GLOBAL EDITION

Analytics, Data Science, & Artificial Intelligence

Systems for Decision Support

ELEVENTH EDITION

Ramesh Sharda • Dursun Delen • Efraim Turban

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ANALYTICS, DATA SCIENCE, & ARTIFICIAL INTELLIGENCE

SYSTEMS FOR DECISION SUPPORT

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Authorized adaptation from the United States edition, entitled Analytics, Data Science, & Artificial Intelligence: Systems for Decision Support, *11th Edition*, *ISBN 978-0-13-519201-6 by Ramesh Sharda, Dursun Delen, and Efraim Turban, published by Pearson Education © 2021.*

Acknowledgments of third-party content appear on the appropriate page within the text.

ISBN 10: 1-292-34155-6
ISBN 13: 978-1-292-34155-2
eBook ISBN 13: 978-1-292-34160-6

eBook formatted by Integra Software Service Pvt. Ltd.

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PREFACE

Analytics has become the technology driver of this decade. Companies such as IBM, Oracle, Microsoft, and others are creating new organizational units focused on analytics that help businesses become more effective and efficient in their operations. Decision makers are using data and computerized tools to make better decisions. Even consumers are using analytics tools directly or indirectly to make decisions on routine activities such as shopping, health care, and entertainment. The field of business analytics (BA)/data science (DS)/decision support systems (DSS)/business intelligence (BI) is evolving rapidly to become more focused on innovative methods and applications to utilize data streams that were not even captured some time back, much less analyzed in any significant way. New applications emerge daily in customer relationship management, banking and finance, health care and medicine, sports and entertainment, manufacturing and supply chain management, utilities and energy, and virtually every industry imaginable.

The theme of this revised edition is analytics, data science, and AI for enterprise decision support. In addition to traditional decision support applications, this edition expands the reader's understanding of the various types of analytics by providing examples, products, services, and exercises by means of introducing AI, machine-learning, robotics, chatbots, IoT, and Web/Internet-related enablers throughout the text. We highlight these technologies as emerging components of modern-day business analytics systems. AI technologies have a major impact on decision making by enabling autonomous decisions and by supporting steps in the process of making decisions. AI and analytics support each other by creating a synergy that assists decision making.

The purpose of this book is to introduce the reader to the technologies that are generally and collectively called *analytics* (or *business analytics*) but have been known by other names such as decision support systems, executive information systems, and business intelligence, among others. We use these terms interchangeably. This book presents the fundamentals of the methods, methodologies, and techniques used to design and develop these systems. In addition, we introduce the essentials of AI both as it relates to analytics as well as a standalone discipline for decision support.

We follow an EEE approach to introducing these topics: **Exposure, Experience**, and **Explore**. The book primarily provides **exposure** to various analytics techniques and their applications. The idea is that a student will be inspired to learn from how other organizations have employed analytics to make decisions or to gain a competitive edge. We believe that such **exposure** to what is being done with analytics and how it can be achieved is the key component of learning about analytics. In describing the techniques, we also introduce specific software tools that can be used for developing such applications. The book is not limited to any one software tool, so the students can **experience** these techniques using any number of available software tools. Specific suggestions are given in each chapter, but the student and the professor are able to use this book with many different software tools. Our book's companion Web site will include specific software guides, but students can gain **experience** with these techniques in many different ways. Finally, we hope that this **exposure** and **experience** enable and motivate readers to **explore** the potential of these techniques in their own domain. To facilitate such **exploration**, we include exercises that direct them to Teradata University Network and other sites as well that include team-oriented exercises where appropriate. In our own teaching experience, projects undertaken in the class facilitate such **exploration** after the students have been **exposed** to the myriad of applications and concepts in the book and they have **experienced** specific software introduced by the professor.

This edition of the book can be used to offer a one-semester overview course on analytics, which covers most or all of the topics/chapters included in the book. It can also be used to teach two consecutive courses. For example, one course could focus on the overall analytics coverage. It could cover selective sections of Chapters 1 and 3–9. A second course could focus on artificial intelligence and emerging technologies as the enablers of modern-day analytics as a subsequent course to the first course. This second course could cover portions of Chapters 1, 2, 6, 9, and 10–14. The book can be used to offer managerial-level exposure to applications and techniques as noted in the previous paragraph, but it also includes sufficient technical details in selected chapters to allow an instructor to focus on some technical methods and hands-on exercises.

Most of the specific improvements made in this eleventh edition concentrate on three areas: reorganization, content update/upgrade (including AI, machine-learning, chatbots, and robotics as enablers of analytics), and a sharper focus. Despite the many changes, we have preserved the comprehensiveness and user friendliness that have made the textbook a market leader in the last several decades. We have also optimized the book's size and content by eliminating older and redundant material and by adding and combining material that is parallel to the current trends and is also demanded by many professors. Finally, we present accurate and updated material that is not available in any other text. We next describe the changes in the eleventh edition.

The book is supported by a Web site (**www.pearsonglobaleditions.com**). We provide links to additional learning materials and software tutorials through a special section of the book Web site.

WHAT'S NEW IN THE ELEVENTH EDITION?

With the goal of improving the text and making it current with the evolving technology trends, this edition marks a major reorganization to better reflect on the current focus on analytics and its enabling technologies. The last three editions transformed the book from the traditional DSS to BI and then from BI to BA and fostered a tight linkage with the Teradata University Network (TUN). This edition is enhanced with new materials paralleling the latest trends in analytics including AI, machine learning, deep learning, robotics, IoT, and smart/robo-collaborative assisting systems and applications. The following summarizes the major changes made to this edition.

- ***New organization.*** The book is now organized around two main themes: (1) presentation of motivations, concepts, methods, and methodologies for different types of analytics (focusing heavily on predictive and prescriptive analytic), and (2) introduction and due coverage of new technology trends as the enablers of the modern-day analytics such as AI, machine learning, deep learning, robotics, IoT, smart/robo-collaborative assisting systems, etc. Chapter 1 provides an introduction to the journey of decision support and enabling technologies. It begins with a brief overview of the classical decision making and decision support systems. Then it moves to business intelligence, followed by an introduction to analytics, Big Data, and AI. We follow that with a deeper introduction to artificial intelligence in Chapter 2. Because data is fundamental to any analysis, Chapter 3 introduces data issues as well as descriptive analytics including statistical concepts and visualization. An online chapter covers data warehousing processes and fundamentals for those who like to dig deeper into these issues. The next section covers predictive analytics and machine learning. Chapter 4 provides an introduction to data mining applications and the data mining process. Chapter 5 introduces many of the common data mining techniques: classification, clustering, association mining, and so forth. Chapter 6 includes coverage of deep learning and cognitive computing. Chapter 7 focuses on

text mining applications as well as Web analytics, including social media analytics, sentiment analysis, and other related topics. The following section brings the "data science" angle to a further depth. Chapter 8 covers prescriptive analytics including optimization and simulation. Chapter 9 includes more details of Big Data analytics. It also includes introduction to cloud-based analytics as well as location analytics. The next section covers Robotics, social networks, AI, and the Internet of Things (IoT). Chapter 10 introduces robots in business and consumer applications and also studies the future impact of such devices on society. Chapter 11 focuses on collaboration systems, crowdsourcing, and social networks. Chapter 12 reviews personal assistants, chatbots, and the exciting developments in this space. Chapter 13 studies IoT and its potential in decision support and a smarter society. The ubiquity of wireless and GPS devices and other sensors is resulting in the creation of massive new databases and unique applications. Finally, Chapter 14 concludes with a brief discussion of security, privacy, and societal dimensions of analytics and AI.

