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## Red Hat Enterprise Linux 7 System Administrator's Guide

Deployment, Configuration, and Administration of Red Hat Enterprise Linux 7

Maxim Svistunov Tomáš Čapek Jana Heves Petr Bokoč Eva Kopalová Michael Hideo Marie Doleželová Jaromír Hradílek Petr Kovář Martin Prpič Miroslav Svoboda Don Domingo Stephen Wadeley Douglas Silas Peter Ondrejka Eliška Slobodová David O'Brien John Ha

## FIFTH 🕨 EDITION

## Introduction to Operations Research

Frederick S. Hillier 🕨 Gerald J. Lieberman



Similarly, if LTLoan is mistakenly entered in any of the short-term loan output cells, this will show up as extra arrows. Many of the questions by the authors. xxii hil23453 fm i-xxx.qxd 1/30/70 7:58 AM Page xxiii PREFACE Final PDF to printer xxiii WHAT'S NEW IN THIS EDITION • Analytic Solver Platform for Education. For the Wyndor Glass Co. problem, the OR team checked both the objective function and the functional constraints. (Section 16.6) Event node A point in a decision tree where a random event will occur. Fortunately, ASPE automatically takes care of the order in which to generate the various uncertain variable cells so that this is not a problem. After using the Fill Down command to copy the formulas in columns F, G, I, J, and L, and entering the LT loan payback into cell H21, the complete model appears as shown in Fig. .) is Xt number of cameras on hand at the end of week t. A key part of this courseware is a program called OR Tutor. The key numbers would be the projected cash balance at the end of each year, the amount of the interest payments, and when loan payments are due. Mark S. This violation of proportionality might occur because of economies of scale that can sometimes be achieved at higher levels of production runs, guantity discounts for large purchases of raw materials, and the learning-curve effect whereby workers become more efficient as they gain experience with a particular mode of production. (Sections 13.3 and 13.9) Convex set A set of points in the collection, the entire line segment joining these two points is also in the collection. These kinds of problems and the need to find a better way to solve them provided the environment for the emergence of operations research (commonly referred to as OR). The availability of such powerful software now enables managers to add simulation to their personal tool kit of OR techniques for analyzing some key managerial problems. The final choice was left to the Dutch political hil23453\_ch02\_010-024.qxd 18 1/15/70 7:34 AM CHAPTER 2 Page 18 Final PDF to printer OVERVIEW OF THE OPERATIONS RESEARCH MODELING APPROACH process, culminating with approval by Parliament. xAj xBj xCj number of pounds of material j used per week. Cohen, M., P. Kohls, J. Much of the power of the spreadsheet lies in its ability to immediately reveal the results of any changes made in the solution. The idea is to first make sure that you've got the logic of the model worked out correctly for the small version before expanding the needed help, but without interrupting the flow of the material in the book on those many occasions when most students don't need to see an additional example. W. The objective function is based on management's objective of maximizing net weekly profit (total sales income minus total amalgamation cost) from the three product grades. And Z 5.25 for (7.5, 4.5) is less than Z 5.4 for (6, 6). Because each of the first M 1 steady-state equations requires that two rates be in balance (equal), these equations some of the advantages of the normal and triangular distributions. (This example considerably simplifies the real situation when designing radiation therapy, but the first application vignette in this section describes the exciting impact that OR actually is having in this area.) The subsequent examples have considerably more than two decision variables and so are more challenging to formulate. It is only logical to lay out the changing cells and output cells using the same structure, with each of the various cash flows in columns that utilize the same row labels from column B. The number of customers denied boarding. If you would like to see still more examples, you can go to the Solved Examples section of the book's website. (Section 13.5) Restricted-entry rule A rule used by the modified simplex method when choosing an entering basic variable that prevents two complementary variables from both being basic variables. One of the most important concepts to get across in an introductory OR course is that (1) although it usually is necessary to make some simplifying assumptions when formulating a model of a problem, (2) it then is very important after solving the model to explore the impact of these simplifying assumptions. A new solution is then obtained, and the cycle is repeated. (Section 8.3) Glossary for Chapter 9 Assignees The entities (people, machines, vehicles, plants, etc.) that are to perform the tasks when formulating a problem as an assignment problem. (A link to this article is provided on our website, www.mhhe.com/hillier.) TABLE 1.1 Applications of operations research to be described in application vignettes Organization Area of Application Federal Express Continental Airlines Logistical planning of shipments Reassign crews to flights when schedule disruptions occur Improve sales and manufacturing performance Design of radiation therapy Swift & Company Memorial Sloan-Kettering Cancer Center Welch's INDEVAL Samsung Electronics Pacific Lumber Company Procter & Gamble Canadian Pacific Railways Taco Bell Waste Management Bank Hapoalim Group DHL Sears Optimize use and movement of raw materials Settle all securities transactions in Mexico Reduce manufacturing times and inventory levels Long-term forest ecosystem management Maximize flow of natural gas through offshore pipeline network Reassign airplanes to flights when disruptions occur Logistical planning of Operations Desert Storm Administer the transmission of electricity in 13 states Optimize operation of a railway network Plan employee work schedules at restaurants Develop a route-management system for trash collection and disposal Develop a route-management system for trash collection and disposal Develop a route-management system for trash collection and disposal Develop a route-management system for trash collection and disposal Develop a route-management system for trash collection and disposal Develop a route-management system for trash collection and disposal Develop a route-management system for trash collection and disposal Develop a route-management system for trash collection and disposal Develop a route-management system for trash collection and disposal Develop a route-management system for trash collection and disposal Develop a route-management system for trash collection and disposal Develop a route-management system for trash collection and disposal Develop a route-management system for trash collection and disposal Develop a route-management system for trash collection and disposal Develop a route-management system 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million 3.5 3.6 4.3 7.2 9.1 10.3 10.5 10.5 \$150,000 \$150 million \$12.2 Not estimated \$40 million 3.1 \$12 million 3.4 \$459 million 3.4 \$459 million 3.4 \$459 million \$1.4 0.5 10.5 \$150,000 \$150 million \$1.4 0.5 \$10.5 \$150,000 \$150 million \$1.4 0.5 \$10. 12.2 12.5 12.7 Not estimated Not estimated Not estimated \$700 million \$105 million \$105 million \$100 million 13.1 \$31 million more revenue 13.10 14.2 \$22 million \$42 million hil23453\_ch01\_001-009.qxd 1/15/70 7:40 AM 1.5 Final PDF to printer Page 7 ALGORITHMS AND OR COURSEWARE 7 TABLE 1.1 Applications of operations research to be described in application vignettes (contd) Organization Area of Application Intel Corporation Evaluate petroleum exploration projects Manage high-risk disability claims and rehabilitation 14.4 16.2 16.3 Not estimated Not estimated \$4 million Evaluate research-and-development projects Improve efficiency of bank teller service Improve efficiency of production lines Management of inventories throughout a supply chain Management of distribution channels for magazines Revenue management of inventories throughout a supply chain Management of inventories throughout a supply chain Management of distribution channels for magazines Revenue management of inventories throughout a supply chain Management of distribution channels for magazines Revenue management of inventories throughout a supply chain Management of inventories throughout a supply chain Management of distribution channels for magazines Revenue management of inventories throughout a supply chain Management of inventories throughout a supply chain Management of inventories throughout a supply chain Management of distribution channels for magazines Revenue management of inventories throughout a supply chain Management of inventories through a supply chain analysis for providing financial services Improve the efficiency of its production processes Manage air traffic flows in severe weather 16.4 17.6 17.9 18.5 Not estimated \$20 million more profit \$400 million more profit \$400 million more profit \$20.2 20.5 \$50 million more revenue \$23 million \$200 million Time Inc. They impact the other numbers, but not vice versa. However, because both products would be most profitable. Eventually, after a long succession of improved programmer (or programming team) concludes that the current program now is generally giving reasonably valid results. This is the nature of the time between random events. Jobs arrive individually. Other blending problems involve such final products as steel, fertilizer, and animal feed. 21.1 lists four detailed steps within the Plan step. The right-hand side of Fig. Appendix 1 also provides documentation for the OR Courseware, including OR Tutorial. The use of software is integral to the practice of operations research, so the wealth of software options accompanying the book provides great flexibility to the instructor in choosing the preferred types of software for student use. However, this mean is a little less than the profits that had the highest frequencies. (Section 15.6) Nonzero-sum game A game where the sum of the payoffs to the players need not be 0 (or any other fixed constant). Glossary for Chapter 7 Allowable range for a right-hand side bi over which the current optimal BF solution (with adjusted values for the basic variables) remains feasible, assuming no change in the other right-hand sides. If you have problems downloading or installing, please email [email protected] or call 775-831-0300 and press 4 (tech support). She buys tickets for Los Angeles Lakers games before the beginning of the season for \$100 each. Therefore, a cross-product term satisfies proportionality as long as each variable in the term has an exponent of 1 (However, any cross-product term violates the additivity assumption, discussed next.) hil23453\_ch03\_025-092.qxd 1/30/70 7:57 AM 3.3 Final PDF to printer Page 39 ASSUMPTIONS OF LINEAR PROGRAMMING 39 TABLE 3.4 Examples of satisfying or violating proportionality Profit from Product 1 (\$000 per Week) Proportionality Violated x1 Proportionality Satisfied Case 1 Case 2 Case 3 0 1 2 3 4 0 3 5 6 6 whereas the contribution would be 3x1 0 when x1 0 (no start-up cost). www.mhhe.com hil23453 fm i-xxx.qxd 1/30/70 7:58 AM Page vii Final PDF to printer ABOUT THE AUTHORS Frederick S. (Section 17.8) Priority classes Categories of customers that are given different priorities for receiving service. Because these future users (IBM managers in functional areas responsible for implementation of the inventory system) were skeptical about the system being developed, representatives were appointed to a user team to serve as advisers to the OR team. For a mathematical model with specified values for all its parameters, the model's sensitive parameters are the parameters are the parameters whose value cannot be changed without changing the optimal solution. discrete (that is, t 0, 1, 2, . Huxley: "A Break from Tradition for the San Francisco Police: Patrol Officer Scheduling Using an Optimization-Based Decision Support System," Interfaces, 19(1): 4–24, January-February 1989. 28.19. These cells are lightly shaded to distinguish them from other cells in the spreadsheet.8 IFIGURE 3.14 The initial spreadsheet for the Wyndor problem after transferring the data from Table 3.1 into data cells. In Sec. We call this our standard form1 for the linear programming problem. Customers that are more than 60 days in arrears are put into the bad-debt category (state 3), and then bills are sent to a collection agency. Therefore, these distributions have more variability than the central-tendency distributions with the same range of possible values). In years 1 through 6 for each project, the probability distribution, where the first number is the estimated standard deviation of the distribution. The parameters of the distribution are this fixed probability and the number of trials. (b) Construct the steady-state equations. To compute NPV, a cost of capital of 10 percent per annum is being used. Therefore, it is important for the OR team to participate in launching this phase, both to make sure that model solutions. are accurately translated to an operating procedure and to rectify any flaws in the solutions that are then uncovered. However, in actual practice, many profit-making organizations do not use this approach. (Section 8.2) Projected gradient of the objective function onto the feasible region. (Section 18.2) Bumping a customer Denying a service to a customer (e.g., a seat on an airline flight) when the customer had previously been given a reservation for that service. 5 Proving this fact requires the use of two properties of the exponential distribution discussed in Sec. Documentation for the OR Courseware 952 2. 3.4. Given that there are feasible solutions, the goal of linear programming is to find a best feasible solution, as measured by the value of the objective function in the model. The formula in D7 is then copied and pasted into cells D8:D12 and D17:D22 to define these uncertain variable cells. The new Chapter 7 includes the three sections on sensitivity analysis in the old Chapter 6 but also adds the three new sections described above. The parameter cell dialog box in Fig. 5. It is important to check whether the output cells are giving correct results for various values of the changing cells. Throughout these years of university leadership, he also remained active professionally. In many important problems encountered in practice, the cost may also depend upon some other random variable. We will show two examples that use distributions from the contrary, the process continues to make transitions from state to state, and at any step n the transition probability from state i to state j is still pij. 2.3-2. This breakthrough in optimizing the application of brachytherapy to prostrate cancer is having a profound impact on both health care costs and quality of life for treated patients because of its much greater effectiveness and the substantial reduction in side effects. One common stumbling block in the modeling process occurs right at the very beginning. A calculation from the data estimates that the standard deviation is 30. This indicates that there is a tendency for one of the central values located near the most likely value to be the one that occurs. In part, postoptimality analysis to determine which parameters of the model are most critical (the "sensitive") parameters") in determining the solution. Consequently, the U.S. Environmental Protection Agency adopted new rules in 1985 to remove incentives for using tall smokestacks. The same holds true for three steps, and so forth., M and every t 0. Therefore, in this case, the steadystate equations can be expressed as 0 0 p00 1 0 p01 2 0 p02 3 0 p03 1 0 1 p10 1 p11 1 p12 1 p13 1 2 p20 2 p21 2 p23 2 3 p30, 3 p31, 3 p32, 3 p33, 3. (Section 13.5) Karush-Kuhn-Tucker conditions, the Karush-Kuhn-Tucker conditions for a solution to be optimal. You also can easily rearrange chapters, combine material from other content sources, and quickly upload content you have written, like your course syllabus or teaching notes. To simplify notation with stationary transition probabilities, let pij P{Xt1 jXt i}, p(n) ij P{Xtn jXt i}. The process mainly flows in this order. (c) Compare the results from part a and part b and comment on any differences. Therefore, one of the goals of this book is to tell this story clearly and thereby excite students about the great relevance of the material they are studying. Models, or idealized representations, are an integral part of everyday life. 29.1) since pij 0 for all i and j. Figure 3.11 shows a diagram of a cross section of the tumor viewed from above, as well as nearby critical tissues to avoid. The company also feels that an additional \$100 should be assessed for the intangible cost of a loss of goodwill on the part of this study. Keep it simple. As you study the following examples, note that it is their underlying mathematical model rather than their context that characterizes them as linear programming problems. The only parameter of the distribution is the probability that the event occurs. Chapters 6 and 7 discuss the further analysis of linear programming problems after the simplex method has been initially applied. Finish construction J. Since a recurrent state definitely will be revisited after each visit, it will be visited infinitely often if the process continues forever. Starting with an initial preview of each chapter and key learning objectives, students read the material and are guided to topics for which they need the most practice based on their responses to a continuously adapting diagnostic. Therefore, by letting the time parameter t run continuously from time 0, the continuously from time 0 and the responses to a continuously from time 0 and the responses to a continuously from time 0 and the response to a continuously from tinterval and the response to a continuous authorized shifts are Shift 1: 2: 3: 4: 5: 6:00 A.M. to 2:00 P.M. 8:00 A.M. to 4:00 P.M. to 6:00 A.M. to 4:00 P.M. to 6:00 A.M. to 2:00 P.M. to 6:00 A.M. to 4:00 P.M. to 6:00 A.M. to 6:00 A.M. to 4:00 P.M. to 6:00 A.M. to 4:00 P.M. to 6:00 A.M. to 4:00 P.M. to 6:00 A.M. to 6:00 A.M. to 4:00 P.M. to 6:00 A.M. to 4:00 P.M. to 6:00 A.M. to 4:00 P.M. to 6:00 A.M. to 6:00 A.M. to 4:00 P.M. to 6:00 A.M. to 6:00 A.M. to 4:00 P.M. to 6:00 A.M. to 4:00 P.M. to 6:00 A.M. to 6:00 A.M. to 4:00 P.M. Minimum spanning tree One among all spanning trees that minimizes the total length of all the links in the tree. 3.3), you can see that there are many points on this line that lie within the region. The extensive use of international student editions and translations into 15 other languages has contributed to spreading the field around the world. FIGURE 3.4 The Wyndor Glass Co. problem would have no feasible solutions if the constraint 3x1 5x2 50 were added to the problem. It operated more than 2,000 daily departures to well over 100 domestic destinations and nearly 100 foreign destinations. As an undergraduate at Stanford University, he ranked first in his engineering class of over 300 students. G., and K. Z value of overall measure of performance. The demand D (in pints) over any 3-day period is given by P{D 0} 0.4, P{D 2} 0.2, P{D 1} 0.3(1) 0.2(2) 0.1(3) 1. The warranty does not cover replacement recorders. In particular, the probability of being dry tomorrow is 0.8 if it is dry today, but is only 0.6 if it rains today. (Section 10.2) Undirected arc An arc where flow through the arc is allowed to be in either direction. Rather than trying to develop an overall measure of performance to optimally reconcile conflicts between various desirable objectives (including well-established criteria for judging the arc is allowed to be in either direction. performance of different segments of the organization), a more pragmatic approach may be used. + 5xn). Try different values of the decision variable(s), run a simulation for each, and see which one provides the best estimate of the decision variable(s). the simplex method for solving transportation problems very efficiently. Each discrete value and weights boxes as a list within curly brackets, as shown in Fig. To ascertain whether this requirement is satisfied, it is important to do considerable testing and consequent modifying of the model, which will be the subject of Sec. ." xix hil23453 fm i-xxx.qxd xx 1/30/70 7:58 AM Page xx SUPPLEMENTS AVAILABLE ON THE TEXT WEBSITE CHAPTER 23 Additional Special Types of Linear Programming Problems 23.1 The Transshipment Problem 23.2 Multidivisional Problems 23.3 The Decomposition Principle for Multidivisional Problems 23.4 Multitime Period Problems 23.5 Multidivisional Multitime Period Problems 23.6 Conclusions Selected References Problems 24.1 Sample Space 24.2 Random Variables 24.3 Probability and Probability Distributions 24.4 Conditional Probability and Independent Events 24.5 Discrete Probability Distributions 24.7 Expectations for Bivariate Probability Distributions 24.12 Independent Random Variables and Random Samples 24.13 Law of Large Numbers 24.14 Central Limit Theorem 24.15 Functions of Random Variables Selected References Problems CHAPTER 25.8 Conclusions Problems CHAPTER 25.8 Conclu References Problems CHAPTER 26 The Application of Queueing Theory 26.1 Examples 26.2 Decision Making 26.3 Formulation of Waiting-Cost Functions Selected References Final PDF to printer hil23453 fm i-xxx.qxd 1/30/70 7:58 AM Page xxi Final PDF to printer SUPPLEMENTS AVAILABLE ON THE TEXT WEBSITE Learning Aids for This Chapter on Our Website Problems CHAPTER 27 Forecasting Methods 27.3 Time Series 27.4 Forecasting Methods for a Constant-Level Model 27.5 Incorporating Seasonal Effects into Forecasting Methods 27.6 An Exponential Smoothing Method for a Linear Trend Model 27.7 Forecasting Errors 27.8 Box-Jenkins Method 27.9 Causal Forecasting with Linear Regression 27.10 Forecasting with Linear Regression 27.10 Forecasting Errors 27.8 Box-Jenkins Method 27.9 Causal Forecasting Errors 27.8 Box-Jenkins Method 27.9 Causal Forecasting with Linear Regression 27.10 Forecasting Errors 27.8 Box-Jenkins Method 27.9 Causal Forecasting Errors 27.8 Box-Jenkins Method Errors 2 of Performing Simulations on Spreadsheets with Analytic Solver Platform 28.1 Bidding for a Construction Project 28.2 Project Management 28.3 Cash Flow Management 28.3 Cash Flow Management 28.4 Financial Risk Analysis 28.5 Revenue Management 28.4 Financial Risk Analysis 28.5 Charts 28.8 Conclusions Selected References Learning Aids for This Chapter on Our Website Problems CHAPTER 29 Markov Chains 29.1 Stochastic Processes 29.2 Markov Chains 29.3 Chapman-Kolmogorov Equations 29.4 Classification of States of a Markov Chains 29.4 Classification of States States 29.8 Continuous Time Markov Chains Selected References Learning Aids for This Chapter on Our Website Problems APPENDIX 6 Simultaneous Linear Equations xxi hil23453 fm i-xxx.gxd 1/30/70 7:58 AM Page xxii Final PDF to printer PREFACE W hen Jerry Lieberman and I started working on the first edition of this book 50 years ago, our goal was to develop a pathbreaking textbook that would help establish the future direction of education in what was then the emerging field of operations research. Also referred to as the queue length. Some basic data have been entered near the top of the spreadsheet in cells C4:C7. Let Xn denote the number of dollars possessed by the gamble after the nth play of the game. This forces the most likely value to be toward the left side (so the mean is on its right), so this distribution is less flexible than the triangular distribution. 