David R. Anderson • Dennis J. Sweeney
Thomas A. Williams • Mik Wisniewski

AN INTRODUCTION TO MANAGEMENT SCIENCE

QUANTITATIVE APPROACHES TO DECISION MAKING

second edition

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An Introduction to Management Science: Quantitative Approaches to Decision Making, 2nd Edition

Anderson, Sweeney, Williams and Wisniewski

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Preface

Welcome to the second Europe, Middle East and Africa Edition of *An Introduction to Management Science* by Anderson, Sweeney, Williams and Wisniewski.

The first edition of this text was based on the best-selling US version and deliberately set out to adapt and tailor the US version for a non-US university audience. The content was adapted to better suit university teaching of quantitative management science in the UK, across Europe, Africa and the Middle East; the focus was given a more global and international feel and cases and examples were internationalized.

The first edition has been extremely successful in its target markets and this edition has further tailored and adapted the content to give broad international appeal.

A quick tour of the text

An Introduction to Management Science continues to be very much applications oriented and to use the problem-scenario approach that has proved to be very popular and successful. This approach means that we describe a typical business scenario or problem faced by many organizations and managers. This might relate to allocating staff to tasks or projects; determining production over the next planning period; deciding on the best use of a limited budget; forecasting sales over the coming time period and so on. We explore and explain how particular management science techniques and models can be used to help managers and decision makers decide what to do in that particular scenario or situation. This approach means that students not only develop a good technical understanding of a particular technique or model but also understand how it contributes to the decision-making process.

In this new edition we have taken advantage of the Internet and world-wide web to make some chapters available online. The chapters that remain in the textbook itself cover the topics most commonly-covered on undergraduate and postgraduate management science programmes. Chapters available online cover topics which, although useful and important, are less frequently included.

Chapter 1 provides an overall introduction to the text; the origins and developments in management science are outlined; there are detailed examples of areas in business and management where management science is frequently applied; there is a detailed discussion of the wider management science methodology and a section on the modelling process itself.

Chapters 2–6 cover the core topic of *Linear Programming (LP)*. The technique is introduced and graphical solution methods developed. This is followed by the development of sensitivity analysis. The Simplex method is then introduced for large scale problem solution and full coverage of simplex based sensitivity is covered. There is a full chapter on applications of LP grouped around five main areas of business application.

Chapter 7 extends the coverage of optimization to look at techniques related to *transshipment, assignment and transportation* problems. Solution methods for each class of problem are given. Chapter 8 introduces the *network* model and examines the *shortest route* problem, the *minimal spanning tree* problem and the *maximal flow* problem. Chapter 9 introduces *project scheduling* and *project management* problems. There is full coverage of PERT/CPM and a short section explaining the use of Gantt charts in project management and expands the section on crashing a project. There is also an appendix discussing activity on arrow networks in some detail.

Chapters 10 and 11 look at two common types of business model. Chapter 10 looks at *inventory* (or stock control) models whilst Chapter 11 looks at *queuing* models. The relevance of both types of model to business decision making is examined and solution techniques developed. Chapter 12 introduces *simulation* modelling and shows how such models can be used alongside the other models developed in the text.

Chapters 13 and 14 look at the area of decision analysis and decision making. Chapter 13 looks at the principles of *decision analysis* and introduces decision trees, expected value and utility. Chapter 14 looks at the topic of *multicriteria decision making* with coverage of goal programming, scoring models and the analytic hierarchy process (AHP) approach.

The textbook closes with discussion of management science in practice, considering some of the practical issues faced when implementing management science techniques for real.

In addition there are four slightly more specialized chapters available on the accompanying online platform. These take exactly the same format and structure as chapters included in the text.

Chapter 15 introduces *integral linear programming* both as an extension to linear programming and as a model in its own right. The chapter looks at the branch and bound solution method in detail. Chapter 16 looks at business *forecasting* techniques and models. Time series models are introduced as well as trend projection models and there is coverage of regression modelling also. Chapter 17 looks at the topic of *dynamic programming* with coverage of the shortest route problem and the knapsack problem. Finally, Chapter 18 introduces *Markov models* which can be useful where we wish to examine behaviour or performance over successive periods of time.

The online platform contains an array of additional resources to aid learning. See the 'Digital Resources' page for further details.

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Key Features of the Text

Learning objectives

By the end of this chapter you will be able to:

- Explain what management science is
- Detail areas in business where management science is commonly used
- Describe the management science approach or methodology
- Build and use simple quantitative models

Learning objectives are set out at the start of each chapter and summarize what the reader should have learned on completion of that chapter. They also serve to highlight what the chapter covers and help the reader review and check knowledge and understanding.

