JAMES R. EVANS

BUSINESS ANALYTICS

Methods, Models, and Decisions

Business Analytics

This page intentionally left blank

Business Analytics

Methods, Models, and Decisions

James R. Evans | University of Cincinnati

SECOND EDITION

PEARSON

Boston Columbus Indianapolis New York San Francisco
Amsterdam Cape Town Dubai London Madrid Milan Munich Paris Montreal Toronto
Delhi Mexico City São Paulo Sydney Hong Kong Seoul Singapore Taipei Tokyo

Editorial Director: Chris Hoag
Editor in Chief: Deirdre Lynch
Acquisitions Editor: Patrick Barbera
Editorial Assistant: Justin Billing
Program Manager: Tatiana Anacki
Project Manager: Kerri Consalvo
Project Management Team Lead: Christina Lepre
Program Manager Team Lead: Marianne Stepanian
Media Producer: Nicholas Sweeney
MathXL Content Developer: Kristina Evans
Marketing Manager: Erin Kelly
Marketing Assistant: Emma Sarconi
Senior Author Support/Technology Specialist: Joe Vetere
Rights and Permissions Project Manager: Diahanne Lucas Dowridge
Procurement Specialist: Carole Melville
Associate Director of Design: Andrea Nix
Program Design Lead: Beth Paquin
Text Design: 10/12 TimesLTStd
Composition: Lumina Datamatics Ltd.
Cover Design: Studio Montage
Cover Image: Aleksandarvelasevic/Getty Images

Library of Congress Cataloging-in-Publication Data

Evans, James R. (James Robert), 1950–
Business analytics: methods, models, and decisions / James R. Evans, University of Cincinnati.—2 Edition.
pages cm
Includes bibliographical references and index.
ISBN 978-0-321-99782-1 (alk. paper)
1. Business planning. 2. Strategic planning. 3. Industrial management—Statistical methods. I. Title.
HD30.28.E824 2016
658.4'01—dc23

2014017342

1 2 3 4 5 6 7 8 9 10—XXX—18 17 16 15 14

PEARSON

ISBN 10: 0-321-99782-4
ISBN 13: 978-0-321-99782-1

Brief Contents

This page intentionally left blank

Contents

Part 2: Descriptive Analytics

This page intentionally left blank

Preface

In 2007, Thomas H. Davenport and Jeanne G. Harris wrote a groundbreaking book, *Competing on Analytics: The New Science of Winning* (Boston: Harvard Business School Press). They described how many organizations are using analytics strategically to make better decisions and improve customer and shareholder value. Over the past several years, we have seen remarkable growth in analytics among all types of organizations. The Institute for Operations Research and the Management Sciences (INFORMS) noted that analytics software as a service is predicted to grow three times the rate of other business segments in upcoming years.[1] In addition, the *MIT Sloan Management Review* in collaboration with the IBM Institute for Business Value surveyed a global sample of nearly 3,000 executives, managers, and analysts.[2] This study concluded that top-performing organizations use analytics five times more than lower performers, that improvement of information and analytics was a top priority in these organizations, and that many organizations felt they were under significant pressure to adopt advanced information and analytics approaches. Since these reports were published, the interest in and the use of analytics has grown dramatically.

In reality, business analytics has been around for more than a half-century. Business schools have long taught many of the core topics in business analytics—statistics, data analysis, information and decision support systems, and management science. However, these topics have traditionally been presented in separate and independent courses and supported by textbooks with little topical integration. This book is uniquely designed to present the emerging discipline of business analytics in a unified fashion consistent with the contemporary definition of the field.

About the Book

This book provides undergraduate business students and introductory graduate students with the fundamental concepts and tools needed to understand the emerging role of business analytics in organizations, to apply basic business analytics tools in a spreadsheet environment, and to communicate with analytics professionals to effectively use and interpret analytic models and results for making better business decisions. We take a balanced, holistic approach in viewing business analytics from descriptive, predictive, and prescriptive perspectives that today define the discipline.

[1]Anne Robinson, Jack Levis, and Gary Bennett, INFORMS News: INFORMS to Officially Join Analytics Movement. http://www.informs.org/ORMS-Today/Public-Articles/October-Volume-37-Number-5/INFORMS-News-INFORMS-to-Officially-Join-Analytics-Movement.

[2]"Analytics: The New Path to Value," *MIT Sloan Management Review* Research Report, Fall 2010.

This book is organized in five parts.

1. Foundations of Business Analytics

   The first two chapters provide the basic foundations needed to understand business analytics, and to manipulate data using Microsoft Excel.

2. Descriptive Analytics

   Chapters 3 through 7 focus on the fundamental tools and methods of data analysis and statistics, focusing on data visualization, descriptive statistical measures, probability distributions and data modeling, sampling and estimation, and statistical inference. We subscribe to the American Statistical Association's recommendations for teaching introductory statistics, which include emphasizing statistical literacy and developing statistical thinking, stressing conceptual understanding rather than mere knowledge of procedures, and using technology for developing conceptual understanding and analyzing data. We believe these goals can be accomplished without introducing every conceivable technique into an 800–1,000 page book as many mainstream books currently do. In fact, we cover all essential content that the state of Ohio has mandated for undergraduate business statistics across all public colleges and universities.

3. Predictive Analytics

   In this section, Chapters 8 through 12 develop approaches for applying regression, forecasting, and data mining techniques, building and analyzing predictive models on spreadsheets, and simulation and risk analysis.

4. Prescriptive Analytics

   Chapters 13 through 15, along with two online supplementary chapters, explore linear, integer, and nonlinear optimization models and applications, including optimization with uncertainty.