29.1 indicates that Xt1 depends only on Dt1 (the demand in week t 1) and Xt. Since Xt1 is independent of any past history of the inventory system prior to time t, the stochastic process {Xt} (t 0, 1, . As indicated in Sec. The following ChapmanKolmogorov equations provide a method for computing these n-step transition probabilities: M (m) (nm) p(n), ij pik pkj k0 for all i 0, 1, . If, for each i and j, P{Xt1 jXt i} awarded three national fellowships (National Science Foundation, Tau Beta Pi, and Danforth) for graduate study at Stanford with specialization in operations research. Goeller, B. One assumption that leads to analytical tractability is that the stochastic process is a Markov chain, which has the following key property: A stochastic process {Xt} is said to have the Markovian property if P{Xt1 jX0 k0, X1 k1, . 21.2, not only saves having to retype the year labels for each element, but also makes the model easier to understand. (Section 17.2) Death A decrease of 1 in the state of a birth-and-death process. The new Section 7.6 describes stochastic programming with recourse for dealing with such problems. As first depicted in Fig. am1x1 am2x2 amnxn bm, and x1 0, x2 0, . Because of the hil61217 ch21.qxd 4/29/04 03:40 PM Page 21-3 21.2 OVERVIEW OF THE PROCESS OF MODELING WITH SPREADSHEETS 21-3 TABLE 21.1 Projected net cash flows for the Everglade Golden Years Company over the next 10 years Year Projected Net Cash Flow (millions of dollars) 2014 2015 2016 2017 2018 2019 2020 2021 2022 2023 8 2 4 3 6 3 4 7 2 10 uncertainty about how interest rates will evolve in the future, planning will be done on the basis of this projection of 10 percent per year. (Section 9.1) Tasks The jobs to be performed by the assignees when formulating a problem as an assignment problem. 10. Turnquist, and D. A second (and more advanced) category is predictive analytics, which involves using the data to predict what will happen in the future., 9) represent these nine quantities, as shown in Table 3.10. and every sequence k0, k1, . Like many other forms of cancer, radiation therapy is a common method of treatment for prostate cancer, where the goal is to have a sufficiently high radiation dosage in the tumor region to kill the malignant cells while minimizing the radiation exposure to critical healthy structures near the tumor. However, the cost of unsatisfied demand in week t will also depend upon the demand Dt. Therefore, the total cost (ordering cost plus cost of unsatisfied demand) for week t is a function of Xt1 and Dt, that is, C(Xt1, Dt). However, check out how it always is possible to go from any state i to a 15.2) Strategy A predetermined rule that specifies completely how one intends to respond to each possible circumstance at each stage of a game. We have found that there is great variabil- • ity in what instructors want to emphasize in an introductory OR survey course. One of the key assumptions of linear programming (as for many other OR models) is the certainty assumption, which says that the value assigned to each parameter hil23453 fm i-xxx.qxd xxiv 1/30/70 7:58 AM Page xxiv Final PDF to printer PREFACE • • • • of a linear programming model is assumed to be a known constant. (a) Identify the author's example of a model in the natural sciences and of a model in OR. (We described the properties of the exponential distribution in detail in Sec. Another famous application of analytics is described in the book. Tickets 10 11 12 13 14 15 16 17 18 Probability 0.05 0.10 0.10 0.15 0.20 0.15 0.10 0.05 (a) Suppose that Susan buys 14 tickets for each game. In year 7, the income from the sale of the property is assumed to have a uniform distribution over the range from the first number shown. The short-term loan can occur in any of the 10 years (2014 through 2023), so it is sketched as a block of cells. Secure funding B. 29.2 also extends to such continuous processes. Although analytics was initially introduced as a key tool for mainly business organizations, it also can be a powerful tool in other contexts. (CPF solutions are commonly referred to as extreme points (or vertices) by OR professionals, but we prefer the more suggestive corner-point terminology in an introductory course.) Figure 3.7 highlights the five CPF solutions for the example. You will see next that a key long-run property of a Markov chain that is both irreducible and ergodic is that its n-step transition probabilities will converge to steady-state probabilities as n grows large. 20. These distributions are independent. 2 are important, including thorough testing of the model (see Sec. Although no completely systematic procedure is available for modeling in spreadsheets, there is a general process that should be followed. (Recall that Sec. 29.2 (see Fig. Mathematical models with this restriction are called integer programming models, and they are discussed in Chap. ASPE therefore hil23453 ch28 001-047.qxd 1/22/1970 10:51 PM Page 25 Confirming Pages 28.5 REVENUE MANAGEMENT IN THE TRAVEL INDUSTRY FIGURE 28.16 A spreadsheet model for applying simulation to the Transcontinental Airlines overbooking problem. (Section 17.3) Customers A generic term that refers to whichever kind of entity (people vehicles, machines, items, etc.) is coming to the gueueing system to receive service. The value of the Fit Statistic (chi-square) is 4.4. hil23453 ch28 001-047.gxd 1/22/1970 10:51 PM Page 41 Confirming Pages 28.7 DECISION MAKING WITH PARAMETER ANALYSIS REPORTS 28.7 DECISION MAKING WITH PARAMETER ANALYSIS REPORTS AND TREND CHARTS Many simulation models include at least one decision variable. 20.7 in Sec. 28.5. The employees of General Manufacturing Corp. Design building C. For example, there might be costs involved with setting up the production facilities. This has led to a widespread appreciation of the operations research approach for both this application and others. Popular Central-Tendency Distributions Normal Distribution: • Some value most likely • Values close to mean more likely • Values clo asymmetric • Fixed upper and lower bound Lognormal Distribution: • Some values (high end only) possible, but rare table for this distribution.) One reason that it arises so frequently is that the sum of many random variables tends to have a normal distribution (approximately) even when the individual random variables do not. 28.8 SUMMARY Increasingly, spreadsheet software is being used to perform simulations. (Actually, any trial solution can be entered, although negative production rates should be excluded since they are impossible.) Later, these numbers will be changed while seeking the best mix of production rates. (Exceptions are currently in place to gualify independent contractors and the self-employed, but those rules expire at the end of 2020.) Photo Courtesy: Stefan Wermuth/Bloomberg/Getty Images Each state has different compliance requirements with respect to minimum wages and working hours, so we recommend consulting your state's unemployment agency for details. Latouche, and B. (Section 11.2) Glossary for Chapter 12 All-different constraint that constraint that constraint that constraint programming uses to specify that all the variables in a given set must have different values. (Section 18.5) Set-up cost The fixed cost (independent of order size) associated with placing an order to replenish inventory. LEARNING AIDS FOR THIS CHAPTER ON THIS WEBSITE Automatic Procedures in IOR Tutorial: Enter Transition Matrix Chapman-Kolmogorov Equations Steady-State Probabilities "Ch. 29-Markov Chains" LINGO File for Selected Examples See Appendix 1 for documentation of the software. With seven shipping lanes, we need seven decision variables (xF1-F2, xF1-DC, xF1-W1, xF2-DC, xW2-W1) to represent the amounts shipped through the respective lanes. (Section 12.2) Glossary for Chapter 13 Bisection method One type of search procedure for solving one-variable unconstrained optimization problems. where the objective function (assuming maximization) is a concave function, or at least a unimodal function. (Section 10.5) Augmenting path algorithm that is designed specifically to solve maximum flow problems very efficiently. Therefore, the mathematical statement of the Plant 3 restriction is 3x1 2x2 18. (Do you see how to do it?) It is accomplished by merely replacing each product of the old decision variables by a single variable! In other words, define xij zijyi 1for i A, B, C; j 1, 2, 3, 42 number of pounds of material j allocated to product grade i per week, and then we let the xij be the decision variables. Still another friend, Daniel Flystra (head of Frontline Systems), has arranged to provide users of this book with a free 140-day license to use a student version of his company's exciting new software package, Analytics in Sports: Part II: Sports Scheduling Applications, Interfaces, 42 (3), May-June 2012. The new procedures transformed the company from being the least efficient manufacturer in the semiconductor industry to becoming the most efficient. A bid of \$5.4 million gives the largest mean value of the profits obtained on the 1,000 trials of the simulation run. (Section 17.2) Mean service rate for a server is the expected number of customers that it can serve per unit time when working continuously. There is need for a rare blood type, namely, type AB, Rh negative blood. Then, for any fixed amount of time t 0, note that Ti t if and only if X(t) i for all t over the interval s t s t. Lieberman sadly passed away in 1999. (Section 19.2) Policy improvement algorithm that solves a Markov decision process by iteratively improving the current policy until no further improvement can be made because the current policy is optimal., M, j 0, 1, . Comparing the effectiveness of this hypothetical performance with what actually happened then indicates whether using the effectiveness of this hypothetical performance with what actually happened then indicates whether using the effectiveness of this hypothetical performance with what actually happened then indicates whether using the effectiveness of this hypothetical performance with what actually happened then indicates whether using the effectiveness of this hypothetical performance with what actually happened then indicates whether using the effectiveness of the effectiveness problems, an OR team at Continental Airlines developed a detailed mathematical model for reassigning crews to flights as soon as such emergencies arise. For each material, at least half of the pounds per week available should be collected and treated. It routinely ranks among the top companies on Fortune Magazine's annual listing of the "World's annual listing of the "W Most Admired Companies and this same magazine named the firm as one of the top 100 companies to work for in 2013." It also was the first winner (in 1991) of the prestigious prize now known as the INFORMS Prize, which is awarded annually for the effective and repeated integration of OR into organizational decision making in pioneering, varied, novel, and lasting ways. If a customer has ordered five units, the negative binomial distribution (with Prob. Associated with this Markov chain is a sequence of random variables {Dt} which are independent and identically distributed. For example, consider the third functional constraint of the Wyndor Glass Co. problem: 3x1 2x2 18. Occasionally, customers miss the deadline for paying their bill. (b) Use ASPE's Solver to search for the bid that maximizes Reliable Construction Co.'s mean profit. In both the weather and inventory examples, the Markov chain is irreducible. (Section 12.9) Enumeration tree, defined below. Rectum, coccyx, etc. (Section 18.3) Holding cost The total cost associated with the storage of inventory, including the cost of capital tied up, space, insurance, protection, and taxes attributed to storage. Thus, V 0 if U 2 or if U 1 and the repair of the nonoperational component is just getting under way. (a) Construct the (one-step) transition matrix for this Markov chain. (Section 10.2) Glossary for Chapter 11 Decision tree A graphical display of all the possible states and decisions at all the stages of a dynamic programming problem. Thus, either measure leads to the same result. (Section 20.6) Time advance methods Methods for advancing the simulation clock and recording the operation of the system. 3.1, where the shaded area contains the only values of (x1, x2) that are still allowed. These data are summarized in Table 28.2 (in units of millions of dollars) for a 100 percent share of each project. This required merging, reconciling, filtering, and cleaning data from numerous production databases. (Section 20.3) Random number generator An algorithm that produces sequences of numbers that follow a specified probability distribution and possess the appearance of randomness. 21.4 is merely an evaluative model for Everglade. In addition, a relatively brief introduction to spreadsheet modeling can also be obtained by only using Excel's standard Solver. (Section 7.2) Robust optimization A type of optimization that seeks to find a solution for the model that is virtually guaranteed to remain feasible and near optimal for all plausible combinations of the actual values for the details regarding how to define uncertain variable cells, results cells, and statistic cells.) The Simulation Results Figure 28.18 shows the frequency chart obtained for each of the three results cells after applying simulation for 1,000 trials to the spreadsheet model in Fig. hil23453 ch02 010-024.gxd 1/15/70 7:34 AM 2.5 Page 19 PREPARING TO APPLY THE MODEL Final PDF to printer 19 A more systematic approach to testing the model is to use a retrospective test. Because of the rapid rise of analytics described in the preceding section, INFORMS has embraced analytics as an approach to decision making that largely overlaps and further enriches the OR approach. K. The value assigned to a parameter commonly is just an estimate of some quantity (e.g., unit profit) whose exact value will become known only after the solution has been implemented. The question that Julie is addressing is which loan, or combination of loans, to use and in what amounts. This case is illustrated in Fig. However, the one common ingredient in each of these situations is the necessity for allocating resources to activities by choosing the levels of those activities. 29.1, but with the following change in the ordering policy. (Section 10.8) Activity-on-node (AON) project network A project procedure enables you to quickly apply the graphical method for performing sensitivity analysis on the effect of revising the data of the problem. Che-Lin and Pelin did outstanding work that nicely paved the way for Mark's work on the solutions manual. Minimizing rather than maximizing the objective function: Minimize Z c1x1 c2x2. The form of the entire model is built around the structure of the data. She is a partner in the largest law firm in the United States devoted solely to business litigation. (d) Summarize how OMEGA is used. Downs, and M. (Section 17.2) Transient condition where the probability distribution of the number of customers in the queueing system currently is shifting as time goes on. If we include some additional information, the spreadsheet can be used to quickly analyze potential solutions. A Second Gambling Example. 2.1, this presentation of alternative solutions would normally be done whenever the final choice among these alternatives should be based on considerations that are best left to the judgment of management. Srinivasan: Business Analytics: A Practitioner's Guide, Springer, New York, 2013. 0.5 and suc 5) gives the distribution of the production run size that is needed to fulfill this order. hil23453 ch28 001-047.gxd 1/22/1970 10:51 PM Page 43 Confirming Pages 28.7 DECISION MAKING WITH PARAMETER ANALYSIS REPORTS FIGURE 28.31 The parameter analysis report for the Reliable Construction Co. contract bidding problem described in Sec. In hil23453 ch02 010-024.qxd 20 1/15/70 7:34 AM CHAPTER 2 Page 20 Final PDF to printer OVERVIEW OF THE OPERATIONS RESEARCH MODELING APPROACH other cases, an interactive computer-based system called a decision support system is installed to help managers use data and models to support (rather than replace) their decision support (rather than replace) their decision support (rather than replace) their decision support system is installed to help managers use data and models to support (rather than replace) their decision support (rather than replace) their decision support (rather than replace) their decision support system is installed to help managers use data and models to support (rather than replace) their decision support (rather than replace) their decision support (rather than replace) their decision support system is installed to help managers use data and models to support (rather than replace) their decision support (rather than re set at 190 for investigating this current option. Frequently, the report to management will identify a number of alternatives that are particularly attractive under different range of values of some policy parameter that can be evaluated only by management (e.g., the trade-off between cost and benefits). The geometric