We should note that several chapters included in this edition have been available in the following companion book: *Business Intelligence, Analytics, and Data Science: A Managerial Perspective*, 4th Edition, Pearson (2018) (Hereafter referred to as BI4e). The structure and contents of these chapters have been updated somewhat before inclusion in this edition of the book, but the changes are more significant in the chapters marked as new. Of course, several of the chapters that came from BI4e were not included in previous editions of this book.

- ***New chapters.*** The following chapters have been added:

  Chapter 2 "Artificial Intelligence: Concepts, Drivers, Major Technologies, and Business Applications" This chapter covers the essentials of AI, outlines its benefits, compares it with humans' intelligence, and describes the content of the field. Example applications in accounting, finance, human resource management, marketing and CRM, and production-operation management illustrate the benefits to business (100% new material)

  Chapter 6, "Deep Learning and Cognitive Computing" This chapter covers the generation of machine learning technique, deep learning as well as the increasingly more popular AI topic, cognitive computing. It is an almost entirely new chapter (90% new material).

  Chapter 10, "Robotics: Industrial and Consumer Applications" This chapter introduces many robotics applications in industry and for consumers and concludes with impacts of such advances on jobs and some legal ramifications (100% new material).

  Chapter 12, "Knowledge Systems: Expert Systems, Recommenders, Chatbots, Virtual Personal Assistants, and Robo Advisors" This new chapter concentrates on different types of knowledge systems. Specifically, we cover new generations of expert systems and recommenders, chatbots, enterprise chatbots, virtual personal assistants, and robo-advisors (95% new).

  Chapter 13, "The Internet of Things as a Platform for Intelligent Applications" This new chapter introduces IoT as an enabler to analytics and AI applications. The following technologies are described in detail: smart homes and appliances, smart cities (including factories), and autonomous vehicles (100% new).

  Chapter 14, "Implementation Issues: From Ethics and Privacy to Organizational and Societal Impacts" This mostly new chapter deals with implementation issues of intelligent systems (including analytics). The major issues covered are protection of privacy, intellectual property, ethics, technical issues (e.g., integration and security) and administrative issues. We also cover the impact of these technologies on organizations and people and specifically deal with the impact on work and

jobs. Special attention is given to possible unintended impacts of analytics and AI (robots). Then we look at relevant technology trends and conclude with an assessment of the future of analytics and AI (85% new).

- ***Streamlined coverage.*** We have optimized the book size and content by adding a lot of new material to cover new and cutting-edge analytics and AI trends and technologies while eliminating most of the older, less-used material. We use a dedicated Web site for the textbook to provide some of the older material as well as updated content and links.
- ***Revised and updated content.*** Several chapters have new opening vignettes that are based on recent stories and events. In addition, application cases throughout the book are new or have been updated to include recent examples of applications of a specific technique/model. These application case stories now include suggested questions for discussion to encourage class discussion as well as further exploration of the specific case and related materials. New Web site links have been added throughout the book. We also deleted many older product links and references. Finally, most chapters have new exercises, Internet assignments, and discussion questions throughout. The specific changes made to each chapter are as follows: Chapters 1, 3–5, and 7–9 borrow material from BI4e to a significant degree.

Chapter 1, "Overview of Business Intelligence, Analytics, Data Science, and Artificial Intelligence: Systems for Decision Support" This chapter includes some material from DSS10e Chapters 1 and 2, but includes several new application cases, entirely new material on AI, and of course, a new plan for the book (about 50% new material).

Chapter 3, "Nature of Data, Statistical Modeling, and Visualization"

- 75% new content.
- Most of the content related to nature of data and statistical analysis is new.
- New opening case.
- Mostly new cases throughout.

Chapter 4, "Data Mining Process, Methods, and Algorithms"

- 25% of the material is new.
- Some of the application cases are new.

Chapter 5, "Machine Learning Techniques for Predictive Analytics"

- 40% of the material is new.
- New machine-learning methods: naïve Bayes, Bayesian networks, and ensemble modeling.
- Most of the cases are new.

Chapter 7, "Text Mining, Sentiment Analysis, and Social Analytics"

- 25% of the material is new.
- Some of the cases are new.

Chapter 8, "Prescriptive Analytics: Optimization and Simulation"

- Several new optimization application exercises are included.
- A new application case is included.
- 20% of the material is new.

Chapter 9, "Big Data, Cloud Computing, and Location Analytics: Concepts and Tools" This material has bene updated substantially in this chapter to include greater coverage of stream analytics. It also updates material from Chapters 7 and 8 from BI4e (50% new material).

Chapter 11, "Group Decision Making, Collaborative Systems, and AI Support" The chapter is completely revised, regrouping group decision support. New topics include

collective and collaborative intelligence, crowdsourcing, swarm AI, and AI support of all related activities (80% new material).

We have retained many of the enhancements made in the last editions and updated the content. These are summarized next:

- ***Links to Teradata University Network (TUN).*** Most chapters include new links to TUN (**teradatauniversitynetwork.com**). We encourage the instructors to register and join **teradatauniversitynetwork.com** and explore the various content available through the site. The cases, white papers, and software exercises available through TUN will keep your class fresh and timely.
- ***Book title.*** As is already evident, the book's title and focus have changed.
- ***Software support.*** The TUN Web site provides software support at no charge. It also provides links to free data mining and other software. In addition, the site provides exercises in the use of such software.

THE SUPPLEMENT PACKAGE: WWW.PEARSONGLOBALEDITIONS.COM

A comprehensive and flexible technology-support package is available to enhance the teaching and learning experience. The following instructor and student supplements are available on the book's Web site, **www.pearsonglobaleditions.com**:

- ***Instructor's Manual.*** The Instructor's Manual includes learning objectives for the entire course and for each chapter, answers to the questions and exercises at the end of each chapter, and teaching suggestions (including instructions for projects). The Instructor's Manual is available on the secure faculty section of **www.pearsonglobaleditions.com**
- ***Test Item File and TestGen Software.*** The Test Item File is a comprehensive collection of true/false, multiple-choice, fill-in-the-blank, and essay questions. The questions are rated by difficulty level, and the answers are referenced by book page number. The Test Item File is available in Microsoft Word and in TestGen. Pearson Education's test-generating software is available from **www.pearsonglobaleditions.com**. The software is PC/MAC compatible and preloaded with all of the Test Item File questions. You can manually or randomly view test questions and drag-and-drop to create a test. You can add or modify test-bank questions as needed. Our TestGens are converted for use in BlackBoard, WebCT, Moodle, D2L, and Angel. These conversions can be found on **www.pearsonglobaleditions.com**. The TestGen is also available in Respondus and can be found on **www.respondus.com**.
- ***PowerPoint slides.*** PowerPoint slides are available that illuminate and build on key concepts in the text. Faculty can download the PowerPoint slides from **www.pearsonglobaleditions.com**.

ACKNOWLEDGMENTS

Many individuals have provided suggestions and criticisms since the publication of the first edition of this book. Dozens of students participated in class testing of various chapters, software, and problems and assisted in collecting material. It is not possible to name everyone who participated in this project, but our thanks go to all of them. Certain individuals made significant contributions, and they deserve special recognition.