5. Making Decisions

   Chapter 16 focuses on philosophies, tools, and techniques of decision analysis.

   The second edition has been carefully revised to improve both the content and pedagogical organization of the material. Specifically, this edition has a much stronger emphasis on data visualization, incorporates the use of additional Excel tools, new features of Analytic Solver Platform for Education, and many new data sets and problems. Chapters 8 through 12 have been re-ordered from the first edition to improve the logical flow of the topics and provide a better transition to spreadsheet modeling and applications.

Features of the Book

- **Numbered Examples**—numerous, short examples throughout all chapters illustrate concepts and techniques and help students learn to apply the techniques and understand the results.
- **"Analytics in Practice"**—at least one per chapter, this feature describes real applications in business.
- **Learning Objectives**—lists the goals the students should be able to achieve after studying the chapter.

- **Key Terms**—bolded within the text and listed at the end of each chapter, these words will assist students as they review the chapter and study for exams. Key terms and their definitions are contained in the glossary at the end of the book.
- **End-of-Chapter Problems and Exercises**—help to reinforce the material covered through the chapter.
- **Integrated Cases**—allows students to think independently and apply the relevant tools at a higher level of learning.
- **Data Sets and Excel Models**—used in examples and problems and are available to students at www.pearsonhighered.com/evans.

Software Support

While many different types of software packages are used in business analytics applications in the industry, this book uses Microsoft Excel and Frontline Systems' powerful Excel add-in, *Analytic Solver Platform* for Education, which together provide extensive capabilities for business analytics. Many statistical software packages are available and provide very powerful capabilities; however, they often require special (and costly) licenses and additional learning requirements. These packages are certainly appropriate for analytics professionals and students in master's programs dedicated to preparing such professionals. However, for the general business student, we believe that Microsoft Excel with proper add-ins is more appropriate. Although Microsoft Excel may have some deficiencies in its statistical capabilities, the fact remains that every business student will use Excel throughout their careers. Excel has good support for data visualization, basic statistical analysis, what-if analysis, and many other key aspects of business analytics. In fact, in using this book, students will gain a high level of proficiency with many features of Excel that will serve them well in their future careers. Furthermore Frontline Systems' *Analytic Solver Platform* for Education Excel add-ins are integrated throughout the book. This add-in, which is used among the top business organizations in the world, provides a comprehensive coverage of many other business analytics topics in a common platform. This add-in provides support for data modeling, forecasting, Monte Carlo simulation and risk analysis, data mining, optimization, and decision analysis. Together with Excel, it provides a comprehensive basis to learn business analytics effectively.

To the Students

To get the most out of this book, you need to do much more than simply read it! Many examples describe in detail how to use and apply various Excel tools or add-ins. We highly recommend that you work through these examples on your computer to replicate the outputs and results shown in the text. You should also compare mathematical formulas with spreadsheet formulas and work through basic numerical calculations by hand. Only in this fashion will you learn how to use the tools and techniques effectively, gain a better understanding of the underlying concepts of business analytics, and increase your proficiency in using Microsoft Excel, which will serve you well in your future career.

Visit the Companion Web site (www.pearsonhighered.com/evans) for access to the following:

- **Online Files:** Data Sets and Excel Models—files for use with the numbered examples and the end-of-chapter problems (For easy reference, the relevant file names are italicized and clearly stated when used in examples.)

- **Software Download Instructions:** Access to Analytic Solver Platform for Education—a free, semester-long license of this special version of Frontline Systems' Analytic Solver Platform software for Microsoft Excel.

Integrated throughout the book, Frontline Systems' Analytic Solver Platform for Education Excel add-in software provides a comprehensive basis to learn business analytics effectively that includes:

- *Risk Solver Pro*—This program is a tool for risk analysis, simulation, and optimization in Excel. There is a link where you will learn more about this software at www.solver.com.
- *XLMiner*—This program is a data mining add-in for Excel. There is a link where you will learn more about this software at www.solver.com/xlminer.
- Premium Solver Platform, a large superset of Premium Solver and by far the most powerful spreadsheet optimizer, with its PSI interpreter for model analysis and five built-in Solver Engines for linear, quadratic, SOCP, mixed-integer, nonlinear, non-smooth and global optimization.
- Ability to solve optimization models with uncertainty and recourse decisions, using simulation optimization, stochastic programming, robust optimization, and stochastic decomposition.
- New integrated sensitivity analysis and decision tree capabilities, developed in cooperation with Prof. Chris Albright (SolverTable), Profs. Stephen Powell and Ken Baker (Sensitivity Toolkit), and Prof. Mike Middleton (TreePlan).
- A special version of the Gurobi Solver—the ultra-high-performance linear mixed-integer optimizer created by the respected computational scientists at Gurobi Optimization.

To register and download the software successfully, you will need a Texbook Code and a Course Code. The Textbook Code is EBA2 and your instructor will provide the Course Code. This download includes a 140-day license to use the software. Visit www.pearsonhighered.com/evans for complete download instructions.

To the Instructors

Instructor's Resource Center—Reached through a link at www.pearsonhighered.com/evans, the Instructor's Resource Center contains the electronic files for the complete Instructor's Solutions Manual, PowerPoint lecture presentations, and the Test Item File.

