Quantitative Analysis for Decision Makers

Seventh edition

Mik Wisniewski & Farhad Shafti

Pearson

Seventh Edition

QUANTITATIVE ANALYSIS
for Decision Makers

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Preface

Welcome to the 7th edition of *Quantitative Analysis for Decision Makers* (previously titled *Quantitative Methods for Decision Makers*).

It's 30 years since this book was first published and much has changed in the world of business and management since then. The internet was only just becoming available to businesses, with the world wide web starting to develop at the same time. Smartphones didn't exist. Apple and IBM were about to introduce their first business laptops. Microsoft was still working on its first version of Windows.

One thing that hasn't changed – and if anything it's got worse – is the pressure that managers are under at every level to make fast, effective decisions that turn out to be the *right* decisions.

The contribution that quantitative analytical techniques can make to such decision making is well researched. There is extensive empirical evidence that the relevant application of such techniques has resulted in significant improvements in efficiency – particularly at the microeconomic level – and has led to improvements in decision making in both profit and not-for-profit organisations. Numerous professional journals regularly provide details of successful applications of such techniques to specific business problems.

This is, arguably, one of the major reasons why in recent years there has been a considerable expansion of the coverage of such topics throughout business studies programmes in the higher education sector, in the UK and across much of the world. Not only postgraduate courses (such as MBAs) and professional courses (in finance, banking and related fields) but most, if not all, business undergraduate courses nowadays expose the student to basic quantitative analytical techniques. It is no longer simply the statistical or mathematical specialist who is introduced to these topics but, in numerical terms far more importantly, a large number of students who go on to a career in general management.

Coupled with this development has been the revolution that has occurred in making available powerful and cost-effective computing power on the manager's desktop, laptop or smartphone. Not only has this meant that the manager now has instant direct access to available business information but also that techniques which used to be the prerogative of the specialist can be applied directly by the manager through the use of appropriate – and relatively cheap and user-friendly – computer software such as Excel.

Because of these developments it is increasingly important for managers to develop a general awareness and understanding of the more commonly used techniques and it is because of this that this textbook was originally written and has continued to be updated.

The text aims to provide the reader with a detailed understanding of both the role and purpose of quantitative techniques in effective management and in the process of managerial decision making. This text focuses not only on the development of appropriate skills but also on the development of an understanding as to how such techniques fit into the wider management process. Above all, such techniques are meant to be of direct, practical benefit to the managers and decision makers of all organisations. By the end of the text the reader should be able to use the techniques introduced, should have an awareness of common areas of business application and should have developed sufficient confidence and understanding to commission appropriate applications of more complex techniques and contribute to the evaluation of the results of such analysis.

To assist in this each chapter includes:

- a fully worked example, usually with real data, applying each technique in a business context and evaluating the implications of the analysis for management decision making;
- short articles from the *Financial Times* illustrating the use of techniques in a variety of business settings;
- Quantitative analysis in action (QADM in action) case studies illustrating how the techniques are used in practice.

There is also a comprehensive, fully worked Instructor's Manual available for lecturers who adopt the text as the main teaching text for their class. The Manual is around 300 pages long, all end-of-chapter exercises have a full, worked solution together with supporting, explanatory text and there are suggestions for other related exercises that can be given to students. Diagrams and tables forming part of the solution are available in A4 size so they can be incorporated into PowerPoint presentations, or photocopied for students.

A number of features have been incorporated into this new edition:

- Dr Farhad Shafti joins as co-author. Farhad has considerable expertise in the areas of operations management, quality management and performance measurement.
- In line with the expanding use of business analytics, the text has been retitled and has an increased focus on the analytical aspect of quantitative methods and models.
- Additional use has been made of Excel.
- The linkages between the various quality management techniques in Chapter 8 has been strengthened.
- Chapter 12 on stock control now includes mention of the periodic review system.
- Chapter 13 on project management now focuses on the 'activity on node' method in line with industry practice.
- Chapter 14 on simulation illustrates the use of simulation software.
- *Financial Times* cases and 'QADM in action' case studies have been updated.
- A Postscript section highlighting recent developments in the quantitative analysis field

Publisher's acknowledgements

Text

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The Institute for Operations Research and the Management Sciences: Based on 'Development and Use of a Modeling System to Aid a Major Oil Company in Allocating Bidding Capital', DL Keeper, F Beckley Smith Jr and HB Back, *Operations Research*, vol. 39 (1), 1991, pp. 28–41. We are grateful to the Operations Research Society of America for permission to reproduce the figures shown in this section. **206 The Financial Times Ltd:** Bond, S. (2019) 'SAP acquires Qualtrics for $8bn' Financial Times, November 12, 2018 © The Financial Times Limited. All Rights Reserved. **208 Thomson Reuters:** Adapted from Kemp, J. (2012) Don't shoot the statisticians, Reuters.com, 26 April, © 2012 reuters.com. All rights reserved, www.reuters.com. Used by permission and protected by the Copyright Laws of the United States. The printing, copying, redistribution, or retransmission of this Content without express written permission is prohibited. **209 Capgemini:** Based on a Capgemini case study, with thanks to Capgemini for permission to use their material. **215 The Financial Times Ltd:** Warrell, H., Smith, A. and Fray, K. (2016) Doubt grows over official migration data as cabinet splits over direction of policy, 30 November © The Financial Times Limited. All Rights Reserved **217 Capgemini:** Based on a Capgemini case study, with thanks to Capgemini for permission to use their material. **218 The Financial Times Ltd:** Mundy, S(2014) Hyundai hit with lawsuit over fuel efficiency © The Financial Times Limited. All Rights Reserved **221 The Financial Times Ltd:** Jackson, F. (2014) Scottish polls: margin call, 13 September © The Financial Times Limited. All Rights Reserved. **239 The Financial Times Ltd:** Sarah O'Connor(2017) Employment Correspondent 'Britain's gig economy 'is a man's world, 27 April © The Financial Times Limited. All Rights Reserved **241 The Financial Times Ltd:** Martin Sandbu (2016) 'Free Lunch: Year-round fool's day' 1 April © The Financial Times Limited. All Rights Reserved **249 Crown copyright:** Office for National Statistics **257 The Financial Times Ltd:** (2019) IHI Corporation: cratering credentials, 6 March © The Financial Times Limited. All Rights Reserved **259 The Financial Times Ltd:** Palmer, M. (2014) Social media and big data come into play, 24 June © The Financial Times Limited. All Rights Reserved **265 Capgemini:** Based on a Capgemini case study, with thanks to Capgemini for permission to use their material. **275 The Financial Times Ltd:** (2005) Adventures in six sigma: how the problem-solving technique helped Xerox, 23 September. © The Financial Times Limited. All Rights Reserved **276 Emerald Publishing Limited:** Adapted from Yazan Al-Zain, Lawrence Alfandi, Mazen Arafeh, Samar Salim, Shouq Al-Quraini, Aisha Al-Yaseen, Demah Abu Taleb, (2019). "Implementing lean six sigma in a Kuwaiti private hospital", *International Journal of Health Care Quality Assurance*, 32:7. © Emerald Group Publishing Limited. All rights reserved. https://doi.org/10.1108/IJHCQA-04-2018-0099 **283 The Financial Times Ltd:** Chris Giles (2018), Forecasters get their 2018 UK economy predictions right, 28 December © The Financial Times Limited. All Rights Reserved **287 The Financial Times Ltd:** Gillian Tett(2019),Davos climate obsessions contain clues for policymaking, 17 January © The Financial Times Limited. All Rights Reserved **291 The Financial Times Ltd:** Myles McCormick and David Sheppard (2018), Oil tumbles after fears of tighter supply recede © The Financial Times Limited. All Rights Reserved **292 The Financial Times Ltd:** Cadman, E. (2013) UK sees steep increase in winter deaths, 26 November. © The Financial Times Limited. All Rights Reserved **296 Capgemini:** Based on a Capgemini case study, with thanks to Capgemini for permission to use their material. **301 The Financial Times Ltd:** Heaney, V. (2003), Technical analysis: How to identify your friend the trend, 24 January. © The Financial Times Limited. All Rights Reserved. **303 Crown copyright:** Office for National Statistics **305 The Financial Times Ltd:** Jackson, G. (2018) Some like it hot—but UK heatwave proves a mixed blessing, 28 July © The Financial Times Limited. All Rights Reserved **306 Capgemini:** Based on a Capgemini case study, with thanks to Capgemini

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1 Introduction

There's no getting away from it. Quantitative data and information is everywhere in business. In the private sector the focus is on share prices, costs, income and revenue levels, profit levels, cash flow figures, productivity figures, customer satisfaction ratings, market share figures, cost and revenue information. The list goes on and on. If you're in a public sector or not-for-profit organisation comparable information is also being generated, such as service response times, patient waiting times, cost benchmarks and productivity figures. The trend seems to be: let's measure and quantify everything we can.

The problem this causes for managers is how to make sense of this mass of quantitative information. How do we use it to help make decisions and to help the organisation deal with the issues and pressures that it increasingly faces? Such decisions may be routine, day-to-day operational issues: deciding how much laser printer paper to order for the office or how many checkouts to open at lunchtime in the store today. They may be longer-term strategic decisions which will have a critical impact on the success of the organisation: which goods/services do we expand? How do we increase market share? How do we balance the pressures on our income with the demand for services?

And – no great surprise here – this is why this textbook has been written: to help managers make sense of quantitative business information and understand how to analyse and use that quantitative information constructively to help make business decisions. However, we're not looking to turn you into mathematical and statistical experts. We want to give you a reasonable understanding of how a variety of quantitative analytical techniques can be used to help decision making in any organisation. We also want to convince you that these techniques are of real, practical benefit. That's why throughout the text we focus on the business application of the techniques rather than the theory behind them. We also illustrate how real organisations have used these techniques to improve their business performance.

We hope you find this textbook useful.

The use of quantitative techniques by business

Okay, let's start with a reality check.

You're *really* looking forward to the quantitative analysis module on your course. Right?

You *really* wish there could be more quantitative analysis on your course. Right?

You *really* see quantitative analysis as the key to a successful management career. Right?

We don't think so!

Like just about every other business degree student around the world you're probably approaching this course and this textbook with a mixture of concern, worry and misunderstanding.

Concern about your ability in statistics and mathematics, especially as these probably weren't your favourite subjects in school either.

Worry about whether you'll be able to pass the exam and assessments in this subject.

Misunderstanding about why you have to do a quantitative analysis course on a business degree. After all, business is about strategy, about marketing, about finance, about human resource management, about IT and e-commerce. We know these are important to every business because company boards have directors in these areas. But whoever heard of a company with a director of quantitative analysis? Well, the world is changing.