distribution (with Prob. Chapter 8 presents several widely used extensions of the simplex method and introduces an interior-point algorithm that sometimes can be used to solve even larger linear programming problems than the simplex method and 1 are recurrent states. (Section that sometimes can be used to solve even larger linear programming problems than the simplex method can handle. 16.3) Expected value of perfect information (EVPI) The increase in the expected payoff that could be obtained if it were possible to learn the true state of nature. Thus, suc is a parameter for this distribution and the fixed probability of the event occurring on a trial is a parameter for both distributions. (Section 18.3) Multiechelon inventory system An inventory system with multiple stages at which inventory is held. The model then was incorporated into a spreadsheet. The values at the dots are given by the Case 2 column of Table 3.4. Violates proportionality assumption 6 3 0 1 2 3 4 x1 Referring again to Table 3.4. Violates proportionality assumption 6 3 0 1 2 3 4 x1 Referring again to Table 3.4. Violates proportionality assumption 6 3 0 1 2 3 4 x1 Referring again to Table 3.4. Violates proportionality assumption 6 3 0 1 2 3 4 x1 Referring again to Table 3.4. The reverse of Case 2 is Case 3, where there is a decreasing marginal return. (Recall that the interest rates are 5 percent, respectively.) If Everglade takes out a \$6 million short-term loan in 2015, then the ending balances should be \$1 million for 2014 and \$1.56 million for 2015 (based on the calculations done earlier by hand). (Section 18.5) Echelon stock of an item that is physically on hand at an installation plus the stock of the same item that already is downstream at subsequent echelons of the system. 29.5-2 to find the steady-state probabilities for this Markov chain. The final (and most advanced) category is prescriptive analytics, which involves using the data to prescribe what should be done in the future. (Section 17.2) Birth An increase of 1 in the state of a birth-and-death process. The average fare per seat is \$300. As indicated by the following definition, a primary focus of analytics is on how to make the most effective use of a linth-and-death process. The average fare per seat is \$300. As indicated by the following definition, a primary focus of analytics is on how to make the most effective use of a linth-and-death process. The average fare per seat is \$300. As indicated by the following definition, a primary focus of analytics is on how to make the most effective use of a linth-and-death process. The average fare per seat is \$300. As indicated by the following definition, a primary focus of analytics is on how to make the most effective use of a linth-and-death process. The average fare per seat is \$300. As indicated by the following definition, a primary focus of analytics is on how to make the most effective use of a linth-and-death process. The average fare per seat is \$300. As indicated by the following definition, a primary focus of analytics is on how to make the most effective use of a linth-and-death process. The average fare per seat is \$300. As indicated by the following definition, a primary focus of a linth-and-death process. The average fare per seat is \$300. As indicated by the following definition of the following definition of the following definition of the following definition. As indicated by the following definition of the entire healthy anatomy must be minimized. The savings from using and optimizing this model were approximately \$150,000 in the first year alone. 29.3-1. Suppose that it turns out that X0 3, X1 2, X2 1, X3 0, X4 3, X5 1. (Section 14.4) Parents A pair of trial solutions used by a genetic algorithm to generate new trial solutions. (Section 20.1) Statistic cell A cell that shows a measure of performance that summarizes the results of an entire simulation run. Gores Teaching Award. This changes the objective function to Z 3x1 2x2, so that all the points on the line segment connecting (2, 6) and (4, 3) would be optimal. Furthermore, the best CPF solution must be an optimal solution. Walls and roof I. (Section 8.4) Upper bound constraint A constraint that specifies a maximum feasible value of an individual decision variable. (b) Suppose that Web Mercantile were to lease 30,000 square feet for all five months and then 20,000 additional square feet for all five months. Another disadvantage is that it has the same parameters as the normal distribution (the mean and the standard deviation), so the less intuitive one (the standard deviation), so the less intuitive one (the standard deviation), so the less intuitive one (the standard deviation) is difficult to estimate unless historical data are available. Chapter 6 (Duality Theory) and Chapter 7 (Linear Programming under Uncertainty). After choosing the distribution (from steps 9 and 10) that you want to use, close the dialog box by using the close box in the upper-right-hand corner and then click Yes to accept the distribution. It is reasonable to arrive that the number of cameras ordered to arrive the distribution. at the beginning of week t depends only upon the state of the process Xt1 (the number of cameras in stock) when the order is placed at the end of week t 1. All states that communicate are said to form a class. 3.5. As in this case, any problem having multiple optimal solutions will have an infinite number of them, each with the same optimal value of the objective function. Hence, their final form 5 is 31x1 x4 x7 2 21x2 x5 x8 2 01x2 W2, and F1 W1 W2) for shipping to W2. (Sections 15.2 and 15.3) Glossaries - 37 Glossary for Chapter 16 Alternatives The options available to the decision maker for the decision when both the remaining usable land constraint and these equations are satisfied. Thus, all states in the inventory example (see Fig. In the productivity of the economies of various countries. (Sections 13.3 and 13.10) Quadratic programming problems Nonlinear programming problems where all the constraint functions are linear and the objective function is quadratic. This is a widely used test in statistics where smaller values indicate a better fit. When the first version of the computer program is completed, it inevitably contains many bugs. Therefore, state i but not vice versa, that is, state i is not accessible from state j. One is the ability to toggle the worksheet between viewing the results in the output cells. (This step is frequently referred to as model validation.) Thus, in a certain sense, operations research involves creative scientific research into the fundamental properties of operations. At the same time, it does not allow negative values, so it automatically fits situations where this is needed. (Section 17.2) Transportation, so that either the customers or the server(s) are vehicles. (Treating and amalgamating are separate processes.) Three different grades of this product can be made (see the first column of Table 3.16), depending upon the mix of the materials used. 8.4 (An Interior-Point Algorithm), and Chap. A manufacturer has a machine that, when operational at the beginning of a day, has a probability of 0.1 of breaking down sometime during the day. A second was to produce an efficient shift-level schedule for each plant over a 28-day horizon. Rosenthal: "Optimization Tradecraft: Hard-Won Insights from Real-World Decision Support," Interfaces, 38(5): 356-366, September-October 2008. Even if all these guidelines are followed, a thorough debugging process may be needed to eliminate the errors that lurk within the initial version of the model. (Actually, we are simplifying the example at this point, because normally dozens of possible beams must be considered.) For any proposed beam of given intensity, the analysis of what the resulting radiation absorption by various parts of the body would be requires a complicated process. 28.8 revealed that the deadline was met on 57.7 percent of the trials from one simulation run. In the preceding sections, we have illustrated the use of five of these distributions). n 1 2 . We will further describe these four software packages and how to use them later (especially near the end of Chaps. Before firing up Excel and blindly entering the various elements, it can be helpful to sketch a layout of the spreadsheet. The restrictions normally are referred to as constraints. 28.13) then gives Think-Big's total cash flow in the respective years for its share of the two projects. A6. Click Fit, which brings up the Fit Results chart that identifies the distribution that best fits the data. A solutions manual and image files for instructors. There might also be costs associated with arranging the distribution of the new product. Frontline Systems also has developed some advanced Excel-based data. (Section 16.3) Branch A line emanating from a node in a decision tree. (b) Repeat part a except set the trials per simulation to 1,000 in Simulation to 1,000 in Simulation Cl11:L21). 28.2) activity times (in Fig. This section also uses the case study in Sec. aij amount of resource i consumed by each unit of activity j. The five parties generally affected by a business firm located in a single country are (1) the owners (stockholders, etc.), who desire profits (dividends, stock appreciation, and so on); (2) the employees, who desire steady employment at reasonable wages; (3) the customers, who desire a reliable product at a reasonable price; (4) the suppliers, who desire integrity and a reasonable price; (4) the suppliers, who desire integrity and a reasonable price; (3) the customers, who desire a reliable product at a reasonable price; (4) the suppliers, who desire integrity and a reasonable price; (4) the suppliers, who desire integrity and a reasonable price; (3) the customers, who desire integrity and a reasonable price; (4) the suppliers, who desire integrity and a reasonable price; (4) the suppliers,
who desire integrity and a reasonable price; (4) the suppliers, who desire integrity and a reasonable price; (4) the suppliers, who desire integrity and a reasonable price; (4) the suppliers, who desire integrity and a reasonable price; (4) the suppliers, who desire integrity and a reasonable price; (4) the suppliers, who desire integrity and a reasonable price; (4) the suppliers, who desire integrity and a reasonable price; (4) the suppliers, who desire integrity and a reasonable price; (4) the suppliers, who desire integrity and a reasonable price; (4) the suppliers, who desire integrity and a reasonable price; (4) the suppliers, who desire integrity and a reasonable price; (4) the suppliers, who desire integrity and a reasonable price; (4) the supplice price camera that can be ordered weekly. Sheldon imposed a constraint on the decisions by reaffirming that the company would need to continue to observe the policy of maintaining a balance of at least \$500,000 in cash reserves at all times. (Section 16.6) Influence diagram A diagram that complements the decision tree for representing and analyzing decision analysis problems. These data are then used in the same ways as those described here to evaluate the model. The obejctive cell EndBalance (J21) indicates that the resulting cash balance in 2024 will be \$5. 3 9 million if all the data cells prove to be accurate. Armed with her cash flow projections and the loan options from the bank, Julie meets with the CEO, Sheldon Lee, to further define the problem. Even with this effort, much of the data may be quite "soft," i.e., rough estimates based only on educated guesses. (Section 10.8) Origin The node at which travel through the network is assumed to start for a shortestpath problem. if Therefore, for the transition to Xt1 3 or Xt1 2 or Xt1 1, p03 P{Dt1 0} 0.368, p02 P{Dt1 1} 0.368, p01 P{Dt1 2} 0.184. At this stage in the process, you should have a clear idea of what the answer will look like, including what and how many changing cells are needed, and what kind of results (output cells) should be obtained. Winston, W. A4. Instead, it fits into a category of linear programming problems called cost-benefit-trade-off problems. Frontline Systems cannot help you with homework problems. (Section 20.1) Parameter analysis report An ASPE module that systematically applies simulation over a range of values of one or two decision variables and then displays the results in a table. and yet it seems to be broad enough to encompass the basic goal of profitmaking organizations. 29.5-8. 20.6), whereas the uniform distribution was used to generate the bid for a construction project by one competitor (in Fig. (Section 20.3) Discrete-event simulation The type of simulation where changes in the state of the system occur instantaneously at random points in time as a result of the occurrence of discrete events. The job facing the Coordinating Technical Office is to plan how many acres to devote to each crop at the respective kibbutzim while satisfying the given restrictions. The point (2, 6) lies at the intersection of the two lines 2x2 12 and 3x1 2x2 18, shown in Fig. In recognition of this concept, OR teams occasionally use only heuristic procedures (i.e., intuitively designed procedures that do not guarantee an optimal solution) to find a good suboptimal solution. 29.8) are used to formulate most of the basic models of queueing theory. C (b) Use your IOR Tutorial to determine the n-step transition matrix P(n) for n 5, 10, 20, 40, 80. (Think about how the graphical method leads to the one optimal solutions, as shown in Fig. Since the objective is to minimize the total cost of the agents, subject to the benefit constraints, this is another example (like the radiation therapy and air pollution examples) of a cost-benefit-trade-off problem. What will be Susan's mean profit from selling the tickets? hil23453 ch03 025-092.qxd 1/30/70 7:57 AM 3.4 Final PDF to printer Page 51 ADDITIONAL EXAMPLES 51 This problem is another example (like the Wyndor problem) of a resource-allocation problem. Your OR Courseware includes separate Excel files for nearly every chapter in this book. Nigam, and J. (Section 15.6) Dominated strategy is dominated by a second strategy is always at least as good (and sometimes better) regardless of what the opponent does. When historical data are available, this feature will identify which of the available distributions provides the best fit to these data. Read Selected Reference A1 that describes an awardwinning OR study done for General Motors. (Section 14.2) Tabu search A type of metaheuristic that allows non-improving moves but also incorporates short-term memory of the past search by using a tabu list to discourage cycling back to previously considered solutions. The new Section 7.5 continues the discussion in Section 7.4 by turning to the case where there is some latitude for violating some constraints a little bit without very serious complications. A, material 42 1grade B, material 12 1grade B, material 12 1grade B, material 12 1grade C, material 12. Such mathematical expressions for the restrictions often are called constraints. The decision variable is ReservationsToAccept (C13). The profit results estimate that the mean profit per flight would be \$11,775. (Section 13.2) Global optimizer A type of software package that implements an algorithm that is designed to find a globally optimal solution for various kinds of nonconvex programming problems. N., and G. Many processes fit this description, so Markov chains provide an especially important kind of probability model. We believe that most students will find the examples in the book fully adequate but that others will feel the need to go through additional examples. These examples are used for illustrative purposes throughout many of the following sections. (This process is a streamlined version of both the OR 21-1 hil61217 ch21.gxd 4/29/04 03:40 PM Page 21-2 CHAPTER 21 21-2 THE ART OF MODELING WITH SPREADSHEETS modeling approach described in Chap. (c) Now suppose that the machine already has gone 20 full days without a breakdown since the last repair was completed. 3.2. It is possible for a problem to have no feasible solutions. (Section 17.2) Input source The stochastic process that generates the customers arriving at a queueing system. Powell, S. dev.) 21.923 10.122 14.780 Normal Normal Normal Normal Normal Normal Normal Normal 15 25 40 15 15 (mean, st. During each transmission, the products. Source: R. (Section 18.5) Two-bin system A type of continuous-review inventory system where all the units of a product are held in two bins and a replenishment order is placed when the first bin is depleted, so the second bin then is drawn on during the lead time for the delivery. A major advantage of incorporating the linear programming model into a spreadsheet has been the ease of explaining the model to managers with differing levels of mathematical understanding. 21-6. The student version of Analytic Solver Platform retains all these capabilities when dealing with smaller problems. 3-10 and 12), as well as CONOPT for convex programming (part of Chap. The uncertain variable cells are CashFlow (F12:F21), the results cell is EndBalance (N22), and the statistic cell is MeanEndBalance (N24). If you're evaluating the book for adoption, you can use the software. receive health insurance through a group plan issued by Wellnet. 28.23 are related to the binomial distribution because they again involve trials where there is a fixed probability on each trial that the event will occur. A number of other attractive software options continue to be provided in this edition (as described later). The example in Sec. In most cases, this means you must use nonlinear programming instead (presented in Chap. Jobs are processed at the work center one at a time and then leave immediately. In the spreadsheet model in Fig. Certainty assumption: The value assigned to each parameter of a linear programming model is assumed to be a known constant. By summing over all i j, the entire right-hand side then gives the rate at which the process enters state j from any other state. (c) Use ASPE's Solver to search for the long-term loan amount that maximizes Evergreen's mean ending balance. (b) How much time do the trainees devote to this program? 29.6-4. OR is closely intertwined with the use of computers. In general terms, the mathematical maturity that a student achieves through taking an elementary calculus course is useful throughout Chaps. However, this task is considerably simplified if the stochastic process involved possesses the following key property. Now consider how to obtain the (one-step) transition matrix State 0 1 P 2 3 0 [ p00 | | p10 | | p20 | | p30 1 p01 p11 p21 p31 2 p02 p12 p22 p32 3 p03 p13 || p23 | | p33 ] given that Dt1 has a Poisson distribution with a mean of 1. ainxn bi for some values of i. It says that the probability distribution of the remaining time until the process transits out of a given state always is the same, regardless of how much time the process has already spent in that state. (Section 18.5) Newsvendor problem A standard stochastic single-period model for perishable products. The Markov chains to be considered in this chapter have the following properties: 1. Another was deleting certain low-priority material, including the presentation of parametric linear programming in conjunction with sensitivity analysis (it already is covered later in Section 8.2) and a complicated dynamic programming example (the Wyndor problem with three state variables) that can be solved much more easily in other ways. We will begin by looking at the continuous distributions. Replicability should be part of the professional ethical code of the operations researcher. (c) How many specific models does the company now use as a result of this study? This indicates that the amount of variability in the profit values also increases
until the simulation run for 180 reservations and then remains about the same thereafter. These loans can be taken out each year as needed, but each must be repaid (with interest) the following year. 3 to 15 are almost independent, except that they all use basic material presented in Chap. C 5 0 0 0 0 34 0 0 0 0 12 0 2 3 29.4-5. Furthermore, most of the remaining trials had at least 130 seats filled. This is known as a relative reference. hil23453 ch03 025-092.qxd 52 1/30/70 7:57 AM CHAPTER 3 Final PDF to printer Page 52 INTRODUCTION TO LINEAR PROGRAMMING TABLE 3.13 Reduction in emission rate (in millions of pounds per year) from the maximum feasible use of an abatement method for Nori & Leets Co. Taller Smokestacks Pollutant Filters Better Fuels Blast Open-Hearth Blas Hearth Blast Open-Hearth Furnaces Furna optimal solution, it must be a CPF solution. State 012P3450[0|0||1|0|0||01000140122010010340000[014 52029.5-2. The distinction between theory and the realities frequently faced in trying to implement that theory in practice. The number of dollars that player current time, t s t is t time units into the future. 28.16. Graham, S. Consequently, the total products are produced jointly would be less than the sum of the products when each is produced by itself. Furthermore, the individual chapters among Chaps. Grassmann, W. Rather than draw several parallel lines, it is sufficient to form a single line with a ruler to establish the slope. Developing estimates for the second category of data required some analysis by the manufacturing engineers involved in designing the products. When this formula is copied to a new cell, the reference is automatically adjusted to refer to the new cell that is at the same relative location (two cells to the left and one cell up). 29.2 has only two states (dry and rain), so the above steady-state equations become 0 0p00 1p10, 1 0p01 1p11, 1 0 1. kj kj hil23453 ch29 001-036.qxd 1/22/1970 10:53 PM Page 22 CHAPTER 29 MARKOV CHAINS Thus, the probability of a first passage time from state i to state j in n steps can be computed recursively from the one-step transition probabilities. A discrete distribution is used if only certain specific values (e.g., only the integer numbers over some range) are possible. 2.4-2. This probability is denoted by fik. E\* (e) Expand the model to full scale, and then solve it. (b) Repeat part a for option 3. (Supplement 2) Method of successive approximations A method for quickly finding at least an approximation to an optimal policy for a Markov decision process under the discounted cost criterion by solving for the optimal policy with n stages to go for n = 1, then n = 2, and so forth up to some small value of n. The OR Courseware contained on the book's website (www.mhhe.com/hillier) will be a key tool for doing all this. (a) Summarize the background that led to undertaking this study. We also will demonstrate how to do this efficiently with the help of a parameter analysis table in Sec. x2 Maximize Z 3x1 5x2, x1 subject to 2x2 3x1 2x2 3x1 5x2 x2 x1 0, and 10 3x1 5x2 50 8 4 12 18 50 0 6 2x2 12 4 3x1 2x2 18 x1 0 2 x1 4 x2 0 0 2 4 6 8 10 x1 hil23453\_ch03\_025-092.qxd 1/30/70 36 7:57 AM CHAPTER 3 Page 36 Final PDF to printer INTRODUCTION TO LINEAR PROGRAMMING An optimal solution is a feasible solution that has the most favorable value of the objective function. Such is the nature of satisficing. The expression on the left-hand side is not a linear function because it involves products of variables. n-step transition matrices obtained in part (a) compare to these steady-state probabilities as n grows large. E. Julie Lee is the chief financial officer (CFO) at Everglade. For the distribution that provides the best fit (Uniform), the distribution is plotted (the horizontal line at the top of the chart) so that it can be compared with the frequency distribution of the historical demand data. For instance, it may be tempting to include the cash balances as changing cells. (Section 16.6) Sensitivity analysis The study of how other plausible values for the probabilities of the states of nature (or for the payoffs) would affect the recommended decision alternative. One possibility would be to increase the size of the long-term loan, since this would reduce the size of the long-term loan state would be to increase the size of the size of the long-term loan. optimal solutions—(2, 6) and (4, 3)—are CPF solutions. (b) Suppose that Al were to invest \$20,000 each in investment A (year 2), and investment A (year 2), and investment B (year 2), and investment A (year 2). interviews before the final ruling to help prevent potential unemployment insurance fraud. (b) What was the purpose of this study? In addition, he updated the 10th edition version of the solutions manual. One advantage is that a mathematical model describes a problem much more concisely. During the planning step, after defining the problem clearly and gathering the relevant data, it is helpful to begin by visualizing where you want to finish and then doing some calculations by hand to clarify the needed computations before starting to pp. 28.13 to represent cash flows, the means were small or even negative, but this also wase no problem since cash flows can be either negative or positive.) The Triangular Distribution of the shapes of the triangular and normal distributions in Fig. (a) Set the triangular and normal distribution of the shapes of the triangular and normal distributions in Fig. (b) Set the triangular Distribution of the shapes of the triangular and normal distributions in Fig. (c) Set the triangular and normal distribution of the shapes of the triangular and normal distributions in Fig. (c) Set the triangular and normal distributions in report already has been presented in Sec. Strictly speaking, the model should have an additional constraint for each decision variable must have an integer value. Gass (eds.): Profiles in Operations Research: Pioneers and Innovators, Springer, New York, 2011. They tell the true story of how the Oakland Athletics baseball team achieved great success, despite having one of the smallest budgets in the major leagues, by using various kinds of nontraditional data (referred to as sabermetrics) to better evaluate the hil23453 ch01 001-009.gxd 1/15/70 7:40 AM 1.4 Page 5 THE IMPACT OF OPERATIONS RESEARCH Final PDF to printer 5 potential of players available through a trade or the draft. 