MANAGEMENT SCIENCE IN ACTION

Scoring Model at Ford Motor Company

Ford Motor Company needed benchmark data in order to set performance targets for future and current model automobiles. A detailed proposal was developed and sent to five suppliers. Three suppliers were considered acceptable for the project.

Because the three suppliers had different capabilities in terms of teardown analysis and testing, Ford developed three project alternatives:

Alternative 1: Supplier C does the entire project alone.

Alternative 2: Supplier A does the testing portion of the project and works with Supplier B to complete the remaining parts of the project.

Alternative 3: Supplier A does the testing portion of the project and works with Supplier C to complete the remaining parts of the project.

For routine projects, selecting the lowest cost alternative might be appropriate. However, because this project involved many nonroutine tasks, Ford incorporated four criteria into the decision process.

The four criteria selected by Ford are as follows: nication; and past Ford experience. In total, 17 subcriteria were considered. A team-consensus weighting process was used to develop percentage weights for the subcriteria. The weights assigned to the skill-level subcriteria were 40 per cent for project manager leadership; 20 per cent for team structure organization; 20 per cent for team players' communication; and 20 per cent for past Ford experience.

Team members visited all the suppliers and individually rated them for each subcriterion using a 1–10 scale (1-worst, 10-best). Then, in a team meeting, consensus ratings were developed. For Alternative 1, the consensus ratings developed for the skill-level subcriteria were 8 for project manager leadership; 8 for team structure organization; 7 for team players' communication; and 8 for past Ford experience. Because the weights assigned to the skill-level subcriteria are 40 per cent, 20 per cent, 20 per cent, and 20 per cent, the rating for Alternative 1 corresponding to the skill-level criterion is

$$\text{Rating} = .4(8) + .2(8) + .2(7) + .2(8) = 7.8$$

Management Science in Action case studies show actual applications of the techniques and models covered in each chapter.

Summary

This chapter has introduced a model commonly used in management science, that of linear programming (LP). LP models are used in many different situations, for many different types of problem and across many different types of business organization.

- LP is an optimization model, where we seek to determine an optimal solution to some problem subject to a number of constraints.
- LP problems can be formulated with an objective function which could be for maximization or for minimization. Constraints in an LP problem place some restriction on what we are able to do in our search for an optimal solution and LP constraints can take one of three forms: $\leq$, $\geq$, or $=$.
- Both the objective function and all constraints must take a linear form mathematically.
- The simplest form of an LP problem involves two decision variables and can be solved graphically.
- At the optimal solution some constraints will be binding and some non-binding. A binding constraint is exactly satisfied at the optimal solution. A non-binding constraint will have slack, or surplus, associated with it.

Summaries are given at the end of each chapter to recap on key points.

WORKED EXAMPLE

We shall return to the Worked Example that we introduced in Chapter 5. Recollect that the Fresh Juice Company had identified the optimal solution in terms of quantities of its three grape juice products to produce tomorrow. We had a formulation such that:

$$
\begin{aligned}
\text{Max} \quad & 1x_1 + 1.2x_2 + 2x_3 \\
\text{s.t.} \quad & \\
& 1x_1 + 2x_2 \leq 150 \\
& 1x_1 + 2x_3 \leq 150 \\
& 2x_1 + 1x_2 \leq 80 \\
& 2x_1 + 3x_2 + 1x_2 \leq 225 \\
& x_1 \leq 25 \\
& x_1,\ x_2,\ x_3 \leq 0
\end{aligned}
$$

The final simplex tableau was:

Basis	x_1	x_2	x_3	s_1	s_2	s_3	s_4	s_5	
C	1	1.2	2	0	0	0	0	0	
Unused kilos of Grape A	0	0	0	1	0	–2	0	–3	65
Litres of Dry Grape juice produced	0	1	1	0	0.5	0	0	0.5	62.5
Litres of Regular Grape juice produced	0	0	0	0	0	1	0	2	30
Unused labour hours	0	0	0	0	–0.5	–3	1	–4.5	22.5
Litres of Sweet Grape juice produced	1	0	0	0	0	0	0	–1	25
z_j	1	1.2	2	0	1	1.2	0	2.4	186
$c_j - z_j$	0	0	0	0	–1	–1.2	0	–2.4	

Let us see what other advice we can provide the company's management team. If we carry out sensitivity analysis on the objective function coefficients we obtain the following results:

Worked Examples are shown at the end of each chapter walking you through a detailed problem step-by-step, showing how a solution to the problem can be obtained using the techniques and models in that chapter.