- **Register, redeem, log in at www.pearsonhighered.com/irc**, instructors can access a variety of print, media, and presentation resources that are available with this book in downloadable digital format. Resources are also available for course management platforms such as Blackboard, WebCT, and CourseCompass.
- **Need help?** Pearson Education's dedicated technical support team is ready to assist instructors with questions about the media supplements that accompany this text. Visit http://247pearsoned.com for answers to frequently asked questions and toll-free user support phone numbers. The supplements are available to adopting instructors. Detailed descriptions are provided at the Instructor's Resource Center.
  - *Instructor's Solutions Manual*—The Instructor's Solutions Manual, updated and revised for the second edition by the author, includes Excel-based solutions for all end-of-chapter problems, exercises, and cases. The Instructor's

Solutions Manual is available for download by visiting www.pearsonhighered.com/evans and clicking on the Instructor Resources link.

- *PowerPoint presentations*—The PowerPoint slides, revised and updated by the author, are available for download by visiting www.pearsonhighered.com/evans and clicking on the Instructor Resources link. The PowerPoint slides provide an instructor with individual lecture outlines to accompany the text. The slides include nearly all of the figures, tables, and examples from the text. Instructors can use these lecture notes as they are or can easily modify the notes to reflect specific presentation needs.
- *Test Bank*—The TestBank, prepared by Paolo Catasti from Virginia Commonwealth University, is available for download by visiting www.pearsonhighered.com/evans and clicking on the Instructor Resources link.
- *Analytic Solver Platform for Education (ASPE)*—This is a special version of Frontline Systems' Analytic Solver Platform software for Microsoft Excel. For further information on **Analytic Solver Platform for Education**, contact Frontline Systems at (888) 831–0333 (U.S. and Canada), 775-831-0300, or academic@solver.com. They will be pleased to provide free evaluation licenses to faculty members considering adoption of the software, and create a unique Course Code for your course, which your students will need to download the software. They can help you with conversion of simulation models you might have created with other software to work with Analytic Solver Platform (it's very straightforward).

Acknowledgements

I would like to thank the staff at Pearson Education for their professionalism and dedication to making this book a reality. In particular, I want to thank Kerri Consalvo, Tatiana Anacki, Erin Kelly, Nicholas Sweeney, and Patrick Barbera; Jen Carley at Lumina Datamatics Ltd.; accuracy checker Annie Puciloski; and solutions checker Regina Krahenbuhl for their outstanding contributions to producing this book. I also want to acknowledge Daniel Fylstra and his staff at Frontline Systems for working closely with me to allow this book to have been the first to include *XLMiner* with *Analytic Solver Platform*. If you have any suggestions or corrections, please contact the author via email at james.evans@uc.edu.

James R. Evans
Department of Operations, Business Analytics, and Information Systems
University of Cincinnati
Cincinnati, Ohio

This page intentionally left blank

About the Author

James R. Evans
Professor, University of Cincinnati College of Business

James R. Evans is professor in the Department of Operations, Business Analytics, and Information Systems in the College of Business at the University of Cincinnati. He holds BSIE and MSIE degrees from Purdue and a PhD in Industrial and Systems Engineering from Georgia Tech.

Dr. Evans has published numerous textbooks in a variety of business disciplines, including statistics, decision models, and analytics, simulation and risk analysis, network optimization, operations management, quality management, and creative thinking. He has published over 90 papers in journals such as *Management Science*, *IIE Transactions, Decision Sciences, Interfaces,* the *Journal of Operations Management,* the *Quality Management Journal,* and many others, and wrote a series of columns in *Interfaces* on creativity in management science and operations research during the 1990s. He has also served on numerous journal editorial boards and is a past-president and Fellow of the Decision Sciences Institute. In 1996, he was an INFORMS Edelman Award Finalist as part of a project in supply chain optimization with Procter & Gamble that was credited with helping P&G save over $250,000,000 annually in their North American supply chain, and consulted on risk analysis modeling for Cincinnati 2012's Olympic Games bid proposal.

A recognized international expert on quality management, he served on the Board of Examiners and the Panel of Judges for the Malcolm Baldrige National Quality Award. Much of his current research focuses on organizational performance excellence and measurement practices.

This page intentionally left blank

Credits

Text Credits

Chapter 1 *Pages 2–3* "The Cincinnati Zoo & Botanical Garden" from Cincinnati Zoo Transforms Customer Experience and Boosts Profits, Copyright © 2012. Used by permission of IBM Corporation. *Pages 4–5* "Common Types of Decisions that can be Enhanced by Using Analytics" by Thomas H. Davenport from How Organizations Make Better Decisions. Published by SAS Institute, Inc. *Pages 10–11* Analytics in the Home Lending and Mortgage Industry by Craig Zielazny. Used by permission of Craig Zielazny. *Page 26* Excerpt by Thomas Olavson, Chris Fry from Spreadsheet Decision-Support Tools: Lessons Learned at Hewlett-Packard. Published by Interfaces. *Pages 29–30* Analytics in Practice: Developing Effective Analytical Tools at Hewlett-Packard: Thomas Olvason; Chris Fry; Interfaces *Page 33* Drout Advertising Research Project by Jamie Drout. Used by permission of Jamie Drout.

Chapter 5 *Page 151* Excerpt by Chris K. Anderson from Setting Prices on Priceline. Published by Interfaces.

Chapter 7 *Page 227* Help Desk Service Improvement Project by Francisco Endara M from Help Desk Improves Service and Saves Money With Six Sigma. Used by permission of The American Society for Quality.

Chapter 12 *Pages 410–411* Implementing Large-Scale Monte Carlo Spreadsheet Models by Yusuf Jafry from Hypo International Strengthens Risk Management with a Large-Scale, Secure Spreadsheet-Management Framework. Published by Interfaces, © 2008.

Chapter 13 *Pages 452–453* Excerpt by Srinivas Bollapragada from NBC's Optimization Systems Increase Revenues and Productivity. Copyright © 2002. Used by permission of Interfaces.