Remodelling MBAs for the digital era

MBA programmes are being recast to keep up with developments in data

By Ross Tieman

Data will surge through business like the earlier tsunamis of personal computers, the internet and smartphones, predicts Alwin Magimay. The partner and head of digital and analytics at KPMG says: "We are entering the fourth wave of digital value creation. I think data scientists are going to be to the present time what computer programmers were in the 1990s."

If Magimay is right, then a generation of school-leavers and university graduates must think very hard about how they learn the skills for an era when digital platforms and data are at the heart of every economic and administrative activity. . . .

As data-gathering snowballs worldwide, understanding fully the story behind the numbers is vital in every field.

FT

Source: Tieman, R. (2016) MBA programmes are being recast to keep up with developments in data, FT.com, 24 January.

The ability to collect, analyse and act upon data is critical for every manager at every level.

ING: A data-driven business

Chief Analytics Officer Görkem Köseoğlu wants ING to be driven by data – a 'smart bank' that uses artificial intelligence (AI) to predict customers' wants and needs. The ING Group is a Dutch multinational banking and financial services organisation headquartered in Amsterdam with around 40 million customers in more than 40 countries.

As Görkem comments, 'we have over have three billion customer interactions a year . . . ' and his team focus on customer intelligence, pricing, risk management, intelligent operations and innovation. But in addition to employing a team of analytical specialists the company is also launching global ING Analytics Academy which is available to all ING employees. Görkem comments, 'Data is the language of the future. If you don't speak it yet, we'll help you master it.'

Source: adapted from www.ing.com/Newsroom/All-news/Data-driven-from-bytes-to-business.htm

ING is not alone at seeing data and analysis as key driver of business success.

One of the major reasons for writing this book was to provide business studies students at both undergraduate and postgraduate levels with a text that is relevant to their own studies, is easy to read and to understand and that demonstrates the practical application – and benefits – of quantitative analysis in the real business world. The book is *not* aimed at students whose main interest is in statistics, mathematics or computing. We assume that, like ourselves, students in the fields of management, accountancy, finance and business have no interest in these in their own right but rather are interested in the practical applications of such topics and techniques to business and to management decision making. The reason why all students in the business area nowadays need a working knowledge of these quantitative analysis techniques is clear. In order to work effectively in a modern business organisation – whether the organisation is a private commercial company, a government agency, a state industry or whatever – managers must be able routinely to use quantitative analysis in a confident and reliable manner. Today's students are striving to become tomorrow's managers. Accountants will make decisions based on the information relating to the financial state of the organisation. Economists will make decisions based on the information relating to the economic framework in which the organisation operates. Marketing staff will make decisions based on customer response to products and design. Personnel managers will make decisions based on the information relating to the levels of employment in the organisation and so on. Such information is increasingly quantitative and it is apparent that managers (both practising and intending) need a working knowledge of the procedures and techniques appropriate for analysing and evaluating such information. Such analysis and certainly the business evaluation cannot be delegated to the specialist statistician or mathematician, who, adept though they might be at sophisticated numerical analysis, will frequently have little overall understanding of the business relevance of such analysis.

Two relatively recent developments in the business world have accelerated the need for managers to make better use of quantitative information in their decision making. The first is the move towards *big data* in many organisations. The second is the development of the area known as *business analytics*. Big data refers to increasingly large, varied and complex data sets that are collected by organisations in both private and public sectors. Thanks largely to modern technology, such as laptops, smartphones, GPS systems and sensors, it has become possible for organisations to collect vast quantities of information

routinely and cheaply. For example, the US-based retailer Walmart routinely collects data on over a million customer transactions *every hour* and it's been estimated that the volume of business data collected worldwide *doubles* every 12 months. The field of business analytics has developed partly to exploit big data. Business analytics focuses on developing insights and understanding of business performance based on data and statistical methods and makes extensive use of statistical analysis, including explanatory and predictive modelling and evidence-based management to drive decision making. Increasingly, organisations will be looking for people who can exploit big data using business analytics and will want managers to be able to make use of the quantitative information generated. The good news is that those managers with the necessary quantitative understanding and skills will be in a prime position.

The US clothing group's chief ignores fashion intuition, using scientific analysis to woo alienated customers.

Numbers man bridges the Gap

By Neil Buckley

The first few times Paul Pressler, chief executive of Gap, the US clothing group, reviewed the new season's products, the designers were baffled.

He would ask only a few basic questions – had they thought of this or that, why had they chosen a particular style – and he would not pass judgment. When he left the room, the designers "were, like, 'OK. Did he *like* it?'", he says, recounting the story in Gap's design office in Chelsea, New York. But for Mr Pressler, a former Disney theme park executive, "it didn't matter whether I liked it or not – what mattered was whether the consumer liked it". His refusal to air stylistic opinions was his way of showing his staff how he planned to manage the company. "I had to demonstrate to everyone that the general manager is here to lead people – not pick the buttons," he says.

Mr Pressler's anecdote illustrates how he runs Gap very differently from his predecessor, Millard "Mickey" Drexler, whom he succeeded two years ago. Whether Mickey Drexler liked things or not was very important indeed.

Popularly known as Gap's "Merchant Prince", Mr Drexler set the tone, designed products and even dictated what quantities of products buyers should order from the company's suppliers. The business was largely run on his instinct. Designers, jokes Mr Pressler, "relied on getting their blessing from the pope".

The approach was successful for 15 years, as Mr Drexler worked with Don Fisher, Gap's founder, to transform into an international fashion retailing giant what had started as a single store in counter-culture 1960s San Francisco. Yet by 2002, when Mr Pressler arrived, Gap Inc – which now includes the lower priced Old Navy and upmarket Banana Republic chains in North America as well as international Gap stores – was in trouble. Comparable sales, or sales from stores open at least a year – an important indicator of a retailer's health – had fallen, year-on-year, for 29 straight months. It was clear Gap had lost touch with its customers.

Mr Drexler's genius had been to be absolutely in tune with the post-war baby boomers – those born between 1946 and 1964 – who were Gap's first customers. Gap grew and adapted with them; when they had children, it clothed them too, launching Gap Kids in 1986 and Baby Gap in 1990. It kept up their interest with quirky and distinctive advertising. By the late 1990s, as the boomers took over America's boardrooms, the internet took off and 'business casual' replaced suits and ties, Gap seemed unstoppable.

It increased the number of stores – and the amount of debt – tossing out Mr Fisher's previously cautious approach of opening just enough stores to ensure 15 per cent compound annual earnings growth.

But, like many of its customers, Gap was about to experience what Mr Pressler calls a mid-life crisis. Gap's massive investment in expansion was not yielding a return. Sassy, youth-orientated retailers such as Abercrombie & Fitch and American Eagle were coming on the scene, offering Gap stiff competition. "Everyone was looking at them and saying 'look how cool and hip they are' and 'Gap is now my father's brand,'" says Mr Pressler.

To address the problem, Mr Drexler decided Gap needed to go after a younger consumer. Out went the khakis and simple white shirts; in came turquoise low-rise jeans and tangerine cropped T-shirts. But the customers deserted the stores in droves. "Mickey took the fashion in a direction that was, to his credit, trying to be more hip and relevant," says Mr Pressler, "but it was too singular, too hip and youthful." At this point, Mr Drexler left Gap, having served 19 years. Mr Pressler, then running Walt Disney's theme park division and considered a possible successor to Michael Eisner as Disney's CEO, says he did not have to think too long about accepting

the Gap job. Like many businessmen of his generation – he is now 48 – he felt a personal connection.

"I thought about it first as a consumer and said: 'Damn! This brand is too good and too awesome'. Many of us went to [business] school on Gap: how it reinvented itself, how it did its marketing. And as consumers we were all a little pissed off that it had alienated us."

Once inside, he spent 90 days reviewing the business, interviewing the 50 most senior people in the company. He was shocked.

"A company that I had thought was this unbelievably consumer-centric company was not a consumer-centric company at all," he says. "The truth is that we made decisions in our head, not in the real world. The tool we used was yesterday's sales – which didn't give you consumer insights, or tell you why people didn't shop at our stores."

There were other problems. The technology system was, as Mr Pressler puts it: "massively, woefully, behind anything I had ever seen in my life for a company of our size." A $15bn-a-year business was run largely on Excel spreadsheets and inventory discipline was non-existent, with little account taken of how much working capital was being tied up.

Mr Pressler set about replacing intuition with science. He carried out a detailed "segmentation" study for each brand and introduced consumer research, interviews with customers and store managers, and focus groups.

The message that came back was clear. Prices aside, consumers could see little difference between Gap and its Old Navy sister chain. In response, Old Navy was repositioned as more of a value chain and Banana Republic was taken upmarket and given a "designer" feel. That left the middle ground for Gap. Mr Pressler stuck with Mr Drexler's strategy of waving goodbye to the boomers, though. "We have brought a more youthful style aesthetic," he says, "but it's a safe one, not a scary one."

"Instead of going to the 15- to 20-year-olds, we pushed the brand back to what it has always been, which is really a 20- to 30-year-olds' brand," says Mr Pressler.

The research also helped identify new product niches that could be added to stores – petite sizes in Banana Republic, so-called "plus" sizes in Old Navy and maternity wear in Gap.

It helped each chain segment its customers into types – mums, mums shopping for families, fashionable teens and more conservative "girl-next-door" teens – so designers had a clearer idea of their likely buyers. In pursuit of what Mr Pressler calls fashion retailing's "Holy Grail" – women's trousers that fit right – Gap stopped using in-house "fit models" who were a perfect size 8. Instead, it organised "fit clinics" across the country, and designers got real people to try on their clothes.

Sizing initiatives did not stop there. Gap's chains used to ship identical proportions of different sizes of products to all stores. But in, say, fitness-obsessed San Francisco, it would be left with lots of surplus extra large sizes. In the Midwest, the surplus would be in extra small sizes.

Mr Pressler got mathematical experts to analyse Gap's electronic sales information. They divided its stores into seven different "clusters" according to the likely sizes of the customers in the local area. Each cluster now gets a different mixture of sizes. As a result, fewer products are out of stock, more customers are satisfied and fewer goods get left over to be marked down.

Meanwhile, systems were updated and sophisticated inventory management software introduced.

Mr Pressler admits that the company's designers were initially sceptical about his analytical approach. But once they saw what was happening to sales they became converts.

Comparable sales began growing again in late 2002 and continued until last month when sales fell 5 per cent year-on-year. This drop was largely attributable to poor weather and higher petrol prices. Operating margins are also getting back towards the mid-teens they reached in the 1990s.