NOTES AND COMMENTS

1. Remember that the goal of data envelopment analysis is to identify operating units that are relatively inefficient. The method *does not* necessarily identify the operating units that are relatively efficient. Just because the efficiency index is $E = 1$, we cannot conclude that the unit being analysed is relatively efficient. Indeed, any unit that has the largest output on any one of the output measures cannot be judged relatively inefficient.
2. It is possible for DEA to show all but one unit to be relatively inefficient. Such would be the case if a unit producing the most of every output also consumes the least of every input. Such cases are extremely rare in practice.
3. In applying data envelopment analysis to problems involving a large group of operating units, practitioners have found that roughly 50 per cent of the operating units can be identified as inefficient. Comparing each relatively inefficient unit to the units contributing to the composite unit may be helpful in understanding how the operation of each relatively inefficient unit can be improved.

Notes and Comments provide extra context and explanatory notes to help the reader's understanding.

Problems

1 The RMC Corporation blends three raw materials to produce two products: a fuel additive and a solvent base. Each ton of fuel additive is a mixture of 0.4 ton of material 1 and 0.6 ton of material 3. A ton of solvent base is a mixture of 0.5 ton of material 1, 0.2 ton of material 2, and 0.3 ton of material 3. RMC's production is constrained by a limited availability of the three raw materials. For the current production period, RMC has the following quantities of each raw material: material 1, 20 tons; material 2, 5 tons; material 3, 21 tons. Management wants to achieve the following P_1 priority level goals.

Problems given at the end of each chapter provide an opportunity to test your knowledge and understanding of that chapter. Some problems test you ability to develop and solve a particular model. Others are more complex requiring you to interpret and explain results in a business context.

Appendix 1.2 The Management Scientist Software

Developments in computer technology play a major role in making managemen science techniques available to decision makers. A software package called *Th Management Scientist* Version 6.0 is available for Windows 95 through to Win dows XP operating systems.[1] This software can be used to solve problems in th text as well as small-scale problems encountered in practice. Using The Manage ment Scientist will provide an understanding and appreciation of the role of th computer in applying management science to decision problems.

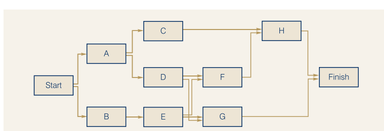
The Management Scientist contains 12 modules, or programs, that will enabl you to solve problems in the following areas:

Chapters 2–6	Linear programming
Chapter 7	Transportation and assignment
Chapter 8	Integer linear programming
Chapter 9	Shortest route and minimal spanning tree
Chapter 10	PERT/CPM

The **Management Scientist Software** Version 6.0 accompanies this text. The software allows you to formulate and solve many of the models introduced in the text.

SELF *test*

6 Consider the following project network and activity times (in weeks).



Activity	A	B	C	D	E	F	G	H
Time	5	3	7	6	7	3	10	8

a. Identify the critical path.
b. How much time will be needed to complete this project?
c. Can activity D be delayed without delaying the entire project? If so, by how many weeks?
d. Can activity C be delayed without delaying the entire project? If so, by how many weeks?
e. What is the schedule for activity E?

Self test problems are linked to specific parts of each chapter and allow you to check your knowledge and understanding of that chapter on an incremental basis. Problems marked with the self test icon are located in Appendix D at the back of the book.

Figure 12.11 Excel Worksheet for the HKSB with One ATM

EXCEL *file*

HKSB1

Hong Kong Savings Bank with One ATM

Interarrival Times (Uniform Distribution)	
Smallest Value	0
Largest Value	5

Service Times (Normal Distribution)	
Mean	2
Std Deviation	0.5

Simulation

Customer	Interarrival Time	Arrival Time	Service Start Time	Waiting Time	Service Time	Completion Time	Time in System
1	1.4	1.4	1.4	0.0	2.3	3.7	2.3
2	1.3	2.7	3.7	1.0	1.5	5.2	2.5
3	4.9	7.6	7.6	0.0	2.2	9.8	2.2
4	3.5	11.1	11.1	0.0	2.5	13.6	2.5
5	0.7	11.8	13.6	1.8	1.8	15.4	3.6
996	0.5	2496.8	2498.1	1.3	0.6	2498.7	1.9
997	0.2	2497.0	2498.7	1.7	2.0	2500.7	3.7
998	2.7	2499.7	2500.7	1.0	1.8	2502.5	2.8
999	3.7	2503.4	2503.4	0.0	2.4	2505.8	2.4
1000	4.0	2507.4	2507.4	0.0	1.9	2509.3	1.9

Summary Statistics	
Number Waiting	549
Probability of Waiting	0.5100
Average Waiting Time	1.59
Maximum Waiting Time	13.5
Utilization of ATM	0.7860
Number Waiting > 1 Min	393
Probability of Waiting > 1 Min	0.4367

Excel, and other spreadsheets, have a key role to play in management science. Output from Excel is used frequently throughout the text to illustrate solutions. Appendices to chapters provide a step-by-step explanation of how to solve particular models using Excel.

