester (born July 14, 1918, died November 16, 2016 (aged 98)) is an American pioneering computer engineer and **1** … . He was a professor at the MIT Sloan School of Management. Forrester is known as the **2** … of system dynamics, which deals with the simulation of **3** … between objects in dynamic systems.

"Industrial Dynamics" was the first book Forrester wrote using system dynamics to analyze industrial **4** … . Several years later, interactions with former Boston Mayor John F. Collins led Forrester to write "Urban Dynamics", which sparked an ongoing debate on the feasibility of modeling broader **5** … .

The urban dynamics model attracted the attention of **6** … around the world, eventually leading Forrester to meet a founder of the Club of Rome. He later met with the Club of Rome to discuss issues surrounding global **7**… ; the book "World Dynamics" followed. "World Dynamics" took on modeling the **8** … interactions of the world economy, population and ecology, which understandably met with much misunderstanding. Forrester has made numerous other **9** … to system dynamics and has promoted system dynamics in education to the present day.

Focus on Reading

Task 11. Match the words with the definitions. Use a dictionary for help [17].

1) extend	a) a group of people employed by a company, individual, etc., for executive, clerical, sales work, etc.
2) simplification	b) uncomplicated

3) considerably	c) a complete list of goods in stock, house contents, etc.
4) execute	d) making less complicated, clearer, or easier
5) due to	e) much; a lot of
6) straightforward	f) to carry out; complete; perform; do
7) patchwork	g) the reduction in volume (causing an increase in pressure) of the fuel mixture in an internal-combustion engine before ignition
8) inventory	h) attributable to or caused by
9) staff	i) to lengthen or make larger in space or time
10) compression	j) to supervise, oversee
11) overlook	k) something, such as a theory, made up of various parts

Task 12. Some of the key terms given above are used in the text (Task 14). Look through the text and underline them.

Task 13. Read the text below (Task 14) and choose the best heading to each of its parts.

A. Advantages of Simulation.

B. Major Characteristics.

C. The Primary Disadvantages of Simulation.

Task 14. Read the text carefully. Say whether the statements below are true or false.

1. To simulate means to assume the appearance or characteristics of idealism.
2. In management science, simulation generally refers to a technique for conducting experiments with a digital computer on a model of a management system over an unlimited period of time.
3. Simulation is strictly a type of model.
4. Simulation is a model for conducting experiments.
5. Simulation is a descriptive rather than a normative tool; that is, there is no automatic search for an optimal solution.
6. A simulation describes and/or predicts the characteristics of a given system under different circumstances.

7. The simulation process rarely consists of the repetition of an experiment many, many times to obtain an estimate of the overall effect of certain actions.

8. Simulation is usually called for only when the problem under investigation is too simple to be treated by analytical models (such as EOQ) or by numerical optimization techniques (such as linear programming).

9. The simulation model is basically the aggregate of many elementary relationships and interdependencies.

10. Managers who employ a trial-and-error approach to problem solving cannot do it faster and cheaper with less risk, using the aid of simulation and computers.

11. The model is built from the management scientist's and in his or her decision structure rather than the manager's perspective.

12. Simulation allows for inclusion of the real-life complexities of problems; simplifications are always necessary.

13. Constructing a simulation model is frequently a fast and rather cheap process.

14. Solutions and inferences from a simulation study are usually transferable to other problems.

What Is Simulation?

Simulation has many meanings, depending on the area where it is being used. To simulate, according to the dictionary, means to assume the appearance or characteristics of reality. In management science, it generally refers to a technique for conducting experiments with a digital computer on a model of a management system over an extended period of time. In rare cases, it is possible to conduct optimization in simulation.

1. ...

To begin, simulation is not strictly a type of model; models in general represent reality, while simulation imitates it. In practical terms, this means that there are fewer simplifications of reality in simulation models than in other models.

Second, simulation is a technique for conducting experiments. Therefore, simulation involves the testing of specific values of the decision variables in the model and observing the impact on the output variables.

Simulation is a descriptive rather than a normative tool; that is, there is no automatic search for an optimal solution. Instead, a simulation describes and/or predicts the characteristics of a given system under different circumstances. Once these characteristics are known, the best among several policies can be selected, though an optimum, as analytic models yield, may be considerably better, but was not selected for testing. The simulation process often consists of the repetition of an experiment many, many times to obtain an estimate of the overall effect of certain actions. It can be executed manually in some cases, but a computer is usually needed.

Finally, simulation is usually called for only when the problem under investigation is too complex to be treated by analytical models (such as EOQ) or by numerical optimization techniques (such as linear programming). Complexity here means that the problem either cannot be formulated mathematically (e.g., because the assumptions do not hold, as in Sunny's case) or the formulation is too involved for a practical or economic solution.

2. ...

The increased acceptance of simulation at the higher managerial levels is probably due to a number of factors:

1. Simulation theory is relatively straightforward.
2. The simulation model is simply the aggregate of many elementary relationships and interdependencies, much of which is introduced slowly by request of the manager and in a patchwork manner.
3. Simulation is descriptive rather than normative. This allows the manager to ask "what if" type questions (especially when used with an on-line computer). Thus, managers who employ a trial-and-error approach to problem solving can do it faster and cheaper with less risk, using the aid of simulation and computers.
4. An accurate simulation model requires an intimate knowledge of the problem, thus forcing the management scientist to constantly interface with the manager.
5. The model is built from the manager's perspective and in his or her decision structure rather than the management scientist's.
6. The simulation model is built for one particular problem and, typically, will not solve any other problem. Thus, no generalized understanding is required of the manager; every component in the model corresponds one to one with a part of the real-life model.

7. Simulation can handle an extremely wide variation in problem types such as inventory and staffing, as well as higher managerial level functions like long-range planning. Thus, it is "always there" when the manager needs it.

8. The manager can experiment with different variables to determine which are important, and with different policies and alternatives to determine which are the best. The experimentation is done with a model rather than by interfering with the system.

9. Simulation, in general, allows for inclusion of the real-life complexities of problems; simplifications are not necessary. For example: simulation utilizes the real-life probability distributions rather than approximate theoretical distributions.

10. Due to the nature of simulation, a great amount of time compression can be attained, giving the manager some feel as to the long-term (1 to 10 years) effects of various policies, in a matter of minutes.

11. The great amount of time compression enables experimentation with a very large sample (especially when computers are used). Therefore, as much accuracy can be achieved as desired at a relatively low cost.

3. ...

1. An optimal solution cannot be guaranteed.
2. Constructing a simulation model is frequently a slow and costly process.
3. Solutions and inferences from a simulation study are usually not transferable to other problems. This is due to the incorporation in the model of the unique factors of the problem.
4. Simulation is sometimes so easy to apply that analytical solutions that can yield optimal results are often overlooked.

(Adapted from [15])

Task 15. Read the text (Task 14) again and answer the questions.

1. What do simulation meanings depend on?
2. What does the word "to simulate" mean according to the dictionary?
3. What does the word "to simulate" refer to in management science?
4. What does simulation represent?
5. What does simulation involve?
6. What does a simulation describe and/or predict?
7. What are the main advantages of simulation according to the text?
8. What are the main disadvantages of simulation according to the text?

Focus on Vocabulary

Task 16. Complete the text with the following words and phrases.

Gathering, contradictory, analytical models, process, real system, consists, statistical, simulation, boundaries, implementation, computer language, validation, issues.

The Methodology of Simulation

Simulation involves setting up a model of a **1** … and conducting repetitive experiments on it. The methodology **2** … of a number of steps. The following is a brief discussion of the process.

Problem definition. The real-world problem is examined and classified. Here we should specify why simulation is necessary. The system's **3** … and other such aspects of problem clarification are attended to here.

Construction of the simulation model. This step involves **4** … the necessary data. In many cases, a flowchart is used to describe the **5** … . Then, if the simulation is to be conducted by a computer, a program is written, often in a special **6** … . A manual simulation may be conducted instead and involves the creation of a summary table and a description of the appropriate functional relationships.

Testing and validating the model. The simulation model must properly imitate the system under study. This involves the process of **7** … .

Design of the experiment. Once the model has been proved valid, the experiment is then designed. Included in this step is determining how long the **8** … should be run (when the experiment should be stopped) and whether all the data should be considered or the transient start-up data should be ignored. This step thus deals with two important and **9** … objectives: accuracy and cost.

Conducting the experiments. There are several types of simulation. Conducting the experiment may involve **10** … such as random number generation, stopping rules, and derivation of the results.

Evaluating the results. The final step, prior to **11** … , is the evaluation of the results. Here, we deal with such issues as: "What constitutes a significant difference?" "What do the results mean?" In addition to **12** … tools, we may also use a sensitivity analysis (in the form of "what if" questions). At this stage, we may even change the model and repeat the experiment.

Implementation. The implementation of simulation results involves the same issues as any other implementation. However, the chances of implementation are better since the manager is usually more involved in the simulation process than with **13** … .

Focus on Reading

Task 17. Match the words with the definitions. Use a dictionary for help [17].

1) steady	a) to enclose within a circle; surround
2) equilibrium	b) strictly correct in amount or value
3) queuing theory	c) an accumulation of uncompleted work, unsold stock, etc., to be dealt with
4) loop	d) free from fluctuation
5) encompass	e) any round or oval-shaped thing that is closed or nearly closed
6) precise	f) a state in which the energy in a system is evenly distributed and forces, influences, etc., balance each other
7) backlog	g) achieving the optimum flow

Task 18. Some of the key terms given above are used in the text (Task 19). Look through the text and underline them.

Task 19. Read the text carefully. Say whether the statements below are true or false.

1. Regular simulation models are most commonly meant to be evaluated under balanced state conditions.
2. Markov chains, queuing models, inventory, and almost all other management science models are applied differently.
3. The real world is static.
4. This engineering-oriented method is based on the concept that complex systems are never composed of chains of causes and effects known as feedback loops.
5. A decision or policy in one area produces a result in another area, which in turn produces the need for another decision or creates another result.

6. Forrester used the system dynamics model to study the effects of population growth on the use of natural resources only.

7. Additional computer runs were made involving only assumptions, such as doubling the estimate of natural resource reserves.

8. In contrast to the other simulation models, which are more precise and deal with policies, system dynamics deals with decision-making situations.

9. System dynamics models allow the manager to formulate several different policies and observe their effect through the feedback loops.

10. The policy that we might test is whether to manufacture or to supply a backlog from existing inventory.

11. The method always requires a computer to develop insight into problems.

System Dynamics

One of the most interesting types of simulation is system dynamics. Regular simulation models, as we have seen, are most commonly meant to be evaluated under steady state (equilibrium) conditions. The same applies to Markov chains, queuing models, inventory, and almost all other management science models. But the real world is not static, it continuously changes; therefore, a model is needed that will allow for dynamic behaviour.

Initiated in the 1960s by J. W. Forrester under the name "industrial dynamics", this engineering-oriented method is based on the concept that complex systems are usually composed of chains of causes and effects known as feedback loops. A decision or policy in one area (the cause) produces a result (effect) in another area, which in turn produces the need for another decision or creates another result. Two types of loops are considered: positive, where an increase in the cause results in an increase in the effect; and negative, where an increase-decrease relationship is observed (Fig. 5.1).

Forrester used the system dynamics model to study the effects of population growth on the use of natural resources. The results of his model indicated a potential disaster for the human species. Population was predicted to reach a peak in the year 2020 and then decline rapidly. Additional computer runs were made involving other assumptions, such as doubling the estimate of natural resource reserves; unlimited resources; population controls; pollution controls and increased agricultural productivity; and perfect birth control. Although the timing varies, all runs eventually ended with disaster.

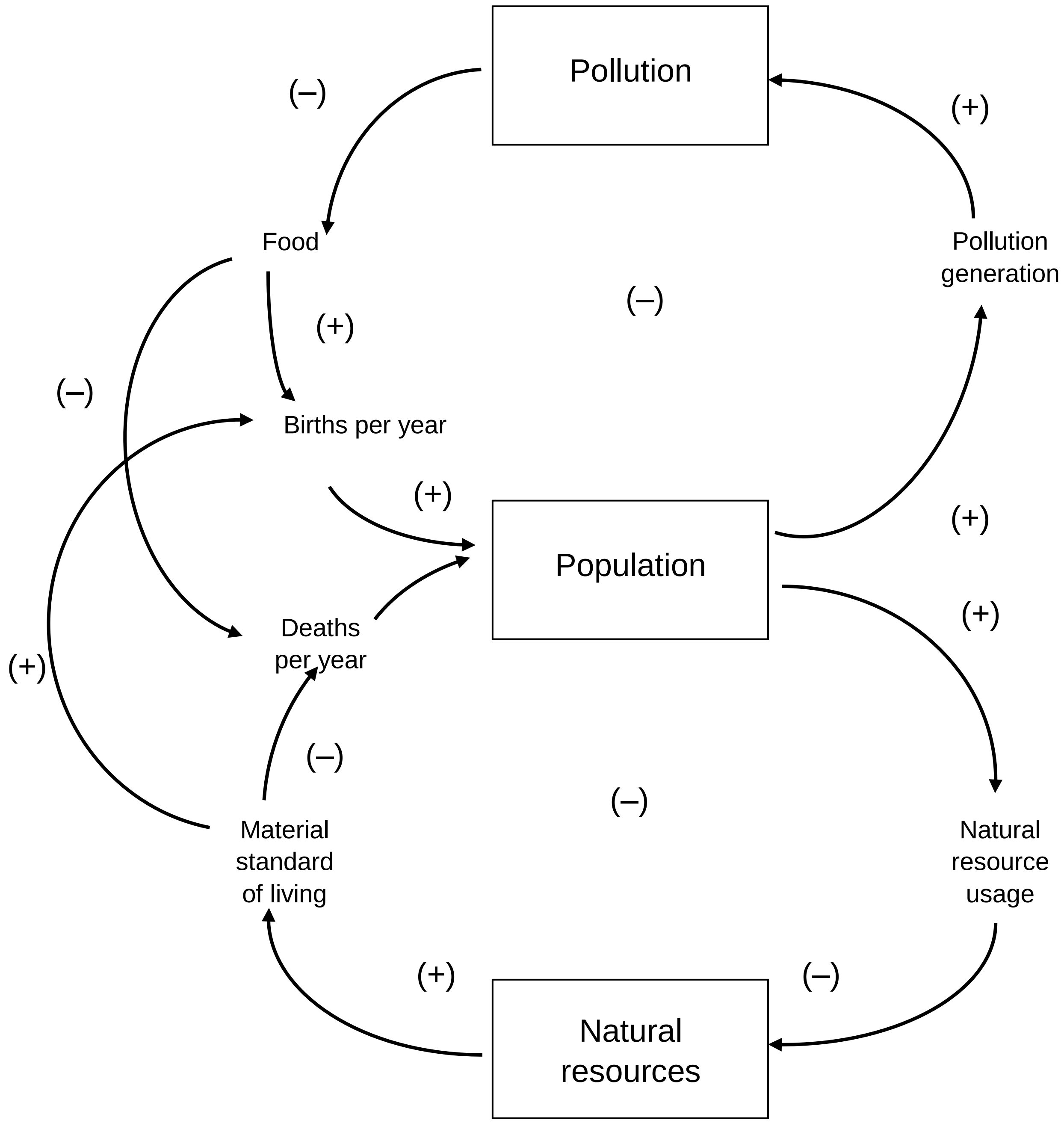


Fig. 5.1. **System dynamics feedback loops**

System dynamics has been used to encompass social, political, corporate, governmental, and even world systems. As with any other simulation, the method permits experimentation with a model of the system under study. However, in contrast to the other simulation models, which are more precise and deal with decision-making situations, system dynamics deals with policies. For example, a policy might state that our company will reduce the price whenever our major competitor reduces price. A decision would be the specific amount of price reduction (e.g., 5 percent). Thus, the focus here is on policymaking rather than decision making. System dynamics models allow the manager to formulate several different policies and observe their effect through the feedback loops. However, a precise impact is not given, only the general directions are provided (e.g., if price is increased, the sales volume will decline). The model, therefore, provides the manager with new insight about the system and its relationship with the environment.