However, at around $20, Gap's shares still remain well below their $50-plus peak in 1999 and the market is clamouring to hear where future growth will come from.

Mr Pressler says Gap is studying how to expand its core brand in its existing overseas markets – Japan, the UK and France – as well as in some other countries. It is also considering whether Old Navy and Banana Republic could work outside the US and Canada. He does not rule out departing from the existing model of company-run stores and using franchising, licensing arrangements or partnerships in these overseas markets.

In the US, Mr Pressler admits that he is contemplating a fourth brand. But he refuses to comment on speculation that Gap is considering a chain catering to boomer women – those aged 35–50 – for whom the core brand is too youthful.

If Gap is targeting the post-boomer generation now, Mr Pressler insists the brand will never lose sight of its 1960s counter-culture origins.

Its autumn advertising campaign, featuring *Sex and the City* star Sarah Jessica Parker, will, he says, affirm its cultural relevance.

"We were always right on the spot, on the cultural phenomenon happening at the moment. And we brought it to you, through our commercials, and through our product, in ways that were compelling," he says. "That piece of the DNA we still feel very strongly."

FT

Source: Buckley, N. (2004) Numbers man bridges the Gap, FT.com, 24 August.

As Gap shows, an analytical approach and the use of quantitative methods can make all the difference to business success or failure.

A report by McKinsey Global Institute in 2011 concluded that the shortage of analytical and managerial talent presented a significant challenge with the United States alone facing a shortage of 1.5 million managers and analysts to analyse big data and make decisions based on their findings. There's no reason to think that this skills gap is any different round the globe.

Amadeus set to soar on airline bookings

By Thomas Hale in Madrid

Amadeus, the Spanish company that provides the technology behind airline flight bookings, is set to report results in stark contrast to the airlines it serves, as it benefits from a 40 per cent share of a growing air travel market.

On Friday, the group's full-year results are expected to show the effect of its expansion from flights into hotel reservations and the growth of its IT solutions business. Its share price has been charting a sustained upward trajectory for much of the past five years, hitting an all-time high on Monday this week, for a market capitalisation of €16bn.

Amadeus makes most of its money through its global flight distribution system, which manages transactions between customers and about 400 of the world's airlines, many of which take place on online price comparison websites. Its growth is therefore linked directly to an increase in global air traffic.

Analysts suggest that much of Amadeus's value lies in what it can glean from the billions of transactions it processes: a perspective on the purchasing habits of consumers.

Improved personalisation – from the interrogation of "big data" – enables airlines to tailor their products and services to the personal whims of individual consumers.

Amadeus has already begun to sell aggregated user information to airlines, revealing customers' search habits. It provides a growing revenue stream for the company.

Source: Andrew Barker/Shutterstock.com

FT

Source: Hale, T. (2015) Amadeus set to soar on airline data sales, FT.com, 26 February.

Big data and business analytics are increasingly becoming big business.

This text introduces the major mathematical and statistical techniques used to help decision making by managers of all types of business organisation: large and small, private sector, public sector, profit-oriented, not-for-profit, manufacturing or service sector. As the article on Gap illustrates, managers are expected to be able to justify the decisions they reach on the basis of logic and hard analysis not just on judgement and experience. In such an environment the quantitative techniques we shall be examining have an important

part to play. We do not pretend that these techniques offer the manager an instant solution to the problems faced. However, they do offer a method of analysing a problem using proven techniques, of providing information about that problem and of assessing the potential outcomes from different decisions. Such techniques can provide valuable information about a business problem that may not be available from any other source. But such information is only part of the problem. The manager must assess the information generated by techniques alongside that available from Finance, from Engineering, from Sales, from Marketing, from Personnel and so on. Like any piece of information, the manager must be in a position to assess its reliability and its potential usefulness.

This is why, in this text, the focus is very much on an understanding of the general principles – from a management perspective – behind each technique. It is not the intention of the text to turn you into an 'expert' in the use of such techniques, although you will develop skills in the practical aspects of many of these as we progress. Rather it is to enable you to appreciate when such techniques may be useful in your decision-making capacity and to provide you with an insight into how the information generated by such techniques can be evaluated and used.

But don't just take our word for this. Let's look at some documented examples.

- An electricity company in the USA developed a computer-based planning system to help improve forecasts of demand. The result was a reduction of some US$140 million in fuel costs over a seven-year period.
- The UK Royal Air Force developed a simulation model to quantify the number of battle damage repair teams likely to be required to maintain aircraft capabilities in the event of hostilities.
- A computer-based simulation model was developed to help evaluate the strategic options in terms of transporting coal in Canada from its source to power stations – a distance of some 3000 km.
- In Canada the technique of linear programming was applied to the use of ambulances in health care and to the related shift systems. This generated annual savings of around CN$250 000.
- A farming cooperative in Holland implemented an interactive optimisation system to help plan bulk deliveries of its sugar beet crop with a resulting reduction of 7 per cent in its operating costs.
- A New Zealand utility company applied quantitative techniques to its car-pooling procedures with the result that the number of vehicles required was reduced by 35 per cent, which generated annual savings of NZ$55 000.
- Quantitative techniques were applied to the problem of transporting mentally handicapped adults to a training centre in the UK. As a result travel time could be reduced by almost 16 per cent and distance travelled by 12 per cent.
- A quantitative model was developed to assist in the planning of transportation of blood from a regional centre to hospitals. The model generated a reduction of over 12 per cent in the number of units of blood which had reached their expiry date before use compared with the manual planning system.
- American Airlines has developed a number of quantitative models in relation to its airline seat reservation systems. The models are estimated to contribute around US$500 million per year to the company's revenue.
- Hewlett-Packard used quantitative techniques to forecast capacity and to determine locations of stocks and supplies in the context of one of its computer printers. As a result, productivity increased by 50 per cent and incremental revenues of US$280 million in sales were generated.

- Forecasting models are estimated to have saved the mail order company L.L. Bean US$300 000 each year through improved prediction of incoming calls and staffing requirements in its call centres.
- Delta Airlines uses mathematical programming models to help in its assignment of airplanes in its fleet to flight routes. The approach saved the company around US$300 million over a three-year period.
- Kentucky Fried Chicken (KFC) reduced waiting times for customers by half and improved productivity, sales and profit through the application of quality management techniques.
- DEC (Digital) saved an estimated US$100 million by applying linear programming to its global manufacturing and distribution strategy.
- Taco Bell, a chain of popular restaurants, used forecasting to help it predict arrivals of customers through the day and developed a simulation model for planning its personnel requirements. The company saved an estimated US$53 million in labour costs in one year alone.
- UPS, the delivery and logistics company, sees business analysis as critical to its operation performance. Finding the best routes for its delivery drivers to take cut total mileage by over 85 million miles a year, reducing fuel consumption (and costs) and the company's carbon footprint.

That made you sit up and take notice, didn't it?

The appropriate use of quantitative techniques can help the business 'bottom line' – whether that bottom line is increased profitability, reduced costs, improved efficiency or better customer service. Quantitative techniques *work*! And they work best when used by managers.

Mathematics offers business a formula for success

By Clive Cookson, Science Editor

Mathematicians have come up with an impressive multiplication formula for British commerce and industry: spend a few million pounds promoting the use of maths as a strategic tool, and add billions of pounds of value to businesses.

That is the thinking about a new government–industry consortium, the Mathematics Knowledge Transfer Network.

The network aims to boost the use of maths throughout the economy from grocery distribution to banking, telecoms to manufacturing.

The Department of Trade and Industry will make a core investment of £1.5m in the network's infrastructure over three years, with other partners contributing £3.5m.

Industry is expected to increase research and development spending by a further £7m as a result of the project. But Robert Leese, the consortium manager, said the indirect benefits could be hundreds or thousands of times greater.

"It is already recognised that the use of mathematics in the R&D process adds billions of pounds of value to UK business," said Mr Leese, who directs the Smith Institute for Industrial Mathematics in Guildford. "I predict the newly-formed KTN will multiply that value by two, three or perhaps even four times."

Mr Leese added: "I do not think many businesses are fully aware of the benefits that maths can bring. Few companies recognise that they have mathematical expertise in-house, and few universities are promoting their maths departments effectively to industry."

Lenny Smith, an American mathematician with academic appointments at the London School of Economics and Oxford University, said: "The quality of mathematics and the ability to do ground-breaking research in the UK are second to none."

But Prof Smith, who works with industry on both sides of the Atlantic, added that UK companies were slower than their US counterparts to apply mathematical ideas.

Huge savings can be made by applying algorithms – mathematical rules – to existing information, according to Prof Smith. For example, the retailing and logistics sectors could find more efficient ways to move goods around the country. "Maths can help Adnams brewery decide how best to collect its empty beer kegs or Sainsbury's decide where to sell two truckloads of lettuce in Birmingham," he said.

Unilever, one of 12 companies on the network industrial steering committee, has recently made extensive use of maths. It says statistical analysis of the relationships between advertising campaigns, sales and market share has made Unilever advertising campaigns 15 per cent more efficient.

"We are also borrowing mathematical simulation methods used in the film industry and gaming world, such as agent-based methods, to model the psychology of how shoppers choose one brand over another," said Shail Patel, mathematical and psychological sciences leader for Unilever Research. "Mathematics is universal as, unlike most other disciplines, it can add value to any function within Unilever."

Mr Leese is most enthusiastic about the ability of maths to "shine a torch" down possible R&D routes so that managers can decide quickly which are dead ends and which should be pursued. "The whole concept of mathematics 'accelerating' the innovation process is simple to state," he said. "It both provides an earlier return on investment in R&D and cuts down on wasted R&D spend."

FT

Source: Cookson, C. (2006) Mathematics offers business a formula for success, *Financial Times*, 13 February.

Global business has started to wake up to the benefits that quantitative methods can bring.

The role of quantitative analysis in business

It is worthwhile at this stage considering the specific role of quantitative analytical techniques in the wider business decision-making context. Although this text inevitably focuses on a number of common techniques, business decision making is more than simply the application of a technique to a problem. It is worth considering what the overall purpose of such techniques is in relation to the decision maker. Such techniques aim to improve decision making within an organisation.

Those of you with experience of management in an organisation will appreciate that life for any manager in any organisation is becoming increasingly difficult and complex. Although there are many factors contributing to this, Figure 1.1 illustrates some of the major pressures making decision making increasingly problematic. Organisations generally find themselves operating in an increasingly complex environment. Changes in government policy, privatisation, increasing involvement of the European Union, and political and economic changes in Eastern Europe all contribute to this complexity. At the same time, organisations face increasing competition from both home and abroad. Markets that were thought to be secure are lost to competitors. In the public sector, services – local authority, health care, emergency services – are increasingly required to operate in a competitive manner. Also, the markets and customers available to organisations are changing. This combines with increasing and constantly changing pressures from customers in terms of both their requirements and their expectations. The drive for quality and customer satisfaction gathers pace in both the public and private sectors.

