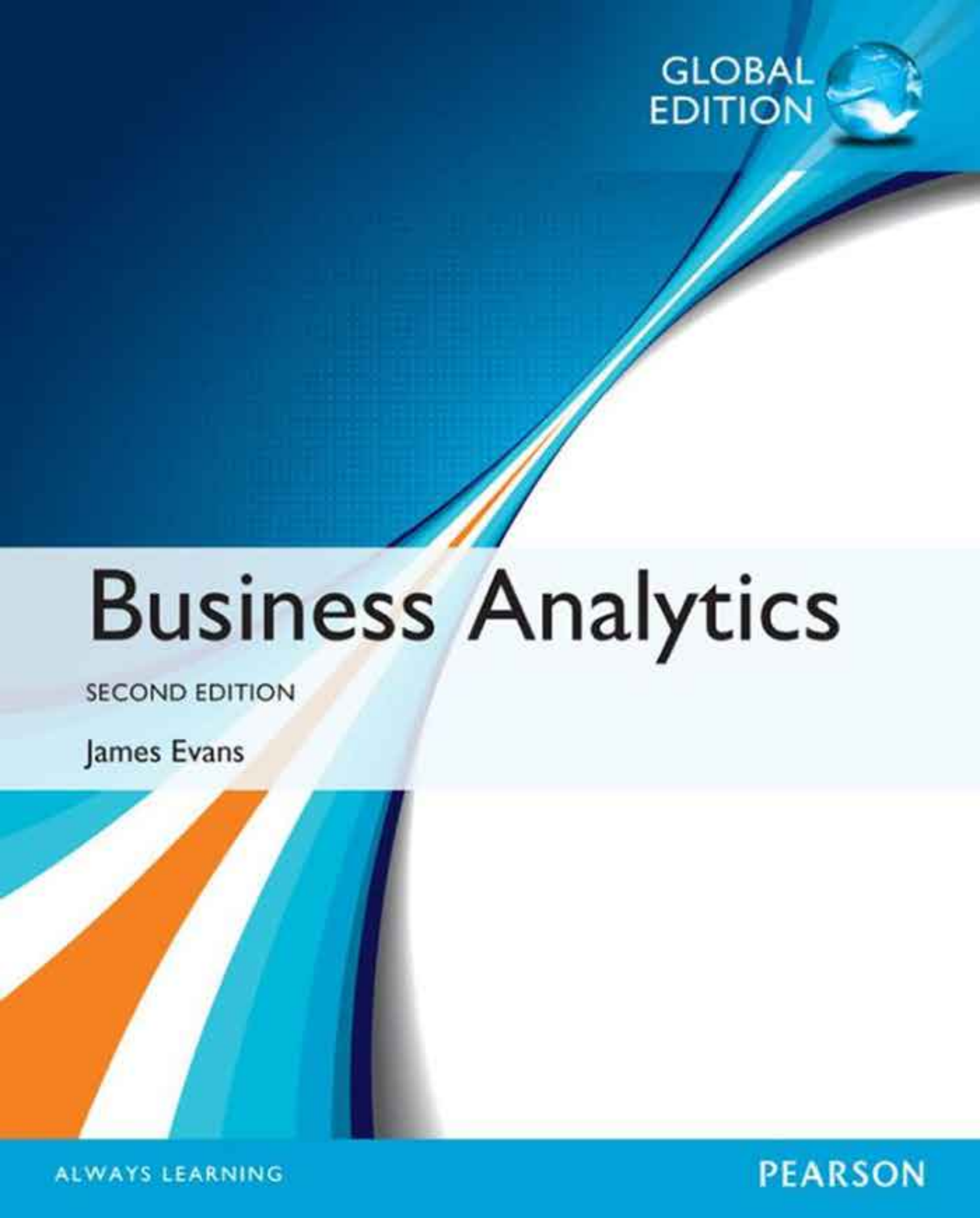
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Methods, Models, and Decisions

James R. Evans | University of Cincinnati

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Online chapters are available for download at www.pearsonglobaleditions.com/Evans.

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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.pearsonglobaleditions.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.pearsonglobaleditions.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.pearsonglobaleditions.com/Evans for complete download instructions.

To the Instructors

Instructor's Resource Center—Reached through a link at www.pearsonglobaleditions.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.

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  - *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.pearsonglobaleditions.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.pearsonglobaleditions.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.pearsonglobaleditions.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.

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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.

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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