高等学校试用

英语理工科教材选

第九分册　管理工程

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机械工业部部属院校选编

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Book IX

Management Engineering

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机械工业部部属院校选编

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(第九分册　管理工程)

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编者的话

为了提高机械工业部部属院校学生的外语水平，培养学生阅读英语科技书刊的能力，我们选编了这套“英语理工科教材选”。整套“教材选”共分九个分册，内容包括数学、物理、理论力学、材料力学（与理论力学合为一个分册）、电工学、工业电子学、金属工艺学、机械原理、机械另件（与机械原理合为一个分册）、计算机算法语言、管理工程等十一门业务课程。各业务课都选了三章英语原版教材（个别也有选四章），供机械工业部部属院校试用。

在业务课中使用部分外语原版教材，这是我们的一次尝试，也是业务课教材改革、汲收国外先进科学技术的探索。在选材时，我们考虑了我国现行各课程的体系、内容以及学生的外语程度，尽可能选用适合我国实际的外国材料。

本“教材选”的选编工作，是在机械工业部教育局的直接领导下，由部属院校的有关教研室做了大量调查研究后选定的，并进行注释和词汇整理工作。由马泰来、卢思源、李国瑞、柯秉衡、谢卓杰、戴炜华、戴鸣钟等同志（以姓氏笔划为序）组成的审编小组，对选材的文字、注释、词汇作了审校。戴鸣钟教授担任整套“教材选”的总审。

由于时间仓促，选材、注释和编辑必有不尽完善之处，希广大读者提出宝贵意见，以利改进。

1983年4月

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HERTZ RENT-A-CAR

Hertz Rent-A-Car is number one in the car rental business and trying hard to ① stay that way. Hertz operates a substantial fleet of vehicles in more than 100 cities in the United States and Canada. Most of the major Hertz field operations are organized as pools consisting of from 2 to 10 cities with fleets of 2,000 to 6,000 cars.[1] The major benefit of the pool arrangement is the potential for improving fleet utilization through the shifting of cars from cities with surplus to cities with shortages.

Imagine though the complexity of Hertz's short-term planning problem. ② How would you allocate cars to each city on a daily basis? Keep in mind the dual and conflicting goals of the Hertz management—assuring adequate vehicle availability for the customer and, at the same time, maintaining a high degree of utilization for each car in the fleet.

The distribution problem has both a "city dimension" and a "time dimension." City demand for cars can vary significantly and the planning horizon must extend well beyond the current day. Arrangements for transfers of cars must be made days in advance. A further complication is that the capacity or available number of cars is highly complex and uncertain. New cars are always being installed and other cars retired; some are moving to and from the maintenance shop. Finally, the Hertz Rent-It-Here, Leave-It-There policy ③ means that future rentals can occur anywhere and return anywhere.

The complexity and importance of the short-range planning problem has long been recognized by the Hertz management. However, until recently their ④ decisions were based on "gut feelings," with heavy reliance on sometimes distorted hand-computed averages and statistics. Spurred by competition and the desire to be more profitable, Hertz decided to turn to a sound analytical approach to the short-range planning problem.

The Hertz Operations Research group responded by developing the Pool ⑤ Control System (PCS). PCS is an interactive model-oriented management tool.

[1]Martin Edelstein and Myron Melnyk, "The Pool Control System," *Interfaces*, 8 (November 1977), 21–36.

It is a descriptive rather than a prescriptive analytical tool, whose purpose is to clarify and evaluate alternatives. Ultimate decision making is left to the manager. (PCS provides the information and reports to aid in the decision.) The PCS system uses a model (a system of equations) to calculate estimates for key variables, such as capacity and demand. It is a time-sharing-based system that answers the following kinds of questions for each city: How many cars will be needed? How many cars will be available or can be moved in from other pool cities? How many reservations can be accepted? How will the actions taken for any city on any day affect future days and other cities?

PCS is an example of a successful decision support system that combines an analytical model with a computerized information system. All levels of management at Hertz have attributed dramatic improvements in both customer service and fleet utilization to PCS. Approximately 50 cities representing over 60% of Hertz's car fleet use PCS daily. Those cities using the system have realized an increase of at least 10 percent in the average number of rentals per car. This directly affects bottom-line performance. This is all accomplished by a system whose total operating cost for each pool city never exceeds $10 a day.

