Mc Graw Hill Education

美国麦格劳－希尔教育出版公司工商管理最新教材（英文版）

运筹学导论（第10版）

[美] 弗雷德里克·S. 希利尔（Frederick S. Hillier）
杰拉尔德·J.利伯曼（Gerald J. Lieberman） 著

Introduction to Operations Research (Tenth Edition)

清华大学出版社

美国麦格劳－希尔教育出版公司工商管理最新教材（英文版）

运筹学导论

（第10版）

[美] 弗雷德里克·S. 希利尔（Frederick S. Hillier）
杰拉尔德·J.利伯曼（Gerald J. Lieberman） 著

Introduction to Operations Research

(Tenth Edition)

清华大学出版社
北京

Frederick S. Hillier, Gerald J. Lieberman

Introduction to Operations Research, 10th Ed.

EISBN: 9780073523453

北京市版权局著作权合同登记号　图字：01-2014-7909

图书在版编目（CIP）数据

运筹学导论：第 10 版=Introduction to operations research:英文/（美）希利尔（Hillier,F.S.），（美）利伯曼（Lieberman,G.J.）著. —北京：清华大学出版社，2015

（美国麦格劳-希尔教育出版公司工商管理最新教材：英文版）

ISBN 978-7-302-39291-0

Ⅰ. ①运… Ⅱ. ①希… ②利… Ⅲ. ①运筹学－高等学校－教材－英文 Ⅳ. ①O22

中国版本图书馆 CIP 数据核字(2015)第 024553 号

责任编辑：王　青

封面设计：常雪影

责任印制：宋　林

出版发行：清华大学出版社

网　　址：http://www.tup.com.cn，http://www.wqbook.com

地　　址：北京清华大学学研大厦 A 座　　**邮　　编**：100084

社 总 机：010-62770175　　**邮　　购**：010-62786544

投稿与读者服务：010-62776969，c-service@tup.tsinghua.edu.cn

质 量 反 馈：010-62772015，zhiliang@tup.tsinghua.edu.cn

课 件 下 载：http://www.tup.com.cn,010-62770175 转 4903

印 装 者：清华大学印刷厂

经　　销：全国新华书店

开　　本：203mm×260mm　　**印　　张**：39.5

版　　次：2015 年 1 月第 1 版　　**印　　次**：2015 年 1 月第1 次印刷

印　　数：1～4000

定　　价：69.00 元

产品编号：062308-01

序

中国的学生要不要使用英文版的教材，一直有争议。有人认为，我们应该使用自己编写的教材，这样才能更准确地反映我们在课堂上所要表述的观点。用国外的原版教材，有些隔靴搔痒，不能解决中国的实际问题。持不同意见的观点认为，尽管各国在管理体制上有意识、制度、文化等差异，但管理本身是在国际环境下具有共同性的问题。特别是，中国的企业在经济全球化的环境下，需要更多地了解国外的管理理论与现状。在这种情况下，就需要引进一些外版的教材。一则，用于满足我们教学的部分需求；二则，更好地了解外版教材的教学服务体系；三则，为我们的师生创造英语教学的环境。

在进行 2004 年本科教指委的工作规划时，我曾特别谈及，要加强对本科教育中教书“育人”、服务于学生的使命的认识，继续优化专业课程设计，扩大精品课程建设，增加专业导向课程，尤其要加强对国际商科与经济管理学科教学进展的研究，并引进最新的教学成果，包括教材及教学资源。这一切都是为了更好地为国家与社会培养更好的人才。

为此，清华大学出版社与美国麦格劳-希尔教育出版公司的合作，引进出版这套“精编版”的英文工商管理教材，也是体现这一理念。这套教材吸收国际最新教学成果，提供全方位的教学资源，并借助英语的语言媒介，将会大力提升与发展中国工商管理教学水平，提高学生使用英语语言和网络手段获得长久的终生学习的能力和兴趣，进而提高我国工商界的国际竞争力。这是一件具有重大意义的工作。