CASE PROBLEM R.C. Coleman

R.C. Coleman distributes a variety of food products that are sold through grocery store and supermarket outlets. The company receives orders directly from the individual outlets, with a typical order requesting the delivery of several cases of anywhere from 20 to 50 different products. Under the company's current warehouse operation, warehouse clerks dispatch order-picking personnel to fill each order and have the goods moved to the warehouse shipping area. Because of the high labour costs and relatively low productivity of hand order-picking, management has decided to automate the warehouse operation by installing a computer-controlled order-picking system, along with a conveyor system for moving goods from storage to the warehouse shipping area.

R.C. Coleman's director of material management has been named the project manager in charge of the automated warehouse system. After consulting with members of the engineering staff and warehouse management personnel, the director compiled a list of activities associated with the project. The optimistic, most probable and pessimistic times (in weeks) have also been provided for each activity.

Case Problems are given at the end of most chapters. These are more complex problems relating to the techniques and models introduced in that chapter. A management report is typically required to be written. The Case Problems are well suited for group work.

Multicriteria analysis

We then have a chapter that introduces a variety of multicriteria methods. Such methods are used where we are making a decision where we must somehow take a variety of criteria into account when deciding what best to do. For example, you may be considering buying a new laptop. In trying to decide which make and model to buy you'll take a variety of conflicting criteria into account: price, reputation, reliability and so on. **Goal programming** is one technique for solving multicriteria decision problems, usually within the framework of linear programming. Analytic Hierarchy Process is another multicriteria decision-making technique which permits the inclusion of subjective factors in arriving at a recommended decision.

NB. The following four chapters are located on the associated premium online platform that is autopackaged with the text. For more information on access, see the 'About the Digital Resources' page.

Integer Linear Programming

Integer linear programming is an approach used for problems that can be set up as linear programs with the additional requirement that some or all of the decision variables take integer values. For example, a car manufacturer may be looking to optimise the number of dealer outlets to supply to, where, clearly, the number of outlets must sensibly be an integer value.

Online Supplements This edition comes with an array of additional online materials. See the 'Digital Resources' page for more details and information on how to access them.

DIGITAL RESOURCES

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To discover the dedicated instructor online support resources accompanying this textbook, instructors should register here for access:
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Student resources

The platform offers a range of interactive learning tools tailored to the second edition of *An Introduction to Management Science* including:

- Four additional online chapters
- More problems, exercises, and answer section
- Datasets referred to throughout the text
- Interactive eBook
- The Management Scientist 6.0 software package
- Glossary, flashcards, crossword puzzles and more

Look out for this symbol throughout the text to denote accompanying digital resources.

Chapter 1

Introduction

Learning objectives

By the end of this chapter you will be able to:

- Explain what management science is
- Detail areas in business where management science is commonly used
- Describe the management science approach or methodology
- Build and use simple quantitative models

1.1 Introduction to Management Science

Air New Zealand; Amazon; American Airlines; AT&T; Boeing; BMW; British Airways; Citibank; Dell; Delta Airlines; Eastman Kodak; Federal Express; Ford; GE Capital; Hanshin Expressway, Japan; an Indian tea producer; IBM; Kellogg; NASA; National Car Rental; Nokia; Procter & Gamble; Renault; UPS; Vancouver Airport.

At first sight it's not obvious what connects these organizations together. They're from different countries; some are private sector, some public sector; some operate internationally, some domestically; they're in different industrial and commercial sectors; they're of different sizes. However, they do have one thing in common – they all successfully use management science to help run their organization.

Management science (MS) has been defined as ***helping people make better decisions***. Clearly, decision-making is at the heart of a manager's role in any organization. Some of these decisions will be strategic and long-term: which new products and services to develop; which markets to expand into and which to withdraw from. Some will be short-term and operational: how many checkouts to open at the supermarket over the weekend; which members of staff to allocate to a new project. Get the decisions right and the organization continues to succeed. Get the decisions wrong and the organization may fail and disappear. Managers in just about any organization round the world will almost certainly tell you that life has never been tougher. There's increasingly fierce competition – in the public sector as well as private sector; customers require more and more but want to pay less; technological changes continue to gather speed; financial pressures mean that costs and productivity are constantly under scrutiny. Organizations are under pressure to do things better, do them faster and do them for less in terms of costs. Making the right decisions under such pressures isn't easy and it's no surprise that many organizations have turned to management science to help.

In today's harsh business environment organizations and managers are looking for structured, logical and evidence-based ways of making decisions rather than relying solely on intuition, personal experience and gut-feel. Management Science (also known as Operational Research) applies advanced analytical methods to business decision problems. ***Management*** emphasizes that we're interested in helping manage the organization better – that MS is very much focussed on the practical, real world. ***Science*** means that we're interested in rigorous, analytical and systematic ways of managing the organization better.

Does it Work?

