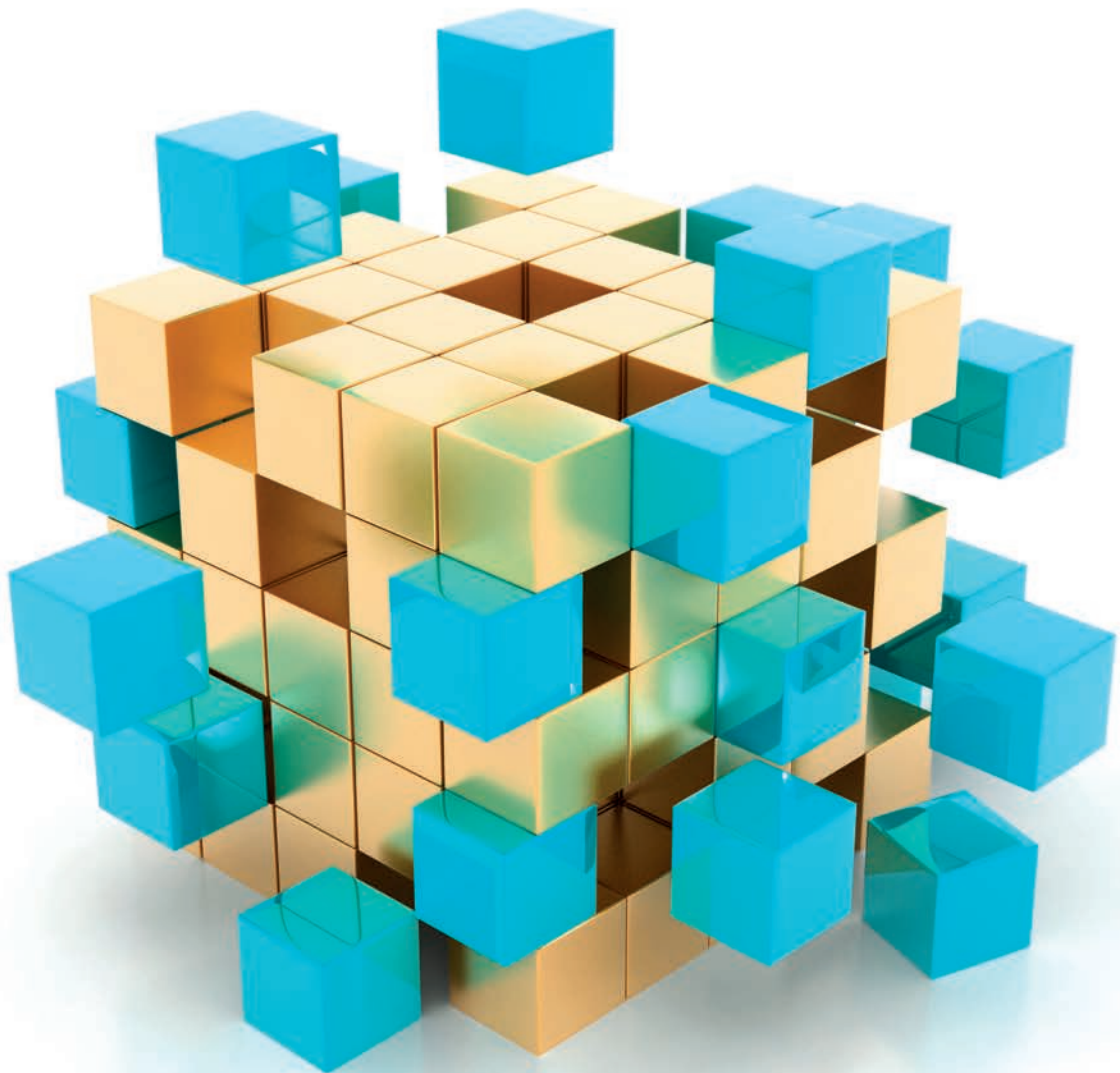


Quantitative Analysis for Decision Makers

Seventh edition

Mik Wisniewski & Farhad Shafti



Seventh Edition

QUANTITATIVE ANALYSIS

for Decision Makers

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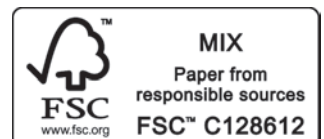
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Lecturer Resources

For password-protected online resources tailored to support the use of this textbook in teaching, including:

- a downloadable Instructor's Manual, with full teaching notes and solutions to the exercises in the book
- data sets in Excel to accompany the exercises in the book
- a list of Useful Online Resources

please visit www.pearsoned.co.uk/wisniewski

ON THE
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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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(2019) Cleaning up steel is key to tackling climate change, 1 January © The Financial Times Limited. All Rights Reserved **70 The Financial Times Ltd:** Smith, A., Fildes, N., Blood, D., Harlow, M., Nevitt, C. and Rininsland, A. (2018) Broadband speed map reveals Britain's new digital divide, © The Financial Times Limited. All Rights Reserved **76 Richard Donkin:** Donkin, R. (2008) The man who helped Japan's quality revolution, FT.com, 6 March. © Richard Donkin, www.richarddonkin.com. **78 Crown copyright:** UK Department for Transport **80 Crown copyright:** Works Department **88 Crown copyright:** Office for National Statistics **95T Crown copyright:** General Registrars Office. **95M The King's Fund:** King's Fund **95B Crown copyright:** Department for International Development. **96 International Organization of Motor Vehicle Manufacturers:** OICA www.oica.net. **96 Crown copyright:** Office for National Statistics **97 Eurostat:** Eurostat Data file 3X-6 **98 Crown copyright:** HMRC **100 Crown copyright:** Office for National Statistics **103 The Financial Times Ltd:** Strauss, D. (2019) House of Lords takes aim at Statistics Authority's failure to fix UK prices index, 17 January © The Financial Times Limited. All Rights Reserved **107 The Financial Times Ltd:** Jackson, G. (2014) Doctor's orders, 30 July © The Financial Times Limited. All Rights Reserved **107 Crown copyright:** Hospital Episode Statistics (HES), Health and Social Care Information Centre. **112 The Financial Times Ltd:** Garcia, C. (2011) Strange day for goldbugs, 23 September © The Financial Times Limited. All Rights Reserved **117 The Financial Times Ltd:** Thompson B., Billy ES, Weisniewska A (2018) Warning to companies that missed gender pay deadline, 5 April © The Financial Times Limited. All Rights Reserved **120 The Financial Times Ltd:** Pickard, J. (2006) Index tracking: Information – a double-edged sword, 10 July © The Financial Times Limited. All Rights Reserved **127 The Financial Times Ltd:** The Financial Times Limited **128 Crown copyright:** Office for National Statistics **129 Crown copyright:** Office for National Statistics **130 The Financial Times Ltd:** Strauss, Delphine (2019) House of Lords takes aim at Statistics Authority's failure to fix UK prices index, 17 January © The Financial Times Limited. All Rights Reserved **132 The Financial Times Ltd:** Giles, C. (2014) A shopping trip with the inflation experts from the ONS, 13 March © The Financial Times Limited. All Rights Reserved **135 Crown copyright:** Office for National Statistics **137 Crown copyright:** Office for National Statistics **138 Crown copyright:** Office for National Statistics, DWP **139 Crown copyright:** Office for National Statistics, DWP **145 The Financial Times Ltd:** Kay, J. (2005) Most of us are highly likely to get probability wrong, 16 August © The Financial Times Limited. All Rights Reserved **149 Royal Statistical Society:** Haigh, J. (2006) Reflections on the UK National Lottery, *Significance*, vol 3 (1), pp 28–9. Copyright © 2006 Royal Statistical Society **152 John Wiley and Sons:** <https://rss.onlinelibrary.wiley.com/doi/epdf/10.1111/j.1740-9713.2004.021.x> Goodman, J. and Heckerman, D. (2004) Fighting spam with statistics, *Significance*, vol 1 (2), pp 69–72. Copyright © 2004 John Wiley and Sons. **158 The Financial Times Ltd:** Cook, C. (2013) Georgian life, FT.com, 24 July © The Financial Times Limited. All Rights Reserved. **175 The Financial Times Ltd:** Jones, C. (2012) Tails of the unexpected, 8 June © The Financial Times Limited. All Rights Reserved. **183 The Financial Times Ltd:** Jacobs, E (2013) What could possibly go wrong? Financial Times, 27 June © The Financial Times Limited. All Rights Reserved **188 The Financial Times Ltd:** Kay, J. (2009) Is insurance worth paying for? Probably, 3 July © The Financial Times Limited. All Rights Reserved **191 Capgemini:** Based on a Capgemini case study, with thanks to Capgemini for permission to use their material. **191 The Financial Times Ltd:** Cookson, C. (2014) Risk savvy: How to make good decisions, 23 May, © The Financial Times Limited. All Rights Reserved **194 The Financial Times Ltd:** Patricia Nilsson (2019) UK police test if computer can predict criminal behaviour, 6 February © The Financial Times Limited. All Rights Reserved **199**

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: catering 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.



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

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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 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.”



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



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



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

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.