在讨论引进国际上在工商管理教学的最新成果时，确定了引进本套教材及教学资源的基本格调，即对“国际最新教学成果”的几个共同认识：一是国际上教学技术的进展究竟走到了哪一步，我们就引进到哪一步。二是要注意教学技术的发展给教学及教材带来了的影响，我们要借鉴新的教学辅助手段。

最近几年，我在美国授课的过程中，注意到教学网络技术：课程管理系统（Course Management System，CMS）。通过这个教学辅助系统，教师可以将所要讲授的课程内容简单地张贴到一个系统化的网页上，包括教学演示文件 PPT、章节提要（Lecture Notes）、在线阅读资料，以及问答题、简答题还有课后大作业等，还可以很简单地开设自己课程的在线论坛 BBS。学生在注册后，便成为在线学生，通过该平台与教师交互，完成习题，在线提交作业，在线考试，自动出评测分析报告。这一切是以教师为中心，完全解决了教师对于自己教学内容以及对学生及教学过程的网络化数字化管理的问题，并可多次复用、异地复用。这个在线学习系统（BlackBoard，WebCT，eCollege）等不同于国内各高校自己研发的以学籍管理或居于录像、课件的远程教学为中心的校园管理平台，直接解决大学的核心问题：即“大师”们对课程教学内容的管理问题，成为对教师授课最好的在线数字化辅助支持平台。

2004 年的春季学期，中国人民大学商学院 247 位教师，所有 364 门课程全面上线，2000 多名学生在线注册学习，引发了人大商学院一场真正意义上的“教学革命”。教师与学生实现了很好地沟通与互动，

学生之间也有了很好地学习谈论的天地。目前，我校商学院的经验，已经成为赛尔毕博支持国内院校教学上线发展的典范，成为 BlackBoard 在国内的示范教学网站。

课堂教学同网络平台结合之后，又给教学带来了新的挑战，也给教材和教材的出版商们带来了新的机遇。历史悠久的麦格劳-希尔教育出版公司积极适应这种挑战，在商科及经管教材的出版上做了战略性的调整：即将教材本身做“薄”，出版一批新型的、跨媒介的教材：将研讨性、探索性、展开式的学习内容放到网上，将动态交互性的内容放到网上；印刷版的教材从过去强调各章节内容全面，呈现教学过程、学习环节，转向注重概念性及引导性，展现学习的核心内容。同时，他们将教材配套的教学资源做得更“全”，将更多的内容上线后全面依托网络，更加动态地呈现教学内容及教学过程；并为不同的教学平台提供完全解决方案，提供跨平台的不同版本的内容“子弹”。无论采用 BlackBoard 或 WebCT 等平台，教师们都可以从出版商处获得标准的教学资源包，为自己采用的教材轻松搭建课程网站，实现教学的在线革命。

总之，教学在革命，教学的手段也在革命。我们要看到工商管理教学在国际上的各种变化，努力跟上时代的发展变化，使我们的学生真正获得国际水准的教育。为此，我衷心地感谢这批教材的国外作者们，正是他们不懈的教学实践，给我们学科的发展带来源源的活力；同时感谢国内外的出版界的人们，感谢他们对教材、教材市场的永恒的追求，不断地帮助我们提升教学的水准；衷心希望这批适应新的教学需要的国际最新教材的出版能抛砖引玉，再次带动整个工商管理教育无论是本科、高职高专教学，还是 MBA、EMBA 教学的发展。