First, we appreciate the efforts of those individuals who provided formal reviews of the first through eleventh editions (school affiliations as of the date of review):

Robert Blanning, Vanderbilt University
Ranjit Bose, University of New Mexico

Warren Briggs, Suffolk University
Lee Roy Bronner, Morgan State University
Charles Butler, Colorado State University
Sohail S. Chaudry, University of Wisconsin–La Crosse
Kathy Chudoba, Florida State University
Wingyan Chung, University of Texas
Woo Young Chung, University of Memphis
Paul "Buddy" Clark, South Carolina State University
Pi'Sheng Deng, California State University–Stanislaus
Joyce Elam, Florida International University
Kurt Engemann, Iona College
Gary Farrar, Jacksonville University
George Federman, Santa Clara City College
Jerry Fjermestad, New Jersey Institute of Technology
Joey George, Florida State University
Paul Gray, Claremont Graduate School
Orv Greynholds, Capital College (Laurel, Maryland)
Martin Grossman, Bridgewater State College
Ray Jacobs, Ashland University
Leonard Jessup, Indiana University
Jeffrey Johnson, Utah State University
Jahangir Karimi, University of Colorado Denver
Saul Kassicieh, University of New Mexico
Anand S. Kunnathur, University of Toledo
Shao-ju Lee, California State University at Northridge
Yair Levy, Nova Southeastern University
Hank Lucas, New York University
Jane Mackay, Texas Christian University
George M. Marakas, University of Maryland
Dick Mason, Southern Methodist University
Nick McGaughey, San Jose State University
Ido Millet, Pennsylvania State University–Erie
Benjamin Mittman, Northwestern University
Larry Moore, Virginia Polytechnic Institute and State University
Simitra Mukherjee, Nova Southeastern University
Marianne Murphy, Northeastern University
Peter Mykytyn, Southern Illinois University
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Loren Rees, Virginia Polytechnic Institute and State University
David Russell, Western New England College
Steve Ruth, George Mason University
Vartan Safarian, Winona State University
Glenn Shephard, San Jose State University
Jung P. Shim, Mississippi State University
Meenu Singh, Murray State University
Randy Smith, University of Virginia

James T. C. Teng, University of South Carolina
John VanGigch, California State University at Sacramento
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Paul J. A. van Vliet, University of Nebraska at Omaha
B. S. Vijayaraman, University of Akron
Howard Charles Walton, Gettysburg College
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Randy S. Weinberg, Saint Cloud State University
Jennifer Williams, University of Southern Indiana
Selim Zaim, Sehir University
Steve Zanakis, Florida International University
Fan Zhao, Florida Gulf Coast University
Hamed Majidi Zolbanin, Ball State University

Several individuals contributed material to the text or the supporting material. For this new edition, assistance from the following students and colleagues is gratefully acknowledged: Behrooz Davazdahemami, Bhavana Baheti, Varnika Gottipati, and Chakradhar Pathi (all of Oklahoma State University). Prof. Rick Wilson contributed some examples and new exercise questions for Chapter 8. Prof. Pankush Kalgotra (Auburn University) contributed the new streaming analytics tutorial in Chapter 9. Other contributors of materials for specific application stories are identified as sources in the respective sections. Susan Baskin, Imad Birouty, Sri Raghavan, and Yenny Yang of Teradata provided special help in identifying new TUN content for the book and arranging permissions for the same.

Many other colleagues and students have assisted us in developing previous editions or the recent edition of the companion book from which some of the content has been adapted in this revision. Some of that content is still included this edition. Their assistance and contributions are acknowledged as well in chronological order. Dr. Dave Schrader contributed the sports examples used in Chapter 1. These will provide a great introduction to analytics. We also thank INFORMS for their permission to highlight content from *Interfaces*. We also recognize the following individuals for their assistance in developing Previous edition of the book: Pankush Kalgotra, Prasoon Mathur, Rupesh Agarwal, Shubham Singh, Nan Liang, Jacob Pearson, Kinsey Clemmer, and Evan Murlette (all of Oklahoma State University). Their help for BI 4e is gratefully acknowledged. The Teradata Aster team, especially Mark Ott, provided the material for the opening vignette for Chapter 9. Dr. Brian LeClaire, CIO of Humana Corporation led with contributions of several real-life healthcare case studies developed by his team at Humana. Abhishek Rathi of vCreaTek contributed his vision of analytics in the retail industry. In addition, the following former PhD students and research colleagues of ours have provided content or advice and support for the book in many direct and indirect ways: Asil Oztekin, University of Massachusetts-Lowell; Enes Eryarsoy, Sehir University; Hamed Majidi Zolbanin, Ball State University; Amir Hassan Zadeh, Wright State University; Supavich (Fone) Pengnate, North Dakota State University; Christie Fuller, Boise State University; Daniel Asamoah, Wright State University; Selim Zaim, Istanbul Technical University; and Nihat Kasap, Sabanci University. Peter Horner, editor of *OR/MS Today*, allowed us to summarize new application stories from *OR/MS Today* and *Analytics Magazine*. We also thank INFORMS for their permission to highlight content from *Interfaces*. Assistance from Natraj Ponna, Daniel Asamoah, Amir Hassan-Zadeh, Kartik Dasika, and Angie Jungermann (all of Oklahoma State University) is gratefully acknowledged for DSS 10th edition. We also acknowledge Jongswas Chongwatpol (NIDA, Thailand) for the material on SIMIO software, and Kazim Topuz (University of Tulsa) for his contributions to the Bayesian networks section in

Chapter 5. For other previous editions, we acknowledge the contributions of Dave King (a technology consultant and former executive at JDA Software Group, Inc.) and Jerry Wagner (University of Nebraska–Omaha). Major contributors for earlier editions include Mike Goul (Arizona State University) and Leila A. Halawi (Bethune-Cookman College), who provided material for the chapter on data warehousing; Christy Cheung (Hong Kong Baptist University), who contributed to the chapter on knowledge management; Linda Lai (Macau Polytechnic University of China); Lou Frenzel, an independent consultant whose books *Crash Course in Artificial Intelligence and Expert Systems* and *Understanding of Expert Systems* (both published by Howard W. Sams, New York, 1987) provided material for the early editions; Larry Medsker (American University), who contributed substantial material on neural networks; and Richard V. McCarthy (Quinnipiac University), who performed major revisions in the seventh edition.

Previous editions of the book have also benefited greatly from the efforts of many individuals who contributed advice and interesting material (such as problems), gave feedback on material, or helped with class testing. These include Warren Briggs (Suffolk University), Frank DeBalough (University of Southern California), Mei-Ting Cheung (University of Hong Kong), Alan Dennis (Indiana University), George Easton (San Diego State University), Janet Fisher (California State University, Los Angeles), David Friend (Pilot Software, Inc.), the late Paul Gray (Claremont Graduate School), Mike Henry (OSU), Dustin Huntington (Exsys, Inc.), Subramanian Rama Iyer (Oklahoma State University), Elena Karahanna (The University of Georgia), Mike McAulliffe (The University of Georgia), Chad Peterson (The University of Georgia), Neil Rabjohn (York University), Jim Ragusa (University of Central Florida), Alan Rowe (University of Southern California), Steve Ruth (George Mason University), Linus Schrage (University of Chicago), Antonie Stam (University of Missouri), Late Ron Swift (NCR Corp.), Merril Warkentin (then at Northeastern University), Paul Watkins (The University of Southern California), Ben Mortagy (Claremont Graduate School of Management), Dan Walsh (Bellcore), Richard Watson (The University of Georgia), and the many other instructors and students who have provided feedback.