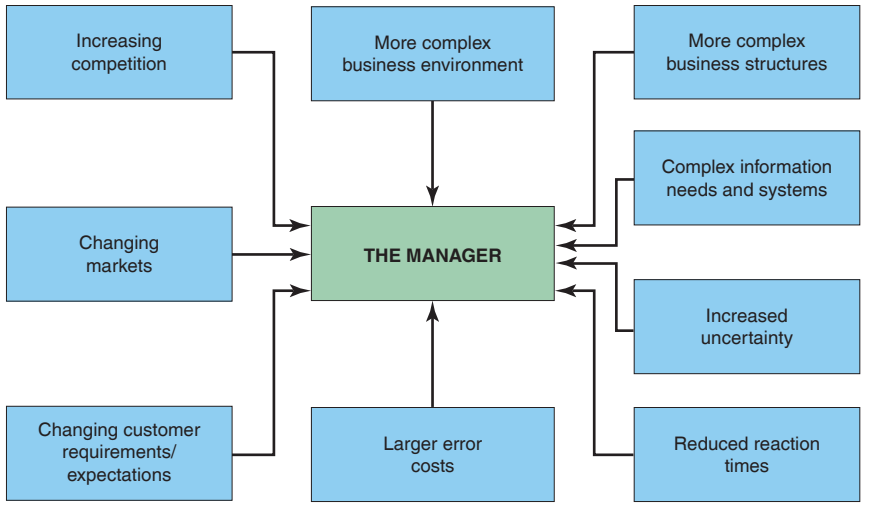


Figure 1.1 The manager and the decision-making environment

Because of the increasing complexity of the business environment in which organisations have to function, the information needs of a manager also become more complex and demanding. With the pace of increasing competition – and with continual improvements in telecommunications – the time available to a manager to assess, analyse and react to a problem or opportunity is much reduced.

Managers, and their supporting information systems, need to take fast – and hopefully appropriate – decisions. Finally, to add to the problems, the consequences of taking wrong decisions become more serious and costly. Entering the wrong markets, producing the wrong products or providing inappropriate services will have major, often disastrous, consequences for organisations.

All of this implies that anything which can help the manager of an organisation in facing up to these pressures and difficulties in the decision-making process must be seriously considered. Not surprisingly, this is where quantitative techniques have a role to play. This is not to say that such techniques will automatically resolve such problems. But they can provide both information about a situation or problem and a different way of examining that situation which may well help. Naturally such quantitative analysis will produce information that must be assessed and used in conjunction with other sources. Business problems are rarely, if ever, tackled solely from the quantitative perspective. Much qualitative assessment must also take place. For example, think about a local authority considering the replacement of some of its refuse collection vehicles. We may well be able to apply a number of quantitative techniques to this situation – using financial analysis principles, examining patterns and trends in refuse collection, comparing one vehicle's performance with other vehicles, forecasting the likely demand for refuse collection over the life of the vehicle and so on. However, before reaching a decision, other factors and information will need to be considered. Is this the right time 'politically' to be making what may be a major capital investment? How will the workforce react to a new vehicle – given this may require some retraining – and to what may be new modes or methods of working? Will the management of this service be able to cope with the problems that such a change will bring? All of these factors and more will need to be taken into account by the manager before reaching a decision. Clearly, quantitative

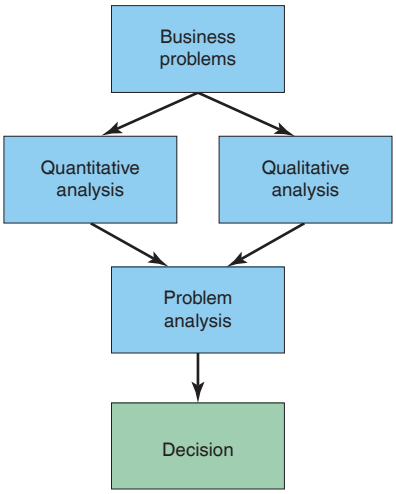


Figure 1.2 The decision-making process

techniques have a potentially important role to play in helping reach a decision but they are not sufficient by themselves. This is illustrated – albeit simplistically – in Figure 1.2. A business situation – at the strategic or operational level – needs to be examined from both a quantitative and a qualitative perspective. Information and analysis from both these perspectives need to be brought together, assessed and acted upon.

However, the techniques we introduce in this text not only are valuable at corporate, strategic level, but they are also particularly useful at the operational level in day-to-day management (although use at this level is rarely publicly reported). We shall be introducing a number of illustrations of this level of use throughout the chapters. In short, knowledge of such techniques, the ability to know when to apply them and the ability to relate the quantitative outputs from such techniques to business decision making is critically important for every manager in every organisation. Not to develop such skills and knowledge will put your own organisation at a critical competitive disadvantage.

Models in quantitative decision making

Throughout the text we shall be introducing what are known as *models* to help develop quantitative techniques in a business context. Models come in a variety of forms in business: they are not just quantitative. A scale model might be constructed of a new office development; a financial model may be developed to assess the impact of budget changes on goods/service delivery; the marketing department may develop a model in terms of assessing customer response to product changes. However, any model, no matter what its form or purpose, has one distinctive feature: it is an attempt to represent a situation in a simplified form. Any model tries to represent the complex real-world situation in a more simplistic and potentially more easily understood form. This is achieved by developing the model so that it focuses on the key aspects of the situation and ignores the rest. By definition, every model is limited in the insights that it provides. It's your job to understand the model outputs and the model limitations when making decisions.

In this text we shall be developing a variety of statistical and mathematical models for use in business decision making. We shall be using such mathematics and statistics to help us make sense of a complex real-world problem, and we shall be utilising techniques to help us focus on what we believe to be the key aspects of the problem. Just as an architect uses a scale model of a new construction or an engineer of some machine, so a manager needs to be able to develop and use quantitative models to help in the decision-making process.

John Hull: Cautious of creating too much complexity

By Bernard Simon in Toronto

John Hull has a confession to make.

As a professor of finance at the University of Toronto's Rotman School of Management, he has won international acclaim for designing and valuing complex financial tools such as options and other derivatives.

But when it comes to managing his own money, Prof Hull has little use for such exotic instruments. His investment portfolio comprises mainly index funds. And while he keeps reminding his students about the importance of hedging risk, his own liabilities are heavily concentrated in Canadian dollars.

Seen from a different angle however, Prof Hull's financial strategy is entirely consistent with the message he hammers home as a teacher, author, consultant and expert witness in derivative-related lawsuits: that is, keep things as simple as possible.

"There's a danger, with all the people with PhDs in physics and maths who have moved into this area, that some of the models become too complicated", Prof Hull says. "There's a tendency for people with that sort of background to just want a really difficult problem to solve. And that's not necessarily what's needed."

Quantitative analysis and analysts have made deep in-roads in trading rooms and financial research departments since two University of Chicago economists, Fischer Black and Myron Scholes, devised a mathematical model for pricing options and corporate liabilities in the early 1970s.

However, the recent turmoil in financial markets has jolted faith in the so-called "quants".

Prof Hull agrees that "there's some ground for concern" that traders and analysts have relied too heavily on mathematical models in their decision-making.

"We need a much more common-sense approach to risk management and must not let quants and traders run free-rein for short-term profits," he says.

The problem, in Prof Hull's view, has been an over-dependence on models that are based chiefly on recent market trends.

Over the past three years, for instance, "we were looking at a period when volatilities were very low", he says, "so values at risk were lower".

"To some extent, that model led to a false confidence on the part of the banks. Somebody should have been saying: 'Let's look at the big picture, what could go wrong? How well will we come out if it does go wrong?'

"In most institutions I don't think anybody was doing that. They were just relying on: 'We're making a lot of money, the value-at-risk model says we're okay'."

But heavy losses since the onset of the US subprime mortgage crisis have prompted a good deal of soul-searching among quants, and those who employ them. "I don't think there is a substitute for sound managerial judgment," Prof Hull says.

"In a few companies, however, rather than senior managers letting the traders run loose on this, they sat back and thought about the environment out there; about what could go wrong and how badly they would suffer if it did."

"It's more looking at a situation, coming up with the simplest model that captures the essence of it, and then writing it up in such a way that people will easily be able to understand it."

FT

Source: Simon, B. (2008) Cautious of creating too much complexity, FT.com, 16 June

Models have a useful role to play in business decision making, but they have to be used in combination with management judgement and experience.

QADM IN ACTION

You've got direct mail: the Marks & Spencer '& More' credit card

Predictive modelling provides a way to increase profitability and customer satisfaction in the financial services sector. ***Omar Mohamed*** *describes the successful use of this technique in recent marketing activities for the M&S '&More' credit card.*

Why use predictive modelling?

The financial services industry is fiercely competitive, with a constant stream of new entrants (e.g. Egg and Virgin) branching out into financial services, and companies must find ways of targeting customers effectively if they are to increase their market share. Knowing which customers are most likely to respond to a particular product offer is invaluable business information. By analysing customers' responses to past offers, businesses can gain insight into which offers individual customers are likely to respond to and decide whether they should be contacted in connection with a particular product offer in future marketing activities.

Effective targeting allows businesses to be extremely cost effective in activities such as direct mail, and also to maintain a good relationship with customers by not bombarding them with offers which do not interest them. This is particularly important because the number of pieces of direct mail the average household receives is constantly increasing.

Predictive modelling is key to effective targeting. Predictive models allow businesses to forecast customer behaviour by analysing the wealth of information stored on large customer databases. These models are used to produce forecasts of customer behaviour commonly known as *scores* or *propensities*, which are then used to decide which customers should be mailed to achieve the most profitable activity or financial target. Customers are usually ranked by their score and then the best customers are selected first until response targets are met.

The challenge

The marketing Credit Card Team wanted to carry out an offer mailing to existing M&S Money customers. The initial problem was to decide which customers were likely to take up the product, with the goal of reaching the desired number of responders at minimum cost. Since the cost per mailing piece is fairly constant, the only way to reduce the cost of the campaign was to send fewer pieces of mail.

However, since the Credit Card Team wanted to reach a target number of responders, the solution was not simply to send fewer mail pieces. If customers were selected for the offer at random from among all available customers, the number of mail pieces could not be reduced without the risk of falling short of the number of responders required to make the campaign successful. So we needed a targeting tool that could be used to select those customers who were most likely to respond to the offer.