Chapter 15 *Pages 536–537* Supply Chain Optimization at Procter & Gamble by Jeffrey D. Camm from Blending OR/MS, Judgment, and GIS: Restructuring P&G's Supply Chain. Published by Interfaces, © 1997.

Chapter 16 *Pages 580–581* Excerpt from How Bayer Makes Decisions to Develop New Drugs by Jeffrey S Stonebraker. Published by Interfaces.

Photo Credits

Chapter 1 *Page 1* Analytics Business Analysis: Mindscanner/Fotolia *Page 30* Computer, calculator, and spreadsheet: Hans12/Fotolia

Chapter 2 *Page 37* Computer with Spreadsheet: Gunnar Pippel/Shutterstock

Chapter 3 *Page 53* Spreadsheet with magnifying glass: Poles/Fotolia *Page 72* Data Analysis: 2jenn/Shutterstock

Chapter 4 *Page 95* Pattern of colorful numbers: JonnyDrake/Shutterstock *Page 125* Computer screen with financial data: NAN728/Shutterstock

Chapter 5 *Page 131* Faded spreadsheet: Fantasista/Fotolia *Page 151* Probability and cost graph with pencil: Fantasista/Fotolia *Page 172* Business concepts: Victor Correia/Shutterstock

Chapter 6 *Page 181* Series of bar graphs: Kalabukhava Iryna/Shutterstock *Page 185* Brewery truck: Stephen Finn/Shutterstock

Chapter 7 *Page 205* Business man solving problems with illustrated graph display: Serg Nvns/Fotolia *Page 227* People working at a helpdesk: StockLite/Shutterstock

Chapter 8 *Page 233* Trendline 3D graph: Sheelamohanachandran/Fotolia *Page 253* Computer and Risk: Gunnar Pippel/Shutterstock *Page 254C* 4 blank square shape navigation web 2.0 button slider: Claudio Divizia/Shutterstock *Page 254L* Graph chart illustrations of growth and recession: Vector Illustration/Shutterstock *Page 254R* Audio gauge: Shutterstock

Chapter 9 *Page 273* Past and future road sign: Karen Roach/Fotolia *Page 298* NBC Studios: Sean Pavone/Dreamstine

Chapter 10 *Page 301* Data Mining Technology Strategy Concept: Kentoh/Shutterstock *Page 337* Business man drawing a marketing diagram: Helder Almeida/Shutterstock

Chapter 11 *Page 341* 3D spreadsheet: Dmitry/Fotolia *Page 349* Buildings: ZUMA Press/Newscom *Page 355* Health Clinic: Poprostskiy Alexey/Shutterstock

Chapter 12 *Page 377* Analyzing Risk in Business: iQoncept/Shutterstock *Page 406* Office Building: Verdeskerde/Shutterstock

Chapter 13 *Page 415* 3D spreadsheet, graph, pen: Archerix/Shutterstock *Page 449* Television acting sign: Bizoo_n/Fotolia

Chapter 14 *Page 457* People working on spreadsheets: Pressmaster/Shutterstock *Page 489* Colored Stock Market Chart: 2jenn/Shutterstock

Chapter 15 *Page 513* Brainstorming Concept: Dusit/Shutterstock *Page 523* Qantas Airbus A380: Gordon Tipene/Dreamstine *Page 533* Supply chain concept: Kheng Guan Toh/Shutterstock

Chapter 16 *Page 553* Person at crossroads: Michael D Brown/Shutterstock *Page 578* Collage of several images from a drug store: Sokolov/Shutterstock

Supplementary Chapter A (online) *Page 1* Various discount tags and labels: little Whale/Shutterstock *Page 9* Red Cross facility: Littleny/Dreamstine

Supplementary Chapter B (online) *Page 1* Confused man thinking over right decision: StockThings/Shutterstock *Page 7* Lockheed Constellation Cockpit: Brad Whitsitt/Shutterstock

CHAPTER 1

Introduction to Business Analytics

Learning Objectives

After studying this chapter, you will be able to:

- Define business analytics.
- Explain why analytics is important in today's business environment.
- State some typical examples of business applications in which analytics would be beneficial.
- Summarize the evolution of business analytics and explain the concepts of business intelligence, operations research and management science, and decision support systems.
- Explain and provide examples of descriptive, predictive, and prescriptive analytics.
- State examples of how data are used in business.
- Explain the difference between a data set and a database.
- Define a metric and explain the concepts of measurement and measures.
- Explain the difference between a discrete metric and continuous metric, and provide examples of each.
- Describe the four groups of data classification, categorical, ordinal, interval, and ratio, and provide examples of each.
- Explain the concept of a model and various ways a model can be characterized.
- Define and list the elements of a decision model.
- Define and provide an example of an influence diagram.
- Use influence diagrams to build simple mathematical models.
- Use predictive models to compute model outputs.
- Explain the difference between uncertainty and risk.
- Define the terms *optimization*, *objective function*, and *optimal solution*.
- Explain the difference between a deterministic and stochastic decision model.
- List and explain the steps in the problem-solving process.

Most of you have likely been to a zoo, seen the animals, had something to eat, and bought some souvenirs. You probably wouldn't think that managing a zoo is very difficult; after all, it's just feeding and taking care of the animals, right? A zoo might be the last place that you would expect to find business analytics being used, but not anymore. The Cincinnati Zoo & Botanical Garden has been an "early adopter" and one of the first organizations of its kind to exploit business analytics.[1]

Despite generating more than two-thirds of its budget through its own fund-raising efforts, the zoo wanted to reduce its reliance on local tax subsidies even further by increasing visitor attendance and revenues from secondary sources such as membership, food and retail outlets. The zoo's senior management surmised that the best way to realize more value from each visit was to offer visitors a truly transformed customer experience. By using business analytics to gain greater insight into visitors' behavior and tailoring operations to their preferences, the zoo expected to increase attendance, boost membership, and maximize sales.