Well, lots of organizations – like those above – think so. And there's plenty of evidence to show that MS really makes a difference. Some examples:

- The UK telecoms company BT used MS in the way it planned the work of its repair engineers, saving around £125 million a year.
- British Airways used MS to review its spare parts policies for its aircraft fleet and identified £21 million of savings.
- Motorola applied MS to its procurement strategy. During the first 18 months of implementation, Motorola saved US$600 million, or approximately 4 per cent, on US$16 billion of parts purchases
- Ford used MS to optimize the way it designs and tests new vehicle prototypes, saving over £150 million
- A leading UK bank, LloydsTSB, used MS to design the seating configuration in its call centres eliminating the need to build, and pay for, additional capacity

MANAGEMENT SCIENCE IN ACTION

Revenue Management at American Airlines*

One of the great success stories in management science involves the work done by the operations research (OR) group at American Airlines. In 1982, Thomas M. Cook joined a group of 12 operations research analysts at American Airlines. Under Cook's guidance, the OR group quickly grew to a staff of 75 professionals who developed models and conducted studies to support senior management decision making. Today the OR group is called Sabre and employs 10 000 professionals worldwide. One of the most significant applications developed by the OR group came about because of the deregulation of the airline industry in the late 1970s. As a result of deregulation, a number of low-cost airlines were able to move into the market by selling seats at a fraction of the price charged by established carriers such as American Airlines. Facing the question of how to compete, the OR group suggested offering different fare classes (discount and full fare) and in the process created a new area of management science referred to as yield or revenue management. The OR group used forecasting and optimization techniques to determine how many seats to sell at a discount and how many seats to hold for full fare. Although the initial implementation was relatively crude, the group continued to improve the forecasting and optimization models that drive the system and to obtain better data. Tom Cook counts at least four basic generations of revenue management during his tenure. Each produced in excess of US$100 million in incremental profitability over its predecessor. This revenue management system at American Airlines generates nearly $1 billion annually in incremental revenue. Today, virtually every airline uses some sort of revenue management system. The cruise, hotel and car rental industries also now apply revenue management methods, a further tribute to the pioneering efforts of the OR group at American Airlines.

*Based on Peter Horner, 'The Sabre Story', OR/MS Today (June 2000).

- Samsung used MS to cut the time taken to produce microchips, increasing sales revenue by around £500 million.
- A UK hospital used MS to develop a computerized appointments system that cut patient waiting times by 50 per cent.
- Peugeot applied MS to its production line in its car body shops where bottlenecks were occurring. MS improved production with minimal capital investment and no compromise in quality contributing US$130 million to revenue in one year alone.
- Air New Zealand wanted to improve the way it scheduled staff allocation and rostering. Applying MS methods enabled the company to save NZ$15 million per year as well as implement staff rosters that built in staff preferences
- Procter and Gamble, the consumer products multinational, used MS to review its approach to buying billions of US$ of supplies. Over a two year period this generated financial savings of over US$300 million.

Source: Operational Research Society and the Institute for Operations Research and the Management Sciences (INFORMS)

And to achieve these results organizations need people who understand the subject – ***management scientists*** – and this is why this textbook has been written. The aim of this text is to provide you with a number of the technical skills that a management scientist needs and also to provide you with a conceptual understanding as to where and how management science can successfully be used. To help with this, and to reinforce the practice of management science, we will be using *Management Science in Action* case studies throughout the text. Each case outlines a real application of management science in practice. The first of these, Revenue Management at American Airlines, describes one of the most significant applications of management science in the airline industry.

1.2 Where Did MS Come From?

Patrick Blackett (1897–1974) – later Baron Blackett – was one of the leading figures in the UK in the early years of operational research during Word War II and after. With a background in physics (for which he was awarded the Nobel Prize), his declared aim was to find numbers on which to base decisions, not emotion.

At this stage you may be wondering; where did MS come from, how did it develop? It is generally accepted that management science as a recognized subject has its origins in the United Kingdom around the time of the Second World War (1939–1945). The UK's very survival was threatened by its military enemies and the UK government established a number of multidisciplinary groups to apply scientific methods to its military planning and activities. Such groups consisted of scientists from a variety of backgrounds: mathematics, statistics, engineering, physics, electronics, psychology as well as military personnel and were tasked with researching into more effective military operational activities (hence the name *operational research*). These groups made significant contributions to the UK's war efforts including: improvements in the early-warning radar system which was critical to victory in the Battle of Britain; the organization of antisubmarine warfare; determination of optimum naval convoy sizes; the accuracy of bombing; the organization of civilian defence systems. The fact that these teams were multidisciplinary but also scientifically trained contributed significantly to their success. Their scientific training and thinking meant they were used to challenging existing ideas, they were used to querying assumptions made by others, they saw experimentation as a routine part of their analysis, they applied logic to problem solving and decision making, they collected and analyzed data to support their thinking and their conclusions. The fact that members of the team had different backgrounds, expertise and experience meant that not only could they challenge each other's thinking but they could also combine different approaches and thinking together for the first time. With the entry of the USA into the Second World War following Pearl Harbor, and given the obvious success of operational research in the UK, a number of similar groups were also established throughout the US military (usually known as *operations* research groups).