Several vendors cooperated by providing development and/or demonstration software: Dan Fylstra of Frontline Systems, Gregory Piatetsky-Shapiro of **KDNuggets.com**, Logic Programming Associates (UK), Gary Lynn of NeuroDimension Inc. (Gainesville, Florida), Palisade Software (Newfield, New York), Jerry Wagner of Planners Lab (Omaha, Nebraska), Promised Land Technologies (New Haven, Connecticut), Salford Systems (La Jolla, California), Gary Miner of StatSoft, Inc. (Tulsa, Oklahoma), Ward Systems Group, Inc. (Frederick, Maryland), Idea Fisher Systems, Inc. (Irving, California), and Wordtech Systems (Orinda, California).

Special thanks to the Teradata University Network and especially to Hugh Watson, Michael Goul, and Susan Baskin, Program Director, for their encouragement to tie this book with TUN and for providing useful material for the book.

Many individuals helped us with administrative matters and editing, proofreading, and preparation. The project began with Jack Repcheck (a former Macmillan editor), who initiated this project with the support of Hank Lucas (New York University). Jon Outland assisted with the supplements.

Finally, the Pearson team is to be commended: Executive Editor Samantha Lewis who orchestrated this project; the copyeditors; and the production team, Faraz Sharique Ali at Pearson, and Gowthaman and staff at Integra Software Services, who transformed the manuscript into a book.

We would like to thank all these individuals and corporations. Without their help, the creation of this book would not have been possible. We want to specifically acknowledge the contributions of previous coauthors Janine Aronson, David King, and T. P. Liang, whose original contributions constitute significant components of the book.

R.S.

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E.T.

GLOBAL EDITION ACKNOWLEDGMENTS

Pearson would like to thank the following people for their work on the Global Edition:

Contributor

Stefania Paladini, Birmingham City University

Reviewers

Xavier Pierron, Edinburgh Napier University
Qizhang Liu, National University of Singapore
Krish Saha, Birmingham City University

Note that Web site URLs are dynamic. As this book went to press, we verified that all the cited Web sites were active and valid. Web sites to which we refer in the text sometimes change or are discontinued because companies change names, are bought or sold, merge, or fail. Sometimes Web sites are down for maintenance, repair, or redesign. Most organizations have dropped the initial "www" designation for their sites, but some still use it. If you have a problem connecting to a Web site that we mention, please be patient and simply run a Web search to try to identify the new site. Most times, the new site can be found quickly. Some sites also require a free registration before allowing you to see the content. We apologize in advance for this inconvenience.

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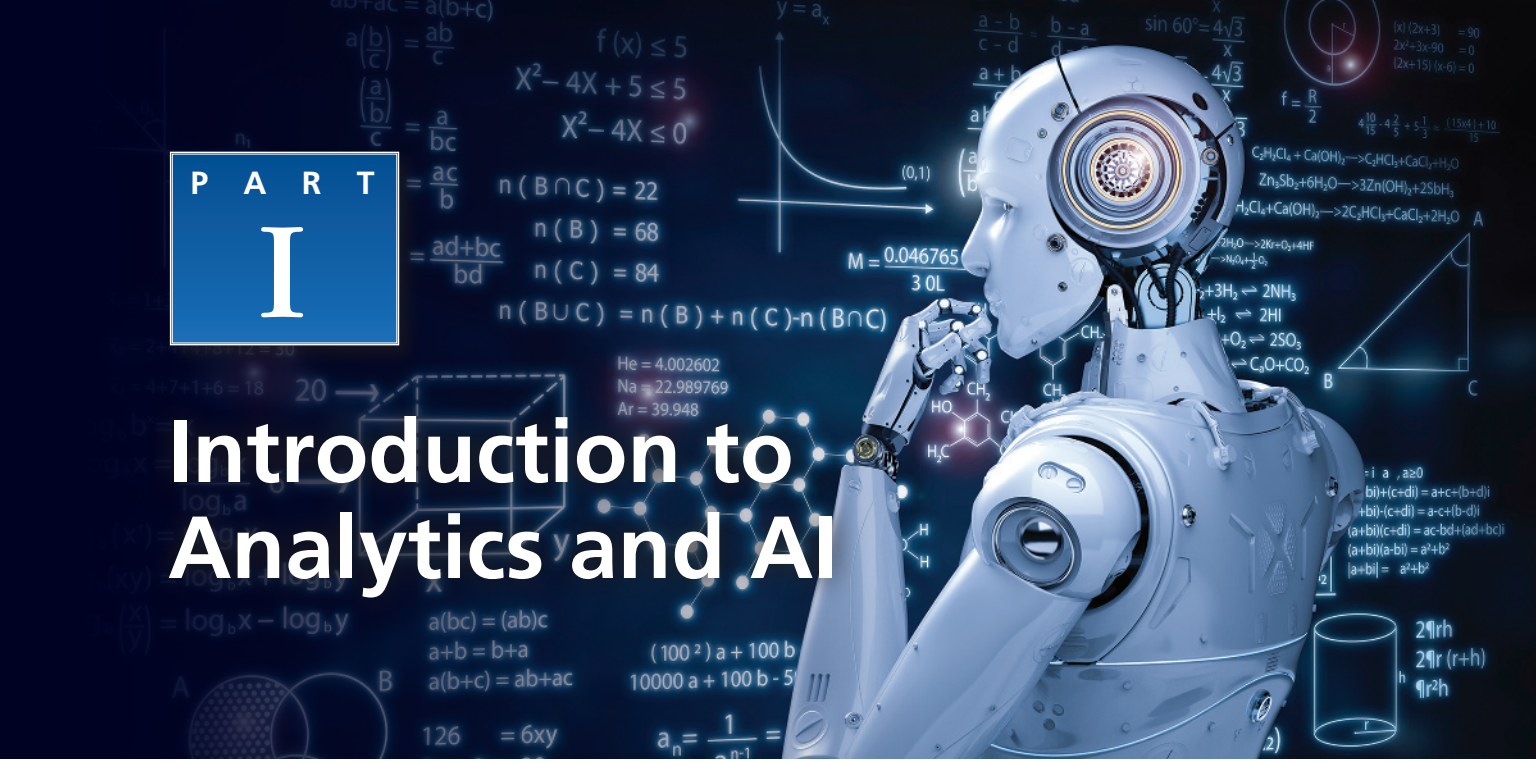
PART
I
Introduction to Analytics and AI

CHAPTER

1

Overview of Business Intelligence, Analytics, Data Science, and Artificial Intelligence: Systems for Decision Support

LEARNING OBJECTIVES

- Understand the need for computerized support of managerial decision making
- Understand the development of systems for providing decision-making support
- Recognize the evolution of such computerized support to the current state of analytics/data science and artificial intelligence
- Describe the business intelligence (BI) methodology and concepts
- Understand the different types of analytics and review selected applications
- Understand the basic concepts of artificial intelligence (AI) and see selected applications
- Understand the analytics ecosystem to identify various key players and career opportunities

The business environment (climate) is constantly changing, and it is becoming more and more complex. Organizations, both private and public, are under pressures that force them to respond quickly to changing conditions and to be innovative in the way they operate. Such activities require organizations to be agile and to make frequent and quick strategic, tactical, and operational decisions, some of which are very complex. Making such decisions may require considerable amounts of relevant data, information, and knowledge. Processing these in the framework of the needed decisions must be done quickly, frequently in real time, and usually requires some computerized support. As technologies are evolving, many decisions are being automated, leading to a major impact on knowledge work and workers in many ways.