子曰：“学而时习之，不亦悦乎。”在这场教学革命中，我们有更大的勇气面临新的教学的挑战，将中国的工商管理教育推向世界一流！

徐二明

中国人民大学

目 录

CHAPTER 1

Introduction

1.1 THE ORIGINS OF OPERATIONS RESEARCH

Since the advent of the industrial revolution, the world has seen a remarkable growth in the size and complexity of organizations. The artisans' small shops of an earlier era have evolved into the billion-dollar corporations of today. An integral part of this revolutionary change has been a tremendous increase in the division of labor and segmentation of management responsibilities in these organizations. The results have been spectacular. However, along with its blessings, this increasing specialization has created new problems, problems that are still occurring in many organizations. One problem is a tendency for the many components of an organization to grow into relatively autonomous empires with their own goals and value systems, thereby losing sight of how their activities and objectives mesh with those of the overall organization. What is best for one component frequently is detrimental to another, so the components may end up working at cross purposes. A related problem is that as the complexity and specialization in an organization increase, it becomes more and more difficult to allocate the available resources to the various activities in a way that is most effective for the organization as a whole. These kinds of problems and the need to find a better way to solve them provided the environment for the emergence of **operations research** (commonly referred to as **OR**).

The roots of OR can be traced back many decades,[1] when early attempts were made to use a scientific approach in the management of organizations. However, the beginning of the activity called *operations research* has generally been attributed to the military services early in World War II. Because of the war effort, there was an urgent need to allocate scarce resources to the various military operations and to the activities within each operation in an effective manner. Therefore, the British and then the U.S. military management called upon a large number of scientists to apply a scientific approach to dealing with this and other strategic and tactical problems. In effect, they were asked to do *research on* (military) *operations*. These teams of scientists were the first OR teams. By developing effective methods of using the new tool of radar, these teams were instrumental in winning the Air Battle of Britain. Through their research on how to better manage convoy and antisubmarine operations, they also played a major role in winning the Battle of the North Atlantic. Similar efforts assisted the Island Campaign in the Pacific.

[1]Selected Reference 7 provides an entertaining history of operations research that traces its roots as far back as 1564 by describing a considerable number of scientific contributions from 1564 to 2004 that influenced the subsequent development of OR. Also see Selected References 1 and 6 for further details about this history.

1

When the war ended, the success of OR in the war effort spurred interest in applying OR outside the military as well. As the industrial boom following the war was running its course, the problems caused by the increasing complexity and specialization in organizations were again coming to the forefront. It was becoming apparent to a growing number of people, including business consultants who had served on or with the OR teams during the war, that these were basically the same problems that had been faced by the military but in a different context. By the early 1950s, these individuals had introduced the use of OR to a variety of organizations in business, industry, and government. The rapid spread of OR soon followed. (Selected Reference 6 recounts the development of the field of operations research by describing the lives and contributions of 43 OR pioneers.)

At least two other factors that played a key role in the rapid growth of OR during this period can be identified. One was the substantial progress that was made early in improving the techniques of OR. After the war, many of the scientists who had participated on OR teams or who had heard about this work were motivated to pursue research relevant to the field; important advancements in the state of the art resulted. A prime example is the *simplex method* for solving linear programming problems, developed by George Dantzig in 1947. Many of the standard tools of OR, such as linear programming, dynamic programming, queueing theory, and inventory theory, were relatively well developed before the end of the 1950s.

A second factor that gave great impetus to the growth of the field was the onslaught of the *computer revolution.* A large amount of computation is usually required to deal most effectively with the complex problems typically considered by OR. Doing this by hand would often be out of the question. Therefore, the development of electronic digital computers, with their ability to perform arithmetic calculations millions of times faster than a human being can, was a tremendous boon to OR. A further boost came in the 1980s with the development of increasingly powerful personal computers accompanied by good software packages for doing OR. This brought the use of OR within the easy reach of much larger numbers of people, and this progress further accelerated in the 1990s and into the 21st century. For example, the widely used spreadsheet package, Microsoft Excel, provides a Solver that will solve a variety of OR problems.Today, literally millions of individuals have ready access to OR software. Consequently, a whole range of computers from mainframes to laptops now are being routinely used to solve OR problems, including some of enormous size.

1.2 THE NATURE OF OPERATIONS RESEARCH

As its name implies, operations research involves "research on operations." Thus, operations research is applied to problems that concern how to conduct and coordinate the *operations* (i.e., the *activities*) within an organization. The nature of the organization is essentially immaterial, and in fact, OR has been applied extensively in such diverse areas as manufacturing, transportation, construction, telecommunications, financial planning, health care, the military, and public services, to name just a few. Therefore, the breadth of application is unusually wide.