PCS has been used most successfully in handling the Florida winter season, the Olympics, the Super Bowl, the summer peak on the West Coast, the presidential inauguration, and major conventions as well as normal business periods. The next time you find yourself walking (not running) through an airport, you might have the Pool Control System to thank.

INTRODUCTION

Prior to the twentieth century, business and other organizations functioned in a less complex environment than that of today. Managers of contemporary organizations (such as Hertz Rent-A-Car) must cope with a dynamic world of increased population, inflation, recession, social consciousness, and shortages of energy resources such as crude oil. Consequently, the decision-making task of modern management is more demanding and more important than ever.

⑥ Fortunately, we human beings can use our ingenuity to find new ways to handle the problems that confront us. Even though contemporary in-
⑦ stitutions face an increasingly complex and uncertain environment, they also have available innovative approaches to dealing with decision problems. This book is concerned with some of the new tools and technology that have been developed specifically to help management in the decision-making process.

management science

operations research

Management science is the discipline devoted to studying and develop- ⑧
ing procedures to help in the process of making decisions. It is also commonly called *operations research*. The two terms have come to be used interchangeably, and we shall use both throughout the text. The principal characteristic of operations research/management science (OR/MS) is its use of the scientific method for decision making. Management can approach complex decision problems in several ways. Managers may resort to intuitive or observational approaches that depend on subjective analyses. Or, putting faith in "proven" procedures, they may simply repeat other managers' solutions. Such attempts at handling problems are sometimes called *seat-of-the-pants* approaches. They may not attack the problems in a systematic manner, and they do little to improve or advance the managerial decision process. On the other hand, a management science approach provides a rational, systematic way to handle decision problems. Using a systematic approach, the decision maker has a better chance to make a proper decision.

Our greatest technical accomplishments have been achieved by utilizing the scientific method. Only recently, however, have we begun to apply this methodology outside the laboratory environment of physics and chemistry. Even though these new environments are less controlled, the operations of organizations and their decision-making processes still lend themselves to analysis through scientific methodology.

How did scientific methodology come to be applied to decision prob- ⑨
lems? The answer to that question will further your comprehension of the field of management science.

HISTORICAL OVERVIEW

Operations research/management science is an interdisciplinary field ⑩
comprising elements of mathematics, economics, computer science, and engineering. Its specific content expanded enormously after the twentieth-century invention of electronic computers. Its fundamental philosophical principle, however—the use of scientific methodology to solve problems—was a recorded management technique much earlier. Venetian shipbuilders of the fifteenth century, for example, are known to have used an assembly line of sorts in outfitting ships.

Progress was not consistent until the Industrial Revolution, however. Based on his analysis of the manufacture of straight pins, Adam Smith proclaimed the merits of division of labor in 1776. Charles Babbage, an English mathematician and mechanical genius, wrote a seminal treatise
titled *On Economy of Machines and Manufactures* (1832). In it, Babbage ⑪
discussed such issues relevant to management science as skill differential in wages and concepts of industrial engineering.

In the late nineteenth century, an American engineer, Frederick Taylor, formally advocated a scientific approach to the problems of manufacturing. Taylor, sometimes called the father of scientific management, was largely responsible for developing industrial engineering as a profession. It was his philosophy that there was one "best way" or most efficient way to accomplish a given task. He used time studies to evaluate worker performance and to analyze work methods.

(12) Henry L. Gantt, a contemporary of Taylor's, refined the content of early scientific management by bringing into consideration the human aspect of management's attitude toward labor. He espoused the importance of the personnel department to the scientific approach to management. Perhaps his greatest contribution, however, was his scheduling system for loading jobs on machines. Basically a recording procedure, Gantt's system was devised to minimize job completion delays; it permitted machine
(13) loadings to be planned months in advance.

The early scientific management era was an important stage of development for OR/MS. However, its progress was mostly limited to establishing or improving efficient performance of specific tasks in the lower levels of organizations. It may not be possible to pinpoint the first true application of management science, but several pioneers should be noted. As early as 1914, an Englishman named Frederick W. Lanchester attempted to predict the outcome of military battles based on the numerical strength of personnel and weaponry. Lanchester's predicting equation may represent the first attempt to model an organizational decision problem mathematically. In 1915, Ford W. Harris published a simple lot-size formula that constituted the basis for inventory control for several decades and still finds wide use today. Just as Harris helped establish inventory control theory, a Danish mathematician, A. K. Erlang, founded modern waiting-line, or queuing theory. He developed mathematical formulas to predict waiting times for callers using automatic telephone exchanges.

