BUSINESS ANALYTICS

PRINCIPLES, CONCEPTS, AND APPLICATIONS

WHAT, WHY, and HOW

MARC J. SCHNIEDERJANS • DARA G. SCHNIEDERJANS • CHRISTOPHER M. STARKEY

Business Analytics Principles, Concepts, and Applications

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This book is dedicated to Miles Starkey.
He is what brings purpose to our lives
and gives us a future.

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About the Authors

Marc J. Schniederjans is the C. Wheaton Battey Distinguished Professor of Business in the College of Business Administration at the University of Nebraska-Lincoln and has served on the faculty of three other universities. Professor Schniederjans is a Fellow of the Decision Sciences Institute (DSI) and in 2014–2015 will serve as DSI's President. His prior experience includes owning and operating his own truck leasing business. He is currently a member of the Institute of Supply Management (ISM), the Production and Operations Management Society (POMS), and Decision Sciences Institute (DSI). Professor Schniederjans has taught extensively in operations management and management science. He has won numerous teaching awards and is an honorary member of the Golden Key honor society and the Alpha Kappa Psi business honor society. He has published more than a hundred journal articles and has authored or coauthored twenty books in the field of management. The title of his most recent book is *Reinventing the Supply Chain Life Cycle*, and his research has encompassed a wide range of operations management and decision science topics. He has also presented more than one hundred research papers at academic meetings. Professor Schniederjans is serving on five journal editorial review boards, including *Computers & Operations Research*, *International Journal of Information & Decision Sciences, International Journal of Information Systems in the Service Sector*, *Journal of Operations Management*, *Production and Operations Management*. He is also serving as an area editor for the journal *Operations Management Research* and as an associate editor for the *International Journal of Strategic Decision Sciences* and *International Journal of the Society Systems Science and Management Review: An International Journal* (Korea). Professor Schniederjans has also served as a consultant and trainer to various business and government agencies.

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Christopher M. Starkey is an economics student at the University of Connecticut-Storrs. He has presented papers at the Academy of Management and Production and Operations Management Society meetings. He currently teaches courses in Principles of Microeconomics and has taught Principles of Macroeconomics. His current research interests include macroeconomic and monetary policy, as well as other decision-making methodologies.

Preface

Like the face on the cover of this book, we are bombarded by information every day. We do our best to sort out and use the information to help us get by, but sometimes we are overwhelmed by the abundance of data. This can lead us to draw wrong conclusions and make bad decisions. When you are a global firm collecting millions of transactions and customer behavior data from all over the world, the size of the data alone can make the task of finding useful information about customers almost impossible. For that firm and even smaller businesses, the solution is to apply *business analytics* (BA). BA helps sort out large data files (called "big data"), find patterns of behavior useful in predicting the future, and allocate resources to optimize decision-making. BA involves a step-wise process that aids firms in managing big data in a systematic procedure to glean useful information, which can solve problems and pinpoint opportunities for enhanced business performance.

This book has been written to provide a basic education in BA that can serve both academic and practitioner markets. In addition to bringing BA up-to-date with literature and research, this book explains the BA process in simple terms and supporting methodologies useful in its application. Collectively, the statistical and quantitative tools presented in this book do not need substantial prerequisites other than basic high school algebra. To support both markets, a substantial number of solved problems are presented along with some case study applications to train readers in the use of common BA tools and software. Practitioners will find the treatment of BA methodologies useful review topics. Academic users will find chapter objectives and discussion questions helpful for serving their needs while also having an opportunity to obtain an Instructor's Guide with chapter-end problem solutions and exam questions.

The purpose of this book is to explain what BA is, why it is important to know, and how to do it. To achieve this purpose, the book presents conceptual content, software familiarity, and some analytic tools.

Conceptual Content

The conceptual material is presented in the first eight chapters of the book. (See Section 1.4 in Chapter 1 for an explanation of the book's organization.) The conceptual content covers much more than what BA is about. The book explains why BA is important in terms of proving answers to questions, how it can be used to achieve competitive advantage, and how to align an organization to make best use of it. The book explains the managerial aspects of creating a BA presence in an organization and the skills BA personnel are expected to possess. The book also describes data management issues such as data collection, outsourcing, data quality, and change management as they relate to BA.