In 1948 the Operational Research Club of Great Britain was established as a way of bringing together those with an interest in seeing OR introduced into industry, commerce and government. The Club became the OR Society in 1953.

After the war, operational research continued to develop in the military and in defence-related industries on both sides of the Atlantic. In the US, there was considerable academic development of management science partially financed by the US military, particularly in the areas of mathematical techniques. In the UK, however, operational research took on a new role contributing to the programme of economic reconstruction and economic and social reform pursued by the new Labour Government at the end of the war. The challenges faced by industry and government in the UK at the time were major. There were issues relating to the move back to a peacetime economy and the huge transition that this would require; there were issues relating to the management and development of the newly nationalized industrial organizations in industries such as coal, steel, gas, electricity, transport; there was the huge demobilization of workers moving away from supporting the war effort and back into peacetime employment. Partly as a result, and partly because of the perceived success of operational research in the military, a number of large operational research groups were established in these industries and in government. Around this time also, academic programmes in management science began to be introduced and the first dedicated textbooks started to appear.

The first Masters and Ph.D academic programmes in OR were established in 1951 at the Case Institute of Technology, Cleveland Ohio.

Since then management science teams and management science techniques have spread into a wide variety of industrial and commercial companies, central government, local government, health and social care, across many different countries. This development was in part facilitated by the huge explosion in computing facilities and computer power. In the twenty-first-century management science techniques are now a standard part of popular computer software, such as Excel, and management science techniques are routinely taught across university business and management programmes. Many countries now have their own professional society for management scientists with the International Federation of Operational Research Societies (IFORS) acting as an umbrella organization comprising the national management science societies of over forty five countries with a total combined membership of over 25 000. Welcome to the club!

IFORS was founded in 1959

1.3 Management Science Applications

At this stage it will be worthwhile providing an overview of some of the decision areas where MS is applied. Later on in the chapter, we shall examine the more common management science techniques that are applied across these application areas and that we shall be developing in detail through the text.

Assignment

Assignment problems arise in business where someone has to *assign* resources or assets (like people, vehicles, aeroplanes) to specific tasks and where we want to do this to minimize the costs involved or to maximize the return or profit we earn. A simple example of this situation arises when an ambulance depot has a given number of emergency ambulances available throughout the day. Based on past experience it expects a number of emergency calls throughout the day to which it has to respond swiftly. Each of its ambulances has a dedicated crew but the crews have differing expertise and experience. The depot has to decide which individual ambulance to assign to each emergency call. It may try to do this to minimize the time taken to reach the location or to minimize the travel distance covered, or to send the 'best' crew to each type of emergency call. Whilst assignment problems often look simple, in real life they can be extremely complex and difficult to get right. Examples of assignment problems include: assigning referees to World Cup soccer matches; assigning students to classes; assigning airline crews to aircraft; assigning surgical teams to patients; assigning construction equipment to different construction projects. Management science has developed special techniques to help formulate and solve such assignment problems.

Data Mining

Largely because of the technology now available, many organizations are collecting large volumes of data about sales, customers, spending patterns, lifestyles and the like. Think about what happens when you use your credit card to buy groceries at the supermarket. The supermarket knows what you've bought (and can track trends in your purchases over time); the supermarket's suppliers know which products are selling and which are not; your bank knows your spending profile across the year. Used smartly, this data can allow organizations to understand better what is happening and to tailor and adapt their strategies, products and services accordingly. The supermarket can send you details of special offers on the items you normally buy (or perhaps on the ones that you don't buy); your bank knows when you might need a loan. Data mining is concerned with sifting through large amounts of data and identifying and analyzing relevant information. Historically, its use has been concentrated on business intelligence and in the financial sector, although its use is rapidly expanding across other business sectors. Data mining goes beyond routine descriptive or quantitative analysis through the application of sophisticated techniques and algorithms.

Financial Decision Making

MS plays a considerable role in financial decision making and the finance sector is a major user of MS techniques. Think about your credit card again. Someone at your bank or finance company had to decide what credit limit to give you when you took out the card. Too little and you might use a card from another bank. Too much and you may get into debt and be unable to pay them back the money they've effectively let you spend. Areas where MS is routinely used include credit scoring – where an individual's or an organization's ability to repay credit or loans is assessed quantitatively so that the lender can assess the risks involved in the loan; capital and investment budgeting – where an organization must decide on the appropriate capital or investment projects it will fund; portfolio management – where a suitable mix of investments must be determined.