System dynamics is composed of flowcharts coupled with equations that describe how the various elements of the system interact. An example is shown in Fig. 5.2. This example describes the savings of a person. The savings (a variable that can be accumulated, i.e., a level) is controlled by income and expenses (rate variables). There are several categories of income (salary and interest), whereby the interest is proportional to the savings. There are also several categories of expenses, namely bank fees, taxes, utility bills, and cost-of-living expenses. The bank fees are also proportional to the savings. If the parameters are set correctly, the modeler can observe whether his or her savings will grow over time, or whether they will get depleted. The two clouds represent sources and sinks of masses. These are dummy models in our library. They were only provided to maintain the look-and-feel of the System Dynamics methodology.

System dynamics models are generally associated with large computer simulations (via the special language DYNAMO). However, the method does not necessarily require a computer to develop insight into problems.

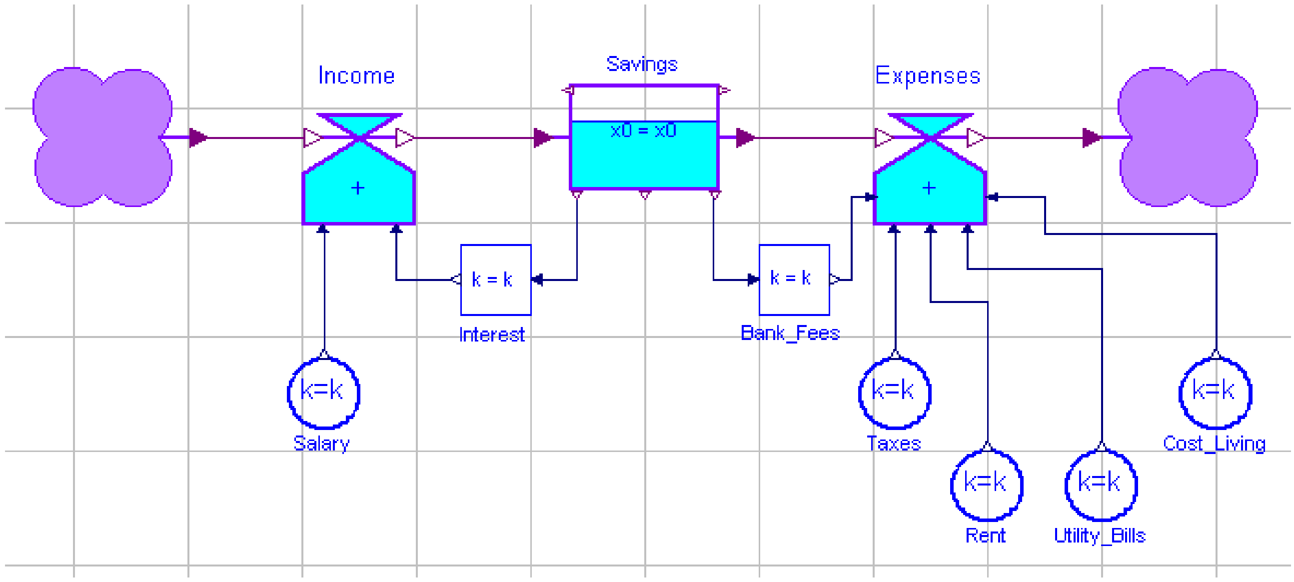


Fig. 5.2. **The system dynamics flowchart**

Task 20. Read the text (Task 19) again and answer the questions.

1. What are regular simulation models meant for?
2. What is this engineering-oriented method based on?
3. Why did Forrester use the system dynamics model?
4. What other assumptions were involved in additional computer runs?
5. Why has system dynamics been used?
6. What do system dynamics models allow the manager to do?
7. What is system dynamics composed of?
8. What are system dynamics models generally associated with?

Focus on Vocabulary

Task 21. Complete the text with the following words and phrases.

Attempt, multidimensional, statistics, assume, boundary, equal, numerical, random variables, originators, estimate, generating, simulation, methods, region.

The Monte Carlo method is a numerical method of solving mathematical problems by the simulation of **1** … .

The generally accepted birth date of the Monte Carlo method is 1949, when an article entitled "The Monte Carlo method" by Metropolis and Ulam appeared. The American mathematicians John von Neumann and Stanislav Ulam are considered its main **2** … .

Curiously enough, the theoretical foundation of the method had been known long before the von Neumann – Ulam article was published. Furthermore, well before 1949 certain problems in **3** … were sometimes solved by means of random sampling – that is, in fact, by the Monte Carlo method. However, because **4** … of random variables by hand is a laborious process, the use of the Monte Carlo method as a universal numerical technique became practical only with the advent of computers.

As for the name "Monte Carlo", it is derived from that city in the Principality of Monaco famous for its casinos. The point is that one of the simplest mechanical devices for **5** … random numbers is the roulette wheel. But it appears worthwhile to answer here one frequently asked question: "Does the Monte Carlo method help one win at roulette?" The answer is *No:* it is not even an **6** … to do so.

Example: the "Hit-or-Miss" method.

We begin with a simple example. Suppose that we need to compute the area of a plane figure *S.* This may be a completely arbitrary figure with a curvilinear **7** … ; it may be defined graphically or analytically, and be either connected or consisting of several parts. Let *S* be the **8** … drawn in Fig. 5.3, and let us **9** … that it is contained completely within a unit square.

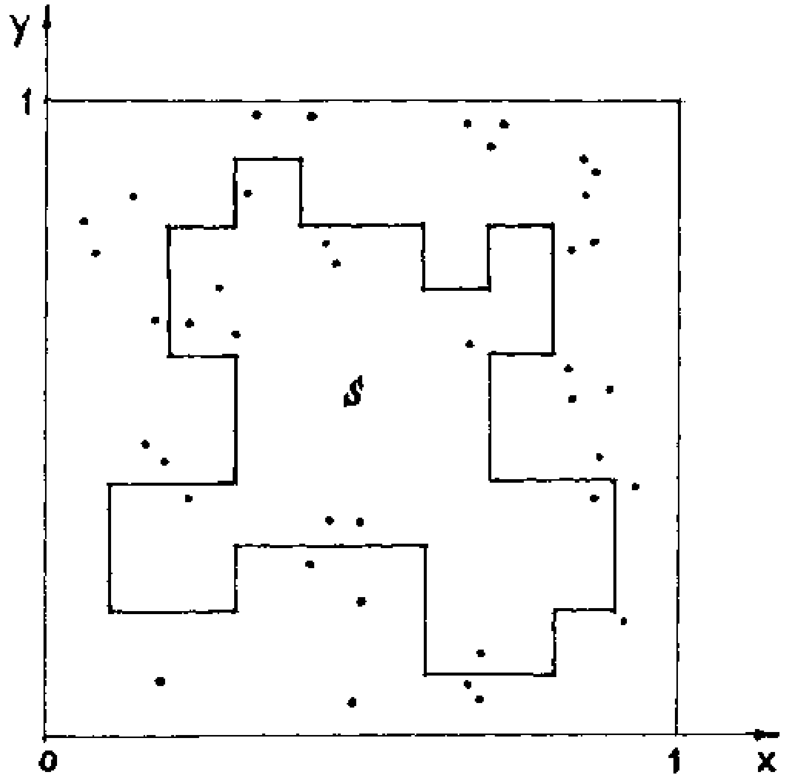


Fig. 5.3. ***N* random points in the square**

Of these, *N'* points are inside *S.* The area of *S* is approximately *N'/N.*

Choose at random *N* points in the square and designate the number of points that happen to fall inside *S* by *N'.* It is geometrically obvious that the area of *S* is approximately **10** … to the ratio *N'/N.* The greater the *N*, the greater the accuracy of this **11** … .

The number of points selected in Fig. 5.3 is *N* = 40. Of these, *N'* = 12 points appeared inside *S.* The ratio *N'* / *N* = 12 / 40 = 0.30, while the true area of *S* is 0.35.

In practice, the Monte Carlo method is not used for calculating the area of a plane figure. There are other **12** … (quadrature formulas) for this, that, though they are more complicated, provide much greater accuracy.

However, the hit-or-miss method shown in our example permits us to estimate, just as simply, the "multidimensional volume" of a body in a **13** …

space; in such a case the Monte Carlo method is often the only **14** … method useful in solving the problem.

(Adapted from [13]).

Task 22. Describe the model Fig. 5.2 (Task 19).

Focus on Listening

Task 23. Give your association with the word "simulation".

Task 24. Discuss with your partner what simulation is and why we use it.

Task 25. Watch Video 5.1 "What is Simulation" and compare your answers. Do they have the same ideas? [https://www.youtube.com/watch?v=LEFK_hMu9PU]

Task 26. Complete the sentences, then watch Video 5.1 (Task 25) again and check them.

1. Simulation is … .
2. Simulation can provide … .
3. FlexSim is powerful simulation software, built from … to make simulation … , without … .
4. FlexSim is a problem solving tool that allows you to … .
5. You'll save time and … .

Task 27. Give the main idea of the text (Task 25).

Task 28. Discuss with your partner the reality of this statement "Inside the simulation you cannot tell any differences between the simulated environment, the virtual reality, and the real environment. In fact this environment we now find ourselves in could be just a simulation".

Task 29. Watch Video 5.2 "Simulation theory" and compare your answers. Do they have the same ideas? [https://www.youtube.com/watch?v=VU1skKoao6Q]

Task 30. Give the main idea of simulation theory (Task 29). Discuss with your partner pros and cons of applying it.

Focus on Speaking

Task 31. Work in pairs and complete each sentence.

1. Sunny's first approach to the data collection problem was … .
2. Sunny can get answers to all her questions by using … .
3. Simulation is not limited to waiting … .
4. Simulation can be applied to … .
5. To simulate means to assume … .
6. Simulation is not strictly a type … .
7. Simulation is a technique for … .
8. Simulation is a descriptive rather than … .
9. A simulation describes and/or predicts the characteristics of … .
10. The simulation process often consists of … .
11. The simulation model is simply the aggregate of … .
12. Simulation allows for inclusion of … .
13. Regular simulation models are most commonly meant … .
14. The real world is not static, it continuously changes; so, a model is needed that … .
15. This engineering-oriented method is based on … .
16. Forrester used the system dynamics model to study … .
17. In contrast to the other simulation models, which are more precise and deal with … .
18. System dynamics models allow the manager … .
19. The method does not necessarily require … .

Task 32. Describe the process of simulation in Fig 5.4.

Focus on Questions and Problems

Task 33. Read the statements and identify which types of simulation can be used in each of the following tasks:

a. Writing poetry.
b. Analyzing biblical passages to determine the author.
c. Determining the effect of monetary policy on a national economy.
d. Locating the most profitable sites for a chain of restaurants.
e. Learning how to run a blast furnace.
f. Imitating a controller's bond purchasing decision.

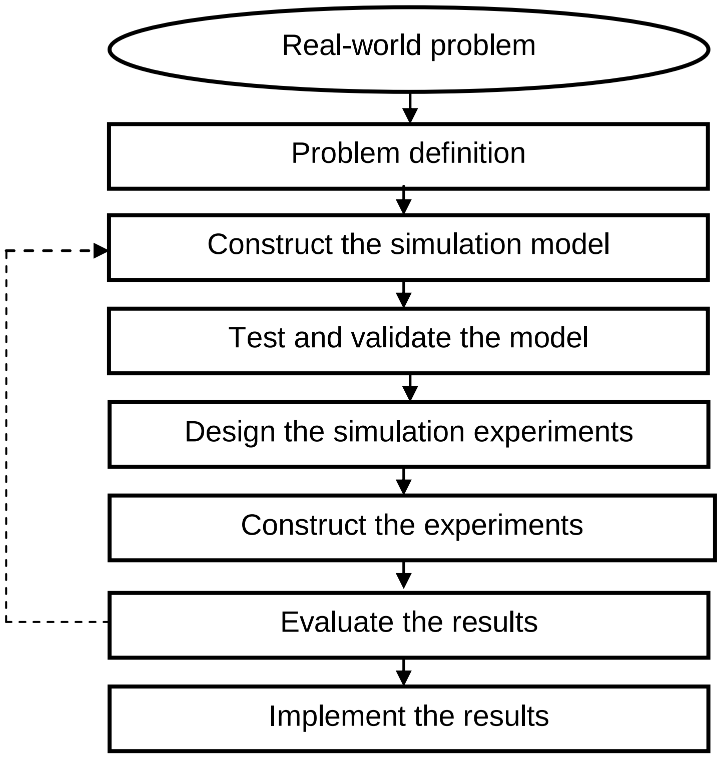


Fig. 5.4. **The process of simulation**

Task 34. Read the text, describe visual interactive decision making and explain its contribution to improved problem solving.

Visual Interactive Simulation

One of the most interesting developments in computer graphics is visual interactive simulation (VIS). The technique, also known as visual interactive modeling, or visual interactive problem solving, has been used in the area of management science with unusual success.

VIS uses computer graphic displays to present the impact of various managerial decisions, thereby differing from regular computer graphics that use the screen simply as a communication device for presenting numeric data. Also, VIS can represent either a static or dynamic system. Static models display a visual image of the result of one decision alternative at a time. (With computer windows, several results can be compared on one screen.) Dynamic models display systems that *evolve* over time, the evolution being represented by animation.

VIS is a decision simulation using visual interactive modeling. The end user watches the progress of the simulation in an animated form on a graphics terminal and interacts with and alters the simulation through various decision strategies.

Task 35. Read the text and then discuss the statements and questions contained in it.

Heuristic Programming

The determination of optimal solutions to some complex decision problems could involve a prohibitive amount of time and cost, or it may even be an impossible task. In such situations, it is sometimes possible to arrive at satisfactory solutions more quickly and less expensively by using heuristics, frequently within a simulation routine. Though not a form of simulation itself, this technique is so common we include a discussion of the approach in this chapter on simulation.

Heuristics (from the Greek word for "discovery") are step-by-step procedures that, in a finite number of steps, arrive at a satisfactory solution. (Note that an algorithm also progresses step-by-step toward a solution, but an optimal one). It is important to note the difference between heuristics and rules of thumb. A rule of thumb is usually developed as a result of a trial-and-error experience. It does not possess any analytical foundation.

Heuristics, on the other hand, are rules that are developed on the basis of a solid and rigorous analysis of the problem, possibly with designed experimentation.

While heuristics are used primarily for solving ill-structured problems, they can also be used to provide satisfactory solutions to certain complex, well-structured problems much more quickly and cheaply than algorithms. The main difficulty in using heuristics is that they are not as general as algorithms. Therefore, they can normally be used only for the specific situation for which they were intended.

Heuristic programming is the approach of employing heuristics to arrive at feasible and "good enough" solutions to such complex problems, similar to the use of heuristic rules in expert systems. "Good enough" is usually in the range of 90 – 99.9 percent of the true optimal solution (depending on the problem and the proposed heuristic). Heuristic programs are usually executed by a computer, although a manual execution is possible in simple cases.

For example, in evaluating investments in the stock market, the investor may have rules such as this; "Only companies whose assets are at least three times larger than their liabilities should be considered". The employment of several similar rules may reduce the number of feasible investment alternatives from thousands to a dozen.

In studying examples of applied heuristic programming, one can observe that the computer attempts to reduce the amount of search for a satisfactory solution. In such a search, the computer is "taught" how to explore only relatively fertile paths and ignore relatively sterile ones. The computer choices are made by using heuristics that can be improved in the course of the search (through learning, as with expert systems).

Heuristic programming has been used to help solve problems such as:

- Sales forecasting.
- Investment decisions (portfolios of stock).
- Facilities location.
- Job shop scheduling.
- Work force and production level determination.
- Plant layout.
- Large project scheduling.
- Inventory control.
- Balancing assembly lines.