Having created a managerial foundation explaining "what" and "why" BA is important, the remaining chapters focus on "how" to do it. Embodied in a three-step process, BA is explained to have descriptive, predictive, and prescriptive analytic steps. For each of these steps, this book presents a series of strategies and best practice guides to aid in the BA process.

Software

Much of what BA is about involves the use of software. Unfortunately, no single software covers all aspects of BA. Many institutions prefer one type of software over others. To provide flexibility, this book's use of software provides some options and can be used by readers who are not even interested in running computer software. In this book, SPSS®, Excel®, and Lingo® software are utilized to model and solve problems. The software treatment is mainly the output of these software systems, although some input and instructions on their use is provided. For those not interested in running software applications, the exposure to the printouts provides insight into their informational value. This book recognizes that academic curriculums prefer to uniquely train students in the use of software and does not duplicate basic software usage. As a prerequisite to using this book, it is recommended that those interested in running software applications for BA become familiar with and are instructed on the use of whatever software is desired.

Analytic Tools

The analytic tool materials are chiefly contained in this book's appendixes. BA is a statistical, management information systems (MIS) and quantitative methods tools-oriented subject. While the conceptual content in the book overviews how to undertake the BA process, the implementation of how to actually do BA requires quantitative tools. Because some practitioners and academic programs are less interested in the technical aspects of BA, the bulk of the quantitative material is presented in the appendixes. These appendixes provide an explanation and illustration of a substantial body of BA tools to support a variety of analyses. Some of the statistical tools that are explained and illustrated in this book include statistical counting (permutations, combinations, repetitions), probability concepts (approaches to probability, rules of addition, rules of multiplication, Bayes' Theorem), probability distributions (binomial, Poisson, normal, exponential), confidence intervals, sampling methods, simple and multiple regression, charting, and hypothesis testing. Although management information systems are beyond the scope of this book, the software applications previously mentioned are utilized to illustrate search, clustering, and typical data mining applications of MIS technology. In addition, quantitative methods tools explained and illustrated in this book include linear programming, duality and sensitivity analysis, integer programming, zero-one programming, forecasting modeling, nonlinear optimization, simulation analysis, breakeven analysis, and decision theory (certainty, risk, uncertainty, expected value opportunity loss analysis, expected value of perfect information, expected value of imperfect information).

We want to acknowledge the help of individuals who provided needed support for the creation of this book. First, we really appreciate the support of our editor, Jeanne Glasser Levine, and the outstanding staff at Financial Times Press/Pearson. They made creating this book a pleasure and worked with us to improve the final product. Decades of writing books with other publishers permitted us to recognize how a top-tier publisher like ours makes a difference. We thank Alan McHugh, who developed the image on our book cover. His constant willingness to explore and be innovative with ideas made a significant contribution to our book. We also want to acknowledge the great editing help we received from Jill Schniederjans. Her skill has reduced the wordiness and enhanced the content (making parts less boring to read). Finally, we would like to acknowledge the help of Miles Starkey, whose presence and charm have lifted our spirits and kept us on track to meet completion deadlines.

While many people have assisted in preparing this book, its accuracy and completeness are our responsibility. For all errors that this book may contain, we apologize in advance.

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Christopher M. Starkey

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What Are Business Analytics?

Chapter objectives:

- Define business analytics.
- Explain the relationship of analytics and business intelligence to the subject of business analytics.
- Describe the three steps of the business analytics process.
- Describe four data classification measurement scales.
- Explain the relationship of the business analytics process with the organization decision-making process.

1.1 Terminology

Business analytics begins with a *data set* (a simple collection of data or a data file) or commonly with a *database* (a collection of data files that contain information on people, locations, and so on). As databases grow, they need to be stored somewhere. Technologies such as *computer clouds* (hardware and software used for data remote storage, retrieval, and computational functions) and *data warehousing* (a collection of databases used for reporting and data analysis) store data. Database storage areas have become so large that a new term was devised to describe them. *Big data* describes the collection of data sets that are so large and complex that software systems are hardly able to process them (Isson and Harriott, 2013, pp. 57–61). Isson and Harriott (2013, p. 61) define *little data* as anything that is not big data. Little data describes the smaller data segments or files that help individual businesses keep track of customers. As a means of sorting through data to find useful information, the application of analytics has found new purpose.