This book is about using business analytics and artificial intelligence (AI) as a computerized support portfolio for managerial decision making. It concentrates on the

theoretical and conceptual foundations of decision support as well as on the commercial tools and techniques that are available. The book presents the fundamentals of the techniques and the manner in which these systems are constructed and used. We follow an EEE (*exposure, experience*, and *exploration*) approach to introducing these topics. The book primarily provides exposure to various analytics/AI techniques and their applications. The idea is that students will be inspired to learn from how various organizations have employed these technologies to make decisions or to gain a competitive edge. We believe that such exposure to what is being accomplished with analytics and that how it can be achieved is the key component of learning about analytics. In describing the techniques, we also give examples of specific software tools that can be used for developing such applications. However, the book is not limited to any one software tool, so students can experience these techniques using any number of available software tools. We hope that this *exposure* and *experience* enable and motivate readers to *explore* the potential of these techniques in their own domain. To facilitate such exploration, we include exercises that direct the reader to Teradata University Network (TUN) and other sites that include team-oriented exercises where appropriate. In our own teaching experience, projects undertaken in the class facilitate such exploration after students have been exposed to the myriad of applications and concepts in the book and they have experienced specific software introduced by the professor.

This introductory chapter provides an introduction to analytics and artificial intelligence as well as an overview of the book. The chapter has the following sections:

1.1 OPENING VIGNETTE: How Intelligent Systems Work for KONE Elevators and Escalators Company

KONE is a global industrial company (based in Finland) that manufactures mostly elevators and escalators and also services over 1.1 million elevators, escalators, and related equipment in several countries. The company employs over 50,000 people.

THE PROBLEM

Over 1 billion people use the elevators and escalators manufactured and serviced by KONE every day. If equipment does not work properly, people may be late to work, cannot get home in time, and may miss important meetings and events. So, KONE's objective is to minimize the downtime and users' suffering.

The company has over 20,000 technicians who are dispatched to deal with the elevators anytime a problem occurs. As buildings are getting higher (the trend in many places), more people are using elevators, and there is more pressure on elevators to handle the growing amount of traffic. KONE faced the responsibility to serve users smoothly and safely.

THE SOLUTION

KONE decided to use IBM Watson IoT Cloud platform. As we will see in Chapter 6, IBM installed cognitive abilities in buildings that make it possible to recognize situations and behavior of both people and equipment. The Internet of Things (IoT), as we will see in Chapter 13, is a platform that can connect millions of "things" together and to a central command that can manipulate the connected things. Also, the IoT connects sensors that are attached to KONE's elevators and escalators. The sensors collect information and data about the elevators (such as noise level) and other equipment in real time. Then, the IoT transfers to information centers via the collected data "cloud." There, analytic systems (IBM Advanced Analytic Engine) and AI process the collected data and predict things such as potential failures. The systems also identify the likely causes of problems and suggest potential remedies. Note the predictive power of IBM Watson Analytics (using machine learning, an AI technology described in Chapters 4–6) for finding problems before they occur.

The KONE system collects a significant amount of data that are analyzed for other purposes so that future design of equipment can be improved. This is because Watson Analytics offers a convenient environment for communication of and collaboration around the data. In addition, the analysis suggests how to optimize buildings and equipment operations. Finally, KONE and its customers can get insights regarding the financial aspects of managing the elevators.

KONE also integrates the Watson capabilities with Salesforce's service tools (Service Cloud Lightning and Field Service Lightning). This combination helps KONE to immediately respond to emergencies or soon-to-occur failures as quickly as possible, dispatching some of its 20,000 technicians to the problems' sites. Salesforce also provides superb customer relationship management (CRM). The people–machine communication, query, and collaboration in the system are in a natural language (an AI capability of Watson Analytics; see Chapter 6). Note that IBM Watson analytics includes two types of analytics: *predictive*, which predicts when failures may occur, and *prescriptive*, which recommends actions (e.g., preventive maintenance).

THE RESULTS

KONE has minimized downtime and shortened the repair time. Obviously, elevators/escalators users are much happier if they do not have problems because of equipment downtime, so they enjoy trouble-free rides. The prediction of "soon-to-happen" can save many problems for the equipment owners. The owners can also optimize the schedule of their own employees (e.g., cleaners and maintenance workers). All in all, the decision makers at both KONE and the buildings can make informed and better decisions. Some day in the future, robots may perform maintenance and repairs of elevators and escalators.

Note: This case is a sample of IBM Watson's success using its cognitive buildings capability. To learn more, we suggest you view the following YouTube videos: (1) **youtube.com/watch?v=6UPJHyiJft0** (1:31 min.) (2017); (2) **youtube.com/watch?v=EVbd3ejEXus** (2:49 min.) (2017).

Sources: Compiled from J. Fernandez. (2017, April). "A Billion People a Day. Millions of Elevators. No Room for Downtime." IBM developer Works Blog. **developer.ibm.com/dwblog/2017/kone-watson-video/** (accessed September 2018); H. Srikanthan. "KONE Improves 'People Flow' in 1.1 Million Elevators with IBM Watson IoT." Generis. **https://generisgp.com/2018/01/08/ibm-case-study-kone-corp/** (accessed September 2018); L. Slowey. (2017, February 16). "Look Who's Talking: KONE Makes Elevator Services Truly Intelligent with Watson IoT." IBM Internet of Things Blog. **ibm.com/blogs/internet-of-things/kone/** (accessed September 2018).

QUESTIONS FOR THE OPENING VIGNETTE

1. It is said that KONE is embedding intelligence across its supply chain and enables smarter buildings. Explain.
2. Describe the role of IoT in this case.
3. What makes IBM Watson a necessity in this case?
4. Check IBM Advanced Analytics. What tools were included that relate to this case?
5. Check IBM cognitive buildings. How do they relate to this case?

WHAT CAN WE LEARN FROM THIS VIGNETTE?

Today, intelligent technologies can embark on large-scale complex projects when they include AI combined with IoT. The capabilities of integrated intelligent platforms, such as IBM Watson, make it possible to solve problems that were economically and technologically unsolvable just a few years ago. The case introduces the reader to several of the technologies, including advanced analytics, sensors, IoT, and AI that are covered in this book. The case also points to the use of "cloud." The cloud is used to centrally process large amounts of information using analytics and AI algorithms, involving "things" in different locations. This vignette also introduces us to two major types of analytics: predictive analytics (Chapters 4–6) and prescriptive analytics (Chapter 8).

Several AI technologies are discussed: machine learning, natural language processing, computer vision, and prescriptive analysis.

The case is an example of *augmented intelligence* in which people and machines work together. The case illustrates the benefits to the vendor, the implementing companies, and their employees and to the users of the elevators and escalators.

1.2 CHANGING BUSINESS ENVIRONMENTS AND EVOLVING NEEDS FOR DECISION SUPPORT AND ANALYTICS

Decision making is one of the most important activities in organizations of all kind—probably the most important one. Decision making leads to the success or failure of organizations and how well they perform. Making decisions is getting difficult due to internal and external factors. The rewards of making appropriate decisions can be very high and so can the loss of inappropriate ones.

Unfortunately, it is not simple to make decisions. To begin with, there are several types of decisions, each of which requires a different decision-making approach. For example, De Smet et al. (2017) of McKinsey & Company management consultants classify organizational decision into the following four groups:

- Big-bet, high-risk decisions.
- Cross-cutting decisions, which are repetitive but high risk that require group work (Chapter 11).
- Ad hoc decisions that arise episodically.
- Delegated decisions to individuals or small groups.

Therefore, it is necessary first to understand the nature of decision making. For a comprehensive discussion, see (De Smet et al. 2017).