Application of predictive modelling

Creating the model

The first step in producing the predictive model was data selection. This step was key, since a model is only as good as the underlying data. Selecting the best data for the development of the targeting model required a good understanding of the market and the objective, and, not surprisingly, this stage took up the most time and effort, identifying, locating and preparing the data. Since there were no previous campaigns offering this product, the data set was selected from customers who had, and who had not, taken up the product of their own accord.

The model's target variable was the probability that a customer would take up our offer. Customers who had taken up the product were given a value of 1 and customers who did not have the product were given a value of 0.

We then identified and located data, from sources both inside and outside the organisation, that could be used to build the model. This covered:

- demographics, including gender, age, household income, marital status, home ownership and type of dwelling;

→

- behavioural information, including types and numbers of purchases;
- product holdings, including characteristics describing the products customers already held (e.g. 'holds an M&S Money Mini Cash ISA, previously held an M&S Money loan');
- third-party data, including products customers purchased, their attitudes, beliefs and opinions, geodemographic data, demographic and lifestyle data.

The next stage was the creation of new variables from these raw data. This is a critical element of good model building as data are often more predictive when transformed into descriptive and summary statistics. Behaviour and product data, such as monthly balances, monthly transactions and the loans a customer had in the past were used in the creation of new fields. For example, balances over the last six months were used to create a new field: 'average balance in the last six months'.

At this point we had generated a modelling data set with several hundred variables, including derived and raw data inputs. We next looked at reducing the number of modelling variables from several hundred to the 100 or so most predictive, by selecting those that were most correlated with the target variable. The tools used included descriptive statistics, crosstabs, χ^2-tests and cumulative modelling.

Next came the modelling stage, for which we separated the modelling data set into a training data set and a validation data set. The training data set was used to develop the model and the validation data set was held back to check that the model was robust.

Stepwise logistic regression was then used for the development of the response model, although other statistical techniques were also investigated. The 100 variables identified as being the most predictive in the previous stage were used for modelling the training data set. This was an iterative process, resulting in several variants of the final model that all performed well. These were compared against each other using a variety of diagnostic tools in order to select the best performing model.

The final model was then validated by running fresh data through it to see how well it performed. The results were very consistent with the results seen in the training stage so we were confident that the model would perform well when implemented.

Implementing the model

The model was then used to produce scores for all available customers on the customer database (a score of 100 meaning that a customer was most likely to take up the product and a score of 1 meaning that the customer was least likely to take up the product).

Customers were then sorted into descending order according to their score. First a small random sample of customers was selected so that the model's performance could be compared against results for a non-targeted campaign, and then a group of the best customers was selected to achieve the required number of responders for the campaign.

The benefits

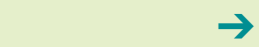
When the responses had come in, we could see how the predictive model performed.

The mailing carried out to a selection of our best customers achieved approximately three times the number of responders we would have received had we mailed a random selection of the same size.

Figure 1.3 shows the total mailed population, ranked according to their model score along the *x*-axis (highest likelihood to respond to lowest likelihood to respond from left to right). The *y*-axis shows the cumulative captured responses, as percentages of the total response to the campaign. The straight line represents the results of a non-targeted campaign within the mailing population; the dotted curve shows the actual response to the campaign.

Table 1.1 further illustrates the efficiency of the model and the benefit to the business. The first column describes the mailing population split into deciles, the second the cumulative percentage of customers who responded, the third the cumulative percentage of customers who did not respond, the fourth the cost per response relative to the overall cost per response and finally the model efficiency, this last being the rate at which responding customers are found in the targeted population.

It can be seen that the model was most efficient at the first decile and least efficient at the bottom decile. In the first decile the cost per response was only 36 per cent of the overall cost per response for the targeted mailing, showing that the cost of acquisition could have been further reduced if we had not needed to meet a target number of respondents.



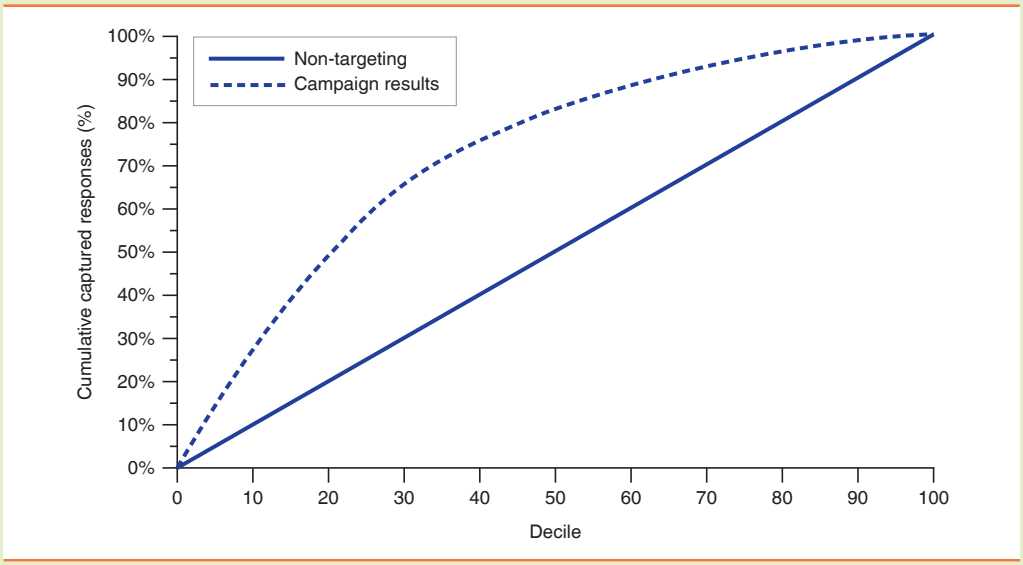


Figure 1.3 Cumulative capture by decile within mailing population

The development and successful implementation of the predictive model had two main benefits. The first was a cheaper and more effective campaign; the second was a reduction in mailing volume. Overall, the reduction in costs and number of customers mailed was good news from both a financial and a customer relationship perspective.

Table 1.1 Efficiency of the model

Cumulative decile	% of responding customers	% of non-responding customers	Cost per response as % of overall cost per response	Model efficiency
1	27.8	9.4	36	278
2	49.2	19.0	41	246
3	65.7	28.8	46	219
4	75.5	38.8	55	189
5	82.1	48.9	61	164
6	88.2	59.1	68	147
7	93.4	69.2	75	133
8	95.6	79.5	84	120
9	98.3	89.7	92	109
10	100.0	100.0	100	100

Source: Mohamed, O. (2004) You've got direct mail, *Significance*, 1 (2), pp 78–80.

Use of computers

Readers will probably be aware already that computers and information technology in general have had a fundamental effect on most business organisations. The same applies to the quantitative analytical techniques that we shall be introducing in the text. It used to be the case that 'solving' quantitative problems – in the sense of completing the mathematics and statistics required – restricted the use of such techniques to large-scale problems, which were analysed by the quantitative analysis specialist. Over the past few decades, however, advances in technology – such as smart devices – have revolutionised both the areas to which techniques are applied and the type of person using such techniques. Software such as spreadsheets or the more common statistical and mathematical packages as well as simulation models now make such analysis readily available to any business decision maker. In the authors' view, this has been one of the major factors behind the explosion of interest in such techniques (mirrored of course by virtually all business undergraduate and postgraduate students being forced to undertake at least one course in such techniques). Naturally the use of such software presupposes that you are able to interpret the computer output that can be generated, not only in a strictly quantitative way but also in terms of assessing its potential to help business decision making. Many of the end-of-chapter exercises, however, are eminently suited for further analysis using either a spreadsheet package or some statistical software, and we would encourage both students and tutors to take advantage of this wherever possible.

Using the text

As we've said, the text is aimed primarily at those students who have a clear interest in management and business decision making but who also appreciate the potential that quantitative analysis brings to the management process (or at worst find themselves required to complete a course in this area). Deliberately we have kept the focus throughout the text on developing a conceptual, rather than a mathematical, understanding of the principles of each topic and on the potential application of the techniques to typical business problems.

At the same time we need to stress that one of the worst ways in which such techniques can be seen by a manager is in terms of the 'toolbox' approach, where the focus is often on finding a technique to fit the problem rather than on focusing on an appropriate method and methodology to help resolve the problem under investigation. It is all too tempting to look at a business problem briefly and assume that it is one of stock control, forecasting or whatever. Once designated as, for example, a stock-control problem, it is tempting then to ignore other quantitative – and qualitative – ways of examining the problem. This can result in the technique being forced to fit the problem and generating information and results that are at best incomplete and immediate and at worst downright misleading to the manager. Business problems rarely, if ever, fit into nice neat compartments labelled 'stock control' and the like. What may on the surface appear to be a problem in the stock department may well turn out to be a problem in production or sales or related to quality management.

Each chapter in the text follows a similar general format. First, we provide an introduction to the focus of that chapter. Then we introduce the relevant topics and place them

in a typical business context. An example problem is then introduced and thoroughly investigated and discussed in terms of both determining a solution to the problem and the wider business applications of the technique. Within each chapter you will also find a number of Progress Check activities. These are tasks for you to complete at that point in your reading of that chapter. Although you may be tempted to 'skip over' an activity we would strongly encourage you not to do so. The activities are an integral part of the learning process and will typically lead you into the next part of that chapter. Solutions to these activities appear either in the next part of the chapter or in Appendix F. Most chapters conclude with a fully worked example showing how to approach a particular problem or question using the techniques introduced thus far. Finally, we present details of actual business applications, illustrating how the techniques introduced in that chapter are used in the real world to help business decision making. We have tried to provide you with the most recent case studies. However we value the relevance and educational richness of a case study more than its publication date. Where a case study appears old by its date of publication but is still highly relevant we have not hesitated in using it.

Summary

It will by now be evident that the topics and techniques that we introduce in this text are not merely of academic interest. They are all techniques that are actively – and profitably – used by a variety of business organisations and, perhaps more importantly, they are being used by the managers of these organisations as well as the 'experts'. Developing your own awareness and understanding of these techniques as well as skills in their use will be a worthwhile investment, not only as part of your current studies but also in terms of your management career.

QADM IN ACTION

British Telecom

British Telecom (BT) is one of the largest UK-based organisations in terms of both employees (over 200 000 at the time this application was undertaken) and financial size (a market capitalisation of over £30 billion in mid-2001). It is also an organisation that was one of the first to be converted from a state organisation controlled by the UK government to a private sector company. Along with other privatised organisations this has led to a fundamental change in attitudes and approaches to customers where customer care, responsiveness to customer requirements and high-quality customer service are seen as critical items on the organisation's strategic agenda.