Forecasting

It seems self evident that business organizations need to undertake effective forecasting of key business variables. Forecasting future sales for a retail organization; forecasting air traffic volumes for a busy airport; forecasting demand for medical care at a new hospital. Getting such forecasts right typically involves analyzing the situation both quantitatively and qualitatively and a number of MS techniques are usefully applied in forecasting situations.

Logistics

Logistics management is typically concerned with managing an organization's supply chain efficiently and effectively. All organization's need to manage the supply of resources that they need to produce goods and services – all the way from having a new factory built, to the supply of machinery to run the factory, to the power needed to run the machinery, to the paper clips that will be used in the factory office. In an increasingly global and competitive economy, good logistics management can make the difference between business success and failure. MS is routinely used to help organizations make logistical decisions.

Marketing

The area of marketing is another that makes extensive use of MS. Managers frequently have to make decisions regarding their organization's marketing strategy – the mixture of different marketing media that will be used to promote goods or services. The decision problem is that different media will incur different costs and will reach different audiences with varying degrees of effectiveness. The problem for the manager is deciding what a suitable marketing strategy looks like.

Networks

A network is typically defined as an interconnected group or system of things. The things might be roads or railways in terms of a transportation network; or computers in a computer network; or telephones in a telecoms network. Planning and managing such networks is a critical task if the network is to function effectively – we've probably all been stuck in a traffic jam at some time where the road network couldn't handle the traffic volumes or we've called through to a call centre to be put on hold because the phone network couldn't cope with demand. MS techniques are applied to examine network flows – how quickly and efficiently things flow, or move, through the network.

Optimization

Organizations are frequently looking for the best, or optimal, solution to a decision problem they have. How do we maximize profit from our sales? How do we minimize production costs? What is the optimum size for our workforce? In the search for such an optimum solution, organizations will not have a totally free hand in deciding what to do. Typically they will face certain restrictions or constraints on what they are able to do. An organization seeking to maximize profit from sales may face constraints in terms of its production capacity, or the finite demand for its products. A company seeking to minimize production costs may be locked into long-term supply contracts with some of its customers and is constrained to meet these contract requirements. An organization looking to determine the optimum size of its workforce may have certain health and safety requirements to meet. MS has developed a number of different techniques for dealing with such optimization problems.

Project Planning and Management

All organizations need to be able to plan and manage projects effectively. The project may be relatively small involving few resources and capable of being completed fairly quickly – organizing the move of a team from one part of the office to another – or it may be large and complex with a large budget and requiring considerable time and effort – planning the 2016 Rio de Janeiro Olympics. Once again, MS has developed techniques to allow for the efficient and effective planning and management of projects.

Queuing

We've all been in one at some time – a queue. It may have been a queue at a supermarket while we're waiting at the checkout; or a queue of cars at a traffic signal; or a queue of print jobs at the network printer. Queues are frustrating for those affected but are also difficult to manage cost-effectively. Putting extra staff on the supermarket checkout may well reduce the time customers spend queuing but this will also increase the supermarket's operating costs, so some compromise will be needed. MS uses queuing theory to examine the impact of management decisions on queues.

Simulation

It's not usual in business and management to be able to experiment before making a major decision. For example, we may be considering a major alteration to our production lines to boost productivity. We may be thinking about altering an airline's global flight timetable to increase competitiveness and market share. We may be thinking about redeploying police patrol vehicles to help tackle crime. It's unlikely that we would in practice be able to experiment and try different solutions to see what happened, although most managers would like to be able to do so, to assess the likely consequences of alternative decisions. However, whilst we can't experiment in the real world we can experiment using computer modelling known as simulation. Computer simulation involves running virtual experiments so that the consequences of alternative decisions can be analyzed.

MANAGEMENT SCIENCE IN ACTION

Workforce Scheduling For British Telecommunications PLC

British Telecommunications (BT) are leading providers of telecommunications services in the UK. BT employs over 50 000 field engineers to maintain telecoms networks, repair faults and provide a variety of services to customers. Managing the workforce effectively is critical to efficiency, profitability, customer service, service quality and to staff morale and motivation. Workforce scheduling is essentially about making sure the right field engineer goes to the right customer at the right time with the right equipment. However, BT faced a very complex task. The skills and experience of engineers varied considerably; their geographical location was effectively fixed; scheduling had to incorporate individual engineer constraints such as breaks and holidays; the difficulty of predicting in advance how much time some jobs would take. The Operational Research department at BT developed Work Manager, an information system that automates work management and field communications. Rolled out in 1997 and reaching 20 000 engineers in 1998, this was saving BT US$150 million a year on operational costs by 2000. When deployed over the targeted workforce of 40 000 people, the system was projected to save an estimated US$250 million a year.