The *research* part of the name means that operations research uses an approach that resembles the way research is conducted in established scientific fields. To a considerable extent, the *scientific method* is used to investigate the problem of concern. (In fact, the term *management science* sometimes is used as a synonym for operations research.) In particular, the process begins by carefully observing and formulating the problem, including gathering all relevant data. The next step is to construct a scientific (typically mathematical) model that attempts to abstract the essence of the real problem. It is then hypothesized that this model is a sufficiently precise representation of the essential features of the situation

that the conclusions (solutions) obtained from the model are also valid for the real problem. Next, suitable experiments are conducted to test this hypothesis, modify it as needed, and eventually verify some form of the hypothesis. (This step is frequently referred to as *model validation.*) Thus, in a certain sense, operations research involves creative scientific research into the fundamental properties of operations. However, there is more to it than this. Specifically, OR is also concerned with the practical management of the organization. Therefore, to be successful, OR must also provide positive, understandable conclusions to the decision maker(s) when they are needed.

Still another characteristic of OR is its broad viewpoint. As implied in the preceding section, OR adopts an organizational point of view. Thus, it attempts to resolve the conflicts of interest among the components of the organization in a way that is best for the organization as a whole. This does not imply that the study of each problem must give explicit consideration to all aspects of the organization; rather, the objectives being sought must be consistent with those of the overall organization.

An additional characteristic is that OR frequently attempts to search for a *best* solution (referred to as an *optimal* solution) for the model that represents the problem under consideration. (We say *a* best instead of *the* best solution because multiple solutions may be tied as best.) Rather than simply improving the status quo, the goal is to identify a best possible course of action. Although it must be interpreted carefully in terms of the practical needs of management, this "search for optimality" is an important theme in OR.

All these characteristics lead quite naturally to still another one. It is evident that no single individual should be expected to be an expert on all the many aspects of OR work or the problems typically considered; this would require a group of individuals having diverse backgrounds and skills. Therefore, when a full-fledged OR study of a new problem is undertaken, it is usually necessary to use a *team approach.* Such an OR team typically needs to include individuals who collectively are highly trained in mathematics, statistics and probability theory, economics, business administration, computer science, engineering and the physical sciences, the behavioral sciences, and the special techniques of OR. The team also needs to have the necessary experience and variety of skills to give appropriate consideration to the many ramifications of the problem throughout the organization.

1.3 THE RISE OF ANALYTICS TOGETHER WITH OPERATIONS RESEARCH

There has been great buzz throughout the business world in recent years about something called **analytics** (or *business analytics*) and the importance of incorporating analytics into managerial decision making. The primary impetus for this buzz was a series of articles and books by Thomas H. Davenport, a renowned thought-leader who has helped hundreds of companies worldwide to revitalize their business practices. He initially introduced the concept of analytics in the January 2006 issue of the *Harvard Business Review* with an article, "Competing on Analytics," that now has been named as one of the ten must-read articles in that magazine's 90-year history. This article soon was followed by two best-selling books entitled *Competing on Analytics: The New Science of Winning* and *Analytics at Work: Smarter Decisions, Better Results*. (See Selected References 2 and 3 at the end of the chapter for the citations.)

So what is analytics? The short (but oversimplified) answer is that it is basically operations research by another name. However, there are some differences in their relative emphases. Furthermore, the strengths of the analytics approach are likely to be increasingly incorporated into the OR approach as time goes on, so it will be instructive to describe analytics a little further.

Analytics fully recognizes that we have entered into the era of *big data* where massive amounts of data now are commonly available to many businesses and organizations to help guide managerial decision making. The current data surge is coming from sophisticated computer tracking of shipments, sales, suppliers, and customers, as well as email, Web traffic, and social networks. As indicated by the following definition, a primary focus of analytics is on how to make the most effective use of all these data.