With the reduction in cost of using computers, there is an increased tendency to use heuristics as an alternative to optimization methods. Heuristics can be fun to develop and use.

1. Give some examples of heuristics.
2. You are looking for syrup in a new grocery store. What heuristics do you employ?
3. You have the following weekend jobs facing you:

- hanging a picture;
- mowing a lawn;
- walking a dog;
- tuning up the car;
- cleaning out the garage.

In what order would you choose to do these? What heuristic decision rules did you employ to choose this order?

(Adapted from [15])

Unit 6. Game Theory

Task 1. Answer the questions.

1. What is Game Theory?
2. What do you know about Game Theory?

Task 2. Translate these words and phrases into you native language.

trace	
theory of games	
economic behavior	
game theory models	
experimental games	
evolutionary biology	
behavioral sciences	

Task 3. Read the text and answer the questions.

1. When did some game theory ideas start?
2. When did the major development of the theory take place?
3. What was the turning point for the development of the theory?
4. When was the theory of games used in economic theory and political science?
5. When were game theoretic methods applied in many different fields?
6. Who was awarded the Nobel Prize in economics and when?

An Outline of the History of Game Theory

Some game theory ideas can be traced to the 18th century, but the major development of the theory began in the 1920s with the work of the mathematician Emile Borel (1871 – 1956) and the polymath John von Neumann (1903 – 1957). A decisive event in the development of the theory was the publication in 1944 of the book "Theory of Games and Economic Behavior" by von Neumann and Oskar Morgenstern. In the 1950s game theory models began to be used in economic theory and political science, and psychologists began studying how human subjects behave in experimental games. In the 1970s game theory was first used as a tool in evolutionary biology.

Subsequently, game theoretic methods have come to dominate microeconomic theory and are also used in many other fields of economics and a wide range of other social and behavioral sciences. The 1994 Nobel Prize in economics was awarded to the game theorists John C. Harsanyi (1920 – 2000), John F. Nash (1928 – 2016), and Reinhard Selten (1930).

(Adapted from [11])

Task 4. Discuss with your partner the evolution of game theory (Task 3).

Focus on Reading

Task 5. Study this example and answer the questions.

1. What kind of problem was General Kenney faced in 1943?
2. What was Kenney's mission?
3. What did the Japanese have?
4. What was Kenney's problem?

In 1943, General Kenney, commander of the Allied Air Forces in the Southwest Pacific, faced with a problem. The Japanese were about to reinforce their army in New Guinea from their base in New Britain. Kenney's mission was to bomb and destroy the convoy of reinforcements. The Japanese had a choice of alternative sailing routes. They could either sail north of New Britain, where the weather was rainy and visibility poor for reconnaissance, or southward, where the weather was generally fair. In either case, the journey would take three days. Kenney's problem was to decide where to concentrate the bulk of his reconnaissance aircraft to search for the convoy. The Japanese wanted their ships to have minimal exposure to enemy bombers and, of course, Kenney wanted as many days of bombing exposure as possible.

The following were the possible "days of bombing exposure":

1. If Kenney concentrated his aircraft on the northern route and the Japanese sailed north, the Japanese would not be found until the second day. There would thus be two days of exposure.

2. If Kenney concentrated on the northern route and the Japanese sailed south, they might easily be missed on the first day. There would again be two days of exposure.

3. If Kenney concentrated on the southern route and the Japanese sailed north, they would not be discovered until the third day, resulting in only one day of exposure.

4. If Kenney concentrated on the southern route and the Japanese sailed south, they would be sighted immediately for three full days of exposure.

The problem faced by both sides was what course of action to take.

(Adapted from [15])

Task 6. Discuss with your partner what were the possible "days of bombing exposure". Compare your answer with the information from the text (Task 7).

Task 7. Read the text carefully. Say whether the statements below are true or false.

1. Game theory aims to hinder us from understanding situations in which decision-makers interact.
2. A game in the everyday sense is "a competitive activity … in which players contend with each other according to a set of rules".
3. A model involves our perceiving relationships between situations, isolating principles that apply to a range of problems, so that we can fit into our thinking any situations that we encounter.
4. A model is not unlikely to help us understand a phenomenon if its assumptions are wildly at odds with our observations.
5. A model derives power from its simplicity; the assumptions upon which it rests should capture irrelevant details.
6. Models can be judged by an absolute criterion: they are neither "right" nor "wrong".
7. One reason for improving our understanding of the world is to enhance our ability to form it to our desires.
8. Studying game theoretic models may also suggest ways in which our behavior may be modified to improve our own welfare.
9. Verbal descriptions tend to be short and imprecise.
10. Game-theoretic modeling starts with an idea related to some aspect of the interaction of decision-makers.
11. Our analysis may yield results that verify our idea, or that suggest it is wrong.

12. The interaction between our ideas and models designed to shed light on them runs in only one direction.

What Is Game Theory?

Game theory aims to help us understand situations in which decision-makers interact. A game in the everyday sense – "a competitive activity … in which players contend with each other according to a set of rules", in the words of my dictionary – is an example of such a situation, but the scope of game theory is vastly larger. Indeed, Martin Osborne devotes very little space to games in the everyday sense; his main focus is the use of game theory to illuminate economic, political, and biological phenomena.

A list of some of the applications he discusses will give you an idea of the range of situations to which game theory can be applied: firms competing for business, political candidates competing for votes, jury members deciding on a verdict, animals fighting over prey, bidders competing in an auction, the evolution of siblings' behavior towards each other, competing experts' incentives to provide correct diagnoses, legislators' voting behavior under pressure from interest groups, and the role of threats and punishment in long-term relationships.

Like other sciences, game theory consists of a collection of models. A model is an abstraction we use to understand our observations and experiences. What "understanding" entails is not clear-cut. Partly, at least, it entails our perceiving relationships between situations, isolating principles that apply to a range of problems, so that we can fit into our thinking new situations that we encounter. For example, we may fit our observation of the path taken by a lobbed tennis ball into a model that assumes the ball moves forward at a constant velocity and is pulled towards the ground by the constant force of "gravity". This model enhances our understanding because it fits well no matter how hard or in which direction the ball is hit, and applies also to the paths taken by baseballs, cricket balls, and a wide variety of other missiles, launched in any direction.

A model is unlikely to help us understand a phenomenon if its assumptions are wildly at odds with our observations. At the same time, a model derives power from its simplicity; the assumptions upon which it rests should capture the essence of the situation, not irrelevant details. For example, when considering the path taken by a lobbed tennis ball we should ignore the dependence of the force of gravity on the distance of the ball from the surface of the earth.

Models cannot be judged by an absolute criterion: they are neither "right" nor "wrong". Whether a model is useful or not depends, in part, on the purpose for which we use it. For example, when we determine the shortest route from Florence to Venice, we do not worry about the projection of the map we are using; we work under the assumption that the earth is flat. When we determine the shortest route from Beijing to Havana, however, we pay close attention to the projection – we assume that the earth is spherical. And were we to climb the Matterhorn we would assume that the earth is neither flat nor spherical!

One reason for improving our understanding of the world is to enhance our ability to mold it to our desires. The understanding that game theoretic models give is particularly relevant in the social, political, and economic arenas. Studying game theoretic models (or other models that apply to human interaction) may also suggest ways in which our behavior may be modified to improve our own welfare. By analyzing the incentives faced by negotiators locked in battle, for example, we may see the advantages and disadvantages of various strategies.

The models of game theory are precise expressions of ideas that can be presented verbally. However, verbal descriptions tend to be long and imprecise; in the interest of conciseness and precision, we frequently use mathematical symbols when describing models. Although we use the language of mathematics, we use few of its concepts. Our aim is to take advantage of the precision and conciseness of a mathematical formulation without losing sight of the underlying ideas.

Game-theoretic modeling starts with an idea related to some aspect of the interaction of decision-makers. We express this idea precisely in a model, incorporating features of the situation that appear to be relevant. This step is an art. We wish to put enough ingredients into the model to obtain nontrivial insights, but not so many that we are led into irrelevant complications; we wish to lay bare the underlying structure of the situation as opposed to describe its every detail. The next step is to analyze the model – to discover its implications. At this stage we need to adhere to the rigors of logic; we must not introduce extraneous considerations absent from the model. Our analysis may yield results that confirm our idea, or that suggest it is wrong. If it is wrong, the analysis should help us to understand why it is wrong. We may see that an assumption is inappropriate, or that an important element is missing from the model; we may conclude that our idea is invalid, or that we need to investigate it further by studying a different model. Thus, the interaction between our ideas and models designed to shed light on them runs in two directions: the implications of models help us determine whether our ideas make sense, and these ideas, in the light of the implications of the models, may show us how the assumptions of our models are inappropriate. In either case, the process of formulating and analyzing a model should improve our understanding of the situation we are considering.

(Adapted from [11])

Task 8. Read the text (Task 7) again and answer the questions.

1. What is the definition of the notion "game"?
2. Where can game theory be applied?
3. What does game theory consist of?
4. What is the reason for improving our understanding of the world?
5. What are the steps that can help express the idea in a model, incorporating features of the situation that appear to be relevant?
6. What are two directions that can shed light on the ideas?

Task 9. Discuss with your partner what game theory is.

Focus on Vocabulary

Task 10. Complete the text with the following words and phrases.

Measured, terminology, decision making, simultaneous, maximize, game theory, circumstance, complex, strategies, decisions, format, viewed, welfare, express, participants, consequences, information.

The Nature of Game Theory Problems

The military situation just presented illustrates **1** … under conflict or competition. Its main characteristic is that two or more decision makers are involved and the **2** … (payoff) to each depend on the courses of action taken by all. Further, objectives do not coincide and may, as illustrated in the military example, be completely resisted. As a matter of fact, each party is usually trying to **3** … his or her overall welfare at the expense of the others.

Such situations are similar to parlor and other types of games. For this reason the name "game theory" was adopted. Yet, situations analyzed with the aid of this tool are a far cry from "games". Marketing strategies, international military conflicts, labor-management negotiations, and potential mergers are just a few examples of real-life **4** … problems.

The complexity of game theory problems

The presence of two or more decision makers with conflicting objectives makes decision making **5** … for mathematical analysis. Game theory thus evolved as a mathematical process for formally developing optimal **6** … for problems under competition or conflict.

Methodology of game theory

The managerial situation, problem, or conflict is presented in game **7**… . The decision makers are **8** … as players. Game theory aims at prescribing optimal playing strategies for the participants. A strategy is defined as a complete, predetermined plan for selecting a course of action, under every possible **9** … . An optimal strategy is the best among all possible strategies. In addition, the model computes the long-run payoffs or consequences of the decisions to all parties involved.

Format, assumptions, and classification of games

The military conflict example will be used to illustrate the presentation of the basic format of games and the related **10** … .

The format of games and major assumptions

Games are arranged in a standard format. Certain rules and regulations that **11** … the assumptions apply, and a specially developed terminology is used. The major aspects of the format concern:

1. The number of **12** … (termed "players"). The military example involved two players. In other situations three, four, or more players may participate. A player can be a single individual or a group of individuals with the same objective.

2. Timing. It would have been easier for Kenney if he could have delayed his decision until the Japanese made their move (and vice versa). However, both had to decide simultaneously. **13** … decisions are assumed in all game situations.

3. Conflicting goals. Each party is interested in maximizing his or her **14** … at the expense of the other.

4. Repetition. The military conflict is an example of a one-shot decision, which is termed "a play". A series of repetitive **15** … (plays) is called "a game". It is generally assumed that most instances involve repetitive situations.

5. Payoff. The consequence of the decisions of the opponents in the military conflict was **16** … in terms of days of bombing exposure. Such results are called payoffs. The average payoff per play is termed "the value of the game". A game whose value is zero is called "a fair game".

6. Information availability. Both Kenney and the Japanese were aware of all pertinent information. In general, it is assumed that each player knows all possible courses of action (finite number) open to the opponent as well as all anticipated payoffs. The cost of collecting this **17** … is not considered relevant to the formal analysis.

Focus on Reading

Task 11. Match the words with the definitions. Use a dictionary for help [17].

1) bid	a) a stable condition in which forces cancel one another
2) payoff	b) having the nature of an image or portrait
3) seal	c) to overcome in a battle or other contest
4) row	d) to admit or grant to be true; concede
5) saddle	e) including or covering everything
6) equilibrium	f) to hold or take part in a conference or consult together
7) iconic	g) not guilty of a particular crime; blameless
8) defeat	h) to settle or decide
9) overall	i) with a task, responsibility
10) confer	j) to offer (an amount) in attempting to buy something, esp. in competition with others as at an auction
11) confess	k) a horizontal rank of squares on a chessboard
12) innocent	l) the final settlement

Task 12. Some of the key terms given above are used in the text (Task 14). Look through the text and underline them.

Task 13. Read the text below (Task 14) and choose the best heading to each of its parts.

A. A Beautiful Mind.

B. Repetitive Games.

C. Two-Person Zero-Sum Games.

D. When Is a Game Determined?

E. When Is a Game not Zero-Sum?

Task 14. Read the text carefully. Say whether the statements below are true or false.

1. John von Neumann was a child prodigy who became a legend in the economic world.
2. Neumann made contributions only to quantum mechanics, logic, algebra.
3. A two-person zero-sum game is simply one "played" by three people, companies, or teams, in which one side wins what the other loses.
4. Each company must make a bid for each country and they will base their decision on the projected increased size of their viewing audiences.
5. Obviously both companies act in each other's best interests.
6. BTV is in a stronger position and can work out a strategy that limits its potential losses and hope for a better payoff table next year.
7. John F. Nash (1928 – 2016) won the Nobel Prize in Economics in 1984 for his contributions to game theory.
8. Nash and others extended game theory to the case of more than two players and to games where cooperation between players occurs, including ganging up on a third player.
9. In this game the maximum of {+1, −1, −3} is equal to the minimum of {+4, +5, +1} and both sides of the equation have the common value of +1.
10. The iconic repetitive game is a very rare game of "paper, scissors, stone".
11. If a player once chooses the same action, say paper, the opponent will detect this and simply choose scissors to win every time.
12. According to the mathematics, players should choose randomly but overall the choices of paper, scissors, stone should each be made a third of the time.
13. The payoffs, in this case jail sentences, only depend on their individual responses to police questioning rather than on how they jointly respond.

14. If the prisoners could cooperate, they would take the optimum course of action and not confess – this would be the "win-win" situation.

Game Theory

Some said Johnny was the smartest person alive. John von Neumann was a child prodigy who became a legend in the mathematical world. When people heard that he arrived at a meeting in a taxi having just scribbled out his "minimax theorem" in game theory, they just nodded. It was exactly the sort of thing von Neumann did. He made contributions to quantum mechanics, logic, algebra, so why should game theory escape his eye? It didn't – with Oskar Morgenstern he coauthored the influential Theory of Games and Economic Behavior. In its widest sense game theory is an ancient subject, but von Neumann was key to sharpening the theory of the "two-person zero-sum game".

1. ...

It sounds complicated, but a two-person zero-sum game is simply one "played" by two people, companies, or teams, in which one side wins what the other loses. If A wins £200 then B loses that £200; that's what zero-sum means. There is no point in A cooperating with B – it is pure competition with only winners and losers. In "win-win" language A wins £200 and B wins −£200 and the sum is 200 + (−200) = 0. This is the origin of the term "zero-sum".

Let's imagine two TV companies ATV and BTV are bidding to operate an extra news service in either Scotland or England. Each company must make a bid for one country only and they will base their decision on the projected increased size of their viewing audiences. Media analysts have estimated the increased audiences and both companies have access to their research. These are conveniently set down in a "payoff table" and measured in units of a million viewers.

		BTV	
		Scotland	England
ATV	Scotland	+5	−3
	England	+2	+4

If both ATV and BTV decide to operate in Scotland then ATV will gain 5 million viewers, but BTV will lose 5 million viewers. The meaning of the minus sign, as in the payoff −3, is that ATV will lose an audience of 3 million. The "+" payoffs are good for ATV and the "−" payoffs are good for BTV.