At the time this application was being conducted, BT was looking at ways of improving the initial interface with customers, the so-called Front Office. This was seen as a single point of contact for the customer, so any customer telephoning the company to make enquiries, to seek assistance or just to obtain service information would be dealt with by the Front Office. The intention was that the customer experience of being transferred from one person in the organisation to another (something that most of us will have experienced at some time with some organisation) could be minimised and, potentially, removed. A specialist team within the company was

given the task of looking at ways of delivering this service.

The first step – as is often the case – involved basic data collection and building up a picture of the situation under investigation. In this context, the team first needed to assess the typical pattern of calls received during the day and during the week, shown in Figures 1.4 and 1.5, in order to assess likely demand on the Front Office.

Using simple presentation techniques, it can readily be seen that there are classic resource implications to the patterns exhibited. From Figure 1.4 we note that the maximum number of calls is around 300 in any one 30-minute period – an indication of current maximum demand on the Front Office. Similarly, we see from Figure 1.5 that Monday is the peak day with around 5000 calls having to be dealt with in total. It is evident, though, that the number of calls not only

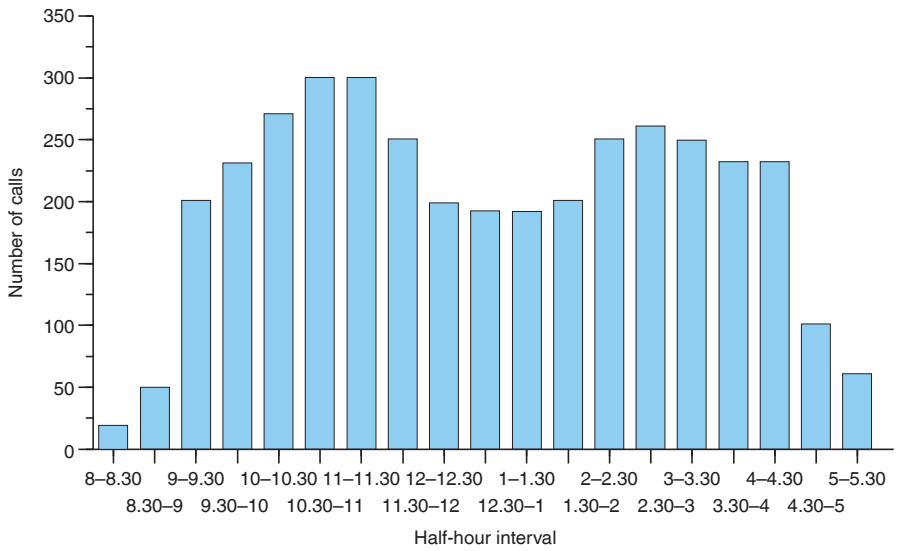


Figure 1.4 Calls by the half-hour throughout the day

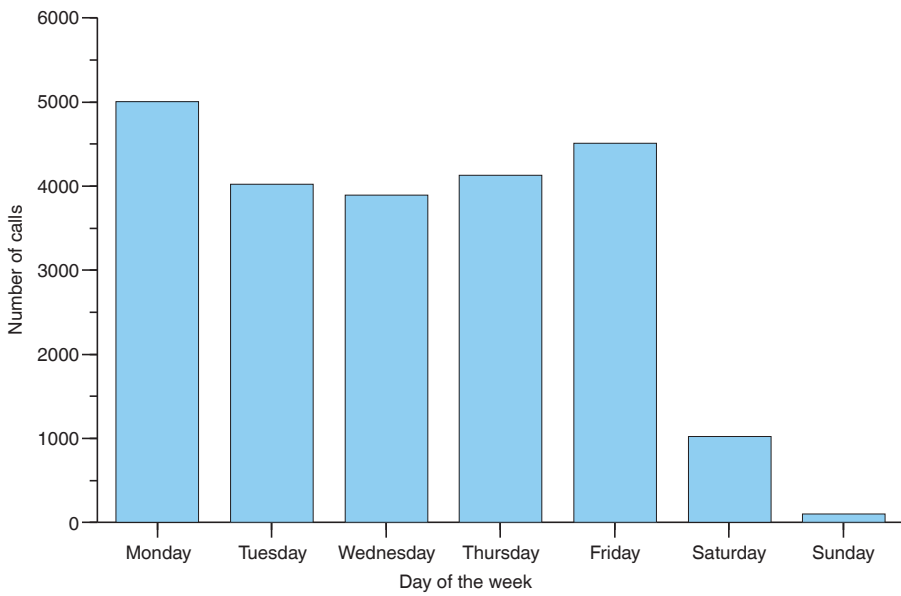


Figure 1.5 Number of calls by day of the week

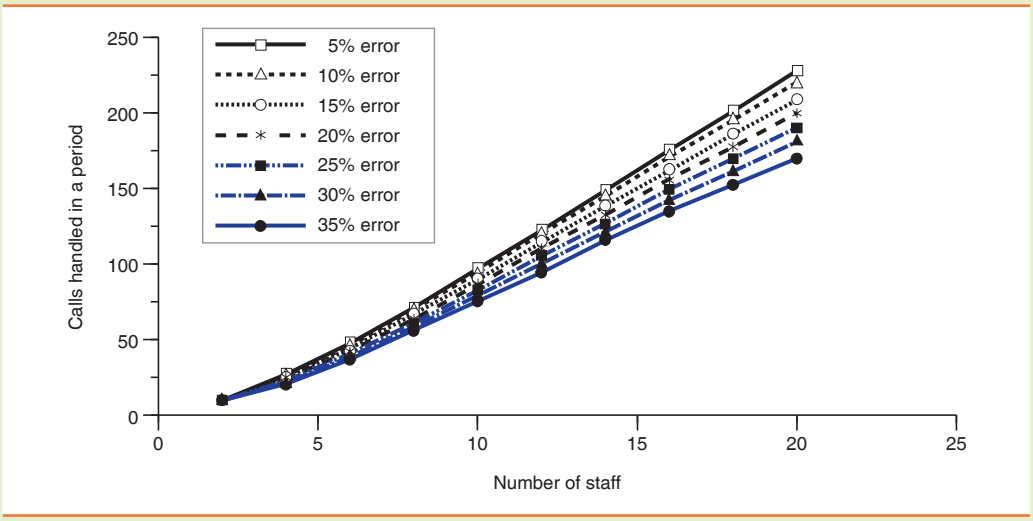


Figure 1.6 Maximum number of calls handled reduces as the forecast error increases

fluctuates during each day, it varies considerably across days of the week. The obvious implication of this fluctuation is in terms of staffing – having people available to respond to the calls. The manager's dilemma is evident. On the one hand the company is keen to have prompt responses to customer calls so that customers will not be kept waiting for the phone call to be answered. From Figure 1.4 this implies a maximum capacity of about 300 calls in a 30-minute period and having enough staff available to deal with this capacity. On the other hand, the company will also want to minimise staff costs associated with this part of its activities, and it is evident that for most of the time this capacity will not be needed, as the number of calls will be less than 300. If the manager provides dedicated staff to deal with the maximum capacity, they will not all be needed at other times of the day and will represent an unnecessary cost, unless the situation can somehow be managed in terms of rotas and shift patterns or ensuring these staff are multi-skilled so that they can undertake other productive work during a quiet period. As if this were not enough of a problem, such call patterns are not likely to remain static: they will change over time as the size of the business changes. As BT's customer base grows the demand on the Front Office is also likely to increase.

Accordingly, the team used a number of forecasting techniques to try to predict future call levels and also carried out some 'what if' analysis around these forecasts, recognising that any particular forecast cannot be 100 per cent guaranteed. In conjunction with this work, the team developed a computer simulation model to simulate staff workloads in a typical Front Office and to assess the impact on staffing levels and performance of different call levels occurring. The call level forecasts, the what-if analysis and the staffing simulation could then be put together to help assess the staff required to deal with particular call levels, as shown in Figure 1.6. The team made great efforts to ensure the results of their analysis would be available in a readily accessible form to the managers taking the actual decisions. Managers in any organisation are, understandably, reluctant to act on information that they do not properly understand, and the team developed a user-friendly computer program based around this analysis to help managers take decisions about staffing the Front Offices for which they were responsible. As the team concluded, '[this] offers managers, for the first time, the ability to understand the full implications and potential consequences of staffing decisions'.

Source: Based on Richardson, C. (1991) Staffing the front office, *Operational Research Insight*, 4 (2), pp. 19–22.

2 Tools of the Trade

Learning objectives

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

- work with fractions, percentages and proportions
- explain the principles of rounding and significant figures
- use common mathematical notation
- use mathematical symbols and equations
- construct and use graphs
- explain what is meant by the term 'real' value

As we said in Chapter 1, the main focus throughout the text is on the practical uses of quantitative analysis in business and management decision making. However, before we can start introducing the more common techniques used by managers, we have to make sure that we have the basic quantitative knowledge and skills we will need. So, in this chapter, we shall be covering the concepts and skills forming the 'tools of the trade' that we will be using throughout the text. Many of you will remember from school some, if not all, of the material we are covering in this chapter. However, don't just skip over it because it looks familiar. Try one of the associated Reality Check activities just to make sure you do know how to do what that section is covering. Also, if later on in the text some of the calculations we're doing are causing you difficulty, come back to this chapter and re-read the relevant section.

Some basic terminology

Like any other academic subject, quantitative analysis has its own jargon. The following sections introduce some of the basic terminology that we shall be using.

Variables

The term *variable* refers to a characteristic we are investigating or analysing. So, for example, the variable in question might relate to company profits, number of employees, salaries, length of service, customer attitudes and so on. In general, a variable may fall into one of three types.

Discrete

A discrete variable is one which can only take certain fixed numerical values. The number of cars sold globally by Toyota in 2020 can only be a whole number. The amount of money in my savings account will be a certain number of pounds and pence. Typically the value of a discrete variable is determined by counting.

Continuous

A continuous variable is one which – in principle at least – can take any numerical value and typically comes from measuring rather than counting. The length of a piece of sheet steel used in the vehicle manufacturing process can be measured to any required degree of accuracy – centimetres, millimetres, hundredths of a millimetre and so on.

Attribute or categorical

An attribute variable is one which is not normally expressed in numerical terms. The gender of the person buying a Toyota car will fall into one of two categories – male or female. For purposes of analysis, however, we may assign an arbitrary numerical value to such a variable. Many of you will have seen and completed personal questionnaires where you are asked to indicate your gender. You may recollect that there is often a numerical value printed alongside the possible responses – for example, Male $= 1$ Female $= 2$ – which will allow the computer system being used to quantify the number of responses in each category.