One of the first to apply sophisticated mathematical models to business problems in the United States was Horace C. Levinson, an astronomer by training. In the 1930s, Levinson studied such market-oriented applications
(14) as the relationship between advertising and sales and the effect of income and residential location upon customer purchases.

Despite such advances in the scientific approach to quantitative management problems before 1940, OR/MS did not emerge as a recognized discipline until World War II. In the late 1930s, the British assembled a team of specialists to investigate the effective use of radar. Subsequently, the British military establishment increasingly called upon the British scientific establishment to study other problems, such as antisubmarine warfare, civilian defense, and the optimal deployment of convoy vessels to accompany supply ships.

This approach to military problem solving called upon experts from various areas of specialization. Perhaps the most famous British group was headed by the distinguished physicist P. M. S. Blackett. Blackett's (15)
Circus, so-called, consisted of three physiologists, two mathematical physicists, an Army officer, a surveyor, two mathematicians, an astrophysicist, and a general physicist. This multidiscipline team approach has become a characteristic of OR/MS. The highly successful British operational research was credited with helping to win the Battle of Britain and the Battle of the North Atlantic.

Such successes influenced the United States military establishment to include "operations analysis" groups on its staff. During World War II, the United States gathered mathematicians, statisticians, probability theorists, and computer experts to work on operations analysis. During the period, John von Neumann made immense contributions in the area of game theory and utility theory, and George Dantzig worked on the simplex method of linear programming.

linear programming

After the war, the military establishment increased its research programs and retained some operations research personnel, but industry largely ignored the methodology of the discipline. Many operations research ideas naturally had a military orientation, and nonmilitary managers tended to regard the techniques either as irrelevant to their problems or impossible to implement. Two events helped to bring operations (16)
research to industry. In 1947, George Dantzig developed *linear programming*, a technique that uses linear algebra to determine the optimal allocation of scarce resources. Obviously, such a method could be applied profitably to many business problems. Operations research began to be regarded as sometimes relevant to industry.

The second, and more important, occurrence to enhance the acceptability of nonmilitary operations research was the development and production of high-speed electronic computers. Some operations research techniques entailed long, complex calculations to solve real-world problems. Computers, capable of performing such calculations millions of times faster than people, were invaluable tools for the operations research profession. With the advent of electronic instruments to perform functions that were previously impossible or unprofitable, OR/MS could be (17)
perceived as valid to, and valuable for, business and industry. The dependence of OR/MS methodology on computers cannot be overemphasized. Even today, certain large-scale problems cannot be solved with current techniques and existing computer hardware. Research will undoubtedly improve the methodology; but it is ultimately the future generations of computers that will allow operations researchers and management scientists to extend the successful applications of their discipline.

Given the favorable climate engendered by industry's acceptance of OR/MS in the 1950s, the discipline developed rapidly. One measure of its formalization was the establishment of professional associations. Chief among these are: Operational Research Society (British, 1950); Operations Research Society of America (1952); The Institute of Management Science (United States, 1953); and American Institute of Decision Sciences (1969).

By the end of the 1950s, many of the standard tools of OR/MS, such as linear programming, dynamic programming, inventory control theory, and queuing theory, were relatively well developed. However, in the 1950s most of the OR/MS applications focused on specialized and very well defined problems. Since the early 1960s, formal OR/MS endeavors have dealt increasingly with planning problems that are less well structured and less realistic. Decision analysis emerged as a process for dealing with decisions associated with much uncertainty. Goal programming and multiobjective linear programming were developed to deal with decision problems that have multiple and sometimes conflicting goals.

During the 1970s and into the 1980s, OR/MS has become increasingly concerned with the interface with management information systems (MIS). Computerized data bases play a vital role in supporting OR/MS models as well as in everyday decision making. The marriage of OR/MS and MIS has resulted in a special kind of information system called a decision support system (DSS). This type of system holds great promise for the enhancement of the decision-making process at all levels of management. It will be interesting to observe future developments in this exciting new area.