We'll assume the companies make their one-off decisions on the basis of the payoff table and that they make their bids simultaneously by sealed bids. Obviously both companies act in their own best interests.

If ATV chooses Scotland, the worst that could happen would be a loss of 3 million; if it bids for England, the worst would be a gain of 2 million. The obvious strategy for ATV would be to choose England (row 2). It couldn't do worse than gain 2 million viewers whatever BTV chooses. Looking at it numerically, ATV works out −3 and 2 (the row minimums) and chooses the row corresponding to the maximum of these.

BTV is in a weaker position but it can still work out a strategy that limits its potential losses and hope for a better payoff table next year. If BTV chooses Scotland (column 1), the worst that could happen would be a loss of 5 million; if it chooses England, the worst would be a loss of 4 million. The safest strategy for BTV would be to choose England (column 2) for it would rather lose an audience of 4 million than 5 million. It couldn't do worse than lose 4 million viewers whatever ATV decides.

2. ...

John F. Nash (1928 – 2016) whose troubled life was portrayed in the 2001 movie "A Beautiful Mind" won the Nobel Prize in Economics in 1994 for his contributions to game theory.

Nash and others extended game theory to the case of more than two players and to games where cooperation between players occurs, including ganging up on a third player. The "Nash equilibrium" (like a saddle point equilibrium) gave a much broader perspective than that set down by von Neumann, resulting in a greater understanding of economic situations.

These would be the safest strategies for each player and, if followed, ATV would gain 4 million extra viewers while BTV loses them.

3. ...

The following year, the two TV companies have an added option – to operate in Wales. Because circumstances have changed there is a new payoff table.

		BTV				row minimum
		Wales	Scotland	England		
ATV	Wales	+3	+2	+1		+1
	Scotland	+4	−1	0		−1
	England	−3	+5	−2		−3
	column maximum	+4	+5	+1		

As before, the safe strategy for ATV is to choose the row which maximizes the worst that can happen. The maximum from {+1, −1, −3} is to choose Wales (row 1). The safe strategy for BTV is to choose the column which minimizes from {+4, +5, +1}. That is England (column 3).

By choosing Wales, ATV can guarantee to win no less than 1 million viewers whatever BTV does, and by choosing England (column 3), BTV can guarantee to lose no more than 1 million viewers whatever ATV does. These choices therefore represent the best strategies for each company, and in this sense the game is determined (but it is still unfair to BTV). In this game the maximum of {+1, −1, −3} = the minimum of {+4, +5, +1} and both sides of the equation have the common value of +1. Unlike the first game, this version has a "saddle-point" equilibrium of +1.

4. ...

The iconic repetitive game is the traditional game of "paper, scissors, stone". Unlike the TV company game which was a one-off, this game is usually played half a dozen times, or a few hundred times by competitors in the annual World Championships.

	paper	scissors	stone		row minimum
paper	draw = 0	lose = −1	win = +1		−1
scissors	win = +1	draw = 0	lose = −1		−1
stone	lose = −1	win = +1	draw = 0		−1
column maximum	+1	+1	+1		

In "paper, scissors, stone", two players show either a hand, two fingers, or a fist, each symbolizing paper, scissors or stone. They play simultaneously on the count of three: paper draws with paper, is defeated by scissors (since scissors can cut paper), but defeats stone (because it can wrap stone). If playing "paper" the payoffs are therefore 0, −1, +1, which is the top row of our completed payoff table.

There is no saddle point for this game and no obvious pure strategy to adopt. If a player always chooses the same action, say paper, the opponent will detect this and simply choose scissors to win every time. By von Neumann's "minimax theorem" there is a "mixed strategy" or a way of choosing different actions based on probability.

According to the mathematics, players should choose randomly but overall the choices of paper, scissors, stone should each be made a third of the time. "Blind" randomness may not always be the best course, however, as world champions have ways of choosing their strategy with a little "psychological" spin. They are good at second-guessing their opponents.

5. ...

Not every game is zero-sum – each player sometimes has their own separate payoff table. A famous example is the "prisoner's dilemma" designed by A. W. Tucker.

Two people, Andrew and Bertie, are picked up by the police on suspicion of highway robbery and held in separate cells so they cannot confer with each other. The payoffs, in this case jail sentences, not only depend on their individual responses to police questioning but on how they jointly respond. If A confesses and B doesn't then A gets only a one year sentence (from A's payoff table) but B is sentenced to ten years (from B's payoff table). If A doesn't confess but B does, the sentences go the other way around. If both confess, they get four years each but if neither confesses and they both maintain their innocence, they get off scot-free!

<table>
<tr><th colspan="2" rowspan="2">A</th><th colspan="2">B</th></tr>
<tr><th>confess</th><th>not confess</th></tr>
<tr><td rowspan="2">A</td><td>confess</td><td>+4</td><td>+1</td></tr>
<tr><td>not confess</td><td>+10</td><td>0</td></tr>
</table>

<table>
<tr><th colspan="2" rowspan="2">B</th><th colspan="2">B</th></tr>
<tr><th>confess</th><th>not confess</th></tr>
<tr><td rowspan="2">A</td><td>confess</td><td>+4</td><td>+10</td></tr>
<tr><td>not confess</td><td>+1</td><td>0</td></tr>
</table>

If the prisoners could cooperate, they would take the optimum course of action and not confess – this would be the "win-win" situation.

(Adapted from [4])

Task 15. Read the text (Task 14) again and answer the questions.

1. Did game theory escape John von Neumann's eye?
2. What did von Neumann contribute to the theory of the "two-person zero-sum game"?
3. What is the main idea of a two-person zero-sum game?
4. What happened with two TV companies ATV and BTV?
5. What did John F. Nash win the Nobel Prize for and when?
6. What happened when the two TV companies had an added option – to operate in Wales?
7. What is the main idea of a "paper, scissors, stone" game?
8. When would the "win-win" situation be?

Focus on Vocabulary

Task 16. Complete the text with the following words and phrases.

Sequence, normal, environments, single, decision, loss, concentrate, preference, top, payoff, analysis, game.

Presentation of games. Games are presented either in tabular (termed normal) or tree (termed extensive) form, depending on **1** … and the type of **2** … or experimentation to be performed. A tree form presents a **3** … of decisions based on accumulated information and previous decisions.

The normal form (a tabular presentation). A game is said to be in **4** … form when the entire sequence of decisions that must be made throughout the game is lumped together in a **5** … strategy. This is the common form of games. This form is limited to the case of two players.

An example of the normal form presentation using the military conflict (Task 31). In this situation, there were two **6** … makers: Kenney, with two possible courses of action: a_1, **7** … on the northern route, or a_2, concentrate on the southern route; and the Japanese, who had to decide either to sail north, (b_1), or south (b_2). The above situation is presented in normal form as a **8** … table in Table 6.1.

Table 6.1

The military conflict as a game payoff table

Japan / Allies	North, b_1	South, b_2
Northern, a_1	2	2
Southern, a_2	1	3

A game payoff table is similar to a decision payoff table. The difference between the two is that in a decision table, there is only one decision maker who makes decisions in uncertain **9** …, expressed as "states of nature". In the game table, on the other hand, there are two decision makers, one on the left and the other at the top. (For this reason, a decision table is sometimes viewed as a "one-player **10** … against nature"). The information in the cells is the payoff (the number of exposure days, in this case). A positive number means a gain to the player situated at the left side of the table ("Allies" in Table 6.1). This gain is the **11** … of the player situated at the top of the table (Japan). A negative number means a loss to the player situated at the left and a gain to the player at the **12** … of the table.

(Adapted from [11])

Focus on Reading

Task 17. Match the words with the definitions. Use a dictionary for help [17].

1) bundle	a) compressed into a small area
2) impose	b) to give out or allot (a task, problem, etc.)
3) altruistic	c) to obtain (a function) by differentiation
4) derive	d) to attempt to persuade or entice to do something
5) implication	e) a number of things or a quantity of material gathered or loosely bound together
6) convey	f) take advantage of
7) tempt	g) the principle or practice of unselfish concern for the welfare of others
8) assign	h) to conduct, transmit, or transfer
9) succinct	i) something that is implied; suggestion

Task 18. Some of the key terms given above are used in the text (Task 19). Look through the text and underline them.

Task 19. Read the text carefully. Say whether the statements below are true or false.

1. The theory of rational choice is a component of only one model in game theory.
2. The theory is based on a model with three components.
3. The decision-maker knows this subset of available choices, and takes it as given.
4. As to preferences, we assume that the decision-maker, when presented with any pair of actions, does not know which of the pair he prefers.
5. How can we describe a decision-maker's preferences? There are many ways to specify, for each possible pair of actions, the action the decision-maker prefers, or to note that the decision-maker is indifferent between the actions.
6. A decision-maker's preferences, in the sense used here, convey only ordinal information.
7. A decision-maker's preferences are represented by one payoff function.
8. The theory of rational choice is that in any given situation the decision-maker chooses the member of the available subset of *A* that is best according to her preferences.
9. In the theory of the firm, the set of available actions is the set of one input-output vector, and the action *a* is preferred to the action *b* if and only if *a* yields a higher profit than does *b*.
10. The theory of rational choice is enormously successful; it is a component of few models that enhance our understanding of social phenomena.

The Theory of Rational Choice

The theory of rational choice is a component of many models in game theory. Briefly, this theory is that a decision-maker chooses the best action according to his preferences, among all the actions available to him. No qualitative restriction is placed on the decision-maker's preferences; his "rationality" lies in the consistency of his decisions when faced with different sets of available actions, not in the nature of his likes and dislikes.

Actions

The theory is based on a model with two components: a set A consisting of all the actions that, under some circumstances, are available to the decision-maker, and a specification of the decision-maker's preferences. In any given situation the decision-maker is faced with a subset of A, from which he must choose a single element. The decision-maker knows this subset of available choices, and takes it as given; in particular, the subset is not influenced by the decision-maker's preferences. The set A could, for example, be the set of bundles of goods that the decision-maker can possibly consume; given his income at any time, he is restricted to choose from the subset of A containing the bundles he can afford.

Preferences and payoff functions

As to preferences, we assume that the decision-maker, when presented with any pair of actions, knows which of the pair he prefers, or knows that he regards both actions as equally desirable (is "indifferent between the actions"). We assume further that these preferences are consistent in the sense that if the decision-maker prefers the action a to the action b, and the action b to the action c, then he prefers the action a to the action c. No other restriction is imposed on preferences. In particular, we do not rule out the possibility that a person's preferences are altruistic in the sense that how much he likes an outcome depends on some other person's welfare. Theories that use the model of rational choice aim to derive implications that do not depend on any qualitative characteristic of preferences.

How can we describe a decision-maker's preferences? One way is to specify, for each possible pair of actions, the action the decision-maker prefers, or to note that the decision-maker is indifferent between the actions. Alternatively we can "represent" the preferences by a *payoff function*, which associates a number with each action in such a way that actions with higher numbers are preferred. More precisely, the payoff function u represents a decision-maker's preferences if, for any actions a in A and b in A,

$$u(a) > u(b) \text{ if and only if the decision-maker prefers } a \text{ to } b. \qquad (6.1)$$

(A better name than "payoff function" might be "preference indicator function"; in economic theory a payoff function that represents a consumer's preferences is often referred to as a "utility function).

A decision-maker's preferences, in the sense used here, convey only ordinal information. They may tell us that the decision-maker prefers the action a to the action b or/and to the action c, for example, but they do not tell us "how much" he prefers a to b, or whether he prefers a to b "more" than he prefers b to c. Consequently a payoff function that represents a decision-maker's preferences also conveys only ordinal information. It may be tempting to think that the payoff numbers attached to actions by a payoff function convey intensity of preference – that if, for example, a decision-maker's preferences are represented by a payoff function u for which $u(a) = 0$, $u(b) = 1$, and $u(c) = 100$, then the decision-maker likes c a lot more than b but finds little difference between a and b. But a payoff function contains no such information. The *only* conclusion we can draw from the fact that $u(a) = 0$, $u(b) = 1$, and $u(c) = 100$ is that the decision-maker prefers c to b and b to a; his preferences are represented equally well by the payoff function v for which $v(a) = 0$, $v(b) = 100$, and $v(c) = 101$, for example, or any other function w for which $w(a) < w(b) < w(c)$.

From this discussion we see that a decision-maker's preferences are represented by many different payoff functions. Looking at the condition (6.1) under which the payoff function u represents a decision-maker's preferences, we see that if u represents a decision-maker's preferences and the payoff function v assigns a higher number to the action a than to the action b if and only if the payoff function u does so, then v also represents these preferences. Stated more compactly, if u represents a decision-maker's preferences and v is another payoff function for which

$$v(a) > v(b) \text{ if and only if } u(a) > u(b), \tag{6.2}$$

then v also represents the decision-maker's preferences. Or, more succinctly, if u represents a decision-maker's preferences, then any increasing function of u also represents these preferences.

Sometimes it is natural to formulate a model in terms of preferences and then find payoff functions that represent these preferences. In other cases it is natural to start with payoff functions, even if the analysis depends only on the underlying preferences, not on the specific representation we choose.

Thus, the theory of rational choice is that in any given situation the decision-maker chooses the member of the available subset of A that is best according to his preferences. Allowing for the possibility that there are several equally attractive best actions, the theory of rational choice is: the action chosen by a decision-maker is at least as good, according to his preferences, as every other available action.

If you have studied the standard economic theories of the consumer and the firm, you have encountered the theory of rational choice before. In the economic theory of the consumer, for example, the set of available actions is the set of all bundles of goods that the consumer can afford. In the theory of the firm, the set of available actions is the set of all input-output vectors, and the action *a* is preferred to the action *b* if and only if *a* yields a higher profit than *b* does.

The theory of rational choice is enormously successful; it is a component of countless models that enhance our understanding of social phenomena. It pervades economic theory to such an extent that arguments are classified as "economic" as much because they apply the theory of rational choice as because they involve particularly "economic" variables.

No general theory currently challenges the supremacy of rational choice theory. But you should bear in mind as you read this book that the model of choice that underlies most of the theories has its limits; some of the phenomena that you may think of explaining using a game theoretic model may lie beyond these limits. As always, the proof of the pudding is in the eating: if a model enhances our understanding of the world, then it serves its purpose.

(Adapted from [11])

Task 20. Read the text (Task 19) again and answer the questions.

1. What is the essence of this theory?
2. What components is the theory based on?
3. What should we assume as to preferences?
4. How can we describe a decision-maker's preferences?
5. What may the model tell us?
6. How can we see the decision-maker's preferences?
7. What is the theory of rational choice?
8. What is the impact of the theory of rational choice on other social fields?

Focus on Vocabulary

Task 21. Complete the text with the following words and phrases.

Cooperation, classified, entire, provides, assumptions, mixed, utility, gains, share, objective, strategy, solvable, payoff, competitive.

Games may be **1** … according to the number of players (e.g., two-person games, three-person games) and whether the game is *zero-sum* or *nonzero-sum.*

1. *Zero-sum games.* In zero-sum games, the winner(s) receives the **2** … amount of the payoff that is contributed by the loser(s). Such a game is always strictly **3** … . The players' **4** … is to win as much as they can at the expense of the rival. That is, the players have diametrically opposed interests with regard to the outcome of the game. Zero-sum games with two decision makers are labeled "two-person, zero-sum games". Two **5** … are necessary for the analysis of these games:

a. All two-person, zero-sum games are **6** … .

b. The **7** … functions of the players, with respect to the outcome of the game, are identical. *This assumption is imperative for defining zero-sum games because if the utility functions of the competitors were not identical, the game would be of nonzero-sum type.* In other words, the payoffs are transferable to either player with the same value to each.