The project team—which consisted of consultants from IBM and BrightStar Partners, as well as senior executives from the zoo—began translating the organization's goals into technical solutions. The zoo worked to create a business analytics platform that was capable of delivering the desired goals by combining data from ticketing and point-of-sale systems throughout the zoo with membership information and geographical data gathered from the ZIP codes of all visitors. This enabled the creation of reports and dashboards that give everyone from senior managers to zoo staff access to real-time information that helps them optimize operational management and transform the customer experience.

By integrating weather forecast data, the zoo is able to compare current forecasts with historic attendance and sales data, supporting better decision-making for labor scheduling and inventory planning. Another area where the solution delivers new insight is food service. By opening food outlets at specific times of day when demand is highest (for example, keeping ice cream kiosks open in the final hour before the zoo closes), the zoo has been able to increase sales significantly. The zoo has been able to increase attendance and revenues dramatically, resulting in annual ROI of 411%. The business

[1]Source: IBM Software Business Analtyics, "Cincinnati Zoo transforms customer experience and boosts profits," © IBM Corporation 2012.

analytics initiative paid for itself within three months, and delivers, on average, benefits of $738,212 per year. Specifically,

- The zoo has seen a 4.2% rise in ticket sales by targeting potential visitors who live in specific ZIP codes.
- Food revenues increased by 25% by optimizing the mix of products on sale and adapting selling practices to match peak purchase times.
- Eliminating slow-selling products and targeting visitors with specific promotions enabled an 18% increase in merchandise sales.
- Cut marketing expenditure, saving $40,000 in the first year, and reduced advertising expenditure by 43% by eliminating ineffective campaigns and segmenting customers for more targeted marketing.

Because of the zoo's success, other organizations such as Point Defiance Zoo & Aquarium, in Washington state, and History Colorado, a museum in Denver, have embarked on similar initiatives.

In recent years, analytics has become increasingly important in the world of business, particularly as organizations have access to more and more data. Managers today no longer make decisions based on pure judgment and experience; they rely on factual data and the ability to manipulate and analyze data to support their decisions. As a result, many companies have recently established analytics departments; for instance, IBM reorganized its consulting business and established a new 4,000-person organization focusing on analytics.[2] Companies are increasingly seeking business graduates with the ability to understand and use analytics. In fact, in 2011, the U.S. Bureau of Labor Statistics predicted a 24% increase in demand for professionals with analytics expertise.

No matter what your academic business concentration is, you will most likely be a future user of analytics to some extent and work with analytics professionals. The purpose of this book is to provide you with a basic introduction to the concepts, methods, and models used in business analytics so that you will develop not only an appreciation for its capabilities to support and enhance business decisions, but also the ability to use business analytics at an elementary level in your work. In this chapter, we introduce you to the field of business analytics, and set the foundation for many of the concepts and techniques that you will learn.

[2]Matthew J. Liberatore and Wenhong Luo, "The Analytics Movement: Implications for Operations Research," *Interfaces*, 40, 4 (July–August 2010): 313–324.

What Is Business Analytics?

Everyone makes decisions. Individuals face personal decisions such as choosing a college or graduate program, making product purchases, selecting a mortgage instrument, and investing for retirement. Managers in business organizations make numerous decisions every day. Some of these decisions include what products to make and how to price them, where to locate facilities, how many people to hire, where to allocate advertising budgets, whether or not to outsource a business function or make a capital investment, and how to schedule production. Many of these decisions have significant economic consequences; moreover, they are difficult to make because of uncertain data and imperfect information about the future. Thus, managers need good information and assistance to make such critical decisions that will impact not only their companies but also their careers. What makes business decisions complicated today is the overwhelming amount of available data and information. Data to support business decisions—including those specifically collected by firms as well as through the Internet and social media such as Facebook—are growing exponentially and becoming increasingly difficult to understand and use. This is one of the reasons why analytics is important in today's business environment.

Business analytics, or simply **analytics**, is the use of data, information technology, statistical analysis, quantitative methods, and mathematical or computer-based models to help managers gain improved insight about their business operations and make better, fact-based decisions. Business analytics is "a process of transforming data into actions through analysis and insights in the context of organizational decision making and problem solving."[3] Business analytics is supported by various tools such as Microsoft Excel and various Excel add-ins, commercial statistical software packages such as SAS or Minitab, and more-complex business intelligence suites that integrate data with analytical software.

Tools and techniques of business analytics are used across many areas in a wide variety of organizations to improve the management of customer relationships, financial and marketing activities, human capital, supply chains, and many other areas. Leading banks use analytics to predict and prevent credit fraud. Manufacturers use analytics for production planning, purchasing, and inventory management. Retailers use analytics to recommend products to customers and optimize marketing promotions. Pharmaceutical firms use it to get life-saving drugs to market more quickly. The leisure and vacation industries use analytics to analyze historical sales data, understand customer behavior, improve Web site design, and optimize schedules and bookings. Airlines and hotels use analytics to dynamically set prices over time to maximize revenue. Even sports teams are using business analytics to determine both game strategy and optimal ticket prices.[4] Among the many organizations that use analytics to make strategic decisions and manage day-to-day operations are Harrah's Entertainment, the Oakland Athletics baseball and New England Patriots football teams, Amazon.com, Procter & Gamble, United Parcel Service (UPS), and Capital One bank. It was reported that nearly all firms with revenues of more than $100 million are using some form of business analytics.