Three terms in business literature are often related to one another: analytics, business analytics, and business intelligence. *Analytics* can be defined as a process that involves the use of statistical techniques (measures of central tendency, graphs, and so on), information system software (data mining, sorting routines), and operations research methodologies (linear programming) to explore, visualize, discover and communicate patterns or trends in data. Simply, analytics convert data into useful information. Analytics is an older term commonly applied to all disciplines, not just business. A typical example of the use of analytics is the weather measurements collected and converted into statistics, which in turn predict weather patterns.

There are many types of analytics, and there is a need to organize these types to understand their uses. We will adopt the three categories (*descriptive*, *predictive*, and *prescriptive*) that the *Institute of Operations Research and Management Sciences* (INFORMS) organization (www.informs.org) suggests for grouping the types of analytics (see Table 1.1). These types of analytics can be viewed independently. For example, some firms may only use descriptive analytics to provide information on decisions they face. Others may use a combination of analytic types to glean insightful information needed to plan and make decisions.

Table 1.1 Types of Analytics

Type of Analytics	Definition
Descriptive	The application of simple statistical techniques that describes what is contained in a data set or database. Example: An age bar chart is used to depict retail shoppers for a department store that wants to target advertising to customers by age.
Predictive	An application of advanced statistical, information software, or operations research methods to identify predictive variables and build predictive models to identify trends and relationships not readily observed in a descriptive analysis. Example: Multiple regression is used to show the relationship (or lack of relationship) between age, weight, and exercise on diet food sales. Knowing that relationships exist helps explain why one set of independent variables influences dependent variables such as business performance.
Prescriptive	An application of decision science, management science, and operations research methodologies (applied mathematical techniques) to make best use of allocable resources. Example: A department store has a limited advertising budget to target customers. Linear programming models can be used to optimally allocate the budget to various advertising media.

The purposes and methodologies used for each of the three types of analytics differ, as can be seen in Table 1.2. It is these differences that distinguish *analytics* from *business analytics*. Whereas analytics is focused on generating insightful information from data sources, business analytics goes the extra step to leverage analytics to create an improvement in measurable business performance. Whereas the process of analytics can involve any one of the three types of analytics, the major components of business analytics include all three used in combination to generate new, unique, and valuable information that can aid business organization decision-making. In addition, the three types of analytics are applied sequentially (descriptive, then predictive, then prescriptive). Therefore, *business analytics* (BA) can be defined as a process beginning with business-related data collection and consisting of sequential application of descriptive, predictive, and prescriptive major analytic components, the outcome of which supports and demonstrates business decision-making and organizational performance. Stubbs (2011, p. 11) believes that BA goes beyond plain analytics, requiring a clear relevancy to business, a resulting insight that will be implementable, and performance and value measurement to ensure a successful business result.

Table 1.2 Analytic Purposes and Tools

Type of Analytics	Purpose	Examples of Methodologies
Descriptive	To identify possible trends in large data sets or databases. The purpose is to get a rough picture of what generally the data looks like and what criteria might have potential for identifying trends or future business behavior.	Descriptive statistics, including measures of central tendency (mean, median, mode), measures of dispersion (standard deviation), charts, graphs, sorting methods, frequency distributions, probability distributions, and sampling methods.
Predictive	To build predictive models designed to identify and predict future trends.	Statistical methods like multiple regression and ANOVA. Information system methods like data mining and sorting. Operations research methods like forecasting models.
Prescriptive	To allocate resources optimally to take advantage of predicted trends or future opportunities.	Operations research methodologies like linear programming and decision theory.