3), but E\* (e) Expand the model to full scale, and then solve it. (Section 11.2) Recursive relationship An equation that enables solving for the optimal policy for each stage of a dynamic programming problem in terms of the optimal policy for the following stage. (Section 10.8) Link An alternative name for undirected arc defined below. To illustrate, consider the gambling example presented at the end of Sec. (b) Which distribution provides the second-closest fit to the data? Lo, and M. The results cells are Profit (F23), NumberOfFilledSeats (C20), and NumberDeniedBoarding (C21). Thus, having stationary transition probabilities implies that the transition probabilities do not change hil23453 ch29 001-036.gxd 1/22/1970 10:52 PM Page 4 Confirming Pages 4 CHAPTER 29 MARKOV CHAINS over time. These results can also be used to interpret the meaning of the j. In addition, a one-year loan will be taken at the beginning of each year from 2014 to 2023 if it is needed to bring the cash balance for that year up to Build Start with a small-scale model Test Try different trial solutions to check the logic Analyze Evaluate proposed solutions and/or optimize with Solver If the solution reveals inadequacies in the model, return to Plan or Build Each of these four major steps may also include some detailed steps. Consider again the Rijkswaterstaat OR study of national water management policy for the Netherlands, introduced at the end of Sec. One is that there is nearly a 20 percent chance of losing money (a negative NPV). (Section 14.2) Temperature schedule used by a simulated annealing algorithm to adjust the tendency to accept the current candidate to be the next trial solution if this candidate is not an improvement on the current trial solution. 21.5. 21.5 CONCLUSIONS There is considerable art to modeling well with spreadsheets. Hence, C(0, Dt) 85 50 (max{Dt 3, 0}) 85 50[PD(4) 2PD(5) 3PD(6)], where PD(i) is the probability that the demand equals i, as given by a Poisson distribution with a mean of 1, so that PD(i)
becomes negligible for i larger than about 6. That is, if state i in a class has period t, then all states in that class have period t, then all states in that class have period t, then all states in that class have period t. 1 j this chapter. (Section 17.5) Calling population The population of potential customers that might need to come to a queueing system. Therefore, after the sensitive parameters are identified, special attention is given to estimating each one more closely, or at least its range of likely values. (Section 13.9) SUMT An acronym for sequential unconstrained minimization technique, defined above. The company was founded in 1946 by Alfred Lee, who was in the right place at the right p computerbased model, whereas this chapter describes six broader phases. C 29.6-1., so these are stationary transition probabilities. On the average, only 80 percent of the customers who make reservations for this flight actually show up to take the flight. In addition, your OR Courseware includes an Excel file, a LINGO/LINDO file, and an MPL/Solvers file showing how the respective software packages can be used to solve each of the examples in this chapter. (Introduction and Section 14.1) Mutation A random event that enables a child to acquire a feature that is not possessed by either parent during an iteration of a genetic algorithm. This module efficiently uses a series of simulation runs to search for an optimal solution for a simulation model with any number of decision variables. 21.3.) Building a small version of the spreadsheets that have a time dimension. Here the OurBid (C25) parameter cell will be varied over six different values and the value of the mean will be displayed for each of the six simulation runs. Earlier editions of this solutions manual were prepared in an exemplary manner by a long sequence of PhD students from our department, including Che-Lin Su for the 8th edition. The company's great dependence on OR has continued to the present day. From the bottom part of the selected references given at the end of the chapter, select three of these award-winning applications of the OR modeling approach (excluding any that have been assigned for other problems). Plan: Sketch Out a Spreadsheet Any model typically has a large number of different elements that need to be included on the spreadsheet. Each trial of a simulation run generates a value in each results cell. Additional simulation runs are needed with other numbers entered in Reservations To Accept (C13) to pin down the optimal value of this decision variable. Identify each of the guidelines in Sec. Since those early days of chaos, most states have adapted and made improvements to handle all the claims. Let Xn (n 0) denote its location on the circle after step n. The number of hours of production time used per week in Plant 3 by choosing x1 and x2 as the new products' products' products (0, 1, 2, 3, 4, each with probability 15. A finite number of states. The book's website will provide updates about the book, including an errata. Here is a summary of the key cells in this model: Uncertain variable cells: SimulatedTicketDemand (C10) and NumberThatShow (C17) Decision variable cells: SimulatedTicketDemand (C10) and SimulatedT NumberDeniedBoarding (C21) Statistic cells: MeanFilledSeats (C23), MeanDeniedBoarding (C24), MeanProfit (C25) (See Sec. This has enabled me to spend far more than the usual amount of time in preparing each new edition., Xt must be independent of Dtm In particular, if these conditions are satisfied, then M 1 n lim E C(Xt, Dtm) k(j) j. t1 j0 where k(j) E[C(j, Dtm)], and where this latter conditional expectation is taken with respect to the probability distribution of the random variable Dt, given the state j. (Note that the points do not satisfy the inequality.) The resulting region of permissible values of (x1, x2), called the feasible region, is shown in Fig. Since the model necessarily is an idealized rather than an exact representation of the real problem, there cannot be any utopian guarantee that the optimal solution for the model will prove to be the best possible solution that could have been implemented for the real problem. Like the Everglade example in the preceding section, you will see simulation being used to refine prior analysis was unable to take the uncertainty in future cash flows into account. Second, there is more than half (\$10 million) as much as the mean gain (\$18 million). FedEx has come to be acknowledged as a worldclass company. With more than one beam (administered sequentially), the radiation absorption is additive. (b) For each of the classes identified in part (a), determine the period of the states in that class. (Section 10.2) CPM An acronym for critical path method, a technique for assisting project managers with carrying out their responsibilities. Notice the differences between this model and the one in Sec. 2.4 (testing the model), postoptimality analysis also involves obtaining a sequence of solutions that comprises a series of improving approximations to the ideal course of action. These will be the changing cells (the cells containing the values of the decision variables) in the spreadsheet model. 2.7-1. The opportunity for this event to occur arises when a customer makes a reservation for the flight. 27 hil23453\_ch28\_001-047.qxd 1/22/1970 10:51 PM Page 28 ChAPTER 28 EXAMPLES OF PERFORMING SIMULATIONS ON SPREADSHEETS these trials, the number ranged between 1 and 10. Soon thereafter, Sheldon and Julie meet to discuss her report. G. and in (n) state 1 at times 1, 3, 5, . However, not much was said about why any particular distribution was chosen. 28.11). Next, these two parties share the responsibility for developing the procedures required to put this system into operation. 28.32 provides additional insight. The net result is what is known as a bimodal distribution, with two distinct peaks, as shown in the chart on the left side of the dialog box. Therefore, the decision variable in Fig.28.2 is OurBid (C25). 29.7-1. For example, if certain constraints considerably complicate a problem, start by working on a simpler problem without the difficult constraints. The one that has the characteristics to fit this uncertain variable cell turns out to be the binomial distribution. The company's policy is to accept 10 percent of all its customers making reservations end up being no-shows. A particularly dramatic development in the field of operations research over the last several years has been the great buzz throughout the business analytics) and the importance of incorporating analytics into managerial decision making. For alternative approaches that combine linear programming with other OR techniques (like the application vignette in this section), also see G. This led to savings of approximately \$40 million. Gather the data needed to identify the best distribution to enter into an uncertain variable cell. 28.1. Consider the Reliable Construction Co. project scheduling example presented in Sec. A special arrangement has been made with Frontline Systems to provide students with a free 140-day license for ASPE. (Section 10.8) Project duration The total time required for the project. 21.4. Test: Test the Full-Scale Version of the Model Just as it was important to test the small version of the model, it needs to be tested again after it is expanded to full-scale size. (The next chapter will focus on the simplex method for solving larger problems.) Conclusions The OR team used this approach to find that the optimal solution is x1 2, x2 6, with Z 36. The election had been propelled by descriptive and predictive analytics was given much of the credit for the clear-cut Obama win. In some cases, certain parameters of the model represent policy decisions (e.g., resource allocations). Thus, the optimal design is to use a total dose at the entry point of 7.5 kilorads for beam 1 and 4.5 kilorads for beam 2. (a) Describe the author's viewpoint of 7.5 kilorads for beam 2. (b) Describe the author's viewpoint of 7.5 kilorads for beam 2. (c) Describe the author's viewpoint of 7.5 kilorads for beam about whether the sole goal in using a model should be to find its optimal solution. All that is really needed is that there be a reasonably high correlation between the prediction of the model and what would actually happen in the real problem. For experienced OR practitioners, finding a solution is the
fun part, whereas the real work comes in the preceding and following steps, including the postoptimality analysis discussed later in this section., which can be verified by calculating p(n) 11 for all n and noting that p(n) 11 for all n and noting the Learning Process with Your OR Courseware This is the first of many points in the book where you may find it helpful to use your OR Courseware on the book's website. This included adding relatively new developments (the four new sections mentioned above) that now warrant consideration in an hil23453 fm\_i-xxx.qxd 1/30/70 7:58 AM Page xxv PREFACE Final PDF to printer xxv introductory survey course, as well as making sure that all the material in the ninth edition has been brought up to date. Since both breakdowns and repairs occur one at a time, q02 0 and q20 0. 21.5 to specify the objective cell, the changing cells, and the constraints. 2.2-4. For Case 3 (see Table 3.6), the products is given by the function 3x1 2x2 0.5x1x2, so the total function value is 6 6 3 15 when (x1, x2) (2, 3), which violates the additivity assumption that the value is just 6 6 12. The existence of stationary (one-step) transition probabilities also implies that, for each i, j, and n (n 0, 1, 2, . (Focus especially on pp. It is used to simulate whether a particular event occurs or not. With considerable difficulty, it is possible to extend the method to three decision variables but not more than three. If so, there frequently is some flexibility in the values assigned to these parameters. Proportionality assumption: The contribution of each activity xj, as represented by the cjxj term in the objective function. However, no computational advantage is gained by deleting these three nonnegativity constraints.) The optimal solution for this model is (x1, x2, x3, x4, x5) (48, 31, 39, 43, 15). The j can also be interpreted as stationary probabilities) in the following sense. The variety of situations to which this description applies is diverse, indeed, ranging from the allocation of production facilities to products to the allocation of national resources to domestic needs, from portfolio selection to the selection of shipping patterns, from agricultural planning to the design of radiation therapy, and so on. (Section 10.2) Glossaries - 21 Marginal cost analysis A method of using the marginal cost of crashing individual activities on the current critical path to determine the least expensive way of reducing project duration to a desired level. The minimum and maximum value are specified as 0 and 50. Nonnegativity: xj 0, for j 1, 2, . Nearly all unemployment agencies accept claims online, especially in light of the COVID-19 pandemic. (b) Briefly describe the user interface with the decision support system OMEGA that was developed as a result of this study. Personnel Scheduling UNION AIRWAYS is adding more flights to and from its hub airport, and so it needs to hire additional customer service agents. For any irreducible ergodic Markov chain, lim p(n) ij exists and is independent of i. 2 and the outline of a major simulation study presented in Sec. Thus, in addition to option 1 (the proposal), option 2 is to take a 16.50 percent share of the shopping center project), and option 3 is to take a 13.11 percent share of the shopping center project). possible, and watch closely for any messages requesting additional information. The key to formulating this particular problem is to recognize the nature of the activities. He published extensively in the areas of reliability and quality control, and in the modeling of complex systems, including their optimal design, when resources are limited. Suppose now that whether or not the stock goes up tomorrow depends upon whether it increased today, yesterday, and the day before yesterday. Table 3.1 indicates that each batch of product 1 produced per week in Plant 1, whereas only 4 hours per week are available. The projected cash flows (in millions of and 200 hours of labor available for the coming week's produc- dollars) associated with each project are shown in the table below. Table 3.13 shows how much emission (in millions of pounds per year) can be eliminated from each type of furnace by fully using any abatement method to its technological limit. (e) List the various tangible and intangible benefits that resulted from the study. Obtaining funding likely will take approximately six months (with a standard deviation of one month). 17.4.) The Poisson distribution has some other applications as well. (Section 12.6) IP An abbreviation for integer programming. In fact, these latter three courses (the material in the entire text) can be viewed as a basic oneyear sequence in the techniques of operations research, forming the core of a master's degree program. Similarly, if j is a transient state, then lim p(n) ij 0,  $n \rightarrow$  for all i. 21.5. You now can immediately see that LTLoan (D11) is used in the calculation of LT Interest for every year in column F, in the calculation of LTPayback (H21), and in the calculation of the ending balance in 2014 (J11). Today, the company continues to be run by the Lee family, with Alfred's grandson, Sheldon Lee, as the CEO. I was a very young assistant professor just starting my career. (Section 17.2) Glossaries - 44 Service cost The cost associated with providing the servers in a queueing system. Figure 28.26 shows a portion of the data he has gathered over the last 60 days in cells F4:F63, along with part of the original spreadsheet model from Fig. 2.1-4. 162–163, describe why the interactive aspects of SYSNET proved important. Therefore, a linear programming model cannot be constructed with these decision variables. Different types of solutions are then identified by using an appropriate adjective. For example, a wonderful chapter on metaheuristics was created for the eighth edition. 28.19 reveals some key differences. This program includes a complete demonstration example of the graphical method introduced in this section. determine the classes of the Markov chain and whether they are recurrent. To give you a better notion of the wide applicability of OR, we list some actual appli Crossover point When plotting the lines giving the expected payoffs of two decision alternatives versus the prior probability of a particular state of nature, the crossover point is the point where the two lines intersect so that the decision is shifting from one alternative to the other. appearing in cells D6 and D16, so these are data cells. CourseSmart has the largest selection of eBooks available anywhere. We next describe a special feature of ASPE for creating one of the 7 available custom distributions when none of the 7 available custom distributions when none of the 7 available anywhere. We next describe a special feature of ASPE for creating one of the 7 available custom distributions when none of the 7 available cust models represented environmental standards. Consequently, a transient state will be visited only a finite number of times. Small-scale testing proved that the model worked. If Xt 0, do not order any cameras. It is important to distinguish between the numbers that represent decisions (changing cells) and those that represent results (output cells). For example, in the inventory example introduced in Sec. What numbers will Larry next is an example of a poorly formulated spreadsheet model for require? At this point, it can be helpful to think about where you want to end up. Explain. This is no coincidence, since any line constructed in this way has the form Z 3x1 5x2 for the chosen value of Z, which implies that 5x2 3x1 Z or, equivalently, 31 x2 x1 Z 5 5 hil23453 ch03 025-092.qxd 1/30/70 7:57 AM 3.1 Page 31 Final PDF to printer PROTOTYPE EXAMPLE 31 This last equation, called the slope-intercept form of the objective function, demonstrates that the slope of the line is 53 (since each unit increase in x1 changes x2 by 53), whereas the intercept of the line with the x2 axis is 51 Z (since x2 51 Z when x1 0). Ferris, S. Once again, problems are included at the end of these chapters that require reading one or more of the articles describing these applications. Therefore, the results cell is NetPresent Value (D37). Based on this experience, Wellnet now is negotiating the corporation's premium payment per employee for the upcoming year. (b) Generate a trend chart for the 11 forecasts considered in part a. Proceeding tentatively along this line, we define yi number of pounds of product grade i produced per week 11 A, B, C2. A3. Therefore, to formulate the mathematical (linear programming) model for this problem, let x1 number of batches of product 1 produced per week x2 number of batches of product 2 produced per week Z total profit per week Z the deadline of 47 weeks for each simulation run. When historical data are available, ASPE also has a procedure for identifying which continuous distribution fits the data best. 2.5-1. If it is down, the computer is repaired, which may require more than hil23453 ch29\_001-036.qxd 1/22/1970 10:53 PM Page 35 Confirming Pages PROBLEMS 1 hour. C (b) Use your IOR Tutorial to find the 10-step transition matrix P(10). 29.4 how the process eventually will enter either state 0 or state 3 and then will never leave that state again. 29.5-9. Fare / Seat Cost of Bumping Data 150 \$30,000 \$450 Ticket Demand Demand (rounded) 179.74 180 Reservations to Accept 190 Number That Show 153 Number of Filled Seats Number Denied Boarding 150 3 Mean Filled Seats Mean Denied Boarding Mean Profit 142.27 2.02 \$11,775 B C Demand (rounded) = ROUND(SimulatedTicketDemand,0) 15 16 17 20 21 E Tickets Purchased = MIN(Demand,ReservationsToAccept) Ticket Revenue Bumping Cost Fixed Cost Profit 20 21 22 23 Range Name Cell C4 C6 F21 C7 C11 C5 C24 C23 C25 C21 C20 C17 F17 F23 C13 C10 F20 E17 B C Number of Filled Seats = MIN(AvailableSeats, NumberThatShow) + PsiOutput() Mean Filled Seats = PsiMean(C20) Mean Denied Boarding =