2. *Nonzero-sum games.* In a nonzero-sum game the **8** … of one player differ from the losses of the other (they can be either smaller or larger, but not equal). This means that some other parties in the environment may **9** … in the gains or the losses. Therefore, nonzero-sum games are not strictly competitive, and there is sometimes a possibility of **10** … .

Solving games. A solution to game problems **11** … us with answers to these two questions:

1. What **12** … should each player follow to maximize his or her welfare?
2. What will the **13** … to each player be if the recommended strategy is followed?

Unfortunately, clear answers can be given only in a few instances of conflicts; namely, for two-person, zero-sum games. The following sections deal with such solutions. Two-person, zero-sum games are divided into two groups: those with a pure strategy solution and those with a **14** … strategy solution.

Focus on Listening

Task 22. Give your association with the phrase "game theory".

Task 23. Discuss with your partner what game theory is and why we use it. Give an example.

Task 24. Watch Video 6.1 "Game Theory: The Science of Decision-Making" and compare your answers. Do they have the same ideas? [https://www.youtube.com/results?search_query=Game+Theory%3AThe+Science+of+Decision-Making]

Task 25. Watch all parts of Video 6.1 and complete the table.

No.	Parts	Description

Task 26. Give the main idea of every part of the text (Task 24).

Task 27. Give the main idea of game theory (Task 24). Discuss with your partner pros and cons of applying it.

Focus on Speaking

Task 28. Work in pairs and complete each sentence.

1. Game theory aims … .
2. Game theory consists of a collection of models … .
3. A model is unlikely to help us understand … .
4. Models cannot be judged by an absolute … .
5. One reason for improving our understanding of the world is … .
6. Studying game theoretic models may also suggest ways … .
7. Game theoretic modeling starts with … .
8. John von Neumann was a child prodigy who became … .
9. A two-person zero-sum game is simply one "played" by … .
10. John F. Nash won … .
11. Nash and others extended game theory to the case of more than two players and to games where cooperation between … .
12. If a player always chooses the same action, say paper, the opponent will … .
13. The theory of rational choice is a component of … .
14. The theory is based on a model with two components … .

15. The decision-maker knows this subset of available choices, and takes it … .

16. A decision-maker's preferences are … .

17. The theory of rational choice is … .

18. The theory of rational choice is enormously … .

Task 29. Read the text and underline its main idea, then work with the partner and discuss it.

You, now familiar with the major concepts and rules of game theory, can appreciate some of the roadblocks in applying it to real situations of conflict. Concepts such as moves, strategies, complete information, payoff matrix, and simultaneous decisions are theoretical idealizations with intuitive meaning but very little practicability. It seems that even the two-person, zero-sum game, the only game model currently completely solved mathematically, is oversimplified. Moreover, even if the assumptions of a given conflict are more or less reasonable and the model replicates reality, behavioral problems such as convincing the players that their best interests lie in using the proportion-mix strategy approach may interfere with any analytical solution.

Game theory only provides a starting point for the study and analysis of conflicts because real-life conflicts are much more complex. Realizing this, one may ask: "Why study game theory if its application is so limited?" The answer is:

1. Game theory stimulates us to think about conflicts in a novel way. It helps form a framework for working on complex problems. Concepts such as strategy and payoff give valuable orientation to those who must think about complicated conflict situations.

2. The game formulation often helps explain much of the phenomena being observed.

3. Game theory formulations and solutions may give decision makers a better understanding of the intricacies of life and help explain social behavior.

Although many of the accomplishments of game theory are of a rather conceptual or general nature, its ideas, methodology, and vocabulary have become part of the daily thinking and language of many decision makers in a broad spectrum of activities ranging from corporation board meetings to top-level political conferences.

Focus on Questions and Problems

Task 30. Dilemma. Study the example, then answer the questions and fulfil the task.

Pub Managers' Game

In the pub managers' game the players are two managers of different village pubs, the King's Head and the Queen's Head. Both managers are simultaneously considering introducing a special offer to their customers by cutting the price of their premium beer. Each chooses between making the special offer or not. If one of them makes the offer but the other doesn't, the manager who makes the offer will capture some customers from the other and some extra passing trade. But if they both make the offer, neither captures customers from the other although they both stand to gain from passing trade. Any increase in customers generates higher revenue for the pub. If neither pub makes the discounted offer, the revenue of the Queen's Head is €7 000 in a week and the revenue to the Kings Head is €8 000. The pay-off matrix for this game is shown in Table 6.4 below which shows the pay-offs as numbers representing revenue per week in thousands of euros.

Table 6.4

Pay-off matrix for the pub managers' game

		King's Head	
		special offer	no offer
Queen's Head	special offer	**10, 14**	**18, 6**
	no offer	4, 20	, 8

The pay-offs of the player whose actions are designated by the rows are written first. So in this game the pay-offs of the manager of the Queen's Head are written first and his strategies and pay-offs are highlighted in bold. The matrix shows that if the Queen's Head manager makes the special offer, his pay-off is 10 (i.e. €10 000) if the King's Head manager also makes the offer, and 18 if he doesn't. Similarly if the King's Head manager makes the offer, his pay-off is 14 if the Queen's Head manager also makes the offer, and 20 if he doesn't.

In the pub managers' game, what are the pay-offs of the managers if neither of them makes the offer? What is the pay-off of the Queen's Head manager if he doesn't make the offer but the manager of the King's Head does? What is the pay-off of the King's Head manager if he doesn't make the offer but the manager of the Queen's Head does?

What do you think will be the outcome of the pub managers' game? What do you think the managers will do?

Although we haven't actually looked at how to solve games yet, the pub managers' game has an equilibrium that you can probably work out just by using a little common sense.

(Adapted from [3])

Task 31. Dilemma. The game of 21. Read the game rules and design the strategy, then present it to your partner.

Two persons, call them A and B, take turns making choices. A begins. To start off, he can choose either 1 or 2. B observes this choice, then increments the "count" by adding one or two. That is, if A chooses 1, then B can follow up with 2 or 3; if A chooses 2, then B can follow up with 3 or 4. A then observes B's choice, and again increments the count by adding one or two. The game continues with the players taking turns, incrementing the count by one or two. The player who reaches 21 wins.

The game of 21 might be played circling numbers on the following strip:

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21

Imagine that you are player B. What would you do? Think about it for a minute before reading on. The exercise may help you appreciate more deeply some of the comments to follow.

A game-theoretic analysis might proceed as follows: First, identify the decision makers in the game, called players. Here they are A and B. Second, identify the strategies for each player, meaning comprehensive descriptions of what a player would do at every conceivable situation that might arise in the game.

For example, a strategy for player B states which choices he would make at each of the counts 1, 2, 3, …, 20, conditional on any sequence of choices up to that count. Finally, add a description of how strategies combine to produce outcomes and specify the players' preferences over these outcomes. In this case, while there are a great number of strategy combinations each of these results in one of only two outcomes, specifying whether A or B wins. A natural assumption about preferences is that each player prefers to win.

The number of strategies a player has in the game of 21 is bewildering. Player B, for example, has (if I calculated correctly) 28 855 of them. This is far more than the estimated number of atoms in the universe. Is there any hope of generating a meaningful prediction for the game? The answer is *yes*. Game-theorists have terminology for describing details regarding the order in which players move as well as the information they have when they do so. The game of 21 is then a finite, two-player, zero-sum, perfect information, two-outcome game with perfect recall. This is not the place to formally define these terms, but it follows from the classification that one of the players can force a win regardless of the other's choices. Specifically, B can guarantee a win by always choosing a multiple-of-three, thus securing that he will make the sequence of choices 3, 6, …, 21. A game theorist would say that this is part of a *dominant strategy*, a strategy with the property of being no worse than any other strategy regardless of the strategy choice of the opponent. Not all games admit dominant strategies, but the game of 21 does (for player B).

The remarks of the previous paragraphs give some flavor of how game-theoretic analysis may proceed. It is not obvious, however, that the described solution is an empirically accurate reflection of how humans play (honestly, what was your choice?). Indeed, experiments reveal that most humans often fail to choose a dominant strategy in this or similar games, at least until they get some practice. Through such experiments one may gain insight about human cognition and the psychology of learning.

(Adapted from [6])

Key

Unit 1

Task 2. 1 – j; 2 – m; 3 – e; 4 – g; 5 – c; 6 – n; 7 – d; 8 – k; 9 – l; 10 – a; 11 – h; 12 – i; 13 – b; 14 – f.

Task 5. 1 – h; 2 – i; 3 – f; 4 – n; 5 – e; 6 – c; 7 – r; 8 – a; 9 – m; 10 – q; 11 – o; 12 – p; 13 – b; 14 – d; 15 – k; 16 – l; 17 – j; 18 – g.

Task 7. 1 – C; 2 – D; 3 – A; 4 – B.

Task 8. 1 – false; 2 – false; 3 – true; 4 – false; 5 – false; 6 – true; 7 – false; 8 – false; 9 – false; 10 – true.

Task 11. 1 – g; 2 – d; 3 – h; 4 – e; 5 – b; 6 – a; 7 – f; 8 – c.

Task 12. 1 – b; 2 – d; 3 – a; 4 – c.

Task 13. 1 – k; 2 – d; 3 – o; 4 – l; 5 – j; 6 – n; 7 – h; 8 – g; 9 – b; 10 – e; 11 – a; 12 – i; 13 – c; 14 – f; 15 – m.

Task 15. 1 – F; 2 – C; 3 – A; 4 – G; 5 – H; 6 – D; 7 – B; 8 – E.

Task 16. 1 – true; 2 – false; 3 – false; 4 – false; 5 – false; 6 – true; 7 – true; 8 – false; 9 – true; 10 – true.

Task 19. 1 – d; 2 – e; 3 – g; 4 – a; 5 – b; 6 – k; 7 – c; 8 – l; 9 – f; 10 – n; 11 – i; 12 – h; 13 – q; 14 – p; 15 – r; 16 – j; 17 – m; 18 – o.

Task 20. 1 – life cycle; 2 – communication; 3 – methodology; 4 – complex; 5 – environment; 6 – process; 7 – feedback; 8 – body; 9 – problem definition; 10 – development.

Unit 2

Task 2. 1 – e; 2 – d; 3 – b; 4 – c; 5 – a.

Task 5. 1 – h; 2 – j; 3 – k; 4 – b; 5 – g; 6 – a; 7 – e; 8 – f; 9 – c; 10 – d; 11 – i.

Task 7. 1 – false; 2 – false; 3 – true; 4 – false; 5 – true; 6 – true; 7 – false; 8 – true; 9 – true; 10 – false.

Task 10. 1 – c; 2 – d; 3 – f; 4 – j; 5 – g; 6 – i; 7 – h; 8 – e; 9 – a; 10 – b.

Task 11. 1 – mathematical modeling; 2 – reflected; 3 – provide; 4 – the problem; 5 – appropriate model; 6 – data; 7 – variables and predictors; 8 – testing; 9 – real-world situations; 10 – gain insight; 11 – underlying phenomenon; 12 – refine.

Task 12. 1 – complex; 2 – model; 3 – guidelines; 4 – mathematical solution; 5 – results; 6 – implementing.

Task 13. 1 – true; 2 – true; 3 – true; 4 – false; 5 – false; 6 – false; 7 – true; 8 – false; 9 – false; 10 – false.

Task 16. 1 – diseases; 2 – social insects; 3 – planning; 4 – traffic flow; 5 – endocrine system; 6 – nature of the ground surface; 7 – fluid flow; 8 – global warming; 9 – human system; 10 – video games.

Task 17. 1 – k; 2 – h; 3 – e; 4 – l; 5 – c; 6 – a; 7 – i; 8 – b; 9 – g; 10 – d; 11 – f; 12 – j.

Task 19. 1 – C; 2 – G; 3 – F; 4 – A; 5 – E; 6 – D; 7 – B.

Task 20. 1 – false; 2 – true; 3 – false; 4 – true; 5 – false; 6 – false; 7 – false.

Task 22. 1 – complex; 2 – equations; 3 – attempt; 4 – predictions; 5 – refine.

Task 26. 1 – understanding or solutions; 2 – represent, analyze, make predictions, provide insight into real-world phenomena; 3 – can be modeled mathematically; 4 – to make a few assumptions; 5 – define your variables; 6 – What can I learn from my model? Does the answer make sense? 7 – Your report; 8 – what assumptions we made; 9 – Math modeling.

Task 32. A suggested answer.

The modeling diagram has 6 nodes and 10 edges; that is, it suggests 16 different processes. Every stage of the modeling process is important. Modeling is complete only if the contribution along all edges becomes insignificant. It is possible that the formulation of the problem itself may change due to the insight gained by the modeling process.

Unit 3

Task 2. 1 – h; 2 – e; 3 – i; 4 – g; 5 – b; 6 – d; 7 – f; 8 – a; 9 – c.

Task 5. 1 – c; 2 – e; 3 – d; 4 – a; 5 – b.

Task 7. 1 – true; 2 – true; 3 – true; 4 – false; 5 – false; 6 – true; 7 – true; 8 – true; 9 – true.

Task 10. 1 – d; 2 – h; 3 – a; 4 – c; 5 – b; 6 – e; 7 – f; 8 – g.

Task 11. 1 – applied; 2 – empirical; 3 – formulation; 4 – testing; 5 – model; 6 – equations; 7 – assumption; 8 – predictions; 9 – depends; 10 – tools.

Task 12. 1 – true; 2 – false; 3 – false; 4 – true; 5 – false; 6 – true; 7 – false; 8 – true.

Task 15. 1 – limitations; 2 – empirical; 3 – multiple; 4 – variables; 5 – confront; 6 – functional; 7 – equation; 8 – two-variable linear; 9 – regressand; 10 – regressor.

Task 16. The terms "explained" and "explanatory" variables are probably the most descriptive. "Response" and "control" are used mostly in the experimental sciences, where the variable *x* is under the experimenter's control. We will not use the terms "predicted variable" and "predictor", although you sometimes see these.

Task 17. 1 – e; 2 – d; 3 – g; 4 – i; 5 – a; 6 – h; 7 – c; 8 – f; 9 – b.

Task 19. 1 – Pearson's Correlation; 2 – Cause and Correlation; 3 – Spearman's Correlation; 4 – Regression Lines.

Task 20. 1 – false; 2 – true; 3 – false; 4 – true; 5 – true; 6 – false; 7 – false; 8 – true; 9 – false; 10 – true; 11 – false; 12 – false; 13 – false; 14 – true.

Task 22. 1 – variables; 2 – bivariate; 3 – two-dimensional; 4 – mathematical; 5 – fundamental.

Task 29. 1 – b; 2 – b; 3 – a; 4 – c; 5 – a; 6 – a; 7 – a; 8 – c; 9 – a; 10 – d; 11 – c; 12 – c; 13 – b; 14 – b; 15 – c; 16 – b; 17 – d; 18 – b; 10 – b; 20 – a; 21 – b; 22 – b; 23 – b; 24 – a.

Unit 4

Task 5. 1 – h; 2 – e; 3 – i; 4 – j; 5 – k; 6 – l; 7 – d; 8 – a; 9 – c; 10 – g; 11 – b; 12 – f.

Task 7. 1 – false; 2 – true; 3 – false; 4 – false; 5 – true; 6 – true; 7 – false; 8 – true.

Task 10. 1 – simplex; 2 – linear-programming; 3 – efficiency; 4 – high-speed digital; 5 – optimization method; 6 – business environment; 7 – assumptions; 8 – mathematical-programming approach; 9 – implementation.

Task 11. 1 – f; 2 – i; 3 – h; 4 – g; 5 – j; 6 – a; 7 – d; 8 – c; 9 – b; 10 – e.

Task 13. 1 – false; 2 – true; 3 – false; 4 – true; 5 – false; 6 – false; 7 – false; 8 – true; 9 – false; 10 – true; 11 – false.

Task 15. 1 – d; 2 – g; 3 – h; 4 – a; 5 – f; 6 – e; 7 – b; 8 – c.

Task 16. 1 – g; 2 – d; 3 – f; 4 – c; 5 – h; 6 – e; 7 – i; 8 – b; 9 – a.