> *Analytics* is the scientific process of transforming data into insight for making better decisions.

The application of analytics can be divided into three overlapping categories. One of these is *descriptive analytics*, which involves using innovative techniques to locate the relevant data and identify the interesting patterns in order to better describe and understand what is going on now. One important technique for doing this is called *data mining* (as described in Selected Reference 8). Some analytics professionals who specialize in descriptive analytics are called *data scientists*.

A second (and more advanced) category is *predictive analytics*, which involves using the data to predict what will happen in the future. Statistical forecasting methods, such as those described in Chap. 27 (on the book's website), are prominently used here.

The final (and most advanced) category is *prescriptive analytics*, which involves using the data to prescribe what should be done in the future. The powerful optimization techniques of operations research described in many of the chapters of this book generally are what are used here.

Operations research analysts also often deal with all three of these categories, but not very much with the first one, somewhat more with the second one, and then heavily with the last one. Thus, OR can be thought of as focusing mainly on *advanced analytics*—predictive and prescriptive activities—whereas analytics professionals might get more involved than OR analysts with the entire business process, including what precedes the first category (identifying a need) and what follows the last category (implementation). Looking to the future, the two approaches should tend to merge over time. Because the name *analytics* (or *business analytics*) is more meaningful to most people than the term *operations research*, we might find that *analytics* may eventually replace *operations research* as the common name for this integrated discipline.

Although analytics was initially introduced as a key tool for mainly business organizations, it also can be a powerful tool in other contexts. As one example, analytics (together with OR) played a key role in the 2012 presidential campaign in the United States. The Obama campaign management hired a multi-disciplinary team of statisticians, predictive modelers, data-mining experts, mathematicians, software programmers, and OR analysts. It eventually built an entire analytics department five times as large as that of its 2008 campaign. With all this analytics input, the Obama team launched a full-scale and all-front campaign, leveraging massive amounts of data from various sources to directly micro-target potential voters and donors with tailored messages. The election had been expected to be a very close one, but the Obama "ground game" that had been propelled by descriptive and predictive analytics was given much of the credit for the clear-cut Obama win. Based on this experience, both political parties undoubtedly will make extensive use of analytics in the future in major political campaigns.

Another famous application of analytics is described in the book *Moneyball* (cited in Selected Reference 10) and a subsequent 2011 movie with the same name that is based on this book. They tell the true story of how the Oakland Athletics baseball team achieved great success, despite having one of the smallest budgets in the major leagues, by using various kinds of nontraditional data (referred to as *sabermetrics*) to better evaluate the

potential of players available through a trade or the draft. Although these evaluations often flew in the face of conventional baseball wisdom, both descriptive analytics and predictive analytics were being used to identify overlooked players who could greatly help the team. After witnessing the impact of analytics, many major league baseball teams now have hired analytics professionals. Some other kinds of sports teams also are beginning to use analytics. (Selected References 4 and 5 have 17 articles describing the application of analytics in various sports.)

These and numerous other success stories about the power of analytics and OR together should lead to their ever-increasing use in the future. Meanwhile, OR already has had a powerful impact, as described further in the next section.

1.4 THE IMPACT OF OPERATIONS RESEARCH

Operations research has had an impressive impact on improving the efficiency of numerous organizations around the world. In the process, OR has made a significant contribution to increasing the productivity of the economies of various countries. There now are a few dozen member countries in the International Federation of Operational Research Societies (IFORS), with each country having a national OR society. Both Europe and Asia have federations of OR societies to coordinate holding international conferences and publishing international journals in those continents. In addition, the Institute for Operations Research and the Management Sciences (INFORMS) is an international OR society that is headquartered in the United States. Just as in many other developed countries, OR is an important profession in the United States. According to projections from the U.S. Bureau of Labor Statistics for the year 2013, there are approximately 65,000 individuals working as operations research analysts in the United States with an average salary of about $79,000.