Some common types of decisions that can be enhanced by using analytics include

- pricing (for example, setting prices for consumer and industrial goods, government contracts, and maintenance contracts),
- customer segmentation (for example, identifying and targeting key customer groups in retail, insurance, and credit card industries),

[3]Liberatore and Luo, "The Analytics Movement."
[4]Jim Davis, "8 Essentials of Business Analytics," in "Brain Trust—Enabling the Confident Enterprise with Business Analytics" (Cary, NC: SAS Institute, Inc., 2010): 27–29. www.sas.com/bareport

- merchandising (for example, determining brands to buy, quantities, and allocations),
- location (for example, finding the best location for bank branches and ATMs, or where to service industrial equipment),

and many others in operations and supply chains, finance, marketing, and human resources—in fact, in every discipline of business.[5]

Various research studies have discovered strong relationships between a company's performance in terms of profitability, revenue, and shareholder return and its use of analytics. Top-performing organizations (those that outperform their competitors) are three times more likely to be sophisticated in their use of analytics than lower performers and are more likely to state that their use of analytics differentiates them from competitors.[6] However, research has also suggested that organizations are overwhelmed by data and struggle to understand how to use data to achieve business results and that most organizations simply don't understand how to use analytics to improve their businesses. Thus, understanding the capabilities and techniques of analytics is vital to managing in today's business environment.

One of the emerging applications of analytics is helping businesses learn from social media and exploit social media data for strategic advantage.[7] Using analytics, firms can integrate social media data with traditional data sources such as customer surveys, focus groups, and sales data; understand trends and customer perceptions of their products; and create informative reports to assist marketing managers and product designers.

Evolution of Business Analytics

Analytical methods, in one form or another, have been used in business for more than a century. However, the modern evolution of analytics began with the introduction of computers in the late 1940s and their development through the 1960s and beyond. Early computers provided the ability to store and analyze data in ways that were either very difficult or impossible to do so manually. This facilitated the collection, management, analysis, and reporting of data, which is often called **business intelligence (BI)**, a term that was coined in 1958 by an IBM researcher, Hans Peter Luhn.[8] Business intelligence software can answer basic questions such as "How many units did we sell last month?" "What products did customers buy and how much did they spend?" "How many credit card transactions were completed yesterday?" Using BI, we can create simple rules to flag exceptions automatically, for example, a bank can easily identify transactions greater than $10,000 to report to the Internal Revenue Service.[9] BI has evolved into the modern discipline we now call **information systems (IS)**.

[5]Thomas H. Davenport, "How Organizations Make Better Decisions," edited excerpt of an article distributed by the International Institute for Analytics published in "Brain Trust—Enabling the Confident Enterprise with Business Analytics" (Cary, NC: SAS Institute, Inc., 2010): 8–11. www.sas.com/bareport

[6]Thomas H. Davenport and Jeanne G. Harris, *Competing on Analytics* (Boston: Harvard Business School Press, 2007): 46; Michael S. Hopkins, Steve LaValle, Fred Balboni, Nina Kruschwitz, and Rebecca Shockley, "10 Data Points: Information and Analytics at Work," *MIT Sloan Management Review*, 52, 1 (Fall 2010): 27–31.

[7]Jim Davis, "Convergence—Taking Social Media from Talk to Action," *SASCOM* (First Quarter 2011): 17.

[8]H. P. Luhn, "A Business Intelligence System." *IBM Journal* (October 1958).

[9]Jim Davis, "Business Analytics: Helping You Put an Informed Foot Forward," in "Brain Trust—Enabling the Confident Enterprise with Business Analytics," (Cary, NC: SAS Institute, Inc., 2010): 4–7. www.sas.com/bareport

Statistics has a long and rich history, yet only rather recently has it been recognized as an important element of business, driven to a large extent by the massive growth of data in today's world. Google's chief economist stated that statisticians surely have the "really sexy job" for the next decade.[10] Statistical methods allow us to gain a richer understanding of data that goes beyond business intelligence reporting by not only summarizing data succinctly but also finding unknown and interesting relationships among the data. Statistical methods include the basic tools of description, exploration, estimation, and inference, as well as more advanced techniques like regression, forecasting, and data mining.

Much of modern business analytics stems from the analysis and solution of complex decision problems using mathematical or computer-based models—a discipline known as operations research, or management science. *Operations research (OR)* was born from efforts to improve military operations prior to and during World War II. After the war, scientists recognized that the mathematical tools and techniques developed for military applications could be applied successfully to problems in business and industry. A significant amount of research was carried on in public and private think tanks during the late 1940s and through the 1950s. As the focus on business applications expanded, the term *management science (MS)* became more prevalent. Many people use the terms *operations research* and *management science* interchangeably, and the field became known as **Operations Research/Management Science (OR/MS)**. Many OR/MS applications use **modeling and optimization**—techniques for translating real problems into mathematics, spreadsheets, or other computer languages, and using them to find the best ("optimal") solutions and decisions. INFORMS, the Institute for Operations Research and the Management Sciences, is the leading professional society devoted to OR/MS and analytics, and publishes a bimonthly magazine called *Analytics* (http://analytics-magazine.com/). Digital subscriptions may be obtained free of charge at the Web site.