Since 1950, the field of OR/MS has progressed steadily. Currently more than 20,000 people are involved in applying, teaching, or researching the field. Most *Fortune 500* companies practice OR/MS. Smaller companies may not require full-time OR/MS programs and personnel, but they often hire management consultants for OR/MS projects. Given such exposure,
(18) business is finding increasingly desirable the employee who has OR/MS training. As a result, many universities offer undergraduate and graduate degrees in the field, and most business schools have requirements in the subjects of operations research, management science, decision science, or quantitative methods.

THE NATURE OF MANAGEMENT SCIENCE

(19) You have probably gained some insight into the nature of management science from the preceding brief historical overview. In this section we define the actual content of this discipline more specifically. Harvey Wag-

ner, past president of The Institute of Management Sciences, has described OR/MS simply and yet precisely. Wagner states that operations research is a scientific approach to problem solving for executive management. The Operations Research Society of America amplifies this basic definition by calling operations research an experimental and applied science devoted to observing, understanding, and predicting the behavior of purposeful human/machine systems. It is logically applied, therefore, to the practical problems of government, business, and society.

As the foregoing definitions suggest, the fundamental characteristic of OR/MS is its scientific or systematic approach to decision making. But how can we apply the scientific method to the often uncontrollable and imprecise environment of the real world? In laboratory experiments, data are rejected unless they are demonstrably accurate, and all conditions are strictly controlled. In modern organizations, data are often imperfect, and the outside world exerts a significant influence on many of the variables under study. Factors relevant to a management science experiment are often impossible to manipulate. Furthermore, the functioning and profitability of the firm usually take precedence over artificial changes induced for the sake of experimentation. For example, a company would not temporarily close its warehouses in order to determine the exact shortage costs for its inventory.

Even though the management scientist usually cannot perform a "pure" scientific experiment, this does not preclude using a scientific approach. The management scientist works in a situation analogous to an astronomer's: Each has little control over a constantly changing universe and (20)
yet each performs scientific experiments and builds mathematical models to account for the observed phenomena.

THE SCIENTIFIC METHOD

In order to see how the management scientists may use a scientific approach, you must recall the basic steps of the scientific method. These are

1. Observation
2. Definition of the problem
3. Formulation of a hypothesis
4. Experimentation
5. Verification

As you would suppose, the first three steps of the scientific method can (21)
be carried out by the management scientist much as they would be by a chemist or a biologist. However, experimentation and verification can pose special problems in real-world applications.

22 Let us consider a hypothetical problem for the manager of a manufacturing firm to see how the scientific method can be applied to the analysis of a business problem. The first step of the scientific method requires the recognition of a particular phenomenon. Suppose that the manager of the manufacturing firm has observed a significant rise in inventory costs over the past year. This observation suggests the existence of a problem that can perhaps be treated, yielding benefits to the firm.

Thus, it is necessary to pinpoint the exact nature of the problem. The manager has observed rising costs. These may simply be due to inflation. Some observations may be directly related to the symptoms of the problem rather than to the problem itself. It is important that the decision maker formulate the problem precisely and address the truly relevant issues. Much time, effort, and money can be wasted looking at the wrong problem.

In our example, suppose that the manager has determined that inventory costs have risen even faster than the national rate of inflation. The manager suspects that a significant part of the increased cost is caused by the firm's current inventory policy and thus is potentially amenable to change. The manager's problem can now be clearly defined: It is necessary to determine a new inventory policy that will reduce inventory costs.

The inventory costs of the company are comprised primarily of inventory holding costs (costs of carrying and storing) and inventory replenishing costs (costs of ordering and restocking). A closer examination by the manager yields the fact that replenishing costs have increased more rapidly than holding costs. This is true primarily because transportation costs and the clerical costs of placing orders have risen sharply. The manager now has a hypothesis: Ordering larger quantities fewer times per year will decrease overall inventory costs. This new policy will increase holding costs somewhat, but it will lower replenishing costs at the same time.