Based on David Lesaint, Christos Voudoris, Noder Azarmi 'Dynamic Workforce Scheduling for British Telecommunications plc', Interfaces 30, no. 1 (Jan/Feb 2000): 45–56

Transportation

Transportation problems involve, predictably enough, situations where items have to be transported in an efficient and effective way. This might involve transporting manufactured products, such as smartphones, from where they're made to where they're sold. It might involve transporting medical supplies, such as blood and plasma, from where they're collected to where they're needed. It might involve transporting food and emergency supplies from donor countries to the site of a natural disaster such as an earthquake or cyclone. MS has developed techniques to help managers make appropriate decisions about transportation problems.

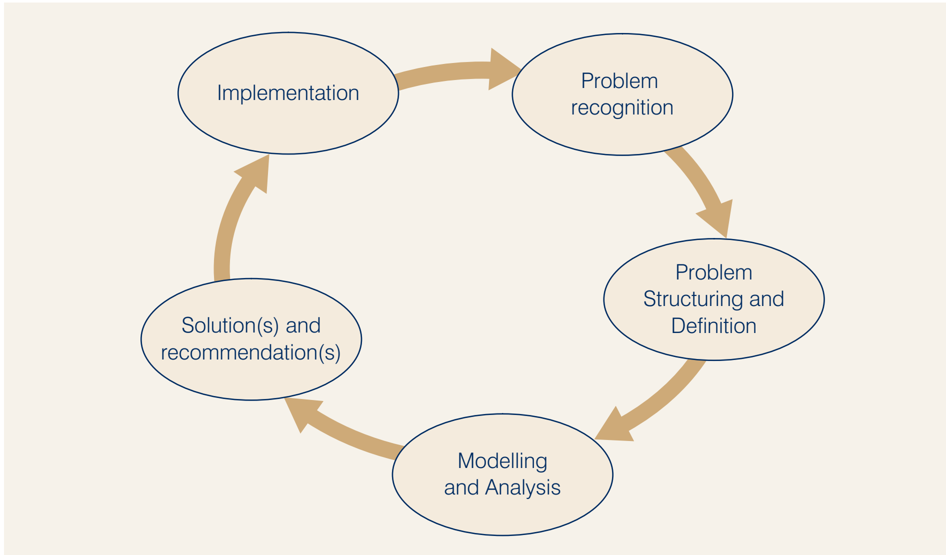
We've tried to show in this section that MS isn't just a collection of specialized techniques only of interest to the MS specialist but rather that MS has a role to play in many organizations where managers face such decisions. Throughout the text, we'll deliberately be introducing MS techniques in a business and management context. That is we'll be looking at a typical business decision problem and then seeing how MS can help managers make better decisions.

1.4 The MS Approach

Not surprisingly, given the emphasis on a *scientific* approach to management, management scientists try to follow a logical, systematic and analytical method when looking at a decision problem. This approach (or methodology) is summarized in Figure 1.1 and follows a sequence of: *Problem Recognition; Problem Structuring and Definition; Modelling and Analysis; Solution and Recommendations; Implementation*. (Note: different management scientists have their own versions of this methodology. However, most of these are similar in content.)

We shall use a simple scenario to show how the methodology is applied. The President of the College where you are studying has heard that you're studying management

Figure 1.1 The MS approach



'scientifically' and has asked for your help. The President has become increasingly concerned about traffic congestion on campus and in the nearby community that neighbours the College. There seem to be an increasing number of cars using the campus, parking is becoming increasingly difficult especially at peak periods, there has been a spill-over effect on the local community with more cars parked off-campus making it difficult for local residents to go about their business or to park themselves. The President has asked for your help in terms of what to do about the problem.

Problem Recognition

The first step is clearly to realize that a problem exists that requires a decision. This may seem obvious – and the College President has already done this – but in a wider management context it implies that an organization has systems in place for undertaking monitoring and observation so that problem situations are identified at an early a stage as possible. This implies that an organization has robust performance monitoring and measurement systems in place at both the operational, day-to-day level and at the strategic, long-term level. It is also worth noting that such observations will typically be undertaken by the manager in an organization – like the College President – rather than the management scientist.

We have used the word 'problem' here which is standard MS terminology. Whilst MS is typically focussed on helping solve problems – as in the case of the College traffic levels – it is also extensively used in situations to help evaluate opportunities. The College may be thinking, for example, of introducing a specialist MS degree programme and wants to know which type of publicity and marketing to use – the Internet? TV and radio? Social media? Business press?

Problem Structuring and Definition

The next stage of the MS approach is to structure the problem. This is about ensuring that the problem is properly understood, it is placed in context and that a clear definition of the problem to be investigated is agreed. This stage is critically important to effective MS. Improper, or inappropriate, structuring and definition of the problem may result in inappropriate analysis and inappropriate solutions being