Task 18. 1 – Operational Exercise; 2 – Gaming; 3 – Simulation; 4 – Analytical Model.

Task 19. 1 – false; 2 – false; 3 – false; 4 – true; 5 – false; 6 – true; 7 – true; 8 – false; 9 – true; 10 – false; 11 – false; 12 – false; 13 – true; 14 – true; 15 – false; 16 – false; 17 – true.

Task 21. 1 – applications; 2 – strategy; 3 – disciplines; 4 – control theory; 5 – mathematical programming; 6 – assumption.

Unit 5

Task 7. 1 – false; 2 – true; 3 – true; 4 – false; 5 – false; 6 – false; 7 – true.

Task 10. 1 – systems scientist; 2 – founder; 3 – interactions; 4 – business cycles; 5 – social problems; 6 – urban planners; 7 – sustainability; 8 – complex; 9 – contributions.

Task 11. 1 – i; 2 – d; 3 – e; 4 – f; 5 – h; 6 – b; 7 – k; 8 – c; 9 – a; 10 – g; 11 – j.

Task 13. 1 – Major Characteristics; 2 – Advantages of Simulation; 3 – The Primary Disadvantages of Simulation.

Task 14. 1 – false; 2 – true; 3 – false; 4 – false; 5 – true; 6 – true; 7 – false; 8 – false; 9 – true; 10 – false; 11 – false; 12 – false; 13 – false; 14 – false.

Task 16. 1 – real system; 2 – consists; 3 – boundaries; 4 – gathering; 5 – process; 6 – computer language; 7 – validation; 8 – simulation; 9 – contradictory; 10 – issues; 11 – implementation; 12 – statistical; 13 – analytical models.

Task 17. 1 – d; 2 – f; 3 – g; 4 – e; 5 – a; 6 – b; 7 – c.

Task 19. 1 – true; 2 – false; 3 – false; 4 – false; 5 – true; 6 – false; 7 – false; 8 – false; 9 – true; 10 – true; 11 – false.

Task 21. 1 – random variables; 2 – originators; 3 – statistics; 4 – simulation; 5 – generating; 6 – attempt; 7 – boundary; 8 – region; 9 – assume; 10 – equal; 11 – estimate; 12 – methods; 13 – multidimensional; 14 – numerical.

Unit 6

Task 7. 1 – false; 2 – true; 3 – false; 4 – false; 5 – false; 6 – false; 7 – true; 8 – true; 9 – false; 10 – true; 11 – true; 12 – false.

Task 10. 1 – decision making; 2 – consequences; 3 – maximize; 4 – game theory; 5 – complex; 6 – strategies; 7 – format; 8 – viewed; 9 – circumstance;10 – terminology; 11 – express; 12 – participants; 13 – simultaneous; 14 – welfare; 15 – decisions; 16 – measured; 17 – information.

Task 11. 1 – j; 2 – l; 3 – h; 4 – k; 5 – i; 6 – a; 7 – b; 8 – c; 9 – e; 10 – f; 11 – d; 12 – g.

Task 13. 1 – Two-Person Zero-Sum Games; 2 – A Beautiful Mind; 3 – When Is a Game Determined?; 4 – Repetitive Games; 5 – When Is a Game not Zero-Sum?

Task 14. 1 – false; 2 – false; 3 – false; 4 – false; 5 – false; 6 – false; 7 – false; 8 – true;9 – true;10 – false;11 – false;12 – true;13 – false;14 – true.

Task 16. 1 – preference; 2 – analysis; 3 – sequence; 4 – normal; 5 – single; 6 – decision; 7 – concentrate; 8 – payoff; 9 – environments; 10 – game; 11 – loss; 12 – top.

Task 17. 1 – e; 2 – f; 3 – g; 4 – c; 5 – i; 6 – h; 7 – d; 8 – b; 9 – a.

Task 19. 1 – false; 2 – false; 3 – true; 4 – false; 5 – false; 6 – true; 7 – false; 8 – true; 9 – false; 10 – false.

Task 21. 1 – classified; 2 – entire; 3 – competitive; 4 – objective; 5 – assumptions; 6 – solvable; 7 – utility; 8 – gains; 9 – share; 10 – cooperation; 11 – provides; 12 – strategy; 13 – payoff; 14 – mixed.

Task 25. 1 – Game Theory – Introduction; 2 – Game Theory – Nash Equilibrium; 3 – Game Theory – Cooperative Game; 4 – Game Theory – The Coockies.

Transcripts*

Script 1
Why should students study System Dynamics?
System Dynamics Society (Jay Forrester)

Well, you should be interested in system dynamic if you want to have a fundamental understanding of the world, if you want to be where the future lies. But you also got to be able to live through all the problems of pioneering. But it's hard to advise given the circumstances. And it will take an unusual person who is daring courageous has a vision or to go and doesn't care where the chips fall in the meantime. And there are some of those I think I consider myself there my career been one of maybe being told about open door somewhere. Maybe somebody suggested, it would be interesting, on the other side, until actually locate let's walk through the door and see because that's how I got into computers, that's how I got into combat Information Systems, that's how I got into system dynamics being willing to move into unknown territory, and figure you can cope with whatever these problems are there maybe you have: to grow up on a farm or ranch in order to be able to feel you can do that. I'm not sure pitch it something you can advise any kindergarten to going to but not any adult. OKEY if I would have to quiz the person about who they think they are how much courage anything to have before I would advise.

The slide

Professor Forrester founded the field of System Dynamics in the mid-1950s. Prior to that, he was a pioneer in early digital computer development and is a member of the National Inventors' Hall of Fame for inventing random-access magnetic-core memory during the first wave of modern computers. His research focused on the behavior of economic systems, including the causes of business cycles and major depressions, a new type of dynamic-based management education and System Dynamics as a unifying theme in pre-college education. He has been recognized with numerous awards for his books and has been awarded nine honorary degrees from universities around the world.

*The scripts reproduce the speakers' original speech.

Script 2

Math Modeling Video Series

Part 1. What is Mathematical Modeling

The world around us is filled with important unanswered questions.

Try this one for size "What is all that math we learnt in high school good for anyway?"

As it turns out all math from arithmetic through calculus and beyond can tell us a lot.

Which recycling programme is better for my city?

How will the new flu outbreak affect the US or even which rollercoaster is the most thrilling.

These are real world scenarios for which math modeling can provide understanding or solutions.

Modeling is a process that uses math to represent, analyze, make predictions or otherwise provide insight into real-world phenomena.

When you are analyzing and looking at the models and everything, you get to see how these numbers are used and how you can actually apply the math that you learn.

In my opinion, anything in our life can be modeled mathematically, so we can always find a pattern in our life.

Here's how it works. Start with a basic definition of your problem.

If you define the problem, research will become a lot easier and actual.

Understand what you are doing rather than just mindlessly researching and having so much research but not really knowing how to apply that research.

To simplify the scope of the problem you'll need to make a few assumptions. If you make assumptions, you can get rid of some extraneous insignificant factors, so your model really only considers the most important variables.

Next, define your variables if you are trying to make a mathematical model. You can define your variables if you are trying to make a mathematical model. You are trying to create an equation of some sort that incorporates certain variables by defining those variables, by figuring out what those variables are especially early on you know what you are looking for.

Now it's time to use the map that you know to build a model, this is where you will see your solutions. We just used algebra entire time, so we didn't have to go into calculus or differential and integral equations. We just make a couple of assumptions so that you can use easily algebra instead of taking some really long complicated method.

Next, you will analyze your model to make sure it works. Ask yourself, "What can I learn from my model? Does it answer the original question? Does the answer make sense?"

The analysis is just essentially looking at your data, showing how your data correlates with the hypothesis that you are giving. Finally you will report.

Finally your report is your results. The model is more than just math. It's what assumptions we made, how we came up with those assumptions of the justification – it is extremely important.

Math modeling can help us answer big messy questions about things like recycling options, spread of disease and even the thrill factor of roller-coasters.

So, instead of asking "What is all this math good for?" the question becomes "What can't we figure out with math?"

Script 3
Economertrics and Operations Research

Worldwider storm update as being generated every day and in every country, government company or organization is in some way or other interested

in this information, because if interpreted correctly by an econometrician it can help to predict future interests. An econometrician is someone who is interested in them, knows economic models. He likes to solve puzzles within the landscape with economic variables on a micro and macroeconomic levels. For instance, a few years ago some big bank in the US crashed, many of the primary economic indicators went down, the US endded in a major recession, and Europe soon followed. As a result, countries and European Union faced many serious challenges. Should we abandon the euro or should we keep it? Should we grounds extra credit loans to Greece? Should we bail out investment banks or let them go bankrupt. As a result of their own choice in the past often politicians have clear opinions on these issues and present these opinions loud and clear. An econometrician on the other hand will try to predict the consequences of abandoning the Euro or Greece for that matter and even also try to predict what will happen if we don't. When you and politicians can base opinions on facts and make an informed decision, econometrics and operations research are also used on a smaller scale influencing your daily life. These techniques are used to set up a logistic system or to determine how many people are needed in the call center. They can also set the price of an airline ticket. Did you ever sit on an airplane and wonder why the person next to you with the same amount of flex space in the same on board lunch take half the price you did. Econometricians know why the electronic ticket reservation services register, how many tickets are sold each day for each flight. When you raised the price of a ticket on a particular day, you will sell fewer tickets. But for a higher price techniques from econometrics and operations research help airline operations to find new their strategies, so they can maximize revenues. So if you are going on a trip by and only take it or even better find out for yourself how, you can sell an airplane ticket today for twice yesterday's price. Massachuset University's School of Business and Economics brings you econometrics, an international econometrician accredited programme that will show you economic landscape and introduce you to a world of puzzle solving and that will prepare you for a job in tomorrow's complex economic environment that's actually a huge shortage of econometricians, so be prepared to work.

Script 4
A New View of Analytics and Operations Research

Information Means

How do you visualize the scope of our increasingly complex world? Let's look at the size of the numbers. We now measure markets and competitors in hundreds, customers and citizens in billions and daily bites have created data in the Quentin's. How can management win in a world with so many variables? The answer is operations research. Applying advanced analytics for revolutionary gains in organizational performance, the France allumines awards celebrate the accomplishments of those who have achieved excellence in operations research. These leading innovators applied a large 21st century technology to redefine environmental dynamics for greater sustainability. Reimagine rail transit logistics and revolutionize product supply and delivery. As the world grows more challenging organizations like yours are innovating towards a better future. Operations research has a broad reach. It offers higher profits and increased market share and it has improved management in business, government, the military, healthcare, education and nonprofits and has applications at all levels of organizations. For example, all overheads governments achieved, environmental balance and sustainability alongside improve public health. When the Delaware River Basin Commission face the challenge in maintaining reservoir levels for having new York city's drinking water while protecting wild fish populations they turn to advanced analytics. Their operations research solution used cost-benefit trade-off analysis to create the flexible flow management policy, a dynamic water release system to balance reservoir storage and wildlife needs. This created a 200 percent increase in trout and shad habitats with minimal impact on risk of drought in New York City. Applying operations research means recognizing the value of the minute. Or in the case have Netherlands railways the minute transporting more than 1.1 million passengers daily. Netherlands railways need to revise their 35-year old railway timetable to more accurately match trains to expected user traffic. The Dutch railway company adopted IBM's I log optimization technology to improve train operations. Measuring variables like average boarding time in seasonal variations. Netherlands railways applied sophisticated analytics to optimize their scheduling processes. Thanks to their OR solution on time train performance reached a new record up 87 percent and the railway increased annual profits by 40 million euros. With the fast data growth is the new normal true managements signs pioneers will ensure mastery throughout their organizations. Take consumer products giant Procter&Gamble which posted 82.6 billion dollars in sale in 2011 with too many manufacturing plants in the supply chain spending continents Procter&Gamble turn to operations research for their solution. Applying new operations research models created insight all the way up to the executive level resolving product redundancies, navigating changing regulations and consolidating factories across the US. The result was more than one billion dollars in cost saving over 15 years. As the world rapidly grows, more intricate, OR and analytics offer us the tools to master the complexity. This means agile business, streamline costs, faster processes. These qualities illustrate the power of all over and analytics to navigate ocean of information and with the work I've innovators like you create a brighter future.

Script 5

5.1. What Is Simulation? It's about Problem Solving

What is simulation? You might already know the answer, but if you don't, it can be explained in as little as two words: problem solving. Should we add a new machine? How can we get rid of this bottleneck? Will we receive a positive return on our investment? Simulation can answer these and many other questions because it provides a virtual environment to learn and experiment on your process, a place where data is easy to come by and where mistakes result in improvement instead of ending careers. FlexSim is powerful simulation software, built from the ground up to make simulation as easy as possible, without sacrificing an ounce of function or visual appeal. You can create beautiful, detailed models that deliver results that make an impact the way spreadsheets or charts never could, and you can do it all just minutes with drag-and-drop controls and easy-to-use features. So what is FlexSim? It's a problem-solving tool that allows you to accurately answer any questions about your business. You'll save time and money by making better choices and avoiding the bad ones – all without the risk in physical experimentation.

5.2. Simulation Theory

You are saying your attempt to understand the fundamental operations of nature leads you to a set of equations that are indistinguishable from the equations that drive search engines and browsers on our computers. That is correct. So, you're saying as you dig deeper you find computer code rich in the fabric of the cosmos into the equations that we want to use to describe the cosmos. Yes, the argument is called the simulation. Argument and argues that we are all very likely not to not living in a real universe but living in a simulated universe and we are being simulated on the hard drives of computers of the future. An advanced civilization would have enough computing power that even if it devoted on the tiny fraction of one percent of that computing power for just one second in the course of its maybe thousand years long existence, that would be nice to create billions and billions of ancestor simulations. In the last five or so years I've been able to show that hidden inside of this equation there are computer codes that make browsers work and so, if the equations that describe our reality have computer codes hidden in them, that's just kind of weird old run simulations of the past in the way that we run simulations Sims games and then there's just one short move that simulated universes but almost by definition will outnumber real universes and therefore we are a lot more likely to be among the simulated ancestors than real ancestors. In the distant future, simulating physical systems with very high accuracy so that they look perfectly real to the user of the virtual reality will become commonplace and tribute. You could see the body as it really did. You feed that 99.999 % of it is mostly empty space and point 0 0 0 0 1 percent of it which you see as matter is also empty space. The matter is just an illusion and artifact of our perceptual experiences. It's as if reality is so connected that note when you look at one small part. You can see things about other parts that the entire whole is contained in the part and in a sense you can divide reality of because we're cutting up the hologram we can't find where one particle is because it's always a reflection of all particles' concept of virtual reality. The star reality is being a virtual informational digital reality that that's better science it's better physics answers for the questions so it's working. In other words, people are seeing that it's a better physics but it does explain more of reality. Inside the simulation you cannot tell any differences between the simulated environment, the virtual reality, and the real environment. In fact, this environment we now find ourselves in could be just a simulation.

Script 6
Game Theory: The Science of Decision-Making

Part 1

When you're hanging out with your friends, you probably don't think too hard about the math behind the decisions you're making. But there's a whole field of math – and science – that applies to social interactions. It's called Game Theory.

Game theory was pioneered in the 1950s by the mathematician John Nash, the guy from that Russell Crowe played in "A Beautiful Mind". But game theory isn't about games the way we normally think about them.

Instead, a game is any interaction between multiple people in which each person's payoff is affected by the decisions made by others.

So, sure, that could apply to a game of poker. But it could also apply to practically any situation where people get together and get up in each other's business.

Like, did you interact with anyone today? Well, you can probably analyze the decisions you made using game theory.

Game theory is incredibly wide-ranging, and it's used all the time by economists, political scientists, biologists, military tacticians, and psychologists, to name just a few.

Game theory has two main branches: cooperative, and noncooperative, or competitive, game theory.