Business intelligence (BI) can be defined as a set of processes and technologies that convert data into meaningful and useful information for business purposes. While some believe that BI is a broad subject that encompasses analytics, business analytics, and information systems (Bartlett, 2013, p.4), others believe it is mainly focused on collecting, storing, and exploring large database organizations for information useful to decision-making and planning (Negash, 2004). One function that is generally accepted as a major component of BI involves storing an organization's data in computer cloud storage or in data warehouses. Data warehousing is not an analytics or business analytics function, although the data can be used for analysis. In application, BI is focused on querying and reporting, but it can include reported information from a BA analysis. BI seeks to answer questions such as what is happening now and where, and also what business actions are needed based on prior experience. BA, on the other hand, can answer questions like why something is happening, what new trends may exist, what will happen next, and what is the best course for the future.

In summary, BA includes the same procedures as in plain analytics but has the additional requirement that the outcome of the analytic analysis must make a measurable impact on business performance. BA includes reporting results like BI but seeks to explain why the results occur based on the analysis rather than just reporting and storing the results, as is the case with BI. Analytics, BA, and BI will be mentioned throughout this book. A review of characteristics to help differentiate these terms is presented in Table 1.3.

Table 1.3 Characteristics of Analytics, Business Analytics, and Business Intelligence

Characteristics	**Analytics**	**Business Analytics (BA)**	**Business Intelligence (BI)**
Business performance planning role	What is happening, and what will be happening?	What is happening now, what will be happening, and what is the best strategy to deal with it?	What is happening now, and what have we done in the past to deal with it?
Use of descriptive analytics as a major component of analysis	Yes	Yes	Yes
Use of predictive analytics as a major component of analysis	Yes	Yes	No (only historically)
Use of prescriptive analytics as a major component of analysis	Yes	Yes	No (only historically)
Use of all three in combination	No	Yes	No
Business focus	Maybe	Yes	Yes
Focus of storing and maintaining data	No	No	Yes
Required focus of improving business value and performance	No	Yes	No

1.2 Business Analytics Process

The complete *business analytic process* involves the three major component steps applied sequentially to a source of data (see Figure 1.1). The outcome of the business analytic process must relate to business and seek to improve business performance in some way.