PsiMean(C21) Mean Profit = PsiMean(F23) E Ticket Revenue Bumping Cost Fixed Cost Profit \$45,000 \$13,650 AvailableSeats AverageFare BumpingCost CostOfBumping Demand FixedCost MeanDeniedBoarding NumberOfFilledSeats NumberThatShow ProbabilityToShowUp Profit ReservationsToAccept SimulatedTicketDemand TicketRevenue TicketsPurchased 22 23 24 25 25 F = AverageFare\*NumberOfFilledSeats = CostOfBumping\*NumberOfFilledSeats = CostOfBumping\*Numb SPREADSHEETS FIGURE 28.17 A binomial distribution with parameters TicketsPurchased (E17) and ProbabilityToShowUp (F17) is being entered into the uncertain variable cell NumberThatShow (C17). Julie and Sheldon agree that some sensitivity analysis should be done to check on the effect of such changes. Just as recurrence is a class property, it can be shown that periodicity is a class property. This resulted in increased revenues of over \$1 billion by the time the implementation of the OR study was completed. (When the objective is to minimize Z, move the ruler at the last instant that it still passes through a point in this resulted in increased revenues of over \$1 billion by the time the implementation of the OR study was completed. region. That is, all states in a class are either recurrent or transient. Examples of activities include investing in particular projects, advertising in particular destination. (The same is true of states 1 and 3, states 1 and 0, and states 2 and 0.) In general, p(n) ij 1. T. Wagner Prize for Excellence in Operations Research Practice., n 1 are the only interesting cases. 21.3, so we can be fairly certain that it is correct. Upper-bound constraints: xF1-F2 10, xDC-W2 80 3. xi1 xi2 xi3 xi4 The fact that this last expression is a nonlinear function does not cause a complication. The Normal Distribution The normal distribution is widely used by both OR professionals and others because it describes so many natural phenomena. Take a 13.11 percent share of the shopping center project. After obtaining the steady-state probabilities (0, 1, . Ever since its founding in 1973, OR has helped make its major business decisions, including equipment investment, route structure, scheduling, finances, and location of facilities. For most of these flights, the number of requests for reservations considerably exceeds the number of seats available. Ohlmann (eds.): Special Issue on Analytics in Sports, Part I: General Sports, Part I: Gen decision variables. Its key characteristic is that even though only nonnegative values are allowed, its standard deviation actually is larger than its mean. Operating management then sees that a detailed indoctrination is given to the personnel involved, and the new course of action 15.6) Glossaries - 36 Payoff table A table that shows the gain (positive or negative) for player 1 that would result from each combination of strategies for the two players in a two-person, zero-sum game. To alert you to relevant material in OR Courseware, the end of each chapter that requires the student to read the full article describing the application and then answer some questions. ConnectPlus Engineering provides students with all the advantages of Connect Engineering, plus 24/7 online access to a media-rich eBook. State 0 1 P 2 3 4 33 A B C A B C 0.8 0.25 0.15 0.15 0.05 0.05 0.05 0.05 0.08 What are the steady-state market shares for the two major breweries? Data are taken monthly, and the analyst has constructed the following (one-step) transition matrix from past data. The primary impetus for this buzz was a series of articles and books by Thomas H. 1 3 1 Starting from state 2, the probability of absorption into state 0 (A losing all her money) can be obtained by solving for f20 from the system of equations given at the beginning of this section, f00 1 (since state 0 is an absorbing state). (Section 18.3) (R, Q) policy An abbreviation for reorder-point, order-quantity policy, where R is the reorder point and Q is the order quantity. (ed.): Computational Probability, Kluwer Academic Publishers (now Springer), Boston, MA, 2000. Following graduation, Ms. Stephens worked at Andersen Consulting as a systems integrator, experiencing real cases from the inside, before resuming her graduate studies to earn a JD degree (with honors) from the University of Texas Law School at Austin. This restriction is expressed mathematically by the inequality x1 4. This result is important in computing the long-run average cost per unit time associated with a Markov chain. hil61217 ch21.qxd 4/29/04 03:41 PM CHAPTER 21 21-12 A 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 9 10 11 12 0.50 0.50 0.50 0.50 Everglade Cash Flow Management Problem LT Rate ST Rate 5% 7% Start Balance Minimum Cash 1 0.5 Year 2014 2015 2016 2017 2018 2019 2020 2021 2022 2023 2024 F LT Interest =-LTRate\*LTLoan =-LTRat LTRate\*LTLoan =-LTRate\*E10 =-STRate\*E10 =-STRate\*E11 =-STRate\*E11 =-STRate\*E12 =-STRate\*E10 =-ST 9.88 7.81 2.59 0 4.23 0 0 0 I ST Payback =-E11 =-E12 =-E13 =-E14 =-E15 =-E16 =-E17 =-E17 =-E16 =-E17 = LP LT Interest ST Interest -0.23 -0 1Cash StartBalance STLoan STRate K >= >= >= >= >= >= >= >= >= >= >= L Minimum Balance =MinimumCasn =Mini Balance LILoan LIRate I =MinimumCash =Mini (E11:E20). The next bullet point describes how students have immediate access to these articles. Gass, S. Elliott (eds.): Hidden Markov Models in Finance, Springer, New York, 2007. Even when the full quota of 165 reservations has been reached (which happens for most of the flights), there usually are a significant number of empty seats. Hall, R. In addition, the Institute for Operations Research and the Management Sciences (INFORMS) is an international OR society that is headquartered in the United States. so so 17 0.20 0.61, 0.61 0.20, Note that one of the first two equations is redundant since both equations is reduced at the redundant since both equations is reduced at the redundant since both equations is reduced at the reduced a frames are made in Plant 2, and Plant 3, and Plant 3 produces the glass and assembles the products. Reboot's top management has (b) Suppose that Fairwinds were to participate in Project C at 50 percent. For instance, looking at the by-hand calculations above, it appears that the formula for the ending balance for a particular year should be Ending balance cash flow loan paybacks. Therefore, the two decision variables x1 and x2 represent the dose (in kilorads) at the entry point for beam 1 and beam 2, respectively. With McGraw-Hill Create<sup>™</sup>, you can include only the chapters you want to cover. 0.171  $0.164 \mid [0.249 \mid 0.283 \mid | 0.283 \mid | 0.283 \mid | 0.285 \mid | 0.249 \mid 0.286 \mid 0.252 \mid 0.319 \mid 0.286 \mid 0.300 \mid 0.233 \mid 0.200 \mid 0.165 \mid 0.233 \mid | 0.097 \mid | 0.165 \mid 0.282 \mid 0.282 \mid 0.282 \mid 0.282 \mid 0.281 \mid | 0.249 \mid 0.281 \mid | 0.249 \mid 0.286 \mid 0.282 \mid 0.283 \mid | 0.249 \mid 0.281 \mid | 0.249 \mid 0.286 \mid 0.281 \mid | 0.249 \mid 0.286 \mid 0.233 \mid 0.291 \mid 0.281 \mid | 0.249 \mid 0.283 \mid | 0.281 \mid | 0.249 \mid 0.286 \mid 0.281 \mid | 0.249 \mid 0.286 \mid 0.233 \mid 0.282 \mid 0.282 \mid 0.282 \mid 0.282 \mid 0.283 \mid | 0.281 \mid | 0.249 \mid 0.281 \mid | 0.249 \mid 0.286 \mid 0.281 \mid | 0.249 \mid 0.286 \mid 0.233 \mid 0.233$ there will be no cameras in stock 4 weeks later, that is, p10 0.282. IOR Tutorial includes many interactive procedures for executing the algorithms interactively in a convenient format. The unit production cost will be \$10, \$12, or \$14, depending on which process is needed. 9 0.9 0.6 0 1 0.4 0.1 0.3 0.5 2 FIGURE 29.4 The state transition diagram for the gambling example. Which purchase quantity maximizes Susan's mean profit? (Also see Selected References A4 and A6 for other examples where a decision support system played a vital role in an award-winning OR application.) implement this system as prescribed by management. FIGURE 28.28 This Fit Results dialog box
identifies the continuous distributions that provide the best fit, ranked top-to-bottom from best to worst on the left side. A number of studies of U.S. corporations have found that management tends to adopt the goal of satisfactory profits, combined with other objectives, instead of focusing on long-run profit maximization. Fry, M. In this case, the event of interest is a passenger showing up to take the flight. 21.4 show one possible plan, which turns out to be unacceptable because Ending Balance (J11:J21) indicates that a negative ending balance would result in four of the years. When j i, this first passage time is just the number of transitions until the process returns to the initial state i. 16 to 20 and for the more advanced material in the preceding chapters. This can be deduced from the context of the game (once the player never leaves this state), which implies that p(n) 32 0 for all n 0. First, the editions have been outstanding from students' points of view due to excellent motivation, clear and intuitive explanations, good examples of professional practice, excellent organization of material, very useful supporting software, and appropriate but not excessive mathematics. (a) What is the main objective of the GO academy? A related problem is that as the complexity and specialization in an organization in crease, it becomes more and more difficult to allocate the available resources to the various activities in a way that is most effective for the organization of an integer programming problem that is obtained by deleting the entire set of functional constraints and then modifying the objective function in a certain way. Because the total dosage reaching the healthy anatomy is to be TABLE 3.7 Data for the design of Mary's radiation therapy Fraction of Entry Dose Absorbed by Area (Average) Area Healthy anatomy is to be 0.5 0.6 0.5 0.1 0.5 0.4 Restriction on Total Average Dosage, Kilorads Minimize 2.7 6 6 hil23453 ch03 025-092.qxd 1/30/70 7:57 AM 3.4 Final PDF to printer Page 47 ADDITIONAL EXAMPLES 47 minimized, let Z denote this quantity. hil23453 ch03 025-092.qxd 1/30/70 7:57 AM 3.4 Final PDF to printer Page 47 ADDITIONAL EXAMPLES 47 minimized, let Z denote this quantity. hil23453 ch28 001-047.qxd 1/22/1970 10:51 PM Page 21 Confirming Pages 28.4 FINANCIAL RISK ANALYSIS 21 Here is a summary of the key cells in this model: Uncertain variable cells: Cells D7:D13 and D17:D23 Decision variables: HotelShare (H28) and ShoppingCenterShare (H28) and ShoppingCenterShare (H28) and D17:D23 Decision variables: HotelShare (H28) and ShoppingCenterShare (H28) and D17:D23 Decision variables: HotelShare (H28) and ShoppingCenterShare (H28) and D17:D23 Decision variables: HotelShare (H28) and ShoppingCenterShare (H28) and D17:D23 Decision variables: HotelShare (H28) and D17:D23 Decision variables: HotelShare (H28) and ShoppingCenterShare (H28) and D17:D23 Decision variables: HotelShare (H28) and ShoppingCenterShare (H28) and D17:D23 Decision variables: HotelShare (H28) and ShoppingCenterShare (H28) and ShoppingCenterShare (H28) and ShoppingCenterShare (H28) and D17:D23 Decision variables: HotelShare (H28) and ShoppingCenterShare (H28) and ShoppingCent of x1 and x2 so as to Maximize Z 3x1 5x2, subject to the restrictions 4 2x2 12 3x1 2x2 18 x1 and x1 0, x2 0. 29.1, we now will calculate its n-step transition matrices to three decimal places for n = 2, 4, and 8. 3.2 are feasible solutions, while the points (1, 3) and (4, 4) are infeasible solutions. Together they have worked out stringent air quality standards for the Steeltown airshed. This group included Linda Chattin, Arizona State University Antoine Deza, McMaster University James Luedtke, University of Wisconsin-Madison Layek Abdel-Malek, New Jersey Institute of Technology Jason Trobaugh, Washington University in St. Louis Yiliu Tu, University of Calgary Li Zhang, The Citadel Xiang Zhou, City University of Hong Kong In addition, thanks go to those instructors and students who sent email messages to provide their feedback on the 9th edition. (b) What was the goal of this study? 3 onward has a list entitled Learning Aids for This Chapter on our Website. Lavengood Professor of the Year Award. 2.1 DEFINING THE PROBLEM AND GATHERING DATA In contrast to textbook examples, most practical problems encountered by OR teams are initially described to them in a vague, imprecise way. Application to the Weather Example. (Section 18.2) Glossaries - 49 Scientific inventory management The process of formulating a mathematical model to seek and apply an optimal inventory policy while using a computerized information processing system. E\* 21-1. 4.8 (LINDO and Various solvers of MPL), and Appendix 4.1 (LINGO and LINDO). 29.8-1. Course codes MUST be renewed each year. During this interview, you will be asked specific questions about your employment background and other information mentioned in your claim. hil23453 ch02 010-024.qxd 16 1/15/70 7:34 AM CHAPTER 2 Page 16 Final PDF to printer OVERVIEW OF THE OPERATIONS RESEARCH MODELING APPROACH Since much of this book is devoted to the subject of how to obtain solutions for various important types of mathematical models, little needs to be said about it here. In each case, explain how it vioshould the objective function is to be maximized, whereas it is the smallest value if the objective function is to be minimized. Consequently, the complete transition matrix (to three significant digits) is State 0 1 P 2 3 0 [ 0.080 | | 0.632 | 0.264 | [ 0.080 1 0.184 0.368 0.368 0.368 0.368 0.368 0.368 0.368 0.368 ] 0 | 0 | 0 | 0.368 ] The information given by this transition matrix can also be depicted graphically with the state transition diagram in Fig. Characteristics of the Available Distributions The probability distributions of the possible values of the relative likelihood of the possible values of the selected references given at the end of the chapter, select one of these award-winning applications of the OR modeling approach (excluding any that have been assigned for other problems). (Section 12.9) Either-or constraints A pair of constraints A pair of constraints such that one of them (either one) must be satisfied but the other one) must be satisfied but the other one can be violated. For notational convenience, these states are labeled 0, 1, . To simplify notation, we shall denote these stationary transition probabilities by pij (t) P{X(t) jX(0) i}, where pij (t) is referred to as the continuous time transition probability function. It was a real pleasure working with McGraw-Hill's thoroughly professional editorial and production staff, including Raghu Srinivasan (Global Publisher), Kathryn Neubauer Carney (the Developmental Editor during most of the development of this edition), Vincent Bradshaw (the Developmental Editor for the completion of this edition), and Mary Jane Lampe (Content Project Manager). Thus, X(t) will take on one of its possible (M 1) values over some interval, 0 t t1, then will jump to another value over the next interval, t1 t t2, etc., where these transit points (t1, t2, . Select the cells containing the data. In other words, there is a limiting probability that the system will be in each state i after a large number of transitions, and this probability that the system will be in each state of this Markov chain? In the same manner, the above expressions for p(n) ij when m 1 and m n 1 indicate that the matrix of n-step transition probability matrix Pn can be obtained by computing the nth power of the one-step transition matrix P. However, when all the integer values over a wide range are possible (all 31 integer values between 40 and 70 in this case), the form of the distribution begins to resemble a continuous distribution. These solvers include CPLEX, GUROBI, CoinMP, and SULUM for linear and integer programming (Chaps. 10.7. Within Chaps. However, we emphasized in Chap. (b) Define part of the problem being addressed by identifying the six directives for the scheduling system to be developed. (Section 12.6) Exponential growth in the difficulty of a problem increases. In words, this Markovian property says that the conditional probability of any future "event," given any past "events" and the present state Xt i, is independent of the past events and depends only upon the present state. (Most of the time in these plants already is committed to current products, so the available capacity for the new products is quite limited.) 2. The other lanes have sufficient shipping capacity to handle everything these factories can send. If the stock increased today and yesterday, it will increase tomorrow with probability 1. The accounts are checked monthly to determine the state of each customer. The custom discrete uniform distributions are also similar. School's European EMBA program (2008, 2009, and 2011) and its Miami EMBA program (2011). A. Suppose that a player has \$1 with probability 1 p 0. Siu: Markov Chains: Models, Algorithms and Applications, 2nd ed., Springer, New York, 2013. Excel's fill commands often can be used to quickly copy the formulas into the remainder of the model. To illustrate, considered sensitive if even a small change in its value can change the optimal solution. 4) to find an optimal solution 1 1x1, x2, x3, x4, x5, x6, x7, x8, x9 2 probabilities of the states of nature. 29.7-2. (Section 6.3) Complementary solutions property or complementary solutions property or complementary solutions property. Nonnegativity constraints: xA1 0, xA2 0, ..., xC4 0, 29.1, so we will not repeat it here. Reiman), and Introduction to Management Science: A Modeling and Case Studies Approach with Spreadsheets (5th ed., McGraw-Hill/Irwin, 2014, co-authored by his son Mark Hillier), 5) Run
SolverSetup/SolverSetup fixed charge or setup cost is incurred when undertaking an activity. (b) Briefly describe the implementation strategy that was developed. Each project requires hours, respectively. Implemented in Java, this innovative package is designed specifically to enhance the learning experience of students using this book. Referring to the transition probabilities given in Sec. Nonnegativity constraints: xF1-F2 0, xF1-DC 0, xF1-W1 0, xF2-DC 0, xW1-W2 0, xW2-W1 0. \$30,000 per week should be used to treat these materials. A8. hil23453 ch29 001-036.qxd 1/22/1970 10:53 PM Page 36 CONFIRMING (c) Let T 3 and p 0.3. Using the notation of Sec. To highlight the changing cells, they are shaded and have a border. The additivity assumption does rule out this latter possibility, as summarized below. If desired, check the box to select distributions to view that are lower on the list on the left side of the dialog box. Consequently, the results cell in the spreadsheet model is Profit (C29). The quantities to be decided upon are the number of acres to devote to each of the three crops at each of the three kibbutzim. The two nodes (circle) represent the two possible states for the weather, and the arrows show the possible transitions (including back to the same state) from one day to the next. The new policy saved hundreds of millions of dollars in investment expenditures and reduced agricultural damage by about \$15 million per year, while decreasing thermal and algae pollution. (Section 9.3) Glossaries - 17 Demand at a destination The number of units that need to be received by this destination from the sources. Lieberman, Gerald J. When significant deviations from the original assumptions occur, the model should be made in the system. hil23453 ch02 010-024.gxd 12 1/15/70 7:34 AM CHAPTER 2 Page 12 Final PDF to printer OVERVIEW OF THE OPERATIONS RESEARCH MODELING APPROACH Furthermore, there are additional considerations involving social responsibilities that are distinct from the profit motive. A14. 6-7 of this article. All the various cash inflows and outflows are then broken out in the columns, starting with the projected cash flow from the business operations (with data for each of the 10 years), continuing with the loan inflows, interest payments, and loan paybacks, and culminating with the ending balance (calculated for each year). The conditional probabilities P{Xt1 jXt i} for a Markov chain are called (onestep) transition probabilities. Bounding A basic step in a branch-and-bound algorithm that bounds how good the best solution in a subset of feasible solutions can be. E\* evening shift, as well as hire three part-time workers for each of the four shifts. Dempsey, and A. 28.5. The spreadsheet model is available on this website. Upon culmination of a study, it is appropriate for the OR team to document its methodology clearly and accurately enough so that the work is reproducible. The ordering policy now is changed to ordering just 2 cameras at the end of the week if none are in stock. Some analytics professionals who specialize in descriptive analytics are called data scientists. (Supplements 1 and 2) Randomized policy A policy where a probability distribution is used for the decision to be made for each of the respective states of a Markov decision process. J., and J. Furthermore, because of the differences between the blast and the open-hearth furnaces, the two types probably should not use the same combination. One is Selected Reference 4, which describes applications in such diverse areas as the classification of customers, DNA sequencing, the analysis of genetic networks, the estimation of sales demand over time, and credit rating. The challenge is to determine the most effective threedimensional geometric pattern for placing these seeds. The inventory example introduced in Sec. Otherwise, they say that no value between these bounds is any more likely than any other possible value.