Progress Check 2.1

Consider the following and determine what type of variable each best represents:

(a) the number of private houses built last year
(b) the average price of a house
(c) the number of people employed in the construction industry
(d) the number of tonnes of concrete used in house construction
(e) the different types of houses constructed.

Solution is given on p 569.

Primary and secondary data

It is always important in business to assess the source of the data which is being analysed and upon which decisions might be based. We distinguish between *primary* data and *secondary* data. Primary data is data which has been collected at first hand for the purposes of some specific analysis. Secondary data, on the other hand, relates to data which has been collected for some purpose other than the analysis currently being

undertaken. It's second-hand data. Consider the Finance Department of a local authority with the responsibility for collecting a local tax from residents in its area. It may well construct a database of those residents who have not paid the tax this year. Clearly for the department this will be primary data: collected by the department for its own use. This database, however, may then be used by the Economic Development Unit in the local authority, which is investigating income and poverty levels in the area and evaluating strategic options to try to alleviate these. Although the database may well be useful for their purposes, it is now a secondary source of data. In principle we would need to be more cautious about analysing and using such information from secondary data. Since we would not have been involved in the initial data collection, we may be uncertain about the precise logistics used to obtain this data. Its quality, therefore, on a secondary basis, must be suspect – guilty until proven innocent. It's worth noting that much of the business data you're likely to encounter in your day job will be secondary and it's worth getting into the habit of asking a few questions about such secondary data – and any analysis based on it – before reaching any conclusions and certainly before making any decisions. This is ever more important when more and more data is available on the internet. Consider the following questions when evaluating any secondary data.

Who collected it?

Your assessment of the reliability of data can be affected by knowing who collected it – their background, qualifications, credibility etc. Data from a government agency is likely to be more reliable than data found on a personal website for example and may be more reliable than that published by a company's marketing department.

What was the purpose in collecting the data?

Why was this data collected – what was the intended purpose? There may be a biased reason for posting the data. Commercial businesses, political groups, lobby groups, marketing departments post data that might represent their own interests but may not be 100 per cent accurate or reliable. Knowing the purpose of data collection will help you evaluate the quality of the data and assess the potential level of bias (or spin!).

When was the data collected?

Timeliness is one of the most important aspects of accuracy, reliability and usefulness. If you're researching the hottest food trends for your start-up restaurant, then analysis from a few years ago probably won't help – and may even lead you to make inappropriate decisions.

How was the data collected?

Is it clear how the data was collected and how reliable and representative it is? This won't always be directly available but you should be able to find out if the data is from a reputable source. Asking a cross-section of the general population whether they use Facebook or Twitter may not be the best approach given that some age/demographics groups (e.g. older people) are more/less likely to be users. Does the data relate to what you're interested in?

Is the data consistent with data from other sources?

Do the numbers make sense? Is this data consistent with that from other sources or is it markedly different? If you happen to see data and 'facts' varying from source to source, you need to do some research as to which are most reliable.

It's also important to realise that primary data can take considerable time to collect accurately, it requires expertise and it can be very costly to collect. Secondary data on the other hand is available immediately and is effectively 'free'. Bear in mind that secondary data will never be perfect for your own requirements. The key question though is: is it reliable and helpful enough for me to use?

Fractions, proportions, percentages

Reality Check 2.1

Take a look at the following question to see if you're familiar with fractions, proportions and percentages. If you are, you don't have to read this section – although you might still find it interesting.

Which is bigger: 1/6, 30%, 0.35?

The 30 per cent struggle

In their book, Michael Blastland and Andrew Dilnot comment on a survey which found that 30 per cent of people struggle to understand what '30%' actually means!

Source: Blastland, M. and Dilnot, D. (2007) *The Tiger That Isn't: Seeing through a World of Numbers*. London: Profile Books.

Fractions, proportions and percentages are all around us. Sale items at half-price, a 20 per cent reduction on original prices, a discount of 0.05 if you buy at least £100 of goods, an internal e-mail saying that your department is facing budget cuts (sorry, 'efficiency savings') of 10 per cent next year. We assume that everyone understands what these mean and the implications. Perhaps surprisingly, there are levels of numerical ignorance around that people/managers are, understandably, reluctant to admit to. After all, it's almost like admitting you can't read and write.

Fractions are simply a way of expressing amounts which are, literally, less than one (in whatever units of measurement we are using). Consider monetary measurement.
The pound sterling (£) is made up of 100 pence. If we insist on our units of measurement being pounds, however, then any amount less than this will need to be shown as part of a pound – a fraction. So, for example, 50p is less than one unit (£1) and since we are insisting on units of measurement being in pounds, it cannot be shown as 50p. Instead, it can be shown as a fraction: £$\frac{1}{2}$. Similarly, 25p would be £$\frac{1}{4}$ as a fraction of a pound. Any number can be shown as a fraction simply by taking that number and dividing by the number that makes up one unit. So for 50p we would have:

$$\frac{50}{100}$$

since 50 is the number we require the fraction for and there are 100p making up one unit (£1). Clearly this does not look like $\frac{1}{2}$. The reason is that 50/100 can be simplified through some basic arithmetic. We note that both numbers are in terms of 10s (five tens and ten tens respectively), so it can be rewritten:

$$\frac{5}{10}$$

These numbers are in turn seen to be in units of 5 (one on top, two on the bottom) so we have $\frac{1}{2}$ as the final fraction. It is important to realise that it really does not matter which of these fractions you use $\left(\frac{50}{100}, \frac{5}{10}, \frac{1}{2}\right)$ since they are the same. Which you use is up to you in terms of whichever you find easiest.

The fraction we have, $\frac{1}{2}$, can also be expressed as a decimal proportion: 0.50. To add to the confusion, if we multiply a proportion by 100 we have a percentage:

$$0.50 \times 100 = 50\%$$

(that is, 50p is 50 per cent of £1). Although it does not matter whether we use fractions, proportions or percentages in terms of the calculations, it may well affect how we view the information that is generated. Perceptions differ, but consider what reactions you might get from employees if you told them that they would receive a salary increase next year of either 1/10, 0.10 or 10 per cent. Do you think that everyone would immediately view these as being identical in terms of the impact on their salary?

We must also be careful when using percentages in terms of how we comment on or explain the results, as not everyone understands them. Consider the following example. We are told that inflation in the UK last year was 5 per cent (that is prices went up on average by 5 per cent). This year inflation is 6 per cent. A typical comment in the press might then be: 'the rate of inflation has increased by 1 per cent'. In fact it has not. To be technical, the rate of inflation has increased by 1 percentage *point* (since our initial unit of measurement is in percentage terms) and by 20 per cent (1/5). It is also easy to become confused over percentage increases and decreases. Consider the following. A manufacturer sells a product for £10 inclusive of a government tax. Because of cost pressures the company increases the price by 15 per cent. Some time later the government reduces the tax on this product, bringing the price down by 15 per cent. It is tempting to conclude that the price will once again be £10 but some simple arithmetic illustrates the error in this conclusion.

Original price: £10 Price increase: $15\% = 15\%(£10) = £1.50$

New price: £11.50

Tax decrease: $15\% = 15\%(£11.50) = £1.72$

New price: £9.78

We see that after these changes the new price is actually lower than the original.

Progress Check 2.2

Calculate the following percentages and fractions of 12 098 and 139.5:
25%, 33%, 90%, 5%, 1/3, 1/8, 3/8

Solutions are given on p 569.

Rounding and significant figures

Reality Check 2.2

Take a look at the following calculation to see if you're familiar with rounding and significant figures. If you are, you don't have to read this section.

Round 6.3467 to three significant figures.

It is often useful to abbreviate – or round – numbers to make them easier to understand and use. For example, if we are out shopping and we see some item on sale for £9.99 most of us would view this as £10 – mentally we round the original figure to the nearest whole number. Similarly, being told as a manager that you have a budget for a particular project of £124 784 doesn't really help you remember what your budget allocation is. If we rounded this to £125 000, however, it becomes much easier to remember (although technically less accurate).

The principle of rounding numbers is based largely on common sense. First, we determine how many *significant figures* we require. The term significant figures relates to the number of digits in the number that are precise and accurate. So, our exact budget figure of £124 784 contains six significant digits (all six numbers are accurate).

The rounded number of £125 000 contains only three significant figures (the last three zeroes are not accurate). Having decided we want the number to be rounded to three significant figures, we then take the last four digits of the original number and round to the nearest whole number: thus 4784 becomes 5000. (The reason for taking the last four digits is that we start with six significant figures, we require only three, so that the last (3 + 1) digits need to be rounded.) The only slight note of caution comes when rounding the number five. For example if we had had 6500, should we round this to 7000 or to 6000? The answer is that it depends on which convention you use. Our preference is to round fives to the nearest *even* number – in this case to 6000, although we should note that it is just as acceptable to round upwards to the nearest whole number.

Progress Check 2.3

A company reports a profit figure for last year of £1 078 245.67. Show this figure with:

(a) 8 significant digits
(b) 6 significant digits
(c) 4 significant digits
(d) 2 significant digits.

Solutions are given on p 570.

What does matter, though, is the degree of accuracy you imply in any calculations you produce using rounded numbers. Consider the following two numbers: 3.4 and 6.23. We know that each number has been rounded to two and three significant digits respectively. If we multiply these two numbers we have:

$$3.4 \times 6.23 = 21.182$$

which appears to imply five significant digits (and a relatively high level of accuracy). However, the result of this arithmetic cannot be accurate to more than two significant digits (the lower of the two original numbers), hence we should report the result as 21. To see why, consider the two original numbers: 3.4 could originally be anywhere between 3.35 and 3.45, and 6.23 anywhere between 6.2251 and 6.2349. The smallest possible value from this multiplication would then be 20.854085(3.35 × 6.2251) and the largest 21.510405 (3.45 × 6.2349). Hence only the first two digits should be seen as significant.

Let us illustrate with another example. Consider the company with an annual profit of £1 078 245.67. This may well have been reported in the local press as a profit of £1.1 million. The company has an agreement with the workforce that 10 per cent of the profit will be distributed equally among the firm's 100 employees. The arithmetic appears to be:

$$\frac{£1.1 \text{ million} \times 10\%}{100} = £1100$$

which is what each member of the workforce may well expect to see in their next pay packet. The actual amount, however, will be £1078.25. A simple misunderstanding may well lead to industrial relations tension. The message is clearly to round numbers *after* completing the arithmetic and not before and to ensure that results which have been rounded are acknowledged as such.

ING cuts 5,000 jobs in branch cull

Belgian and Dutch networks hit low interest rates, regulation and online rivals cited

By Jim Brunsden in Brussels

Dutch bank ING yesterday announced a significant scaling back of its branch network in Belgium and the Netherlands, with the loss of more than 5,000 jobs, and gave a stark warning of the challenges facing the industry.