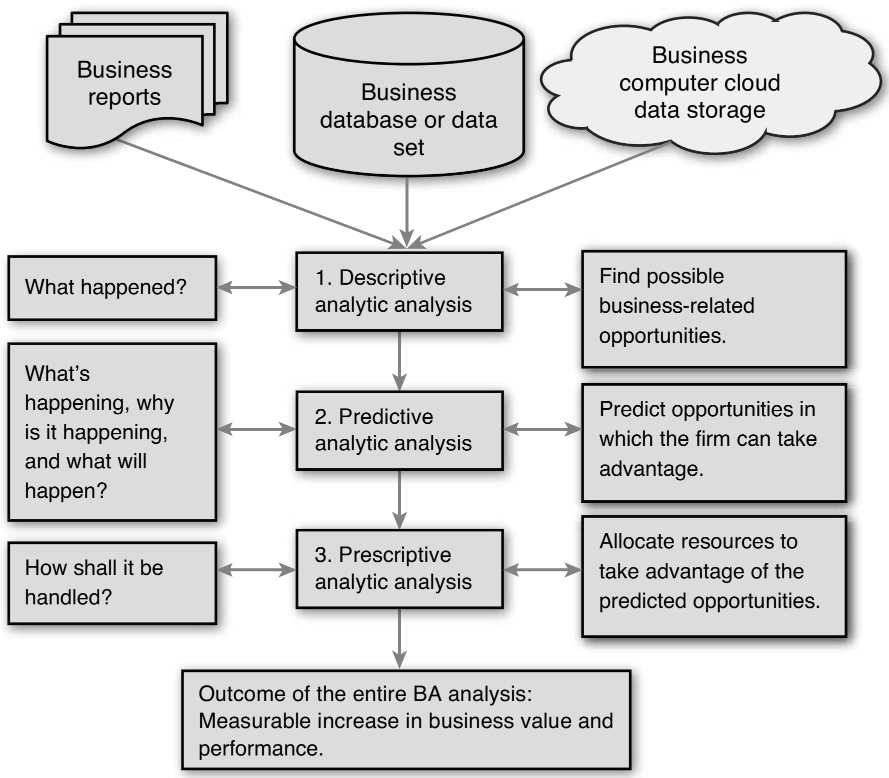

Figure 1.1 Business analytic process

The logic of the BA process in Figure 1.1 is initially based on a question: What valuable or problem-solving information is locked up in the sources of data that an organization has available? At each of the three steps that make up the BA process, additional questions need to be answered, as shown in Figure 1.1. Answering all these questions requires mining the information out of the data via the three steps of analysis that comprise the BA process. The analogy of digging in a mine is appropriate for the BA process because finding new, unique, and valuable information that can lead to a successful strategy is just as good as finding gold in a mine. SAS, a major analytic corporation (www.sas.com), actually has a step in its BA process, *Query Drilldown*, which refers to the mining effort of questioning and finding answers to pull up useful information in the BA analysis. Many firms routinely undertake BA to solve specific problems, while other firms undertake BA to explore and discover new knowledge to guide organizational planning and decision-making to improve business performance.

The size of some data sources can be unmanageable, overly complex, and generally confusing. Sorting out data and trying to make sense of its informational value requires the application of descriptive analytics as a first step in the BA process. One might begin simply by sorting the data into groups using the four possible classifications presented in Table 1.4. Also, incorporating some of the data into spreadsheets like Excel and preparing cross tabulations and contingency tables are means of restricting the data into a more manageable data structure. Simple measures of central tendency and dispersion might be computed to try to capture possible opportunities for business improvement. Other descriptive analytic summarization methods, including charting, plotting, and graphing, can help decision makers visualize the data to better understand content opportunities.

Table 1.4 Types of Data Measurement Classification Scales

Type of Data Measurement Scale	Description
Categorical Data	Data that is grouped by one or more characteristics. Categorical data usually involves cardinal numbers counted or expressed as percentages. Example 1: Product markets that can be characterized by categories of "high-end" products or "low-income" products, based on dollar sales. It is common to use this term to apply to data sets that contain items identified by categories as well as observations summarized in cross-tabulations or contingency tables.
Ordinal Data	Data that is ranked or ordered to show relational preference. Example 1: Football team rankings not based on points scored but on wins. Example 2: Ranking of business firms based on product quality.
Interval Data	Data that is arranged along a scale where each value is equally distant from others. It is ordinal data. Example 1: A temperature gauge. Example 2: A survey instrument using a Likert scale (that is, 1, 2, 3, 4, 5, 6, 7), where 1 to 2 is perceived as equidistant to the interval from 2 to 3, and so on. Note: In ordinal data, the ranking of firms might vary greatly from first place to second, but in interval data, they would have to be relationally proportional.
Ratio Data	Data expressed as a ratio on a continuous scale. Example 1: The ratio of firms with green manufacturing programs is twice that of firms without such a program.

From Step 1 in the *Descriptive Analytic analysis* (see Figure 1.1), some patterns or variables of business behavior should be identified representing targets of business opportunities and possible (but not yet defined) future trend behavior. Additional effort (more mining) might be required, such as the generation of detailed statistical reports narrowly focused on the data related to targets of business opportunities to explain what is taking place in the data (what happened in the past). This is like a statistical search for predictive variables in data that may lead to patterns of behavior a firm might take advantage of if the patterns of behavior occur in the future. For example, a firm might find in its general sales information that during economic downtimes, certain products are sold to customers of a particular income level if certain advertising is undertaken. The sales, customers, and advertising variables may be in the form of any of the measurable scales for data in Table 1.4, but they have to meet the three conditions of BA previously mentioned: clear relevancy to business, an implementable resulting insight, and performance and value measurement capabilities.

To determine whether observed trends and behavior found in the relationships of the descriptive analysis of Step 1 actually exist or hold true and can be used to forecast or predict the future, more advanced analysis is undertaken in Step 2, *Predictive Analytic analysis,* of the BA process. There are many methods that can be used in this step of the BA process. A commonly used methodology is multiple regression. (See Appendix A, "Statistical Tools," and Appendix E, "Forecasting," for a discussion on multiple regression and ANOVA testing.) This methodology is ideal for establishing whether a statistical relationship exists between the predictive variables found in the descriptive analysis. The relationship might be to show that a dependent variable is predictively associated with business value or performance of some kind. For example, a firm might want to determine which of several promotion efforts (independent variables measured and represented in the model by dollars in TV ads, radio ads, personal selling, and/or magazine ads) is most efficient in generating customer sale dollars (the dependent variable and a measure of business performance). Care would have to be taken to ensure the multiple regression model was used in a valid and reliable way, which is why ANOVA and other statistical confirmatory analyses are used to support the model development. Exploring a database using advanced statistical procedures to verify and confirm the best predictive variables is an important part of this step in the BA process. This answers the questions of what is currently happening and why it happened between the variables in the model.