Modern business is full of uncertainties and rapid changes. To deal with these, organizational decision makers need to deal with ever-increasing and changing data. This book is about the technologies that can assist decision makers in their jobs.

Decision-Making Process

For years, managers considered decision making purely an art—a talent acquired over a long period through experience (i.e., learning by trial and error) and by using intuition. Management was considered an art because a variety of individual styles could be used in approaching and successfully solving the same types of managerial problems. These styles were often based on creativity, judgment, intuition, and experience rather than on systematic quantitative methods grounded in a scientific approach. However, recent research suggests that companies with top managers who are more focused on persistent work tend to outperform those with leaders whose main strengths are interpersonal communication skills. It is more important to emphasize methodical, thoughtful, analytical decision making rather than flashiness and interpersonal communication skills.

Managers usually make decisions by following a four-step process (we learn more about these in the next section):

1. Define the problem (i.e., a decision situation that may deal with some difficulty or with an opportunity).
2. Construct a model that describes the real-world problem.
3. Identify possible solutions to the modeled problem and evaluate the solutions.
4. Compare, choose, and recommend a potential solution to the problem.

A more detailed process is offered by Quain (2018), who suggests the following steps:

1. Understand the decision you have to make.
2. Collect all the information.
3. Identify the alternatives.
4. Evaluate the pros and cons.
5. Select the best alternative.
6. Make the decision.
7. Evaluate the impact of your decision.

We will return to this process in Section 1.3.

The Influence of the External and Internal Environments on the Process

To follow these decision-making processes, one must make sure that sufficient alternative solutions, including good ones, are being considered, that the consequences of using these alternatives can be reasonably predicted, and that comparisons are done properly. However, rapid changes in internal and external environments make such an evaluation process difficult for the following reasons:

- Technology, information systems, advanced search engines, and globalization result in more and more alternatives from which to choose.
- Government regulations and the need for compliance, political instability and terrorism, competition, and changing consumer demands produce more uncertainty, making it more difficult to predict consequences and the future.
  - **Political factors.** Major decisions may be influenced by both external and internal politics. An example is the 2018 trade war on tariffs.
  - **Economic factors.** These range from competition to the genera and state of the economy. These factors, both in the short and long run, need to be considered.

- **Sociological and psychological factors regarding employees and customers.** These need to be considered when changes are being made.
- **Environment factors.** The impact on the physical environment must be assessed in many decision-making situations.

Other factors include the need to make rapid decisions, the frequent and unpredictable changes that make trial-and-error learning difficult, and the potential costs of making mistakes that may be large.

These environments are growing more complex every day. Therefore, making decisions today is indeed a complex task. For further discussion, see Charles (2018). For how to make effective decisions under uncertainty and pressure, see Zane (2016).

Because of these trends and changes, it is nearly impossible to rely on a trial-and-error approach to management. Managers must be more sophisticated; they must use the new tools and techniques of their fields. Most of those tools and techniques are discussed in this book. Using them to support decision making can be extremely rewarding in making effective decisions. Further, many tools that are evolving impact even the very existence of several decision-making tasks that are being automated. This impacts future demand for knowledge workers and begs many legal and societal impact questions.

Data and Its Analysis in Decision Making

We will see several times in this book how an entire industry can employ analytics to develop reports on what is happening, predict what is likely to happen, and then make decisions to make the best use of the situation at hand. These steps require an organization to collect and analyze vast stores of data. In general, the amount of data doubles every two years. From traditional uses in payroll and bookkeeping functions, computerized systems are now used for complex managerial areas ranging from the design and management of automated factories to the application of analytical methods for the evaluation of proposed mergers and acquisitions. Nearly all executives know that information technology is vital to their business and extensively use these technologies.

Computer applications have moved from transaction-processing and monitoring activities to problem analysis and solution applications, and much of the activity is done with cloud-based technologies, in many cases accessed through mobile devices. Analytics and BI tools such as data warehousing, data mining, online analytical processing (OLAP), dashboards, and the use of cloud-based systems for decision support are the cornerstones of today's modern management. Managers must have high-speed, networked information systems (wired or wireless) to assist them with their most important task: making decisions. In many cases, such decisions are routinely being fully automated (see Chapter 2), eliminating the need for any managerial intervention.

Technologies for Data Analysis and Decision Support

Besides the obvious growth in hardware, software, and network capacities, some developments have clearly contributed to facilitating the growth of decision support and analytics technologies in a number of ways:

- **Group communication and collaboration.** Many decisions are made today by groups whose members may be in different locations. Groups can collaborate and communicate readily by using collaboration tools as well as the ubiquitous smartphones. Collaboration is especially important along the supply chain, where partners—all the way from vendors to customers—must share information. Assembling a group of decision makers, especially experts, in one place can be

costly. Information systems can improve the collaboration process of a group and enable its members to be at different locations (saving travel costs). More critically, such supply chain collaboration permits manufacturers to know about the changing patterns of demand in near real time and thus react to marketplace changes faster. For a comprehensive coverage and the impact of AI, see Chapters 2, 10, and 14.

- **Improved data management.** Many decisions involve complex computations. Data for these can be stored in different databases anywhere in the organization and even possibly outside the organization. The data may include text, sound, graphics, and video, and these can be in different languages. Many times it is necessary to transmit data quickly from distant locations. Systems today can search, store, and transmit needed data quickly, economically, securely, and transparently. See Chapters 3 and 9 and the online chapter for details.
- **Managing giant data warehouses and Big Data.** Large data warehouses (DWs), like the ones operated by Walmart, contain huge amounts of data. Special methods, including parallel computing and Hadoop/Spark, are available to organize, search, and mine the data. The costs related to data storage and mining are declining rapidly. Technologies that fall under the broad category of Big Data have enabled massive data coming from a variety of sources and in many different forms, which allows a very different view of organizational performance that was not possible in the past. See Chapter 9 for details.
- **Analytical support.** With more data and analysis technologies, more alternatives can be evaluated, forecasts can be improved, risk analysis can be performed quickly, and the views of experts (some of whom may be in remote locations) can be collected quickly and at a reduced cost. Expertise can even be derived directly from analytical systems. With such tools, decision makers can perform complex simulations, check many possible scenarios, and assess diverse impacts quickly and economically.This, of course, is the focus of several chapters in the book. See Chapters 4–7.
- **Overcoming cognitive limits in processing and storing information.** The human mind has only a limited ability to process and store information. People sometimes find it difficult to recall and use information in an error-free fashion due to their cognitive limits. The term *cognitive limits* indicates that an individual's problem-solving capability is limited when a wide range of diverse information and knowledge is required. Computerized systems enable people to overcome their cognitive limits by quickly accessing and processing vast amounts of stored information. One way to overcome humans' cognitive limitations is to use AI support. For coverage of cognitive aspects, see Chapter 6.
- **Knowledge management.** Organizations have gathered vast stores of information about their own operations, customers, internal procedures, employee interactions, and so forth through the unstructured and structured communications taking place among various stakeholders. Knowledge management systems (KMS) have become sources of formal and informal support for decision making to managers, although sometimes they may not even be called *KMS*. Technologies such as text analytics and IBM Watson are making it possible to generate value from such knowledge stores. (See Chapters 6 and 12 for details.)
- **Anywhere, anytime support.** Using wireless technology, managers can access information anytime and from any place, analyze and interpret it, and communicate with those using it. This perhaps is the biggest change that has occurred in the last few years. The speed at which information needs to be processed and converted into decisions has truly changed expectations for both consumers and businesses. These and other capabilities have been driving the use of computerized decision support since the late 1960s, especially since the mid-1990s. The growth of mobile technologies, social media platforms, and analytical tools has enabled a different level of information systems (IS) to support managers. This growth in providing

data-driven support for any decision extends not just to managers but also to consumers. We will first study an overview of technologies that have been broadly referred to as BI. From there we will broaden our horizons to introduce various types of analytics.