Decision support systems (DSS) began to evolve in the 1960s by combining business intelligence concepts with OR/MS models to create analytical-based computer systems to support decision making. DSSs include three components:

1. *Data management*. The data management component includes databases for storing data and allows the user to input, retrieve, update, and manipulate data.
2. *Model management*. The model management component consists of various statistical tools and management science models and allows the user to easily build, manipulate, analyze, and solve models.
3. *Communication system*. The communication system component provides the interface necessary for the user to interact with the data and model management components.[11]

DSSs have been used for many applications, including pension fund management, portfolio management, work-shift scheduling, global manufacturing and facility location, advertising-budget allocation, media planning, distribution planning, airline operations planning, inventory control, library management, classroom assignment, nurse scheduling, blood distribution, water pollution control, ski-area design, police-beat design, and energy planning.[12]

---

[10]James J. Swain, "Statistical Software in the Age of the Geek," Analytics-magazine.org, March/April 2013, pp. 48–55. www.informs.org

[11]William E. Leigh and Michael E. Doherty, *Decision Support and Expert Systems* (Cincinnati, OH: South-Western Publishing Co., 1986).

[12]H. B. Eom and S. M. Lee, "A Survey of Decision Support System Applications (1971–April 1988)," *Interfaces*, 20, 3 (May–June 1990): 65–79.

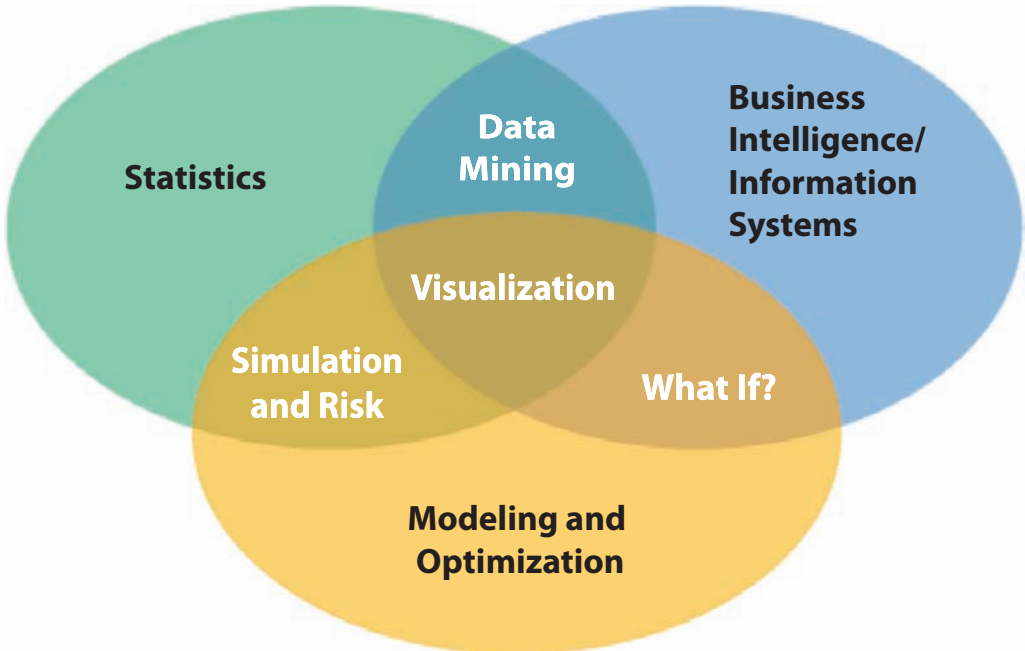

Figure 1.1 A Visual Perspective of Business Analytics

Modern business analytics can be viewed as an integration of BI/IS, statistics, and modeling and optimization as illustrated in Figure 1.1. While the core topics are traditional and have been used for decades, the uniqueness lies in their intersections. For example, **data mining** is focused on better understanding characteristics and patterns among variables in large databases using a variety of statistical and analytical tools. Many standard statistical tools as well as more advanced ones are used extensively in data mining. **Simulation and risk analysis** relies on spreadsheet models and statistical analysis to examine the impacts of uncertainty in the estimates and their potential interaction with one another on the output variable of interest. Spreadsheets and formal models allow one to manipulate data to perform **what-if analysis**—how specific combinations of inputs that reflect key assumptions will affect model outputs. What-if analysis is also used to assess the sensitivity of optimization models to changes in data inputs and provide better insight for making good decisions.

Perhaps the most useful component of business analytics, which makes it truly unique, is the center of Figure 1.1—**visualization**. Visualizing data and results of analyses provide a way of easily communicating data at all levels of a business and can reveal surprising patterns and relationships. Software such as IBM's Cognos system exploits data visualization for query and reporting, data analysis, dashboard presentations, and scorecards linking strategy to operations. The Cincinnati Zoo, for example, has used this on an iPad to display hourly, daily, and monthly reports of attendance, food and retail location revenues and sales, and other metrics for prediction and marketing strategies. UPS uses telematics to capture vehicle data and display them to help make decisions to improve efficiency and performance. You may have seen a **tag cloud** (see the graphic at the beginning of this chapter), which is a visualization of text that shows words that appear more frequently using larger fonts.