A single or multiple regression model can often forecast a trend line into the future. When regression is not practical, other forecasting methods (exponential smoothing, smoothing averages) can be applied as predictive analytics to develop needed forecasts of business trends. (See Appendix E.) The identification of future trends is the main output of Step 2 and the predictive analytics used to find them. This helps answer the question of what will happen.

If a firm knows where the future lies by forecasting trends as they would in Step 2 of the BA process, it can then take advantage of any possible opportunities predicted in that future state. In Step 3, *Prescriptive Analytics analysis*, operations research methodologies can be used to optimally allocate a firm's limited resources to take best advantage of the opportunities it found in the predicted future trends. Limits on human, technology, and financial resources prevent any firm from going after all opportunities they may have available at any one time. Using prescriptive analytics allows the firm to allocate limited resources to optimally achieve objectives as fully as possible. For example, *linear programming* (a constrained optimization methodology) has been used to maximize the profit in the design of supply chains (Paksoy et al., 2013). (Note: Linear programming and other optimization methods are presented in Appendixes B, "Linear Programming," C, "Duality and Sensitivity Analysis in Linear Programming," and D, "Integer Programming.") This third step in the BA process answers the question of how best to allocate and manage decision-making in the future.

In summary, the three major components of descriptive, predictive, and prescriptive analytics arranged as steps in the BA process can help a firm find opportunities in data, predict trends that forecast future opportunities, and aid in selecting a course of action that optimizes the firm's allocation of resources to maximize value and performance. The BA process, along with various methodologies, will be detailed in Chapters 5 through 10.

1.3 Relationship of BA Process and Organization Decision-Making Process

The BA process can solve problems and identify opportunities to improve business performance. In the process, organizations may also determine strategies to guide operations and help achieve competitive advantages. Typically, solving problems and identifying strategic opportunities to follow are organization decision-making tasks. The latter, identifying opportunities, can be viewed as a problem of strategy choice requiring a solution. It should come as no surprise that the BA process described in Section 1.2 closely parallels classic organization decision-making processes. As depicted in Figure 1.2, the business analytic process has an inherent relationship to the steps in typical organization decision-making processes.

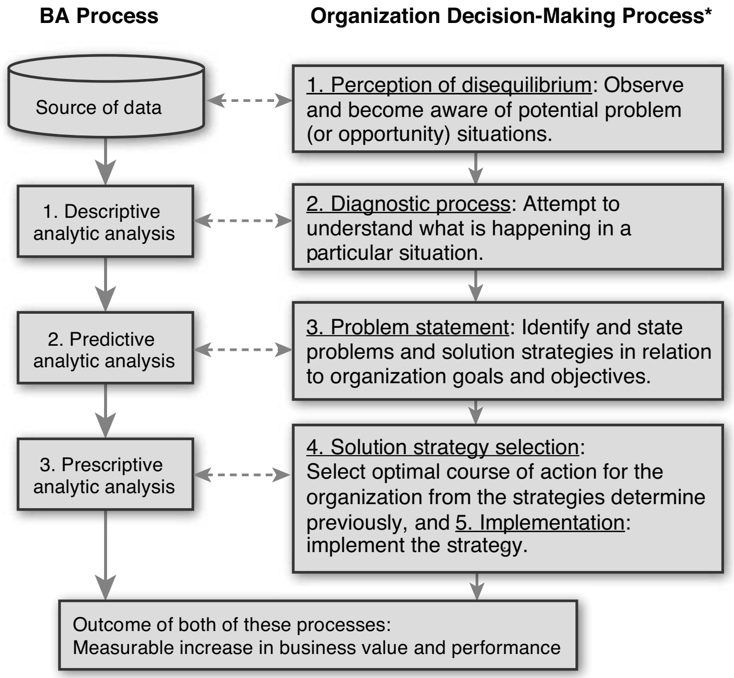

Figure 1.2 Comparison of business analytics and organization decision-making processes