The lender said that the equivalent of 3,150 full-time jobs would be lost in Belgium by 2021, close to a third of the total in the country. In the Netherlands, 2,300 jobs are to be shed, equivalent to about 15 per cent of full-time staff.

FT

Source: Brunsden, J. (2016) ING cuts 5,000 jobs in branch cull: Belgian and Dutch networks hit low interest rates, regulation and online rivals cited, *Financial Times* (UK), 4 October, Section: Companies & Markets, p 15.

Rounding numbers can change the impact

The headline shows 5000 job losses although the actual number in the article is 5450. Which is easier to remember? Which has most impact?

Common notation

One aspect of quantitative analysis that many students encounter in the early stages of their studies relates to the use of mathematical 'shorthand' – the use of mathematical notation in analysing and presenting results. Tell people that the average salary of a group of employees is £23 500 and there is no problem. Tell them that the arithmetic

mean for a random sample taken from the statistical population is 23 500 and the eyes glaze over and the mental shutters start to come down. Clearly this is a barrier we must break if we are to progress through the text, since we require this shorthand frequently.

Symbols

The first thing to get accustomed to is the use of symbols rather than descriptive text. We might use the symbol S to represent the salary of an individual, for example. This makes it much more convenient when we need to indicate that $S = 12\,000$ rather than having to spell out that 'the salary of an individual is £12 000'. Similarly we might use D to denote taxes and other salary deductions, with T representing take-home pay for the individual. A simple equation then becomes:

$$T = S - D$$

That is, take-home pay is salary minus deductions, which is much easier to note and use than its verbal equivalent.

Arithmetic operators and symbols

You will already be familiar with the more common mathematical operators: $+, -, \times, \div$. Some of the other operators and symbols that we shall be using include:

- $<$ less than
  <10 implies all numbers taking a value less than 10.
- $>$ greater than
- $\leq$ less than or equal to
  So, for example, ≤ 10 means any number up to and including 10 but excludes all numbers greater than 10.
- $\geq$ greater than or equal to
  ≥ 10 implies all numbers of 10 or more.
- $\neq$ not equal to
  So $\neq 10$ implies all values which are different from 10.

Reality Check 2.3

Take a look at the following question to see if you're familiar with arithmetic operators. If you are, you don't have to read this section.

What's $(58 - 3) \times 10 + (42 + 6) / 20$?

The sequence of calculation when there are several operators in an expression is also important. For example, consider:

$$10 + 3 \times 6 - 3 \times 2$$

Arithmetic operators have an established order of priority and this order must be followed to obtain the correct numerical result. The logic is generally straightforward. We use the convention in terms of using different operators that we evaluate in the priority of: $\times$, $\div$, $+$, $-$. That is, we perform:

- any multiplications
- then any divisions
- then any additions
- then any subtractions.

Multiplying (3×6) first, and then (3×2) we have:

$$10 + 18 - 6$$

And then we complete the arithmetic as:

$$28 - 6 = 22$$

We will frequently encounter expressions which also involve brackets. Consider the expression:

$$(10 + 3) \times 6 - (3 \times 2)$$

The approach is as before in terms of priority but we must first evaluate all expressions *inside* brackets. This gives:

$$(13) \times 6 - (6) = 78 - 6 = 72$$

It is also worth noting that computer logic acts in exactly the same way when it comes to undertaking some assigned calculation. Spreadsheets, for example, will tend to calculate the expression in the same way and same order as we do.

Note also that we may frequently omit the multiplication symbol, $\times$, in complex expressions. We might have, for example:

$$10 \times (6 - 4)$$

although this would normally be shown as:

$$10\,(6 - 4)$$

Progress Check 2.4

Work out the following expressions:

(a) $100.2(34 - 7)\,/13$
(b) $0.5 - 0.8 \times 13 + 3$
(c) $(100 \times 2) - (5/2) \times 10$

Solutions are given on p 570.

Powers and roots

Reality Check 2.4

Try the following to check that you're OK working with powers.

What's 42^3?

What's $\sqrt[3]{74088}$?

Frequently we may be involved in arithmetic that requires one number to be multiplied by itself some number of times. For example, we may want:

$$3 \times 3 \times 3 \times 3 \times 3$$

The shorthand way of writing this is as 3^5 (read as three to the power of five). The superscript number (5) is known as the *exponent* and simply shows that we take the actual number (3) and multiply it by itself five times. So, we would have:

$$3^5 = 3 \times 3 \times 3 \times 3 \times 3 = 243$$

As with most mathematics there is an opposite to taking the power of a number. This is known as taking the *root* of a number. For example, we might have:

$$10^2 = 100$$

and then require what is known as the root of 100, which we would denote as:

$$\sqrt{100}$$

where $\sqrt{\ }$ is the root symbol. A root implies that we require a number such that when we square the number (raise to the power 2) then we will obtain 100. Clearly in this case we have:

$$\sqrt{100} = 10 \text{ since } 10^2 = 100$$

This example is known as the square root of 100. Other roots – the third, fourth, etc. – are possible. So we might have:

$$\sqrt[5]{243} = 3$$

since as we saw earlier, $3^5 = 243$. (We'll see how to work out the answer of 3 shortly.) To make matters worse, however, it is possible to denote roots as fractional powers. Thus:

$$\sqrt{100} \text{ can be written as } 100^{1/2} \quad \text{or} \quad 100^{0.5}$$

and

$$\sqrt[5]{243} \text{ as } 243^{1/5} \quad \text{or} \quad 243^{0.2}$$

It is worth remembering that whenever you see a number raised to a fractional power it is simply another way of writing a root expression. We should also note two special cases. Any number raised to the power 1 simply equals that number:

$$10^1 = 10$$

and any number raised to the power zero equals 1:

$$123^0 = 1$$

(Don't ask why! Just remember it!) And if you think only statisticians are interested in square roots have a look at the next FT case study!

Multiple answers to Europe's maths problem

By Wolfgang Munchau

What is a fair voting system for the European Union? It looks as though, thanks to Poland, European leaders will be forced to debate this difficult question at their summit this week.

Since the simplified draft treaty is substantively identical to the old and rejected constitution – minus some cosmetics – the voting system proposed is going to be the same one: passage of legislation requires a coalition of countries representing at least 55 per cent of the member states and 65 per cent of the population. The Poles have threatened a veto unless the second of those two numbers is based on the square root of the population size – to reduce Germany's influence. It sounds arbitrary, but the Poles have a point. Mathematics is on the side of Poland.

To an uninitiated observer, this does not appear immediately obvious. Does it not seem fair that the voting power of a country in an international organisation should be proportional to its population size? The answer is no. In fact, it is totally unfair. The reason is that effective voting power in multi-nation settings such as the EU depends not on voting size but on the ability to form winning coalitions. Large countries are better placed than their relative population size would suggest.

The original, six-member Community is a good example of this counter-intuitive idea. Germany, France and Italy each had four votes in the council of ministers, the Netherlands and Belgium had two and Luxembourg one vote. Germany then had more than 100 times the population of Luxembourg, yet only four times the number of votes.

Intuition might suggest that tiny Luxembourg was surely over-represented. In truth, the opposite was the case. The threshold for a majority was set at 12 votes. Since every member except Luxembourg had an even number of votes, Luxembourg was never in a position to cast a make-or-break vote. Despite being numerically over-represented, Luxembourg in effect had zero voting power. That would have been different if, for example, an odd number had been chosen as the threshold.

So how do you measure effective voting power? Lionel Penrose, the British mathematician and psychiatrist who developed a theory of voting power in the 1940s, concluded that votes in international organisations should be based on the square root of the population. This is where the Poles got their idea. . . .

Is Poland's square root solution the only alternative? Of course not. EU leaders could, for example, raise the threshold for population size and number of countries from their 55 and 65 per cent respectively or introduce some complicated new formula – perhaps with a square root in it. There is a quite a bit a leeway left without creating Nice-style gridlock. Professors Baldwin and Widgrén propose another simple and effective solution: drop the voting rules of the constitution and just repair the Nice rules by reducing some of the high thresholds.

The Poles have put their finger on an important issue, though their own answer is not as compelling as they think. If and when EU leaders set out to amend the rules, they should heed the lessons of the past. Any new system needs to fulfil two parallel goals: it needs to make the voting system more effective and it needs to be fair. The Nice system is fair and ineffective. The constitution is effective but unfair.

If they get this wrong again, they will be back at the negotiating table not too long from now. But if they get it right, they will have managed to create the one and only substantive change from the original treaty.

Source: Munchau, W. (2007) Multiple answers to Europe's maths problem, *Financial Times*, 18 June.

Politics and a square root! You may want to find out if the idea was adopted.

Logarithms

Reality Check 2.5

Try the following to check you're OK working with logarithms.

What's the log of 18.75?

What's the antilog of 0.2568?

It may have occurred to you that using power and roots notation is all very well but how do we actually work out the answer? Consider:

$$\sqrt[4]{365.3}$$

How do we actually determine what the fourth root of 365.3 is? To obtain such a result we must turn to the use of logarithms. You will find it useful to have a calculator with logarithmic facilities available for this next section. We have already seen that the exponent of a number indicates the power to which it is to be raised. Let us consider the number 10. We then might write:

$$10^2 = 100$$
$$10^3 = 1000$$
$$10^4 = 10\,000$$

and so on with the exponents being 2, 3 and 4 respectively. We can describe the logarithm of a number as the exponent of 10 which equates to that number. That is, we say that the logarithm of 100 is 2 (since $10^2 = 100$), the logarithm of 1000 is 3, of 10 000 is 4 and so on. In fact any number (not just those involving 10) can be expressed in logarithmic form. For example, from a pocket calculator:

$$\log(13) = 1.11394 \text{ since } 10^{1.11394} = 13$$
$$\log(540) = 2.73239 \text{ since } 10^{2.73239} = 540 \text{ and so on.}$$

Calculators vary but there should be a key marked 'log'. Press the log key, key in 13 and then press the = key and you should get the same answer as us −1.11394. Effectively with logarithms what we are doing is converting all numbers to a common base of 10 (with the exponent allowing us to use 10 raised to some power to denote any other number). But how do we use such logarithms? Suppose you were asked to calculate:

$$3^2 \times 3^4$$

With a little thought you might realise that this would be 3^6 (since it is actually $3 \times 3 \times 3 \times 3 \times 3 \times 3$). That is, if we require to multiply two numbers together that have a common base (3 in our example) we can simply *add* their exponent parts together to get the result. With logarithms that is exactly what we do, given that logarithms use the base 10. So, for example, if we wanted:

$$13 \times 540$$