The most influential developments that propelled the use of business analytics have been the personal computer and spreadsheet technology. Personal computers and spreadsheets provide a convenient way to manage data, calculations, and visual graphics simultaneously, using intuitive representations instead of abstract mathematical notation. Although the early

Analytics in Practice: Harrah's Entertainment[13]

One of the most cited examples of the use of analytics in business is Harrah's Entertainment. Harrah's owns numerous hotels and casinos and uses analytics to support revenue management activities, which involve selling the right resources to the right customer at the right price to maximize revenue and profit. The gaming industry views hotel rooms as incentives or rewards to support casino gaming activities and revenues, not as revenue-maximizing assets. Therefore, Harrah's objective is to set room rates and accept reservations to maximize the expected gaming profits from customers. They begin with collecting and tracking of customers' gaming activities (playing slot machines and casino games) using Harrah's "Total Rewards" card program, a customer loyalty program that provides rewards such as meals, discounted rooms, and other perks to customers based on the amount of money and time they spend at Harrah's. The data collected are used to segment customers into more than 20 groups based on their expected gaming activities. For each customer segment, analytics forecasts demand for hotel rooms by arrival date and length of stay. Then Harrah's uses a prescriptive model to set prices and allocate rooms to these customer segments. For example, the system might offer complimentary rooms to customers who are expected to generate a gaming profit of at least $400 but charge $325 for a room if the profit is expected to be only $100. Marketing can use the information to send promotional offers to targeted customer segments if it identifies low-occupancy rates for specific dates.

applications of spreadsheets were primarily in accounting and finance, spreadsheets have developed into powerful general-purpose managerial tools for applying techniques of business analytics. The power of analytics in a personal computing environment was noted some 20 years ago by business consultants Michael Hammer and James Champy, who said, "When accessible data is combined with easy-to-use analysis and modeling tools, frontline workers —when properly trained—suddenly have sophisticated decision-making capabilities."[14] Although many good analytics software packages are available to professionals, we use Microsoft Excel and a powerful add-in called *Analytic Solver Platform* throughout this book.

Impacts and Challenges

The impact of applying business analytics can be significant. Companies report reduced costs, better risk management, faster decisions, better productivity, and enhanced bottom-line performance such as profitability and customer satisfaction. For example, 1-800-flowers.com uses analytic software to target print and online promotions with greater accuracy; change prices and offerings on its Web site (sometimes hourly); and optimize its marketing, shipping, distribution, and manufacturing operations, resulting in a $50 million cost savings in one year.[15]

Business analytics is changing how managers make decisions.[16] To thrive in today's business world, organizations must continually innovate to differentiate themselves from competitors, seek ways to grow revenue and market share, reduce costs, retain existing customers and acquire new ones, and become faster and leaner. IBM suggests that

[13]Based on Liberatore and Luo, "The Analytics Movement"; and Richard Metters et al., "The 'Killer Application' of Revenue Management: Harrah's Cherokee Casino & Hotel," *Interfaces*, 38, 3 (May–June 2008): 161–175.
[14]Michael Hammer and James Champy, *Reengineering the Corporation* (New York: HarperBusiness, 1993): 96.
[15]Jim Goodnight, "The Impact of Business Analytics on Performance and Profitability," in "Brain Trust—Enabling the Confident Enterprise with Business Analytics" (Cary, NC: SAS Institute, Inc., 2010): 4–7. www.sas.com/bareport
[16]*Analytics: The New Path to Value*, a joint MIT Sloan Management Review and IBM Institute for Business Value study.

traditional management approaches are evolving in today's analytics-driven environment to include more fact-based decisions as opposed to judgment and intuition, more prediction rather than reactive decisions, and the use of analytics by everyone at the point where decisions are made rather than relying on skilled experts in a consulting group.[17] Nevertheless, organizations face many challenges in developing analytics capabilities, including lack of understanding of how to use analytics, competing business priorities, insufficient analytical skills, difficulty in getting good data and sharing information, and not understanding the benefits versus perceived costs of analytics studies. Successful application of analytics requires more than just knowing the tools; it requires a high-level understanding of how analytics supports an organization's competitive strategy and effective execution that crosses multiple disciplines and managerial levels.

A 2011 survey by Bloomberg Businessweek Research Services and SAS concluded that business analytics is still in the "emerging stage" and is used only narrowly within business units, not across entire organizations. The study also noted that many organizations lack analytical talent, and those that do have analytical talent often don't know how to apply the results properly. While analytics is used as part of the decision-making process in many organizations, most business decisions are still based on intuition.[18] Therefore, while many challenges are apparent, many more opportunities exist. These opportunities are reflected in the job market for analytics professionals, or "data scientists," as some call them. The *Harvard Business Review* called data scientist "the sexiest job of the 21st century," and McKinsey & Company predicted a 50 to 60% shortfall in data scientists in the United States by 2018.[19]

Scope of Business Analytics

Business analytics begins with the collection, organization, and manipulation of data and is supported by three major components:[20]

1. *Descriptive analytics*. Most businesses start with **descriptive analytics**—the use of data to understand past and current business performance and make informed decisions. Descriptive analytics is the most commonly used and most well-understood type of analytics. These techniques categorize, characterize, consolidate, and classify data to convert it into useful information for the purposes of understanding and analyzing business performance. Descriptive analytics summarizes data into meaningful charts and reports, for example, about budgets, sales, revenues, or cost. This process allows managers to obtain standard and customized reports and then drill down into the data and make queries to understand the impact of an advertising campaign, for example, review business performance to find problems or areas of opportunity, and identify patterns and trends in data. Typical questions that descriptive analytics helps answer are "How much did we sell in each region?" "What was our revenue and profit last quarter?" "How many and what types of complaints did we

[17]"Business Analytics and Optimization for the Intelligent Enterprise" (April 2009). www.ibm.com/qbs/intelligent-enterprise

[18]Bloomberg Businessweek Research Services and SAS, "The Current State of Business Analytics: Where Do We Go From Here?" (2011).

[19]Andrew Jennings, "What Makes a Good Data Scientist?" *Analytics Magazine* (July–August 2013): 8–13. www.analytics-magazine.org

[20]Parts of this section are adapted from Irv Lustig, Brenda Dietric, Christer Johnson, and Christopher Dziekan, "The Analytics Journey," *Analytics* (November/December 2010). www.analytics-magazine.org