Because of the rapid rise of *analytics* described in the preceding section, INFORMS has embraced analytics as an approach to decision making that largely overlaps and further enriches the OR approach. Therefore, this leading OR society now includes an annual Conference on Business Analytics and Operations Research among its major conferences. It also provides a Certified Analytics Professional credential for those individuals who satisfy certain criteria and pass an examination. In addition, INFORMS publishes many of the leading journals in the field, including one called *Analytics*, and another, called *Interfaces*, regularly publishes articles describing major OR studies and the impact they had on their organizations.

To give you a better notion of the wide applicability of OR, we list some actual applications in Table 1.1 that have been described in *Interfaces*. Note the diversity of organizations and applications in the first two columns. The third column identifies the section where an "application vignette" devotes several paragraphs to describing the application and also references an article that provides full details. (You can see the first of these application vignettes in this section.) The last column indicates that these applications typically resulted in annual savings in the many millions of dollars. Furthermore, additional benefits not recorded in the table (e.g., improved service to customers and better managerial control) sometimes were considered to be even more important than these financial benefits. (You will have an opportunity to investigate these less tangible benefits further in Probs. 1.3-1, 1.3-2, and 1.3-3.) A link to the articles that describe these applications in detail is included on our website, www.mhhe.com/hillier.

Although most routine OR studies provide considerably more modest benefits than the applications summarized in Table 1.1, the figures in the rightmost column of this table do accurately reflect the dramatic impact that large, well-designed OR studies occasionally can have.

An Application Vignette

FedEx Corporation is the world's largest courier delivery services company. Every working day, it delivers many millions of documents, packages, and other items throughout the United States and hundreds of countries and territories around the world. In some cases, these shipments can be guaranteed overnight delivery by 10:30 A.M. the next morning.

The logistical challenges involved in providing this service are staggering. These millions of daily shipments must be individually sorted and routed to the correct general location (usually by aircraft) and then delivered to the exact destination (usually by motorized vehicle) in an amazingly short period of time. How is all this possible?

Operations research (OR) is the technological engine that drives this company. Ever since its founding in 1973, OR has helped make its major business decisions, including equipment investment, route structure, scheduling, finances, and location of facilities. After OR was credited with literally saving the company during its early years, it became the custom to have OR represented at the weekly senior management meetings and, indeed, several of the senior corporate vice presidents have come up from the outstanding FedEx OR group.

FedEx has come to be acknowledged as a world-class company. It routinely ranks among the top companies on *Fortune Magazine*'s annual listing of the "World's Most Admired Companies and this same magazine named the firm as one of the top 100 companies to work for in 2013." It also was the first winner (in 1991) of the prestigious prize now known as the INFORMS Prize, which is awarded annually for the effective and repeated integration of OR into organizational decision making in pioneering, varied, novel, and lasting ways. The company's great dependence on OR has continued to the present day.

Source: R. O. Mason, J. L. McKenney, W. Carlson, and D. Copeland, "Absolutely, Positively Operations Research: The Federal Express Story," *Interfaces*, **27**(2): 17–36, March—April 1997. (A link to this article is provided on our website, www.mhhe.com/hillier.)

TABLE 1.1 Applications of operations research to be described in application vignettes