- **Innovation and artificial intelligence.** Because of the complexities in the decision-making process discussed earlier and the environment surrounding the process, a more innovative approach is frequently need. A major facilitation of innovation is provided by AI. Almost every step in the decision-making process can be influenced by AI. AI is also integrated with analytics, creating synergy in making decisions (Section 1.8).

SECTION 1.2 REVIEW QUESTIONS

1. Why is it difficult to make organizational decisions?
2. Describe the major steps in the decision-making process.
3. Describe the major external environments that can impact decision making.
4. What are some of the key system-oriented trends that have fostered IS-supported decision making to a new level?
5. List some capabilities of information technologies that can facilitate managerial decision making.

1.3 DECISION-MAKING PROCESSES AND COMPUTERIZED DECISION SUPPORT FRAMEWORK

In this section, we focus on some classical decision-making fundamentals and in more detail on the decision-making process. These two concepts will help us ground much of what we will learn in terms of analytics, data science, and artificial intelligence.

Decision making is a process of choosing among two or more alternative courses of action for the purpose of attaining one or more goals. According to Simon (1977), managerial decision making is synonymous with the entire management process. Consider the important managerial function of planning. Planning involves a series of decisions: What should be done? When? Where? Why? How? By whom? Managers set goals, or plan; hence, planning implies decision making. Other managerial functions, such as organizing and controlling, also involve decision making.

Simon's Process: Intelligence, Design, and Choice

It is advisable to follow a systematic decision-making process. Simon (1977) said that this involves three major phases: intelligence, design, and choice. He later added a fourth phase: implementation. Monitoring can be considered a fifth phase—a form of feedback. However, we view monitoring as the *intelligence phase* applied to the *implementation phase*. Simon's model is the most concise and yet complete characterization of rational decision making. A conceptual picture of the decision-making process is shown in Figure 1.1. It is also illustrated as a decision support approach using modeling.

There is a continuous flow of activity from intelligence to design to choice (see the solid lines in Figure 1.1), but at any phase, there may be a return to a previous phase (feedback). Modeling is an essential part of this process. The seemingly chaotic nature of following a haphazard path from problem discovery to solution via decision making can be explained by these feedback loops.

The decision-making process starts with the **intelligence phase**; in this phase, the decision maker examines reality and identifies and defines the problem. *Problem ownership* is established as well. In the **design phase**, a model that represents the system is constructed. This is done by making assumptions that simplify reality and by writing down

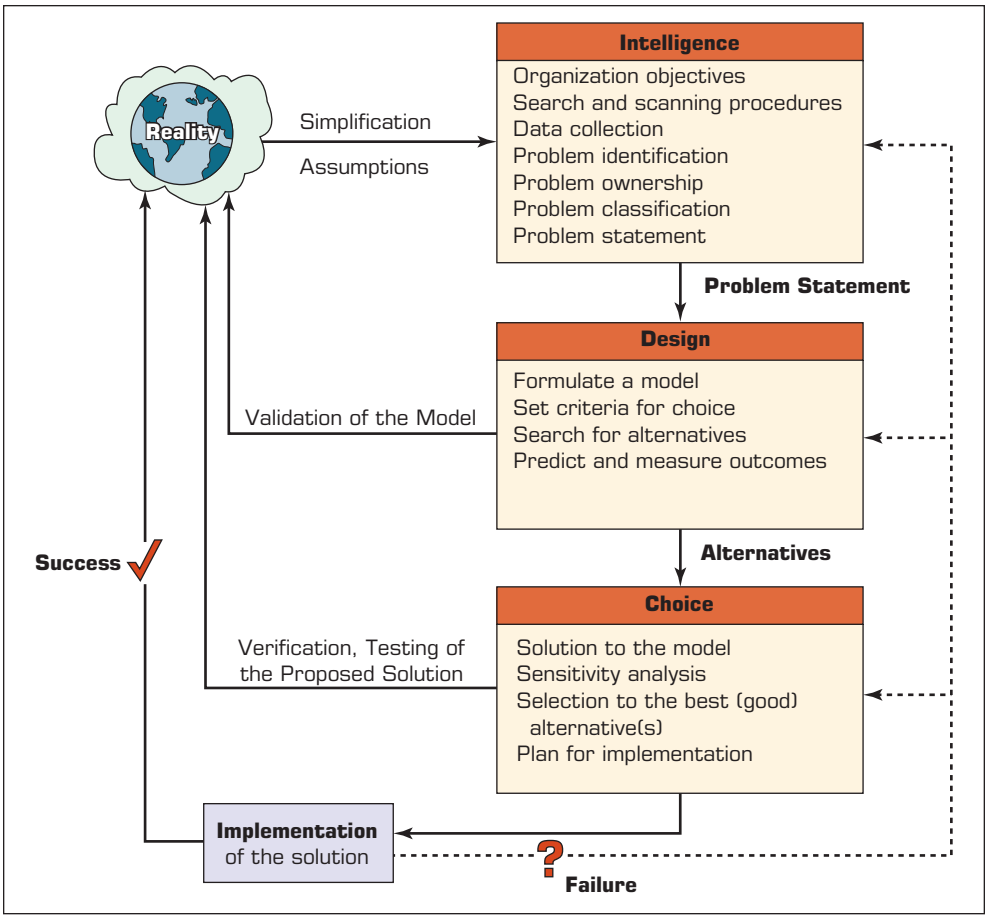

FIGURE 1.1 **The Decision-Making/Modeling Process.**

the relationships among all the variables. The model is then validated, and criteria are determined in a principle of choice for evaluation of the alternative courses of action that are identified. Often, the process of model development identifies alternative solutions and vice versa.

The **choice phase** includes the selection of a proposed solution to the model (not necessarily to the problem it represents). This solution is tested to determine its viability. When the proposed solution seems reasonable, we are ready for the last phase: implementation of the decision (not necessarily of a system). Successful implementation results in solving the real problem. Failure leads to a return to an earlier phase of the process. In fact, we can return to an earlier phase during any of the latter three phases. The decision-making situations described in the opening vignette follow Simon's four-phase model, as do almost all other decision-making situations.

The Intelligence Phase: Problem (or Opportunity) Identification

The intelligence phase begins with the identification of organizational goals and objectives related to an issue of concern (e.g., inventory management, job selection, lack of or incorrect Web presence) and determination of whether they are being met. Problems occur because of dissatisfaction with the status quo. Dissatisfaction is the result of a difference between what people desire (or expect) and what is occurring. In this first phase, a decision maker attempts to determine whether a problem exists, identify its symptoms, determine its magnitude, and

explicitly define it. Often, what is described as a problem (e.g., excessive costs) may be only a symptom (i.e., measure) of a problem (e.g., improper inventory levels). Because real-world problems are usually complicated by many interrelated factors, it is sometimes difficult to distinguish between the symptoms and the real problem. New opportunities and problems certainly may be uncovered while investigating the causes of symptoms.

The existence of a problem can be determined by monitoring and analyzing the organization's productivity level. The measurement of productivity and the construction of a model are based on real data. The collection of data and the estimation of future data are among the most difficult steps in the analysis.