Now the manager needs to determine how much larger the orders should be. A trial-and-error approach can be implemented by changing the order quantity and observing the effects on total inventory costs. Observations will then confirm or disprove the initial hypothesis. Another approach is to use a mathematical inventory model (Chapter 14) that "fits" the particular problem. This approach, if applicable, eliminates the need for trial and error, for the model determines the order quantity. A third approach is computer simulation (Chapter 13). In any of these situations, the manager ultimately determines whether the hypothesis is valid by comparing the cost of the new solution with the cost before experimentation. Higher costs may indicate that the original hypothesis is in-
23 correct. In that case, further experiments are called for to try to develop a better hypothesis.

Verification of the conclusions of the experiment can be made in sev-

eral ways. The most accurate, of course, is actually to implement the new 24
solution within the company and then observe its effects. This procedure can be very dangerous in practice, and it may have far-reaching consequences throughout the organization. Usually, it is best to try to forecast the success of the new solution by applying it to hypothetical data or data that represent past transactions of the firm. However, since costs, prices, and demand are constantly changing, success on past data does not necessarily guarantee success in future inventory transactions for the company. Thus, complete verification in the real world is not always possible.

A SYSTEMS APPROACH

systems approach

The scientific method is extremely useful for trying to solve certain very specific problems the management scientist encounters. It is usually applied, however, within a much broader context known as the *systems approach*. The word *system* is much used in our society. We hear of computer systems, solar systems, nervous systems, political systems, and systems we usually cannot beat. In this book, we shall refer to a system as a 25
whole comprising interrelated parts intended to accomplish a specific objective. Thus, a computer system is made up of hardware components (such as the central processing unit, card reader, and disk and tape drives) and software components (such as the operating system software and various compilers). These components interact to accomplish the objective of processing computer jobs.

Organizations, too, conform to our definition of a system. One kind of 26
organization that can use management science to its advantage—the kind with which we will be concerned primarily—is a human/machine system comprising components such as machinery, departments, divisions, and individual people. The main purpose of the management scientist is to aid in the achievement of the goals of the organization as a whole. Viewing the organization as a system permits us to consider the individual components in relation to the entire organization.

This perspective is essential, for the good of the whole may not necessarily derive from the greatest good for each of the parts. In other words, concentrating only on a particular component of the organizational system may result in *optimization*, or best achievement of goals, for that component but a less than optimal solution or *suboptimization*, for the 27
organization as a whole. Optimizing the organization's goals is sometimes accomplished by optimizing its subsystems. In other cases, however, suboptimization of various components is necessary for the sake of the organization's greatest good. A systems approach best equips the decision 28
maker to determine which alternative actually will maximize the realization of the goals of the organization.

Just as a systems approach helps us to have a balanced perspective concerning an organization's components, it also helps us to view the organization as a component, or subsystem, of the environment in which it exists. Today's human/machine organizations operate under conditions of rapid change and ever-increasing complexity. Good decision making, therefore, requires that management take a broad view. Just as an inventory problem, for example, within a single component may affect an organization's production, finance, accounting, and personnel functions, so too the organization's inventory decisions can affect external supply, demand, and prices in the general market.

Usually, no single decision maker is sufficiently multitalented to understand the ramifications of proposed solutions on all aspects of the organization, including its internal and external environments. Often, a team of specialists is formed to attack quantitative management problems. The concept of the team approach to decision making is a key characteristic of the OR/MS approach. You may recall that one of the first operations research teams, Blackett's Circus, consisted of 11 different specialists. Depending on the type of application, an OR/MS team might include experts in mathematical programming, accounting, finance, marketing research, engineering, mathematics, behavioral science, statistics, computer programming, and other fields. This interdisciplinary approach tends to treat the individual phases of a problem most effectively; consequently, the success of the entire project is enhanced.

㉙ To summarize, management science applications include any approach to problem solving that incorporates all, or most of, the following characteristics:

1. Viewing the problem within a systems perspective
2. Applying the scientific method to develop the solution methodology
3. Using a team, or interdisciplinary, approach
4. Using a mathematical model
5. Using a high-speed electronic computer

We have not yet said much about the fourth essential characteristic of management science, model building. Your introduction to mathematical models is in the following section. Most of the topics you will encounter in this text involve some use of a mathematical model.

MODELS IN MANAGEMENT SCIENCE

In general terms, a model is a representation or an abstraction of an object or a particular real-world phenomenon. A good model accurately displays the key properties of the entity it represents. Many different dis-