Build: Expand the Model to Full-Scale Size Once a small version of the spreadsheet has been tested to make sure all the formulas are correct and everything is working properly, the model can be expanded to full-scale size. Determining this allocation involves choosing the levels of the activities that achieve the best possible value of the overall measure of performance. Don't forget, we accept financial aid and scholarship funds in the form of credit or debit cards. (This number includes lost sales when the inventory is depleted.) It is assumed that the Dt are independent and identically distributed random variables having a Poisson distribution with a mean of 1. Lieberman MD DALIM 1265980 12/23/13 CYAN MAG YELO BLACK McGraw-Hill Connect® Engineering provides online presentation, assignment, and assessment solutions. 29.6-5. (a) Generate a parameter analysis report to consider five possible long-term loan amounts between \$0 million and \$20 million the OR team monitors the initial experience with the course of action taken and seeks to identify any modifications that should be made in the future. This includes nine complete chapters and a considerable number of supplements to chapters in the book, as well as a substantial number of additional cases. 29.5-5. The n-step transition matrices for this example will be shown in the next section. Three questions need to be answered to begin the process of using the spreadsheet to formulate a linear programming model for the problem. Using the spreadsheet to formulate a linear programming model for the problem. (Section 10.8) Residual capacity The remaining arc capacities for assigning additional flows after some flows have been assigned to the arcs by the augmenting path algorithm for a maximum flow procedures have been developed, and are presented in this book, for finding such solutions for certain kinds of problems. The Tij are independent random variables, where each Tij has an exponential distribution with parameter qij, so E[Tij] 1/qij. Try, for example, Z 10 3x1 5x2 to see if there are in the permissible region any values of (x1, x2) that yield a value of Z as large as 10. 21-2. She also gathered the relevant data for analyzing the problem. The application vignette in Sec. 30-50 (with 40 the most likely) if our company's product comes to market first. The Custom Distributions included in the Distribution of the 46 probability distributions included in the Distribution of the most likely) if our company's product comes to market first. in a course on probability and statistics. H., J. The rightmost column of Table 3.19 shows the number of agents needed for the time periods given in the first column. Linear programming models usually are formulated to select some future course of action. (Section 12.9) Glossaries - 26 Contingent decision A yes-or-no decision is a contingent decision if it can be yes only if a certain other yes-or-no decision is yes. By acting now, the company may parboots is highly seasonal. 29.1, suppose that the costs to be considered are the ordering cost and the penalty cost for unsatisfied demand (storage costs are so small they will be ignored). However, the successful team does so in full recognition of the overriding need of the decision maker to obtain a satisfactory guide for action in a reasonable period of time. Thus, for any given fraction of the corresponding quantity in Table 3.14. Now notice in Fig. (a) Formulate the evolution of the status of a recorder as a Markov chain whose states include two absorption states that involve needing to honor the warranty or having the recorder survive the warranty period. The repair of a component starts at the beginning of the first available period and is completed at the end of the next period. Use relative and absolute references to simplify copying formulas. In particular, a 10-year loan of \$4.65 million will be taken now (the beginning of 2014). Then, just after the publication of the recipient of the prestigious 2004 INFORMS Expository Writing Award for this book, including receiving the following citation: Over 37 years, successive editions of this book have introduced more than one half million students to the field and have attracted many people to enter the field for academic activity and professional practice. In addition to the usual nonnegativity constraints, there are two upper-bound constraints, there are two upper-bound constraints, xF1-F2 ≤ 10 and xDC-W2 ≤ 80, imposed by the limited shipping capacities for the two lanes, F1 F2 and DC W2. Such a model is necessarily an abstract idealization of the problem, so approximations and simplifying assumptions generally are required if the model is to be tractable (capable of being solved). Given each of the following (one-step) transition matrices of a Markov chain, determine the classes of the Markov chain and whether they are recurrent. 20.7 to enter the integer hil23453\_ch28\_001-047.qxd 1/22/1970 10:51 PM Page 40 Confirming Pages 40 CHAPTER 28 EXAMPLES OF PERFORMING SIMULATIONS ON SPREADSHEETS FIGURE 28.27 This Fit Options dialog box specifies (1) the range of the data in Fig. Palacios: "A Markov Chain Approach to Baseball," Operations Research, 45: 14-23, 1997. The other major cost is the start-up cost (the initial capital outlay) required to install the method. 21.4. For example, selecting cells G12:G21 and choosing Fill Down will take the formula in cell G12:G21 and choosing G21. Since the only parameter is the mean time until the next random event occurs, this distribution is a relatively easy one to use. A stochastic process often has the following structure. His professional honors included being elected to the National Academy of Engineering, receiving the Shewhart Medal of the American Society for Quality Control, receiving the Cuthbertson Award for exceptional service to Stanford University, and serving as a fellow at the Center for Advanced Study in the Behavioral Sciences. The short (but oversimplified) answer is that it is basically operations research by another name. (Section 18.6) Reorder point The inventory level at which an order is placed to replenish inventory in a continuous-review inventory system. Texas, for example, waived their work search requirement for many months but reinstated it on November 1. By entering 0 into the Likelihood box reports that 98.6 percent of the trials resulted in a profit for that day's flight. Because the objective is to minimize the total cost of the agents assigned to the five shifts, the coefficients in the objective function are given by the last row of Table 3.19. 28.4, including its results shown in Fig. Therefore, a potential stumbling block can arise when trying to organize and lay hil61217 ch21.gxd 4/29/04 03:40 PM Page 21-7 21.2 OVERVIEW OF THE PROCESS OF MODELING WITH SPREADSHEETS 21-7 out the spreadsheet model. Terminology for Solutions of the Model You may be used to having the term solution mean the final answer to a problem, but the convention in linear programming (and its extensions) is quite different. Thus, the role of simulation is to provide the information needed for making a sound decision, but it is management that uses its best judgment to make the decision. E\* (d) Build a spreadsheet model for quarters 1 and 2, and then thoroughly test the model. produces high-quality glass products, including windows and glass doors. Orders are filled immediately. For example, in the Everglade problem, we could get started by building a model for just the first two years (2014 and 2015), like the spreadsheet shown in Fig. bi amount of resource i that is available for allocation to activities (for i 1, 2, ..., m). To the point now where I don't bother trying the nice clean mathematical models on any big problem because it's a waste of time. In this light, here are the predicted thousands of sales for our company's new product: 0-20 (with 10 the most likely) if the competitive product comes to market first. After entering a positive integer into the suc field in its dialog box, the negative binomial distribution of the number of trials until the event occurs the number of
trials until the event occurs the number of the number of successful events that must occur). Solving the last four equations simultaneously provides the solution 0 0.286, 1 0.285, 2 0.263, 3 0.166, which is essentially the result that appears in matrix P(8) in Sec. The queue does not include customers who are already being served. and related mathematical expressions that describe the essence of the problem. Murty, K. That is, wherever this formula is copied, the formula is copied, the formula will still refer to the cell STRate (C4). 4 and 5 focus on the simplex method. xij proportion of material j in product grade i. A2. G., and R. 29.6-3. Similarly, the probability of A finishing with \$4 (B going broke) when starting with \$2 (state 2) is obtained by solving for f24 from the system of equations, f04 0 (since state 0 is an absorbing state). One is that, in many situations, rare extreme values far into the tails are possible, so it is quite artificial to have fixed minimum and maximum values. The statistic cells are MeanFilledSeats (C23), MeanDeniedBoarding (C24), and MeanProfit (C25). 13). Assume that the storage costs are the same as given in the second subsection of Sec. hil23453 fm\_i-xxx.qxd xxvi 1/30/70 7:58 AM Page xxvi Final PDF to printer PREFACE • Great Flexibility for What to Emphasize. Each year, the balance must be greater than the minimum required balance (\$500,000). This problem has six decision variables that are set equal to zero in a basic solution. If this occurs when the balance is 7. (Section 5.1) Nonbasic variables that are set equal to zero in a basic solution. If this occurs when the balance is 7. within 30 days in arrears, the store views the customer as being in state 1. One danger with using the normal distribution for some applications is that it can give negative values even when such values actually are impossible. Students can benefit greatly by reading about top-quality applications of operations research. Ascertaining the appropriate objectives is a very important aspect of problem definition. Any state communicates with itself (because p(0) ii P{X0 iX0 i} 1). Sheldon indicates that any of the loan options would be acceptable as long as they observe the company policy of maintaining a balance of at least \$500,000 in cash reserves at all times. These data are given in Table 3.8. The crops suited for this region include sugar beets, cotton, and sorghum, and these are the three being considered for the upcoming season. The ending balance in 2015 is the ending balance in 2015 is the ending balance in 2015 (cell J11) plus the sum of all the various cash flows that occur in 2015 (cell J11) plus the sum of all the various cash flows that occur in 2015 (cell J11) plus the sum of all the various cash flows that occur in 2015 is the ending balance in 2015 (cell J11) plus the sum of all the various cash flows that occur in 2015 (cell J11) plus the sum of all the various cash flows that occur in 2015 (cell J11) plus the sum of all the various cash flows that occur in 2015 (cell J11) plus the sum of all the various cash flows that occur in 2015 (cell J11) plus the sum of all the various cash flows that occur in 2015 (cell J11) plus the sum of all the various cash flows that occur in 2015 (cell J11) plus the sum of all the various cash flows that occur in 2015 (cell J11) plus the sum of all the various cash flows that occur in 2015 (cell J11) plus the sum of all the various cash flows that occur in 2015 (cell J11) plus the sum of all the various cash flows that occur in 2015 (cell J11) plus the sum of all the various cash flows that occur in 2015 (cell J11) plus the sum of all the various cash flows that occur in 2015 (cell J11) plus the sum of all the various cash flows that occur in 2015 (cell J11) plus the sum of all the various cash flows that occur in 2015 (cell J11) plus the sum of all the various cash flows that occur in 2015 (cell J11) plus the sum of all the various cash flows that occur in 2015 (cell J11) plus the various cash flows that occur in 2015 (cell J11) plus the various cash flows that occur in 2015 (cell J11) plus the various cash flows that occur in 2015 (cell J11) plus the various cash flows that occur in 2015 (cell J11) plus the various cash flows that occur in 2015 (cell J11) plus the various cash flows that occur in 2015 (cell J11) plus the various cash flows that occur in package the material into a course. If you're wondering how to file a claim after all the changes, we can help you figure it out. Therefore, the total cost of bumping a customer is estimated to be \$450. Consequently, there is an extremely wide range of possible values for each sale price in year 7. For example, for 2:00 P.M. to 4:00 P.M., the total number of agents assigned to the shifts that cover this time period (shifts 2 and 3) must be at least 64, so x2 x3 64 is the functional constraint for this time period. The choice between these two distributions are close to this peak, so it seems clear that the most profitable number of reservations lies somewhere between 180 and 190. By entering 0 into the box in dicates that 81 percent of the trials resulted in a profit (a positive value of NPV). Distinguishing what students know from what they don't, and honing in on concepts they are most likely to forget, SmartBook personalizes content for each student. The other phases described here also are very important to the success of the study. Again, Fig. Justify your answer. Analyze the Model Before using Solver, the spreadsheet in Fig. (d) Use ASPE's Solver to search for the purchase quantity that maximizes Susan's mean profit. Ching, W.-K., X. The transition matrix that shows each probability of going from a particular state today to a particular state today transition diagram for this example is exactly the same as for the weather example shown in Fig. Although some minor bugs undoubtedly remain hidden in the program now can be reliably used. H.: "The Occasional Observer: Some Simple Precepts for Project Success," Interfaces, 28(5): 25-28, September-October 1998. If you fail to file your weekly claim, your benefits may be delayed or stopped altogether. Based on this chart, which activities have the largest impact on the project completion time? I. (Section 9.2) Transportation simplex tableau A table that is used by the transportation simplex method to record the relevant information at each iteration. Spreadsheet software (such as the Excel add-in called Solver) includes basic OR algorithms, so various types of spreadsheet models can be solved as soon as they have been formulated. In addition, some Excel add-ins now are available that greatly extend these capabilities. FORMULATING AND SOLVING LINEAR PROGRAMMING MODELS ON A SPREADSHEET Spreadsheet software, such as Excel and its Solver, is a popular tool for analyzing and solving small linear programming problems. 29.2), p(2) ij 0 for all i and j, so every state is accessible from every other state. Reboot would like to meet all the expected demand, so it with a cash balance of at least \$1 million. Because a major cost is saved for the second TABLE 3.5 Examples of satisfying or violating additivity for the objective function Value of Z Additivity Violated (x1, x2) Additivity Satisfied Case 1 Case 2 (1, 0) (0, 1) 3 5 3 5 3 5 (1, 1) 8 9 7 hil23453\_ch03\_025-092.qxd 42 1/30/70 7:57 AM CHAPTER 3 Final PDF to printer Page 42 INTRODUCTION TO LINEAR PROGRAMMING product, their joint profit is somewhat more than two jobs are present, the time until the next arrival has an exponential distribution with a mean of 2 days. 21.3, if zeroes are entered for the loan amounts, then the interest payments and loan payback quantities should also be zero. In Excel 2010, choose File > Help and look in the lower right. (b) Suppose that Larry were to hire three full-time workers for the lates the guideline and why the model in Fig. As in Case 3, suppose that the two products require the same type of machinery and equipment. If state i communicates with state j, then state j communicates with state i, then state is said to be an absorbing state if, upon entering this state, the process never will leave this state again. These arrows indicate that the ST Interest cell for 2015 (G12) refers to the ST Loan in 2014 (E11) and to STRate (C4). In giving my email address, let me also assure instructors that I will continue to follow the policy of not providing solutions to problems and cases in the book to anybody (including your students) who contacts me. Lieberman, who was one of the true giants of our field hil23453 fm i-xxx.qxd 1/30/70 7:58 AM Final PDF to printer Page xi TABLE OF CONTENTS PREFACE xxii CHAPTER 1 Introduction 1 1.1 The Origins of Operations Research 2 1.3 The Rise of Analytics Together with Operations Research 1 1.2 The Nature of Operations Research 2 1.3 The Rise of Analytics Together with Operations Research 2 1.3 The Rise of Analytics Together with Operations Research 2 1.4 The Impact of Operations Research 2 1.5 Algorithms and OR Courseware 7 Selected References 9 Problems 9 3 CHAPTER 2 Overview of the Operations Research Model 13 2.3 Deriving Solutions from the Model 15 2.4 Testing the Model 18 2.5 Preparing to Apply the Model 19 2.6 Implementation 20 2.7 Conclusions 21 Selected References 21 Problems 23 CHAPTER 3 Introduction to Linear Programming 38 3.4 Additional Examples 44 3.5 Formulating and Solving Linear Programming Models on a Spreadsheet 3.6 Formulating Very Large Linear Programming Models 71 3.7 Conclusions 79 Selected References 79 Learning Aids for This Chapter on Our Website 80 Problems 81 Case 3.2 Cutting Cafeteria Costs 92 Case 3.3 Staffing a Call Center 92 Case 3.4 Promoting a Breakfast Cereal 92 62 xi hil23453 fm ixxx.qxd xii 1/30/70 7:58 AM Final PDF to printer Page xii CONTENTS CHAPTER 4 Solving Linear Programming Problems: The Simplex Method 93 4.2 Setting Up the Simplex Method 93 4.3 Setting Up the Simp Method 112 4.6 Adapting to
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Problems 519 12.9 The Incorporation of Constraint Programming 519 12.9 The Incorporation Programm Chapter on Our Website 533 Problems 534 Case 12.1 Capacity Concerns 543 Previews of Added Cases on Our Website 545 Case 12.2 Assigning Art 545 Case 12.3 Stocking Sets 545 Case 12.4 Assigning Art 545 Case 12.4 Assigning Art 545 Case 12.3 Stocking Sets 545 Case 12.4 Assigning Students to Schools, Revisited Again 546 CHAPTER 13 Nonlinear Programming 13.1 13.2 13.3 13.4 13.5 13.6 13.7 547 Sample Applications 548 Graphical Illustration of Nonlinear Programming Problems 552 Types of Nonlinear Programming 577 573 hil23453 fm i-xxx.qxd 1/30/70 7:58 AM Final PDF to printer Page xv CONTENTS xv 13.8 Separable Programming 583 13.9 Convex Programming 583 13.9 Convex Programming 590 13.10 Nonconvex Programming 590 Nonconvex Programming 590 Nonconvex Programming 590 Nonconvex Our Website 616 Case 13.2 International Investments 616 Case 13.3 Promoting a Breakfast Cereal, Revisited 616 CHAPTER 14 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Formulation of Two-Person, Zero-Sum Games 668 15.2 Solving Simple Games—A Prototype Example 663 15.3 Games with Mixed Strategies 668 15.4 Graphical Solution Procedure 670 15.5 Solving by Linear Programming 672 15.6 Extensions 676 15.7 Conclusions 677 Selected References 677 Learning Aids for This Chapter on Our Website 677 Problems 678 CHAPTER 16 Decision Making with Experimentation 684 16.3 Decision Making with Experimentation 684 16.3 Decision Trees 16.6 Utility Theory 707 16.7 The Practical Application of Decision Analysis 715 16.8 Conclusions 716 Selected References 716 Learning Aids for This Chapter on Our Website 717 Problems 718 Case 16.1 Brainy Business 728 700 hil23453 fm i-xxx.qxd xvi 1/30/70 7:58 AM Final PDF to printer Page xvi CONTENTS Preview of Added Cases on Our Website 730 Case 16.2 Smart Steering Support 730 Case 16.3 Who Wants to be a Millionaire? hil61217\_ch21.qxd 21-6 4/29/04 03:40 PM Page 21-6 CHAPTER 21 THE ART OF MODELING WITH SPREADSHEETS If you are getting stuck at this point, it can be a very useful exercise to do some calculations by hand. amn c1 c2 ... The adoption of the recommendations of the study led to a one-year increase of nearly \$50 billion in client assets held and nearly \$80 million more revenue. Also see Selected References A1, A10, and A14 for other examples where data collection and processing played a particularly key role in an award-winning OR study.) hil23453\_ch02\_010-024.qxd 1/15/70 7:34 AM 2.2 2.2 Page 13 FORMULATING A MATHEMATICAL MODEL Final PDF to printer 13 FORMULATING A MATHEMATICAL MODEL After the decision-maker's problem in a form that is convenient for analysis. 29.2. To start, the two-step transition matrix is P(2) P P 0.6 0.8 0.2 0.4 0.6 0.8 0.76 0.76 0.2 0.72 0.4 0.24 . 2.4) and postoptimality analysis (see Sec. The resulting optimal value of the objective function is Z = 633, 333 13, that is, a total net return of \$633,333.33. 1.3-3. (Section 12.3) Binary integer programming The type of integer prog prime example is the simplex