ISSUES IN DATA COLLECTION The following are some issues that may arise during data collection and estimation and thus plague decision makers:

- Data are not available. As a result, the model is made with and relies on potentially inaccurate estimates.
- Obtaining data may be expensive.
- Data may not be accurate or precise enough.
- Data estimation is often subjective.
- Data may be insecure.
- Important data that influence the results may be qualitative (soft).
- There may be too many data (i.e., information overload).
- Outcomes (or results) may occur over an extended period. As a result, revenues, expenses, and profits will be recorded at different points in time. To overcome this difficulty, a present-value approach can be used if the results are quantifiable.
- It is assumed that future data will be similar to historical data. If this is not the case, the nature of the change has to be predicted and included in the analysis.

When the preliminary investigation is completed, it is possible to determine whether a problem really exists, where it is located, and how significant it is. A key issue is whether an information system is reporting a problem or only the symptoms of a problem. For example, if reports indicate that sales are down, there is a problem, but the situation, no doubt, is symptomatic of the problem. It is critical to know the real problem. Sometimes it may be a problem of perception, incentive mismatch, or organizational processes rather than a poor decision model.

To illustrate why it is important to identify the problem correctly, we provide a classical example in Application Case 1.1.

Application Case 1.1 Making Elevators Go Faster!

This story has been reported in numerous places and has almost become a classic example to explain the need for problem identification. Ackoff (as cited in Larson, 1987) described the problem of managing complaints about slow elevators in a tall hotel tower. After trying many solutions for reducing the complaint—staggering elevators to go to different floors, adding operators, and so on—the management determined that the real problem was not about the *actual* waiting time but rather the *perceived* waiting time. So the solution was to install full-length mirrors on elevator doors on each floor. As Hesse and Woolsey (1975) put it, "The women would look at themselves in the mirrors and make adjustments, while the men would look at the women, and before they knew it, the elevator was there." By reducing the perceived waiting time, the problem went away. Baker and Cameron (1996)

(*Continued*)

Application Case 1.1 (Continued)

give several other examples of distractions, including lighting and displays, that organizations use to reduce perceived waiting time. If the real problem is identified as *perceived* waiting time, it can make a big difference in the proposed solutions and their costs. For example, full-length mirrors probably cost a whole lot less than adding an elevator!

Sources: Based on J. Baker and M. Cameron. (1996, September). "The Effects of the Service Environment on Affect and Consumer Perception of Waiting Time: An Integrative Review and Research Propositions," *Journal of the Academy of Marketing Science, 24,* pp. 338–349; R. Hesse and G. Woolsey (1975). *Applied Management Science: A Quick and Dirty Approach.* Chicago, IL: SRA Inc; R. C. Larson. (1987, November/December). "Perspectives on Queues: Social Justice and the Psychology of Queuing." *Operations Research, 35*(6), pp. 895–905.

Questions for Case 1.1

1. Why this is an example relevant to decision making?
2. Relate this situation to the intelligence phase of decision making.

PROBLEM CLASSIFICATION Problem classification is the conceptualization of a problem in an attempt to place it in a definable category, possibly leading to a standard solution approach. An important approach classifies problems according to the degree of structuredness evident in them. This ranges from totally structured (i.e., programmed) to totally unstructured (i.e., unprogrammed).

PROBLEM DECOMPOSITION Many complex problems can be divided into subproblems. Solving the simpler subproblems may help in solving a complex problem. Also, seemingly poorly structured problems sometimes have highly structured subproblems. Just as a semistructured problem results when some phases of decision making are structured whereas other phases are unstructured, and when some subproblems of a decision-making problem are structured with others unstructured, the problem itself is semistructured. As a decision support system is developed and the decision maker and development staff learn more about the problem, it gains structure.

PROBLEM OWNERSHIP In the intelligence phase, it is important to establish problem ownership. A problem exists in an organization only if someone or some group takes the responsibility for attacking it and if the organization has the ability to solve it. The assignment of authority to solve the problem is called *problem ownership*. For example, a manager may feel that he or she has a problem because interest rates are too high. Because interest rate levels are determined at the national and international levels and most managers can do nothing about them, high interest rates are the problem of the government, not a problem for a specific company to solve. The problem that companies actually face is how to operate in a high interest-rate environment. For an individual company, the interest rate level should be handled as an uncontrollable (environmental) factor to be predicted.

When problem ownership is not established, either someone is not doing his or her job or the problem at hand has yet to be identified as belonging to anyone. It is then important for someone to either volunteer to own it or assign it to someone.

The intelligence phase ends with a formal problem statement.

The Design Phase

The design phase involves finding or developing and analyzing possible courses of action. These include understanding the problem and testing solutions for feasibility. A model of the decision-making problem is constructed, tested, and validated. Let us first define a model.

MODELS A major characteristic of computerized decision support and many BI tools (notably those of business analytics) is the inclusion of at least one model. The basic idea is to perform the analysis on a model of reality rather than on the real system. A *model* is a simplified representation or abstraction of reality. It is usually simplified because reality is too complex to describe exactly and because much of the complexity is actually irrelevant in solving a specific problem.

Modeling involves conceptualizing a problem and abstracting it to quantitative and/or qualitative form. For a mathematical model, the variables are identified and their mutual relationships are established. Simplifications are made, whenever necessary, through assumptions. For example, a relationship between two variables may be assumed to be linear even though in reality there may be some nonlinear effects. A proper balance between the level of model simplification and the representation of reality must be obtained because of the cost–benefit trade-off. A simpler model leads to lower development costs, easier manipulation, and a faster solution but is less representative of the real problem and can produce inaccurate results. However, a simpler model generally requires fewer data, or the data are aggregated and easier to obtain.

The Choice Phase

Choice is the critical act of decision making. The choice phase is the one in which the actual decision and the commitment to follow a certain course of action are made. The boundary between the design and choice phases is often unclear because certain activities can be performed during both of them and because the decision maker can return frequently from choice activities to design activities (e.g., generate new alternatives while performing an evaluation of existing ones). The choice phase includes the search for, evaluation of, and recommendation of an appropriate solution to a model. A solution to a model is a specific set of values for the decision variables in a selected alternative. Choices can be evaluated as to their viability and profitability.

Each alternative must be evaluated. If an alternative has multiple goals, they must all be examined and balanced against each other. Sensitivity analysis is used to determine the robustness of any given alternative; slight changes in the parameters should ideally lead to slight or no changes in the alternative chosen. What-if analysis is used to explore major changes in the parameters. Goal seeking helps a manager determine values of the decision variables to meet a specific objective. These topics are addressed in Chapter 8.

The Implementation Phase

In *The Prince*, Machiavelli astutely noted some 500 years ago that there was "nothing more difficult to carry out, nor more doubtful of success, nor more dangerous to handle, than to initiate a new order of things." The implementation of a proposed solution to a problem is, in effect, the initiation of a new order of things or the introduction of change. And change must be managed. User expectations must be managed as part of change management.

The definition of *implementation* is somewhat complicated because implementation is a long, involved process with vague boundaries. Simplistically, the **implementation phase** involves putting a recommended solution to work, not necessarily implementing a computer system. Many generic implementation issues, such as resistance to change, degree of support of top management, and user training, are important in dealing with information system–supported decision making. Indeed, many previous technology-related waves (e.g., business process reengineering [BPR] and knowledge management) have faced mixed results mainly because of change management challenges and issues. Management of change is almost an entire discipline in itself, so we recognize its importance and encourage readers to focus on it independently. Implementation also includes