Organization	Area of Application	Section	Annual Savings
Federal Express	Logistical planning of shipments	1.4	Not estimated
Continental Airlines	Reassign crews to flights when schedule disruptions occur	2.2	$40 million
Swift & Company	Improve sales and manufacturing performance	3.1	$12 million
Memorial Sloan-Kettering Cancer Center	Design of radiation therapy	3.4	$459 million
Welch's	Optimize use and movement of raw materials	3.5	$150,000
INDEVAL	Settle all securities transactions in Mexico	3.6	$150 million
Samsung Electronics	Reduce manufacturing times and inventory levels	4.3	$200 million more revenue
Pacific Lumber Company	Long-term forest ecosystem management	7.2	$398 million NPV
Procter & Gamble	Redesign the production and distribution system	9.1	$200 million
Canadian Pacific Railway	Plan routing of rail freight	10.3	$100 million
Hewlett-Packard	Product portfolio management	10.5	$180 million
Norwegian companies	Maximize flow of natural gas through offshore pipeline network	10.5	$140 million
United Airlines	Reassign airplanes to flights when disruptions occur	10.6	Not estimated
U.S. Military	Logistical planning of Operations Desert Storm	11.3	Not estimated
MISO	Administer the transmission of electricity in 13 states	12.2	$700 million
Netherlands Railways	Optimize operation of a railway network	12.2	$105 million
Taco Bell	Plan employee work schedules at restaurants	12.5	$13 million
Waste Management	Develop a route-management system for trash collection and disposal	12.7	$100 million
Bank Hapoalim Group	Develop a decision-support system for investment advisors	13.1	$31 million more revenue
DHL	Optimize the use of marketing resources	13.10	$22 million
Sears	Vehicle routing and scheduling for home services and deliveries	14.2	$42 million

TABLE 1.1 Applications of operations research to be described in application vignettes *(contd)*

Organization	Area of Application	Section	Annual Savings
Intel Corporation	Design and schedule the product line	14.4	Not estimated
Conoco-Phillips	Evaluate petroleum exploration projects	16.2	Not estimated
Workers' Compensation Board	Manage high-risk disability claims and rehabilitation	16.3	$4 million
Westinghouse	Evaluate research-and-development projects	16.4	Not estimated
KeyCorp	Improve efficiency of bank teller service	17.6	$20 million
General Motors	Improve efficiency of production lines	17.9	$90 million
Deere & Company	Management of inventories throughout a supply chain	18.5	$1 billion less inventory
Time Inc.	Management of distribution channels for magazines	18.7	$3.5 million more profit
InterContinental Hotels	Revenue management	18.8	$400 million more revenue
Bank One Corporation	Management of credit lines and interest rates for credit cards	19.2	$75 million more profit
Merrill Lynch	Pricing analysis for providing financial services	20.2	$50 million more revenue
Sasol	Improve the efficiency of its production processes	20.5	$23 million
FAA	Manage air traffic flows in severe weather	20.5	$200 million

1.5 ALGORITHMS AND OR COURSEWARE

An important part of this book is the presentation of the major **algorithms** (systematic solution procedures) of OR for solving certain types of problems. Some of these algorithms are amazingly efficient and are routinely used on problems involving hundreds or thousands of variables. You will be introduced to how these algorithms work and what makes them so efficient. You then will use these algorithms to solve a variety of problems on a computer. The **OR Courseware** contained on the book's website (www.mhhe.com/hillier) will be a key tool for doing all this.

One special feature in your OR Courseware is a program called **OR Tutor.** This program is intended to be your personal tutor to help you learn the algorithms. It consists of many *demonstration examples* that display and explain the algorithms in action. These "demos" supplement the examples in the book.

In addition, your OR Courseware includes a special software package called **Interactive Operations Research Tutorial,** or **IOR Tutorial** for short. Implemented in Java, this innovative package is designed specifically to enhance the learning experience of students using this book. IOR Tutorial includes many *interactive procedures* for executing the algorithms interactively in a convenient format. The computer does all the routine calculations while you focus on learning and executing the logic of the algorithm. You should find these interactive procedures a very efficient and enlightening way of doing many of your homework problems. IOR Tutorial also includes a number of other helpful procedures, including some *automatic procedures* for executing algorithms automatically and several procedures that provide graphical displays of how the solution provided by an algorithm varies with the data of the problem.

In practice, the algorithms normally are executed by commercial software packages. We feel that it is important to acquaint students with the nature of these packages that they will be using after graduation. Therefore, your OR Courseware includes a wealth of material to introduce you to four particularly popular software packages described next. Together, these packages will enable you to solve nearly all the OR models encountered in this book very efficiently. We have added our own *automatic procedures* to IOR Tutorial in a few cases where these packages are not applicable.