method for solving linear programming problems, developed by George Dantzig in 1947. This example is small enough to be solved graphically in a straightforward way. 3 hil23453 ch29 001-036.qxd 1/22/1970 10:53 PM Page 10 Confirming Pages 10 CHAPTER 29 MARKOV CHAINS These equations point out that in going from state i to state j in n steps, the process of reformulating any feasible solutions. Thus, x1 x2 65 is a redundant constraint that can be deleted. Therefore, the state of the system now has been observed at times t s and t r. Source: A. (Section 5.1) Indicating variable Each constraint's boundary equation is satisfied by the current solution. The original spreadout for the data cells, changing cells, output cells, and objective cell. The team members are not just given a problem and told to solve it however they see fit. As described in the introduction to this chapter, the most common type of application of linear programming involves allocating resources to activities. hil23453 ch28 001-047.qxd 1/22/1970 10:51 PM Page 46 CHAPTER 28 EXAMPLES OF PERFORMING SIMULATIONS ON SPREADSHEETS Activity A. (Section 18.6) Glossaries - 50 Glossary for Chapter 19 Average cost criterion for measuring the performance of a Markov decision process by using its expected average cost per unit time. If so, what are the possible states? The time spent in state i until a imum (over j i) of the Tij. But suppose now that the time req uired to switch from one product to 🔳 TABLE 3.6 Examples of satisfying or violating additivity for hil23453\_ch03\_025-092.qxd 1/30/70 7:57 AM 3.3 Page 43 Final PDF to printer ASSUMPTIONS OF LINEAR PROGRAMMING 43 the other would be relatively small. Because these are one-time costs, they would need to be amortized on a per-week basis to be commensurable with Z (profit in thousands of dollars per week). (Section 10.5) Cycle A path that begins and ends at the same node. (Section 17.7) Poisson input process A stochastic process for counting the number of customers arriving to a queueing system that is a Poisson process. These distributions receive considerable use for this reason. CourseSmart eBooks can be viewed online or downloaded to a computer. (Selected Reference A5 describes this study in detail.) 2.5 PREPARING TO APPLY THE MODEL What happens after the testing phase has been completed and an acceptable model has been and the probability that the NPV will be greater than 0 for option 2 after performing a simulation with 1,000 trials for this option. When all U.S clinics adopt this procedure, it is estimated that the annual cost savings will approximate \$500 million due to eliminating the need for a pretreatment planning meeting and a postoperation CT scan, as well as providing a more efficient surgical procedure and reducing the need to treat subsequent side effects. The probabilities for these individual discrete values of the cost are the following: 20 percent chance of \$10 50 percent chance of \$12 30 percent chance of \$14 To enter this distribution, first choose Discrete from the Custom submenu under the Distribution, first choose Discrete from the Custom submenu under the Distribution are under the Distribution and the Custom submenu under the Distribution are under seats and avoiding bumping many customers. Clerkx, and W. (Section 18.8) Glossaries - 46 Dependent demand for a products. If they're not, this suggests an error in the spreadsheet model (assuming the hand calculations are correct). An OR team from the Center for Operations Research in Medicine and HealthCare at Georgia Institute of Technology worked with physicians at MSKCC to develop a highly sophisticated next-generation method of optimizing the application of brachytherapy to prostrate cancer. (Section 6.3) Primal problem The original linear programming problem of interest when using duality theory to define an associated dual problem. (You will have an opportunity to investigate these less tangible benefits further in Probs. Generate a frequency chart and a statistics table. (Section 11.2) State variable that gives the state of the system at a particular stage of a dynamic programming problem. toppriority assignment for a full-time maintenance person is to repair them whenever needed. (Section 16.3) Exponential utility function A utility function A utility function for a simulation model with any number of decision variables. For other problems, if additivity is not a reasonable assumption, so that some of or all the mathematical functions of the model need to be nonlinear programming (Chap. Included with standard Excel is an add-in, called Solver (a product terms), you definitely enter the realm of nonlinear programming (Chap. Included with standard Excel is an add-in, called Solver (a product terms), you definitely enter the realm of nonlinear programming (Chap. Included with standard Excel is an add-in, called Solver (a product terms), you definitely enter the realm of nonlinear programming (Chap. Included with standard Excel is an add-in, called Solver (a product terms), you definitely enter the realm of nonlinear programming (Chap. Included with standard Excel is an add-in, called Solver (a product terms), you definitely enter the realm of nonlinear programming (Chap. Included with standard Excel is an add-in, called Solver (a product terms), you definitely enter the realm of nonlinear programming (Chap. Included with standard Excel is an add-in, called Solver (a product terms), you definitely enter the realm of nonlinear programming (Chap. Included with standard Excel is an add-in, called Solver (a product terms), you definitely enter the realm of nonlinear programming (Chap. Included with standard Excel is an add-in, called Solver (a product terms), you definitely enter the realm of nonlinear programming (Chap. Included with standard Excel is an add-in, called Solver (a product terms), you definitely enter the realm of nonlinear programming (Chap. Included with standard Excel is an add-in, called Solver (a product terms), you definitely enter the realm of nonlinear programming (Chap. Included with standard Excel is an add-in, called Solver (a product terms), you definitely enter terms Inc.), that can be used to solve many of these models. One strategy is to begin with a small version of the model to establish its basic logic and then, after testing verifies its accuracy, to expand to a full-scale model. (Sections 17.2 and 17.7) service times for a queueing system. 21.6. The data for the Hours Used Per Batch Produced have been laid out in the center of the spreadsheet in cells C7:D9. If desired, you can use Create to search for useful supplementary material in various other leading McGraw-Hill textbooks. Ask your McGraw-Hill Representative for more information, and visit www.mhlearnsmart.com for a demonstration. 3) On the download page, change 32-bit to 64-bit ONLY if you've confirmed that you have 64-bit Excel. (Section 20.3) Random integer number A random observation from a discretized uniform distribution is a continuous distribution, whereas the number of reservations must have an integer value, Demand (C11) uses Excel's ROUND function to round the number in SimulatedTicketDemand (C10) to the nearest integer. 20.9 for an integer uniform distribution) is used in a similar way to enter the parameters (minimum and maximum) for this kind of distribution into the uncertain variable cells D13 and D23. To illustrate these definitions, reconsider the inventory example introduced in Sec. One was the substantial progress that was made early in improving the techniques of OR. The artisans' small shops of an earlier era have evolved into the billion-dollar corporations of today. The purpose of this chapter is to place things into better perspective by describing all the major phases of a typical large OR study. Describe how the product at two different factories, and then the product must be shipped to two warehouses, where either factory can supply either warehouse. However, Think-Big management understands very well that such decisions should not be made without taking risk into account. The procedure for defining an uncertain variable cell includes selecting one of 46 types of probability distributions from the Distributions menu to enter into the cell. Clicking Fit then brings up the Fit Results chart displayed in Fig. ACKNOWLEDGMENT A somewhat longer version of this chapter (with slight differences) also appears as Chap. (Section 10.8) PERT An acronym for program evaluation and review technique, a technique for assisting project managers with carrying out their responsibilities. Although other airlines subsequently scrambled to apply operations research in a similar way, this initial advantage over other airlines in being able to recover more quickly from schedule disruptions with fewer delays and canceled flights left Continental Airlines in a relatively strong position as the airline industry struggled through a difficult period during the initial years of the 21st century. (Section 5.1) Glossaries - 13 Glossary for Chapter 6 Complementary slackness A relationship involving each pair of associated variables is a basic variable and the other is a nonbasic variable. We are delighted to have integrated the student version of this package, Analytic Solver Platform for Education (ASPE), into this new edition. The basic trade-off under constant consideration is between the precision and the tractability of the model. Each of these distributions has a most likely value where the probability density function reaches a peak. (Section 13.3) Local maximum (or minimum) A feasible solution that maximizes (or minimizes) the value of the objective function within a local neighborhood of that solution. 28.25. 28.5 REVENUE MANAGEMENT IN THE TRAVEL INDUSTRY As described in Sec. The difference lies in the last row, which gives the function value for Z when the two products are produced jointly. Referring to the chapter titles in this
book's table of contents, list these kinds of models. Refer to Selected Reference A4 that describes an OR study done for Yellow Freight System, Inc. (d) Referring to p. 12.) The optimization is done in a matter of minutes by an automated computerized planning system that can be operated readily by medical personnel when beginning the procedure of inserting the seeds into the patient's prostrate. It is then hypothesized that this model is a sufficiently precise representation of the essential features of the situation hil23453\_ch01\_001-009.qxd 1/15/70 7:40 AM 1.3 Page 3 Final PDF to printer THE RISE OF ANALYTICS TOGETHER WITH OPERATIONS RESEARCH 3 that the conclusions (solutions) obtained from the model are also valid for the real problem. 13.8 that a certain important kind of nonproportionality can still be handled by linear programming by reformulating the problem appropriately. Say that you have Analytic Solver Platform for Education, and have your course code and textbook code available Liberatore, and R. Similarly, the first version of a large mathematical model inevitably contains many flaws. 29.1, where the solution for the j was obtained in an earlier subsection. 13 in the 5th edition of Introduction to Management Science: A Modeling and Case Studies Approach with Spreadsheets by Frederick S. Typical decisions include what recipes to use for major product groups, the transfer of grape juice between plants, and the mode of transportation for these transfers. Also note that these elements are obtained by multiplying the matrix of one-step transition probabilities by itself; i.e., P(2) P P P2. This article soon was followed by two best-selling books entitled Competing on Analytics: The New Science of Winning and Analytics at Work: Smarter Decisions, Better Results. (a) Explain why the stated assumptions imply that the Markovian property holds for the evolution of the weather. It was a particular pleasure to have the field's leading professional society, the international Institute for Operations Research and the Management Sciences (INFORMS), award the 6th edition honorable mention for the 1995 INFORMS Lanchester Prize (the prize awarded for the year's most outstanding English-language publication of any kind in the field of operations research). (Section 16.2) Bayes' theorem A formula for calculating a posterior probability of a state of nature These steps may take place as you're filing your application, or they could be the last steps in determining your eligibility. The number of agents assigned to each shift needs to be an integer. (Section 20.1) Trend chart that shows the trend of the values in a results cell as a decision variable increases. 16 to 20 (probabilistic models), a previous the trend of the values in a result cell as a decision variable increases. introduction to probability theory is assumed, and calculus is used in a few places. P(8) P8 P(4) P(4) [ 0.289 | 0.282 | 0.284 | 0.289 | 0.282 | 0.284 | 0.289 | 0.282 | 0.286 | 0.286 | 0.286 | 0.286 | 0.285 0.2 0.264 3 0.166 0.166 0.166 0.166 0.166 0.285 0.283 0.286 0.261 0.268 0.261 0.268 0.261 0.164 0.171 0.166 0.171 0.164 Like the five-step transition matrix for the weather example, this matrix has the interesting feature that its rows have identical entries (after rounding). The discussion thus far has implied that an OR study seeks to find only one solution, which may or may not be required to be optimal. When starting in state i, another possibility is that the process definitely will return to this state. Formulate a mathematical model to represent the problem. We are excited about a partnership with The Institute for Operations Research and the Management Sciences (INFORMS), our field's preeminent professional society, to provide a link on this book's website to approximately 100 articles describing award winning OR applications, including the ones described in all of the application signettes. Section 3.5 describes how linear programming models of modest size can be conveniently displayed and solved on a spreadsheet. Next suitable experiments are conducted to test this hypothesis, modify it as needed, and eventually verify some form of the hypothesis. Most problems will have just one optimal solution. Reconsider the example presented at the end of Sec. We now describe the various components of the modeling process in the context of the Everglade cash flow problem 29.1 STOCHASTIC PROCESSES A stochastic process is defined as an indexed collection of random variables {Xt}, where the index t runs through a given set T. State 3 is a transient state because if the process is in state 3, there is a positive probability that it will never return. Because of its great importance, we devote this and the next seven chapters specifically to linear programming. Read Selected Reference A11 that describes an OR study done for Philips Electronics. hil23453\_ch29\_001-036.qxd 1/22/1970 10:53 PM Page 25 Confirming Pages 29.7 ABSORBING STATES 25 A Credit Evaluation Example. If Fairwinds participates at less than quarters 1, 2, 3, and 4, respectively. Read the referenced article that fully describes the OR study summarized in the application vignette presented in Sec., n 1, n m 1, m 2, . (A link to this article is provided on our website, www.mhhe.com/hillier.) production rate is defined as the number of batches produced per week.) Any combination of production rates that satisfies these restrictions is permitted, including producing none of one product and as much as possible of the other. As the incremental cost goes down, the incremental profit will go up (assuming constant marginal schedules in a cost-effective manner while honoring all government regulations, contractual obligations, and quality-of-life requirements. Fourth, many selected references of award winning OR applications are given at the end of some of the chapters. After the war, many of the scientists who had participated on OR teams or who had participated to pursue research relevant to the field; important advancements in the state of the art resulted. (A link to this article is provided on our website, www.mhhe.com/hillier.) You will see later that the spreadsheet is made easier to interpret by using range names. In addition, your OR Courseware includes a special software package called Interactive Operations Research Tutorial, or IOR Tutorial for short. After defining a parameter cell, all the desired simulations are run and the results soon are displayed nicely in the parameter analysis report. Bixby, B. This approach is particularly valuable for those problems where the decisions will be made in two (or more) stages, so the decisions in stage 2 can help compensate for any stage 1 decisions that do not turn out as well as hoped because of errors in estimating some parameter values. 2.4. Although this testing phase is placed later in the chapter, much of this model. The evolution of the weather from day to day in Centerville is a stochastic process. Throughout the entire period during which the new system is being used, it is important to continue to be satisfied. All five parties make essential contributions to the firm, and the firm should not be viewed as the exclusive servant of any one party for the exploitation of others. The underlying model fits the structure for linear programming with one exception. (Section 7.5) Deterministic equivalent of a chance constraint that no longer includes random variables. 29.2) into these equations leads to the equations 0 0.0800 0.6321 0.2642 0.0803, 1 0.1840 0.3681 0.3682 0.1843, 2 0.3680 0.3683, 3 0.3680 0.3683, 3 0.3680 0.3683, 3 0.3680 0.3683, 1 0 1 2 3. The uncertain variable cells are SimulatedTicketDemand (C10) and NumberThatShow (C17). When the transition occurs, the probability that it is to state j is pij qij /qi. 2. hil23453\_ch28\_001 047.qxd 1/22/1970 10:51 PM Page 42 Confirming Pages 42 CHAPTER 28 EXAMPLES OF PERFORMING SIMULATIONS ON SPREADSHEETS FIGURE 28.29 This parameter cell dialog box specifies the characteristics of the decision variable OurBid (C25) in Fig.28.2 for the Reliable Construction Co. contract bidding
problem. A5. Te hallmark features continue to be clear and comprehensive coverage of fundamentals, an extensive set of interesting problems and cases, and a wealth of state-of-the-art, user-friendly software. Every September, growers begin delivering grapes to processing plants that then press the raw grapes into juice. 2.2 that a mathematical model is intended to be only an idealized representation of the real problem. (Section 6.3) Dual feasible for the dual problem. On the other hand, a disadvantage of retrospective testing is that it uses the same data that guided the formulation of the model. Armed with all this information, a managerial decision now can be made about whether the likelihood of a sizable profit justifies the significant risk of incurring a loss and perhaps even a very substantial loss. (b) Summarize the purpose of each of the five mathematical models described on pp. 13.10), among others. This recursive relationship is best explained in matrix notation (see Appendix 4). However, it is natural to pair this distribution with the exponential distribution for the following reason. hil23453 fm\_i-xxx.qxd 1/30/70 7:58 AM Page xxix PREFACE Final PDF to printer xxix The content of the book is aimed largely at the upper-division undergraduate level (including well-prepared sophomores) and at firstyear (master's level) graduate students. Lim, M. This program features many interactive procedures for interactively executing the logic of the method efficiently while the computer does the number crunching. A New Section on Chance Constraints Also shown are the entry point and direction for the only two beams that can be used with any modicum of safety in this case. At the same time, we also point out some common stumbling blocks encountered while building a spreadsheet model and how these cals. (Section 17.5) Birth-anddeath process A special type of continuous time Markov chain where the only possible changes in the current state of the system are an increase of 1 (a death). When moving to the next stage of solving OR models automatically, surveys have found instructors almost equally split in preferring one of the following options for their students' use: (1) Excel spreadsheets, including Excel's Solver (and now ASPE), (2) convenient traditional software (LINDO and LINGO), and (3) stateof-the-art OR software (MPL and its elite solvers). Time must pass before the grape juice is ready for conversion into finished jams, jellies, juices, and concentrates. (Section 7.6) Glossaries - 15 Reduced cost The reduced cost for a nonbasic variable measures how much its coefficient in the objective function can be increased (when maximizing) or decreased (when maximizing) or decreased (when maximizing) or decreased (when maximizing) before the optimal solution would change and this nonbasic variable. Wyndor Glass Co. problem. 28.1. A B 1 OurBid Mean 2 3 4.8 5.0 5.2 5.4 5.6 5.8 0.188 0.356 0.472 0.482 0.257 0.024 4 5 6 7 43 parameter cell OurBid is varied over six major axis points. Periodicity Properties Another useful property of Markov chains is periodicities. Assume that this time has a normal distribution. (Section 7.1) Soft constraint A constraint that actually can be violated a little bit without very serious consequences. Meanwhile, OR already has had a powerful impact, as described further in the next section. Would the recommended plan still be a good one if those kinds of changes were to occur? (Section 10.2) Path through a project network One of the routes following the arcs from the start node to the finish node. One of these is descriptive analytics, which involves using innovative techniques to locate the relevant data and identify the interesting patterns in order to better describe and understand what is going on now. The weather example introduced in Sec. (Section 18.5) Inventory A stock of goods being held for future use or sale. Most users have 64-bit Windows and 32-bit Excel. Miser, H. With only \$1 million in cash reserves, it appears that Everglade will need to take out loans in order to meet its financial obligations. Then find what happens to these steady-state probabilities if, at each step, the probability of moving one point clockwise changes to 0.9 and the probability of moving one point counterclockwise changes to 0.1. 29.5-4. Yu, with D. Together, these packages will enable you to solve nearly all the OR models encountered in this book. (Information about INFORMS journals, meetings, job bank, scholarships, awards, and teaching materials is at www.informs.org.) These articles and the corresponding end-of-chapter problems provide instructors with the option of having their students delve into real applications that dramatically demonstrate the relevance of the material being covered in the lectures A Parameter Analysis Report for the Reliable Construction Co. Bidding Problem We turn now to generating a parameter analysis report for the Reliable Construction Co. Bidding problem presented in Sec. The appropriate measure of performance (e.g., profit) is then expressed as a mathematical function of these decision variables (for example, P = 3x1 + 2x2 + . 28.26 is already entered into the Range box of this dialog box. (Introduction) BIP An abbreviation for binary integer programming, defined above. Photo Courtesy: SDI Productions/E+/Getty Images When you file your claim, you will be asked for some personal information, including your name, address(es), social security number (SSN), last 18 months of employment history, a record of wages earned and the reason and dates for your employment termination. These probabilities do not change if information about the weather before today is also taken into account. He also says that the objective should be to have as large a cash balance as possible at the end of the 10 years after paying off all the loans. However, the gambling example contains three classes. Updating to Reflect the Current State of the Art. Hence, the (unconditional) probability that there will be three cameras in stock 2 weeks after the inventory system began is P{X2 3} (1)p(2) 33 0.165. Number of hours of production time available per week in each plant for these new products. .), P{Xtn jXt i} P{Xn jXt i} represented as decision variables (say, x1, x2, . Janssen, J. But to, 1, . Therefore, the company's OR group is analyzing what number of reservations should be accepted to maximize the expected profit from the flight. Thus, if there are n related quantifiable decisions to be made, they are represented as decision variables (say, x1, x2, . Janssen, J. But don't be fooled - the success criteria for many projects in this domain is "I got a paper published in a good journal", which in my experience is negatively correlated with "I got it to solve the real, full problem and got people to actually use it". With this adjustment, the three quantities given above lead directly to all the functional constraints of the model. As discussed in Sec. (to be continued in Sec. The results have been spectacular. Even with an appropriate formulation, the initial versions of large spreadsheet models commonly will include some small but troublesome errors, such as inaccurate references to cell addresses or typographical errors when entering equations into cells. (Section 14.4) Glossaries - 33 Genetic algorithm A type of metaheuristic that is based on the concepts of genetics, evolution, and survival of the future also can be read in the same way from the three-step, four-step, and five-step transition matrices calculated to three significant digits below. What should the and capital recovery costs. (Section 13.9) Sequential unconstrained algorithms that convert the original constrained optimization problems whose optimal solutions converge to an optimal solution for the original problem 8. With Connect, instructors can deliver assignments, quizzes, and tests easily online. Yu, M. She identified the nature of the problem (projected cash deficits in some future years), the alternative hil61217 ch21.qxd 4/29/04 03:40 PM Page 21-5 21.2 OVERVIEW OF THE PROCESS OF MODELING WITH SPREADSHEETS 21-5 courses of action (the different types of loan options), and the decisions to be made (the size of the long-term 1-year loans in the respective years). F. In addition, the company gives the customer a voucher worth \$200 for use on a future flight. (Section 18.3) Glossaries - 47 Installation stock of an item that is physically a function of the size of on hand at an installation. (Sections 17.2 and 17.6) Hyperexponential distribution occasionally used for either interarrival times or service times. Therefore, the amount of overbooking needs to be set carefully so as to achieve an appropriate trade-off between filling seats and avoiding the need to turn away customers who have a reservation. (a) What was the objective of this study? For many of the models in the book, an Excel template also is provided that already includes all the equations necessary to solve the model. (d) Suppose that the ordering cost is given by (2 2m) if an order is placed and zero otherwise. These will be output cells (the cells that show quantities that are calculated from the changing cells) in the spreadsheet model. Another learning aid provided on our website is a set of Solved Examples for each chapter (from Chap. If a solution is found that enables all these goals to be met, it is likely to be adopted without further ado. C. hil23453 ch01 001-009.qxd 4 1/15/70 7:40 AM CHAPTER 1 Page 4 Final PDF to printer INTRODUCTION Analytics fully recognizes that we have entered into the era of big data where massive amounts of data now are commonly available to many businesses and organizations to help guide managerial decision making. However, from a modeling viewpoint, these mathematical properties of a linear programming model imply that certain assumptions must hold about the activities and data of the problem being modeled, including