Noncooperative game theory covers competitive social interactions, where there will be some winners … and some losers. Probably the most famous thought experiment in competitive game theory is the Prisoner's Dilemma. The prisoner's dilemma describes a game – a social interaction – that involves two prisoners.

Part 2

We'll call them Wanda and Fred. Wanda and Fred were arrested fleeing from the scene of a crime, and based on the evidence the police have already collected, they're going to have to spend two years in jail.

But, the DA wants more. So he offers them both a deal: if you confess to the crime, and your partner does not, you'll be granted immunity for cooperating. You'll be free to go. Your partner, though, will serve ten years in jail. If you both confess, and dish up loads of dirt about each other, then you will both end up spending five years in jail.

But if neither of you confess, you'll both spend only two years in jail.

Those are their options. Then, Wanda and Fred are split up. They don't know what their partner is going to do.

They have to make their decisions independently. Now, Wanda and Fred they – they've had some wild times stealing diamonds or whatever, but they don't have any special loyalty to each other.

They're not brother and sister; they're hardened criminals. Fred has no reason to think Wanda won't stab him in the back, and vice versa.

Competitive game theory arranges their choices and their potential consequences into a grid that looks like this:

If both Wanda and Fred choose not to confess, they'll both serve two years.

In theory, this is the best overall outcome. Combined, they would spend as little time in prison as possible. But … that immunity sounds pretty good.

If one of them chooses to confess, and the other one doesn't, the snitch gets to walk. Then the math looks like this:

That's the problem: Wanda and Fred have no reason to trust each other. Wanda might consider not confessing, because if Fred doesn't confess either, they both only serve two years. If they could really trust each other, that would be their best bet. But Wanda can't be sure that Fred won't snitch.

He has a LOT to gain by confessing. If he does decide to confess, and she keeps silent, she's risking ten years in jail while he goes free.

Compared to that, the five years they'd get for both turning on each other doesn't sound so bad. And that is game theory's solution: they should both confess and rat each other out.

So, right now you're thinking, "Wow, game theory is a jerk".

But it actually makes sense. That square in the grid where they both confess is the only outcome that's reached what's known as Nash Equilibrium. This is a key concept in competitive game theory. A player in a game has found Nash Equilibrium when they make the choice that leaves them better off no matter what their opponents decide to do.

If Wanda confesses, and Fred does not confess… she's better off. She gets to walk!

By confessing, she went from serving two years in prison to serving none. If Fred does confess... she's still better off. If she'd kept her mouth shut, she'd be spending ten years in prison. Now, she only has to serve five. Sure, if she decides not to confess, and Fred keeps his pinky promise too, they both get out in two years. But that's an unstable state.

Because Wanda can't trust Fred – she doesn't know what he's going to do. This is not a cooperative game: all of the players stand to gain from stabbing each other in the back.

The Prisoner's Dilemma is just one example of a competitive game, but the basic idea behind its solution applies to all kinds of situations. Generally, when you're competing with others, it makes sense to choose the course of action that benefits you the most no matter what everyone else decides to do.

Part 3

Then there are cooperative games, where every player has agreed to work together toward a common goal.

This could be anything from a group of friends deciding how to split up the cost to pay the bill at a restaurant, to a coalition of nations deciding how to divvy up the burden of stopping climate change.

In game theory, a coalition is what you call a group of players in a cooperative game. When it comes to cooperative games, game theory's main question is how much each player should contribute to the coalition, and how much they should benefit from it. In other words, it tries to determine what's fair. Where competitive game theory has the Nash Equilibrium, cooperative game theory has what's called the Shapley Value.

The Shapley Value is a method of dividing up gains or costs among players according to the value of their individual contributions. It works by applying several axioms. Number one: the contribution of each player is determined by what is gained or lost by removing them from the game.

This is called their marginal contribution. Let's say that every day this week, you and your friends are baking cookies. When you get sick for a day, probably from eating too many cookies, the group produces fifty fewer cookies than they did on the days that you were there.

So, your marginal contribution to the coalition, every day, is fifty cookies. Number two: Interchangeable players have equal value. If two parties bring the same things to the coalition, they should have to contribute the same amount, and should be rewarded for their contributions equally.

Like if two people order the same thing at the restaurant, they should pay the same amount of the bill. If two workers have the same skills, they should receive the same wages.

Number three: Dummy players have zero value. In other words, if a member of a coalition contributes nothing, then they should receive nothing.

This one's controversial. It could mean that if you go to dinner with your friends, but you don't order anything, you shouldn't have to chip in when the bill comes.

Which seems fair, in that case. But it could also mean that if somebody can't contribute to the work force, they shouldn't receive any compensation. The thing is, there are good reasons why somebody might not be able to contribute: maybe they're on maternity leave. Or they got in an accident. Or they have some kind of a disability.

In situations like that, the coalition might want to pay something out to them in spite of them not being able to contribute. The fourth axiom says that if a game has multiple parts, cost or payment should be decomposed across those parts.

This just means that, for example, if you did a lot of work for the group on Monday, but you slacked off on Tuesday, your rewards on each day should be different. Or if you ordered a salad one night, but a steak dinner the next, you probably should pay more on the second night.

In other words, it's not always fair to use the same solution every time. The numbers should be reviewed regularly, so that the coalition can make adjustments. If you find a way of dividing up costs or divvying up payment to all of the players that satisfies all of those axioms, that's the Shapley value.

The Shapley value can be expressed mathematically like this:

Part 4

Which, yeah, is kind of complicated. But we can break down the concepts into something less … mathy.

Let's go back to looking at cookies.

You're baking cookies, and your friend is baking cookies.

In an hour, you can bake ten cookies when you're working alone.

Your friend though, is like a cookie wizard, and in the same hour, working alone, he can bake twenty cookies. When you decide to team up... When you work together, you streamline your process. One person can mix up all the batter at once or whatever, which saves you a lot of time.

So after an hour, you have forty cookies. But if you'd each been working alone, you'd only have made 30 cookies in the same hour. Then you sell each of those cookies for a dollar. Now you've got forty dollars. How do you divide up the loot?

The Shapley value equation tells you to think about it like this:

If you take the fact that you can make ten cookies an hour, and subtract them from the total, that gives your friend credit for the other thirty cookies.

That's what happens when you remove your friend from the system: their marginal contribution to you is thirty cookies.

But if you take the fact that your friend can make twenty cookies an hour, and subtract that from the total, that gives YOU credit for twenty cookies.

Because if you're removed from your friend's cookie-making system, your marginal contribution to them is twenty cookies.

In the first case, your value to the coalition was only ten cookies. But in the second case, your value to the coalition is twenty cookies. According to the Shapley value equation, you should average those two numbers together. Ten plus twenty is thirty, divided by two is fifteen.

So, the Shapley value equation says that you should get fifteen dollars, and your friend should get twenty-five.

This method can be scaled up to coalitions with hundreds of players, by finding their marginal contributions to every other player and then calculating the average of all of those numbers. Interactions can get much more complicated than the Prisoner's Dilemma or baking cookies, so there's a lot more to game theory. But it comes down to this: in a competitive situation, game theory can tell you how to be smart.

And in a cooperative situation, game theory can tell you how to be fair.

Glossary

Unit 1

Adaptive capacity – an important part of the resilience of systems in the face of a perturbation, helping to minimise loss of function in individual human, and collective social and biological systems.

Black box – a technical term for a device or system or object when it is viewed primarily in terms of its input and output characteristics.

Boundaries – the parametric conditions, often vague, always subjectively stipulated, that delimit and define a system and set it apart from its environment.

Cascading failure – failure in a system of interconnected parts, where the service provided depends on the operation of a preceding part, and the failure of a preceding part can trigger the failure of successive parts.

Closed system – a system which can exchange energy (as heat or work), but not matter, with its surroundings.

Complexity – a systemic characteristic that stands for a large number of densely connected parts and multiple levels of embeddedness and entanglement. Not to be confused with complicatedness, which denotes a situation or event that is not easy to understand, regardless of its degree of complexity.

Culture – the result of individual learning processes that distinguish one social group of higher animals from another. In humans culture is the set of interrelated concepts, products and activities through which humans express themselves, interact with each other, and become aware of themselves and the world around them.

Development – the process of liberating a system from its previous set of limiting conditions. It is an amelioration of conditions or quality.

Dissipative structure – a term invented by Ilya Prigogine to describe complex chemical structures undergoing the process of chemical change through the dissipation of entropy into their environment, and the corresponding importation of "negentropy" from their environment.

Embeddedness – a state in which one system is nested in another system.

Emergence – the appearance of novel characteristics exhibited on the level of the whole ensemble, but not by the components in isolation.

Entropy is a measure of energy that is expended in a physical system but does no useful work, and tends to decrease the organizational order of the system.

Environment – the context within which a system exists. It is composed of all things that are external to the system, and it includes everything that may affect the system, and may be affected by it at any given time.

Evolution – a tendency toward greater structural complexity, ecological and/or organizational simplicity, more efficient modes of operation, and greater dynamic harmony. A cosmic process specified by a fundamental universal flow toward ever increasing complexity that manifests itself through particular events and sequences of events that are not limited to the domain of biological phenomenon, but extend to include all aspects of change in open dynamic systems with a throughput of information and energy. In other words, evolution relates to the formation of stars from atoms, of Homo sapiens from the anthropoid apes, and the formation of complex societies from rudimentary social systems.

Evolutionary systems design (ESD) – a form of systems design that responds to the need for a future design creating design praxis, that embraces not only human interests and life-spans, but those on planetary and evolutionary planes as well. The primary vehicle for the implementation of ESD is the Evolutionary Learning Community (ELC).

Feedback – a functional monitoring signal obtained from a given dynamic and continuous system. A feedback function only makes sense if this monitoring signal is looped back into an eventual control structure within a system and compared with a known desirable state. The difference between the feedback monitoring signal and the desirable state of the system gives the notion of error. The amount of error can guide corrective actions in the system that can bring the system back to the desirable state.

Holism – a non-reductionist descriptive and investigative strategy for generating explanatory principles of whole systems. Attention is focused on the emergent properties of the whole rather than on the reductionist behavior of the isolated parts. The approach typically involves and generates empathetic, experiential, and intuitive understanding, not merely analytic understanding, since by the definition of the approach, these forms are not truly separable (as nothing is).

Holon – a whole in itself as well as a part of a larger system.

Homeostasis – the property of either an open system or a closed system, especially a living organism, which regulates its internal environment so as to maintain a stable, constant condition.

Human activity systems – designed social systems organized for a purpose, which they attain by carrying out specific functions.

Isolated system – a system in which the total energy-mass is conserved without any external exchange happening.

Metastability – the ability of a non-equilibrium state to persist for some period of time.

Model building – a disciplined inquiry by which a conceptual (abstract) representation of a system is constructed or a representation of expected outcomes/output is portrayed.

Open system – a state and characteristics of that state in which a system continuously interacts with its environment. Open systems are those that maintain their state and exhibit the characteristics of openness previously mentioned.

Process – a naturally occurring or designed sequence of actions of an agent or changes of properties or attributes of an object or system.

Process model – an organized arrangement of system's concepts and principles that portray the behavior of a system through time. Its metaphor is the "motion-picture" or "movie" of the system.

Reductionism – one kind of scientific orientation that seeks to understand phenomena by: a) breaking them down into their smallest possible parts (the process known as analytic reductionism) or conversely; b) conflating them to a one-dimensional totality (the process known as holistic reductionism).

Self-organization – a process in which the internal organization of a system, normally an open system, increases in complexity without being guided or managed by an outside source.

Self-organizing systems – systems which typically (though not always) display emergent properties.

Steady state – a more general situation than dynamic equilibrium. If a system is in steady state, then the recently observed behaviour of the system will continue into the future. In stochastic systems, the probabilities that various states will be repeated will remain constant.

Strong emergence – a type of emergence in which the emergent property is irreducible to its individual constituents.

Subsystem – a major component of a system. It is made up of two or more interacting and interdependent components. Subsystems of a system interact in order to attain their own purpose(s) and the purpose(s) of the system in which they are embedded.

Suprasystem – the entity that is composed of a number of component systems organized in interacting relationships in order to serve their embedding suprasystem.

Sustainability – the ability of a system to maintain itself with no loss of function for extended periods of time. In human terms it is the creative and responsible stewardship of resources – human, management, natural, and financial – to generate stakeholder value while contributing to the well-being of current and future generations of all beings.

Synergy – the process by which a system generates emergent properties resulting in the condition in which a system may be considered more than the sum of its parts, and equal to the sum of its parts plus their relationships. This resulting condition can be said to be one of synergy.

Systems design – a decision-oriented disciplined inquiry that aims at the construction of a model that is an abstract representation of a future system.

Soft systems methodology – systemic approach for tackling real-world problematic situations, which provides a framework for users to deal with the kind of messy problem situations that lack a formal problem definition.

Weak emergence – a type of emergence in which the emergent property is reducible to its individual constituents.

White box – a technical term for a device or system analyzed or tested based on knowledge of its internal structure (compare to Black box).

Wholeness – in reference to systems, the condition in which systems are seen to be structurally divisible, but functionally indivisible wholes with emergent properties.

Unit 2

Analog model – a model which although physical in form, does not have a physical appearance similar to the real object or situation it represents.

Analysis – attacking a problem by breaking it into sub-problems. The second step in the system development life cycle (following problem definition) during which the responsible people determine exactly what must be done to solve the problem.

Boundary – an entity that serves to delimit or separate a system from its environment.

Breakeven point – the volume at which total revenue equals total cost.

Constraints – restrictions or limitations imposed on a problem.

Control – an expected value that can be compared with feedback. If the feedback suggests a deviation from the expected value (the control), the system reacts by attempting to adjust itself.

Controllable inputs – the inputs that are controlled or determined by the decision maker.

Decision making – the process of defining the problem, identifying the alternatives, determining the criteria, evaluating the alternatives, and choosing an alternative.

Decision – the alternative selected.

Decision variable – another term for controllable input.

Design – the third step in the system development life cycle (following analysis and preceding development) during which the responsible people determine how the problem will be solved by specifying the system's physical components.

Deterministic model – a model in which all uncontrollable inputs are known and cannot vary.

Development – the fourth step in the system development life cycle (following design and preceding testing) during which the system is created.

Feasible solution – a decision alternative or solution that satisfies all constraints.

Feedback – the return of a portion of the system's output to its input.

Fixed cost – the portion of the total cost that does not depend on the volume; this cost remains the same no matter how much is produced.

Iconic model – a physical replica, or representation, of a real object.

Implementation – the sixth step in the system development life cycle (following testing and preceding maintenance) during which the system is installed and released to the user.

Infeasible solution – a decision alternative or solution that does not satisfy one or more constraints.

Information system – a set of hardware, software, data, human, and procedural components intended to provide the right data and information to the right person at the right time.

Interface – a mechanism or point of interaction between two or more system components.

Maintenance – the final step in the system development life cycle (following implementation) intended to keep the system functioning at an acceptable level.

Marginal cost – the rate of change of the total cost with respect to volume.

Marginal revenue – the rate of change of total revenue with respect to volume.

Mathematical model – mathematical symbols and expressions used to represent a real situation.

Methodology – a body of practices, procedures, and rules used by those who work in a discipline or engage in an inquiry; often implemented as a set of well-defined steps or phases, each of which ends with a clear, measurable set of exit criteria.

Model – a representation of a real object or situation.

Multicriteria decision problem – a problem that involves more than one criterion; the objective is to find the best solution, taking into account all the criteria.

Objective function – a mathematical expression that describes the problem's objective.

Optimal solution – the specific decision-variable value or values that provide the best output for the model.

Problem definition – the first step in the system development lifecycle during which the problem is identified, its cause is determined, and a strategy for solving it is developed.

Problem solving – the process of identifying a difference between the actual and the desired state of affairs with further taking action to resolve the difference.

Process – an activity that changes a system in some way.

Single-criterion decision problem – a problem in which the objective is to find the best solution with respect to just one criterion.