**Source:* Adapted from Figure 1 in Elbing (1970), pp. 12–13.

The *organization decision-making process* (ODMP) developed by Elbing (1970) and presented in Figure 1.2 is focused on decision making to solve problems but could also be applied to finding opportunities in data and deciding what is the best course of action to take advantage of them. The five-step ODMP begins with the perception of disequilibrium, or the awareness that a problem exists that needs a decision. Similarly, in the BA process, the first step is to recognize that databases may contain information that could both solve problems and find opportunities to improve business performance. Then in Step 2 of the ODMP, an exploration of the problem to determine its size, impact, and other factors is undertaken to diagnose what the problem is. Likewise, the BA descriptive analytic analysis explores factors that might prove useful in solving problems and offering opportunities. The ODMP problem statement step is similarly structured to the BA predictive analysis to find strategies, paths, or trends that clearly define a problem or opportunity for an organization to solve problems. Finally, the ODMP's last steps of strategy selection and implementation involve the same kinds of tasks that the BA process requires in the final prescriptive step (make an optimal selection of resource allocations that can be implemented for the betterment of the organization).

The decision-making foundation that has served ODMP for many decades parallels the BA process. The same logic serves both processes and supports organization decision-making skills and capacities.

1.4 Organization of This Book

This book is designed to answer three questions about BA:

- What is it?
- Why is it important?
- How do you do it?

To answer these three questions, the book is divided into three parts. In Part I, "What Are Business Analytics?", Chapter 1 answers the "what" question. In Part II, the "why" question is answered in Chapter 2, "Why Are Business Analytics Important?" and Chapter 3, "What Resource Considerations Are Important to Support Business Analytics?"

Knowing the importance of explaining how BA is undertaken, the rest of the book's chapters and appendixes are devoted to answering that question. Chapter 4, "How Do We Align Resources to Support Business Analytics within an Organization?", explains how an organization needs to support BA. Chapter 5, "What Are Descriptive Analytics?", Chapter 6, "What Are Predictive Analytics?", and Chapter 7, "What Are Prescriptive Analytics?", detail and illustrate the three respective steps in the BA process. To further illustrate how to conduct a BA analysis, Chapter 8, "A Final Case Study Illustration," provides an example of BA. Supporting the analytic discussions is a series of analytically oriented appendixes that follow Chapter 8.

Part III includes quantitative analyses utilizing computer software. In an effort to provide some diversity of software usage, SPSS, Excel, and LINGO software output are presented. SPSS and LINGO can be used together to duplicate the analysis in this book, or only Excel with the necessary add-ins can be used. Because of the changing nature of software and differing educational backgrounds, this book does not provide extensive software explanation.

In addition to the basic content that makes up the body of the chapters, there are pedagogy enhancements that can aid learning. All chapters begin with chapter objectives and end with a summary, discussion questions, and, where needed, references.

In addition, Chapters 5 through 8 have sample problems with solutions, as well as additional assignment problems.

Some of the more detailed explanations of methodologies are presented in the appendixes. Their positioning in the appendixes is designed to enhance content flow and permit more experienced readers a flexible way to select only the technical content they might want to use. An extensive index allows quick access to terminology.

Summary

This chapter has introduced important terminology and defined business analytics in terms of a unique process useful in securing information on which decisions can be made and business opportunities seized. Data classification measurement scales were also briefly introduced to aid in understanding the types of measures that can be employed in BA. The relationship of the BA process and the organization decision-making process was explained in terms of how they complement each other. This chapter ended with a brief overview of this book's organization and how it is structured to aid learning.

Knowing *what* business analytics are about is important, but equally important is knowing *why* they are important. Chapter 2 begins to answer the question.

Discussion Questions

1. What is the difference between analytics and business analytics?
2. What is the difference between business analytics and business intelligence?
3. Why are the steps in the business analytics process sequential?
4. How is the business analytics process similar to the organization decision-making process?
5. Why does interval data have to be relationally proportional?

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