Stochastic (probabilistic) model – a model in which at least one uncontrollable input is uncertain and subject to variation; stochastic models are also referred to as probabilistic models.

System development life cycle (SDLC) – a set of steps for solving information system problems; the basis for most systems analysis and design methodologies.

System life cycle – a model that stresses the stages of system usefulness. The stages are birth, development, growth, maturity, and death.

Testing – the fifth step in the system development life cycle (following development and preceding implementation) intended to ensure that the system does what it was designed to do.

Uncontrollable inputs – the environmental factors or inputs that cannot be controlled by the decision maker.

Variable cost – the portion of the total cost that is dependent on and varies with the volume.

Unit 3

Categorical variable – a variable which can take a value from a finite set of values. Survey questions that require respondents to answer on the basis of a Likert scale result in categorical variables.

Chi-square goodness of fit – a test of whether or not data follow the assumed distribution. This can be used to determine if the model data fit the observed data. If the test statistic is large, then the observed data does not fit that expected based on the model and the model should be rejected.

Confidence intervals – a range of values we are fairly sure our true value lies in. For example, if an interval is given for 95 percent confidence, there is a 95 percent probability that the true value lies within the range of the estimated parameter.

Continuous variable – a variable which in the simplest term can take "any" value. For example, survey respondent's age or distance from a respondent's home to a visitor site.

Dependent variable – a variable that is observed to arise based on the levels of all independent variables.

Dummy variables – categorical variables believed to influence the outcome of a regression model that can be coded as 1 or 0 for existing or not existing ones respectively. Inclusion of dummy variables can help to increase the fit of a model, but at a loss of generality of the model (i.e. more dummy variables means a more case-specific model). If multiple categorical variables are related, one must be excluded in the regression analysis, to act as the baseline from which the effect of the other categories is measured.

Econometric analysis – in relation to economic valuation of non-market goods and services, econometric analysis focuses on identifying the separate effects of different factors that act in common to determine the economic value generated by a particular good or service. This is relevant to revealed preference (e.g. hedonic pricing, travel cost and multi-site recreation demand models), stated preference (e.g. contingent valuation, choice experiments) and other valuation methods such as the production function approach. Typically analysis is via regression techniques that enable a statistical analysis of the quantitative relationship (correlation) between one or more independent variables and one dependent variable. Approaches and methods are determined by the nature of the data analysed.

Fixed effects estimation – fixed effects estimation controls for unobserved heterogeneity in observations by assuming that all unobserved variables create an individual specific effect on the depdenant variable that is fixed between observations.

Independent variable – a variable that is considered changeable and affecting the dependent variable.

Log-likelikood statistic – statistic similar to R^2, but instead of measuring the variation based on the mean value; it compares the predicted outcome based on the model to the actual observed outcomes. When comparing between models using the same data, a greater (or less negative) log-likelihood statistic indicates a better fitting model.

Multiple regression – predicts the change in a dependent variable based on the effects of multiple independent variables.

Ordinary least squares (OLS) regression – a linear model. The dependent variable is continuous and the independent variables are generally continuous, although there are methods of including categorical variables as dummy variables. Additionally, the linear relationship can be modified by transforming variables. For example, the relationship between income and value of water quality may not be significant, but the relationship between the square of income and value of water quality may be. OLS refers to the statistical method of fitting the line of best fit to the data available. Specifically the distance between each data point and the regression line is squared and added together. The OLS model minimises this number, essentially minimising the total distance of data points from the line of best fit.

R^2 (R-squared) – a measure of fit of a linear model. Essentially it describes how much of the variance data is explained by the model, based on how much variation there was to explain in the first place. It does so by comparing the differences between the data points and the mean (original variation) to the differences between the model function and the mean (model variation). The value ranges from 0 to 1, with values closer to one representing greater explanatory power of the model.

Random effects estimation – the estimation which assumes that the individual specific effects are uncorrelated with the independent variables, and so change between observations.

Random utility models (RUM) – the basis for discrete choice analysis methods (such as choice experiments and multi-site recreation demand models). An equation is used to estimate the total utility of a choice based on independent variables, each having their own utility coefficients.

Robust standard error – robust statistics provide alternative methods of calculating estimators (such as mean, standard error, etc.) that are not affected by small departures from model assumptions or outliers in a sample. Robust standard errors are adjusted correlations of error terms across observations.

Sampling – all economic analyses attempt to make conclusions about a particular population. It is infeasible to survey everyone in a given population, so a sample of that population is used for research purposes. A sample should be representative: it should have similar socio-economic characteristics as the entire population (e.g. if population is 53 percent female, the sample should ideally be 53 percent female).

Standard deviation – a measure of variability (or dispersion) of the population from the mean.

Standard error – standard deviation of the sampling distribution around the estimated mean (note that this can be different from the true mean and standard deviation of the population).

Variable – a value that may vary and in the context of economics refers to any characteristic of the subject matter that may vary (e.g. income level of a respondent).

Independent variable – variable that is considered changeable and affecting the dependent variable.

Unit 4

Alternative optimal solutions – the case in which more than one solution provides the optimal value for the objective function.

Artificial variable – a variable that has no physical meaning in terms of the original linear programming problem, but serves merely to enable a basic feasible solution to be created for starting the simplex method. Artificial variables are assigned an objective function coefficient of $-M$, where M is a very large number.

Basic feasible solution – a basic solution that is also feasible; that is, it satisfies the nonnegativity constraints. A basic feasible solution corresponds to an extreme point.

Basic solution – given a linear program in standard form, with *n* variables and *m* constraints, a basic solution is obtained by setting *n* - *m* of the variables equal to zero and solving the constraint equations for the values of the other *m* variables. If a unique solution exists, it is a basic solution.

Basis – the set of variables that are not restricted to equal zero in the current basic solution. The variables that make up the basis are termed basic variables, and the remaining variables are called nonbasic variables.

Canonical form for a maximization problem – a maximization problem with all less than or equal to constraints and nonnegativity requirements for the decision variables.

Canonical form for a minimization problem – a minimization problem with all greater than or equal to constraints and nonnegativity requirements for the decision variables.

Constraints – restrictions or limitations imposed on a problem.

Degeneracy – situation, when one or more of the basic variables has a value of zero.

Degenerate solution – a solution to a transportation problem in which fewer than *m* - *n* - 1 arcs (cells) have a positive flow; *m* is the number of origins and *n* is the number of destinations.

Dummy destination – a destination added to a transportation problem to make the total supply equal to the total demand. The demand assigned to the dummy destination is the difference between the total supply and the total demand.

Dummy origin – an origin added to a transportation problem in order to make the total supply equal to the total demand. The supply assigned to the dummy origin is the difference between the total demand and the total supply.

Extreme point – graphically speaking, extreme points are the feasible solution points occurring at the vertices or "corners" of the feasible region. With two-variable problems, extreme points are determined by the intersection of the constraint lines.

Feasible region – the set of all feasible solutions.

Feasible solution – a solution that satisfies all the constraints.

Heuristic – a commonsense procedure for quickly finding a solution to a problem. Heuristics are used to find initial feasible solutions for the transportation simplex method and in other applications.

Infeasibility – the situation in which no solution to the linear programming problem satisfies all the constraints.

Iteration – the process of moving from one basic feasible solution to another.

Linear functions – mathematical expressions in which the variables appear in separate terms and are raised to the first power.

Linear programming model – a mathematical model with a linear objective function, a set of linear constraints, and nonnegative variables.

Minimum cost method – a heuristic used to find an initial feasible solution to a transportation problem; it is easy to use and usually provides a good (but not optimal) solution.

Nonnegativity constraints – a set of constraints that requires all variables to be nonnegative.

Objective function – a mathematical expression that describes the problem's objective.

Parameters – numerical values that appear in the mathematical relationships of a model. Parameters are considered known and remain constant over all trials of a simulation.

Primal problem – the original formulation of a linear programming problem.

Problem formulation – the process of translating the verbal statement of a problem into a mathematical statement called the *mathematical model.*

Range of feasibility – the range of values over which a *bi* may vary without causing the current basic solution to become infeasible. The values of the variables in the solution will change, but the same variables will remain basic. The dual prices for constraints do not change within these ranges.

Range of optimality – the range of values over which an objective function coefficient may vary without causing any change in the optimal solution (i.e., the values of all the variables will remain the same, but the value of the objective function may change).

Redundant constraint – a constraint that does not affect the feasible region. If a constraint is redundant, it can be removed from the problem without affecting the feasible region.

Simplex method – an algebraic procedure for solving linear programming problems. The simplex method uses elementary row operations to iterate from one basic feasible solution (extreme point) to another until the optimal solution is reached.

Slack variable – a variable added to the left-hand side of a less-than-or-equal-to constraint to convert the constraint into an equality. The value of this variable can usually be interpreted as the amount of the unused resource.

Standard form – a linear program in which all the constraints are written as equalities. The optimal solution of the standard form of a linear program is the same as the optimal solution of the original formulation of the linear program.

Transportation problem – a network flow problem that often involves minimizing the cost of shipping goods from a set of origins to a set of destinations; it can be formulated and solved as a linear program by including a variable for each arc and a constraint for each node.

Transportation simplex method – a special-purpose solution procedure for the transportation problem.

Unbounded – if the value of the solution may be made infinitely large in a maximization linear programming problem or infinitely small in a minimization problem without violating any of the constraints, the problem is said to be unbounded.

Unit 5

A range of numbers – a representative range of numbers.

Business games – operational games that deal with decision making at the top of a business corporation.

Deterministic simulation – a simulation that does not account for uncertainties, consisting of a single realization of the system. The input parameters for a determinstic simulation are represented using single values (which are typically described either as "the best guess" or "worst case" values).

Discrete event simulation – a modeling methodology that utilizes a transaction-flow approach to modeling systems. Models consist of entities (units of traffic), resources (elements that service entities), and control elements (elements that determine the states of the entities and resources). Discrete event simulators are generally designed for simulating detailed processes such as call centers, factory operations, and shipping facilities.

DYNAMO – a special-purpose simulation language for system dynamics.

Flowchart (or diagram) – a schematic presentation of all computational activities used in the simulation written in a symbolic language.

Heuristic programming – a step-by-step procedure using heuristics that, in a finite number of steps, arrives at a satisfactory solution.

Heuristics – decision rules that are developed on the basis of logical problem analysis and, possibly, designed experimentation.

Industrial dynamics – a computerized system simulation of a whole company or industry.

Model – an abstract representation or facsimile of an existing or proposed system (e.g., a project, a business, a mine, a watershed, a forest, the organs in your body).

Monte Carlo simulation – a simulation that uses a random number mechanism to describe the behavior of systems with probabilistic elements.

Operational (management) games – simulation of a competitive situation arranged in the form of a game. Participants make periodic decisions and the results are then analyzed. Such games are mainly used for training purposes.

Performance assessment – a simulation of an environmental system that includes some man-made components (e.g., a waste disposal facility) in which one is attempting to predict the performance or the degree of safety or reliability of the system.

Probabilistic simulation – a simulation that explicitly represents uncertainty by specifying inputs as probability distributions.

Probability distribution – a mathematical representation of the relative likelihood of an uncertain variable having certain specific values.

Pseudorandom number – a random number generated by a mathematical process.

Random numbers – numbers sampled from a uniform distribution. Each number has the same chance of being drawn.

Random number generation – a process of generating random numbers, usually by a computer. Can be done manually by drawing pieces of papers with numbers from a hat or from a specially constructed table.

Realization – a single simulation run representing a particular "future" (i.e., one possible path the system may follow through time). When running probabilistic simulations, multiple realizations are carried out in order to simulate a large number of possible futures.

Rules of thumb – rules of decision making that are based on trial and error and that yield acceptable solutions for managerial problems.

Simulation – a procedure that involves the use of a mathematical model that imitates reality for the purpose of conducting experiments on the model. These trial-and-error-type experiments intend to predict the behavior of the system under different situations.

Simulation runs – a simulation run is one simulation experiment with one set of input data.

Stochastic process – a process that often has some underlying trend or pattern, but inherently has a random component, and as a result, can only be described statistically. Examples of stochastic variables include rainfall, exchange rates, and the rate of insurance claims.

System dynamics – a simulation methodology based on the standard stock and flow approach developed by Professor Jay W. Forrester at MIT in the late 1950s and early 1960s. Models based on system dynamics are built using three principal element types (stocks, flows, and converters), and put emphasis on understanding the feedback structure of systems.

Time compression – the ability to simulate years of operations in seconds or minutes of computer time.

Time dependent – simulation where the exact time of each event is required and tracked.

Time independent – simulation where the exact time of each event is not needed.

Trial – one period in a simulation run. A run is composed of many trials.

Validation – determining how closely the model predicts the behavior of the system.

Visual simulation – visual interactive decision making in real time using simulation and computer graphics.

Unit 6

Additivity assumption (of utilities) – the utility of two or more items equals the sum of the utilities of the individual items.

Certainty equivalent (CE) – a subjective evaluation of the monetary worth of a gamble to a decision maker.

Conflict – a decision situation where the payoff is conditioned by the decisions made by two or more decision makers with conflicting objectives.

Dominance – a case where one decision alternative is superior to another alternative under all circumstances.

Expected utility (EU) – the long-run average utility per decision.

Fair game – a game whose value is zero.

Game – a series of repetitive decisions (plays).

Minimax theorem – the theorem that is the basis for the solution to the two-person, zero-sum game. The theorem maintains that each player acts to maximize his or her minimum possible gain (or minimize his or her maximum loss.)

Mixed strategy – a case where the decision maker should change the alternative courses of action at random, according to a predetermined proportion.

Multiple goals – a situation in which the impact of a decision is evaluated for several goals simultaneously.

Nonzero-sum game – a game where the winner(s) receives either less or more than what the loser(s) contributed.

N-person game – a conflict involving more than two decision makers.

Play – one move (one decision) in a game.

Preference theory – a measure of attitude toward risk using probabilities of a gamble.

Pure strategy – a case where the best strategy is to repeatedly stick to one decision alternative no matter what the opposition does.

Risk premium – the attitude toward risk, as measured by the difference between EMV and CE.

Risk profile – a list of the payoffs and probabilities for each alternative.

Strategy – a complete, predetermined plan for selecting the appropriate course of action for every possible circumstance.

Two-person game – a conflict with two parties.

Utile – a unit of measurement of utility.

Utility curve – the relationship between the quantity of money and its benefit to the decision maker.

Utility – the subjective value of the outcome to the decision maker.

Value of the game – the average payoff per play.

Zero-sum game – a game where the winner(s) receives, and the loser(s) contributes, the entire amount at stake.

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Unit 1

* Figures indicate the number of the task.

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Contents

НАВЧАЛЬНЕ ВИДАННЯ

Борова Тетяна Анатоліївна
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АНГЛІЙСЬКА МОВА ДЛЯ БІЗНЕС-АНАЛІТИКІВ

Навчальний посібник
У трьох частинах

ЧАСТИНА 2. МОДЕЛІ ТА МЕТОДИ
(англ. мовою)

Самостійне електронне текстове мережеве видання

Відповідальний за видання *Т. А. Борова*

Відповідальний редактор *М. М. Оленич*

Редактор *З. В. Зобова*

Коректор *З. В. Зобова*

Запропоновано матеріал щодо оволодіння англійською мовою для бізнес-аналітиків. Друга частина посібника присвячена дисциплінам математичного циклу економічної підготовки, які є основою бізнес-аналізу, а саме: системному аналізу, моделюванню, дослідженню операцій, економетриці, імітаційному моделюванню і теорії ігор. Зазначені дисципліни забезпечують розуміння різних економічних і математичних аспектів бізнес-аналізу. Посібник може бути використаний як для навчання у групах, так і для самостійного вивчення.

Рекомендовано для студентів спеціальності "Економіка", викладачів, а також усіх, хто вивчає та використовує англійську мову в своїй професійній діяльності, що пов'язана з використанням математичних методів в економіці.

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