assumptions about the effect of varying the levels of the activities. hil61217\_ch21.qxd 4/29/04 03:41 PM Page 21-24 CHAPTER 21 21-24 THE ART OF MODELING WITH SPREADSHEETS (c) Make a rough sketch of a spreadsheet model with blocks laid out for the data cells, changing cells, output cells, and objective cell. Similarly, if the weather is 0.28. In this section, we focus on the issue of how to choose the right distribution. The steelworks has two primary sources of pollution, namely, the blast furnaces for making pig iron and the open-hearth furnaces for changing iron into steel. The resulting total shipping cost is \$49,000. 3 onward). However, no harm is done (except a little more computational effort) by including unnecessary constraints, so you don't need to worry about identifying and deleting them in models you formulate. (Section 10.8) Crashing the project Crashing a number of activities to reduce the duration of the project below its normal value. During these otherwise idle periods, these facilities can be used by the other product. Focus instead on using spreadsheet modeling to address Larry Edison's problem by doing the 21-8 Having attempted many of the methods in that book including LP, MILP, MDP, graph algorithms, SA, GA, Decision trees, Markov chains, some queuing models, OptQuest..... These distributions in ASPE's Distributions menu are (1) the geometric distribution and (2) the negative binomial distribution. What is best for one component frequently is a component frequent of the method is component frequent of the method is a component of the method i detrimental to another, so the components may end up working at cross purposes. H., and J. As indicated at the end of Sec. 20.6, ASPE's Distributions menu provides a wealth of choices. Thus, if state i is transient and the process visits this state, there is a positive probability (perhaps even a probability of 1) that the process will later move to state and so will never return to state i. If the output cells are not giving the results that you expect, then carefully look through the formulas to see if you can determine and fix the problem. 12. Among the special features of ASPE that are highlighted in this book are a greatly enhanced version of the basic Solver included with Excel (as described in Sec. In fact, some people believe that all other legitimate objectives can be translated into this one. The fourth category then adds some side constraints. In addition, three statistic cells for the simulation run. Therefore, the book and its website should fit a course where the instructor wants the students to have a single selfcontained textbook that complements and supports what happens in the classroom. hil23453 ch03\_025-092.qxd 1/31/70 11:17 AM Final PDF to printer Page 25 3 C H A P T E R Introduction to Linear Programming T he development of linear programming T he development of linear programming has been ranked among the most important scientific advances of the mid-20th century, and we must agree with this assessment, 147-149 of this article, summarize the background that led to undertaking this study. The long-term loan is taken in a single lump sum. SmartBook includes powerful reports that identify specific topics and learning objectives students need to study. In this environment, locating the particularly relevant data and identifying the interesting patterns in these data can become an overwhelming task. As one example, analytics (together with OR) played a key role in the 2012 presidential campaign in the United States. Normally, several beams are precisely administered from different angles in a twodimensional plane. There may be thousands of sources of data, and the total amount of data may be measured in gigabytes or even terabytes. Therefore, the additivity assumption was adopted as a reasonable approximation. Define the problem of interest and gather relevant data. The hil23453 ch28 001-047.qxd 1/22/1970 10:51 PM Page 36 Confirming Pages 36 CHAPTER 28 EXAMPLES OF PERFORMING SIMULATIONS ON SPREADSHEETS custom cumulative, custom general, and custom histogram distributions are all similar in that they are all s Western College Publishing, Mason, OH, 2012. Norton & Company, New York, 2003. Thus, the n-step transition probability p(n) ij is just the conditional probability p(n) ij is just the conditional probability p(n) ij is just the conditional probability that the system will be in state j after exactly n steps (time units), given that it starts in state i at any 1 time t. (Section 8.4) Parametric linear programming The systematic study of how the optimal solution changes as several of the model's parameters continuously change simultaneously over some intervals. Risk profiles now are needed to evaluate the latter two. Just pick some numbers for the changing cells and determine with a calculator or pencil and paper what the results should be. Because of the war effort, there was an urgent need to allocate scarce resources to the various military operations and to the activities within each operation in an effective manner. (The dose strength at any point in the body is measured in units called kilorads.) Once the treatment design has been developed, it is administered in many installments, spread over several weeks. Operations Research (IOR) Tutorial for efficiently learning and executing algorithms interactively, implemented in Java 2 in order to be platform independent. thoroughly tested to try to find and correct as many bugs as possible. Note that the steady-state equations consist of M 2 equations in M 1 unknowns. 20.6). If the computer is found to be up, the probability of its remaining up for the next hour is 0.95. (Section 15.2) Fair Game A game that has a value of 0. 29.2 indicates that p23 p 0. 21.10. (Section 15.2) 9.1) Hungarian algorithm An algorithm An algorithm that is designed specifically to solve assignment problems very efficiently. T., Spreadsheet Modeling and Decision Analysis, 6th ed., South-Western College Publishing, Mason, OH, 2012. This includes determining such things as the appropriate objectives, constraints on what can be done, interrelationships between the area to be studied and other 10 hil23453 ch02 010-024.qxd 1/15/70 7:34 AM 2.1 Page 11 DEFINING THE PROBLEM AND GATHERING DATA Final PDF to printer 11 areas of the organization, possible alternative courses of action, time limits for making a decision, and so on. II. paper) — ISBN 0-07-352345-3 (alk. After OR was credited with literally saving the company during its early years, it became the custom to have OR represented at the weekly senior management meetings and, indeed, several of the senior corporate vice presidents have come up from the outstanding FedEx OR group., Xt1 kt1, Xt i} P{Xt1 jXt i}, for t 0, 1, . (d) Describe the impact and potential impact of this study on public policy. In addition, the Ministry of Agriculture has set a maximum quota for the total acreage that can be devoted to each of these crops by the Southern Confederation of Kibbutzim, as shown in Table 3.9. Feet) 1 2 3 400 600 300 600 800 375 hil23453 ch03\_025-092.qxd 1/30/70 7:57 AM 3.4 Final PDF to printer Page 49 ADDITIONAL EXAMPLES 49 TABLE 3.9 Crop data for the Southern Confederation of Kibbutzim Crop Sugar beets Cotton Sorghum Maximum Quota (Acres) Water Consumption (Acre Feet/Acre) Net Return (\$/Acre) 600 500 325 3 2 1 1,000 750 250 Because of the limited water available for irrigation, the Southern Confederation of Kibbutzim will not be able to use all its irrigable land for planting crops in the upcoming season. For that reason no I don't think this book will introduce you to many practical techniques you can apply to real world problems. Although the construction costs during the first three years can be estimated fairly roughly, the net incomes during the following three years of operation are very uncertain. The nature of the organization is essentially immaterial, and in fact, OR has been applied extensively in such diverse areas as manufacturing, transportation, construction, telecommunications, financial planning, health care, the military, and public services, to name just a few. 3.1. Figure 3.12 shows the graphical solution. The proportionality satisfied column of Table 3.4 shows the case that was assumed in Sec. 3.4-9 (Chap. However, some linear programming problems) encountered in practice require truly massive models. (Section 20.1) Distributions menu A menu on the ASPE ribbon that includes 46 probability distributions from which one is chosen to enter into any uncertain variable cell. (c) Summarize the "impact measures" (measures of performance) for comparing policies that are described on pp. This would mean that the contribution from product 1 to Z should be 3x1 1 for x1 > 0, 2 When the function includes any cross-product terms, proportionality should be interpreted to mean that changes in the function 6.2) SOB method See sensible-odd-bizarre method. Alden, J. Each SmartBook contains four components: Preview, Read, Practice, and Recharge. Combining this result with the third equation immediately yields the following steady-state probabilities: 0 = 0.75, 1 = 0.25 These are the same probabilities: 0 = 0.75, 1 = 0.25 These are the same probabilities as obtained in each row of the five-step transition matrix calculated in Sec. He was promoted to associate professor in 2001 and received tenure in 2005. Given a complicated situation like the one facing Julie at Everglade, it sometimes can be difficult to decide how to even get started. Finally, keep in mind that unemployment benefits are taxable, so it's generally wise to choose to have taxes withheld from each payment when you first open your claim. Step 5: Collect Your Unemployment BenefitsMost claims are processed within two to three calendar weeks or 10 business days, although delays could occur during times of high claim volumes. I., "Model World: On the Evolution of Operations Research",
Interfaces, 41 (4): 389-393, July-August 2011. Such models are invaluable for abstracting the essence of the subject of inquiry, showing interrelationships, and facilitating analysis. There is no systematic procedure that invariably will lead to a single correct spreadsheet model. 29.3), it follows that all states are recurrent since pi(2) j 0 for all i and j. (Section 17.4) Pollaczek-Khintchine formula The equation for Lg (or Wg) for the M/G/1 model. 2.4-1. (Section 20.6) Seed An initial random numbers be laid out in a row or a column, or as a two-dimensional table? The amounts to be shipped from F1 and F2 are shown to their left, and the amounts to be received at W1 and W2 are shown to their right. After chairing the Department of Operations Research, vice provost and dean of research, vice provost and dean of research, vice provost and dean of research, he served as associate dean of the School of Humanities and Sciences, vice provost and dean of research, vice provost and dean of research, be served as associate dean of the School of Humanities and Sciences, vice provost and dean of research, vice provost and dean of research, be served as associate dean of the School of Humanities and Sciences, vice provost and dean of research, be served as associate dean of the School of Humanities and Sciences, vice provost and dean of the School of Humanities and Sciences, vice provest and dean of the School of Humanities and Sciences, vice provest and dean of the School of Humanities and Sciences, vice provest and dean of the School of Humanities and Sciences, vice provest and dean of the School of Humanities and Sciences, vice provest and dean of the School of Humanities and Sciences, vice provest and dean of the School of Humanities and Sciences, vice provest and dean of the School of Humanities and Sciences, vice provest and dean of the School of Humanities and Sciences, vice provest and dean of the School of Humanities and Sciences, vice provest and dean of the School of Humanities and Sciences, vice provest and the School of Humanities and Sciences, vice provest and the School of Humanities and Sciences, vice provest and the Sciences, vice provest and chair of the Centennial Celebration Committee. (Section 12.2) Glossaries - 25 Binary representation of a bounded integer variable as a linear function of a bounded integer variable. Assume that the number of reservations to accept may be any integer value between 150 and 200. In combination with the fact that demand actually must be integer, this confirms that the choice made in Freddie's original spreadsheet model in Fig. Create even allows you to personalize your book's appearance by selecting the cover and adding your name, school, and course information. (Section 13.2) Convex function A function that is always "curving upward" (or not curving at all), as defined further in Appendix 2. Based on the new schedule of flights, an analysis has been made of the minimum number of customer service agents that need to be on duty at different times of the day to hil23453 ch03 025-092.qxd 58 1/30/70 7:57 AM CHAPTER 3 Final PDF to printer Page 58 INTRODUCTION TO LINEAR PROGRAMMING provide a satisfactory level of service. If a model has many sets of output cells, you can build up a model piece by working on one set of output cells at a time, making sure each set works correctly before moving on to the next. 29.2 can be used to calculate the two-step transition matrix P(2) as follows: 0.080 0.632 P(2) P2 0.264 0.080 0.184 0.368 0.368 0.184 0.368 0.368 0.368 0.368 0.368 0.368 0.368 0.368 0.368 0.368 0.368 0.368 0.252 0.319 0.283 0.233 is somewhat less than the sum of their individual profits when each is produced by itself. Thus, the cash flow in year n is divided by (1.1)n before adding these discounted cash flows to obtain NPV. If the number of cameras on hand at the end of each week is 0 or 1, two additional cameras will be ordered. What numbers will the 1 4 8 10 COO need? (Section 18.3) Discount factor The amount by which a cash flow 1 year hence should be multiplied to calculate its net present values, including noninteger values standard distributions will be just what is needed for an uncertain variable cell. If you fail to answer the questions correctly — or don't consent to this process — you will most likely be asked to provide the agency with documents that verify your identity. Step 4: File Your ClaimOnce you confirm your eligibility, it's time to file your claim. Photo Courtesy: JGI/Tom Grill/Getty Images After you've lost your job, contact your state unemployment agency as soon as possible. Finally, with the custom histogram distribution, the range between the minimum and maximum is divided into a number of equal-sized segments and weights are provided for each segment to indicate how likely it should be (relative to the other segments) for a random outcome to fall within that segment. The course code is free, and it can usually be issued within 24 to 48 hours (often the same day). 3 1 0 0 0 1 0 1 1 0 1 1 2 2 0 1 1 1 2 2 0 0 2 2 9.4-2. Furthermore, there are many more continuous distributions (31) available in ASPE than discrete distributions (8). Moreover, if you willingly guit your job, are an independent contractor or otherwise self-employed, or can't go back to work for health or other reasons, you might not gualify. Liao, R. (Section 13.9) Genetic algorithm A type of algorithm A type of algorithm for nonconvex programming that is based on the concepts of genetics, evolution, and survival of the fittest. E\* (d) Build a spreadsheet model for months 1 and 2, and then thoroughly test the model. Albright, S. If only integer values are possible, then the integer values are possible, then the referable one. In the first example, a company is developing a new product but it is unclear which of three production processes will be needed to produce the product. This condition is especially crucial when controversial public policy issues are being studied. This is exactly what we want, since we always want the interest payment to be based on the short-term loan that was taken one year ago (two cells to the left and one cell up). All of the supplementary chapters include problems and selected references. A New Chapter on Linear Programming under Uncertainty That Includes These New Sections. An infeasible region to the line constraint is violated. (Note that the equality constraint limits the feasible region to the line constraint is violated.) the two endpoints of the line segment.) The dashed line is the objective function line that passes through the optimal solution (x1, x2) (7.5, 4.5) with Z 5.25. 28.6. Refer to the financial risk analysis example presented in Sec. (d) List the various tangible and intangible benefits that resulted from the study. The goal of this chapter is to provide a solid foundation for becoming a successful spreadsheet modeler. The standard Excel Solver can solve most of these examples. (b) Use the steady-state equations to solve manually for the steady-state equations to solve most of these examples. of the team. By analyzing cost data from these same engineers and the marketing division, along with a pricing decision from the marketing division, the accounting department developed estimates for the third category. Thus, for t 0, 1, 2, . (Section 12.6) Yes-or-no decision whose only possible choices are (1) yes, go ahead with a certain option, or (2) no, decline this option. (a) Construct the rate diagram for this Markov chain. .} provides a mathematical representation of how the status of the power and versatility of ASPE, we no longer include a number of Excel-based software packages (Crystal Ball, Premium Solver for Education, TreePlan, SensIt, RiskSim, and Solver Table) that were bundled with recent editions. (Section 17.2) Internal service system A queueing system A queueing system are internal to the organization providing the service. Make a rough sketch of a spreadsheet model, with blocks laid out for the data cells, changing
cells, output cells, and objective cell. Because each product goes through a sequence of production operations, individual production facilities normally dedicated to that product would incur occasional idle periods. Observe in Fig. Recalculate the (long-run) expected average cost per week under this new inventory policy. The current example actually fits one of these models (the finite calling population variation of the M/M/s model included in Sec. Any problem that mixes some or all of these forms with the remaining problem. (See Selected Reference 9 for a detailed description of this process.) A crucial step in formulating an OR model is the construction of the objective function. A Gambling Example. Many Additional Examples Are Available. An interesting feature of the transitions from state i to state j are impossible in one step. Therefore, the parameter values used would be

based on a prediction of future conditions, which inevitably introduces some degree of uncertainty. 1 2 3 4 5 6 7 8 9 10 11 12 Final PDF to printer Page 64 INTRODUCTION TO LINEAR PROGRAMMING B C D E F G Wyndor Glass Co. Product-Mix Problem Doors 3 Profit Per Batch (\$000) Plant 1 Plant 2 Plant 3 Windows 5 Hours Used Per Batch Produced Used 0 1 0 3 that is defined by an equation. Since the games all sell out, Susan is able to sell the tickets for \$150 on game day. Unfortunately, this is not a legitimate linear programming constraint. For n 2, these expressions become M p(2) ij pik pkj, for all states i and j, k0 (2) where the p(2) ij are the elements of a matrix P. Suppose that there are 3 days between deliveries. A third was to accurately determine whether a plant can ship a requested order-line-item quantity on the requested order-line order-line order-line order-line order order-line order order-line order orde 1/22/1970 10:51 PM Page 31 Confirming Pages 28.6 CHOOSING THE RIGHT DISTRIBUTION 31 When a positively skewed distribution that does not allow negative values is needed, the lognormal distribution that does not allow negative values is needed. parameters that are entered into the corresponding cells of the spreadsheet. 28.29, so simulations will be run for bids of 4.8, 5.0, 5.2, 5.4, 5.6, and 5.8 (in millions of dollars). Since this will be a constraint in the model, it is logical to arrange the balance and minimum balance blocks of numbers adjacent to each other in the spreadsheet. (Section 13.3) Frank-Wolfe algorithm An important example of sequential-approximation algorithms for convex programming. This application of linear programming and its extensions led to the OR team winning the prestigious First Prize in the 2007 international competition for the Franz Edelman Award for Achievement in Operations Research and the Management Sciences. Such products as Welch's grape jelly and Welch's grape juice have been enjoyed by generations of American consumers. hil23453 ch03 025-092.qxd 1/30/70 7:57 AM 3.4 Page 45 ADDITIONAL EXAMPLES Final PDF to printer 45 Design of Radiation Therapy FIGURE 3.11 Cross section of Mary's tumor (viewed from above) nearby critical tissues, and the radiation beams being used. The j satisfy the equations M j i pij (t), for j 0, 1, . Because no substantial costs will be incurred to initiate the produced times the number of batches produced.) Obtaining reasonable estimates of these quantities required enlisting the help of key personnel in various units of the company. Merrill Lynch responded by conducting a major OR study that led to a complete overhaul in how it charged for its services, ranging from a full-service asset-based option (charge a fixed percentage of the value of the assets held rather than for individual trades) to a low-cost option for clients wishing to invest online directly. Hillier). (Section 17.2) Queueing network A network of service facilities where each customer must receive service at some or all of these facilities. 28.2) and the future sale price for real estate property (in Fig. Figure 28.14 shows the Normal Distribution dialog box that is used to enter the parameters (mean and standard deviation) for the normal distribution into the first uncertain variable cell D7 by referencing cells F7 and G7. Then, even as personnel changes, the system can be called on at regular intervals to provide a specific numerical solution. Assume that each of these construction times has a triangular distribution. SELECTED REFERENCES 1. Milligan, R. (Section 14.3) Traveling salesman problem A classic type of combinatorial optimization problem that can be described in terms of a salesman seeking the shortest route for visiting a number of cities exactly once each. In this particular example, the cost is the damage to healthy anatomy and the benefit is the radiation reaching the center of the tumor. A little planning at this stage can go a long way toward building a spreadsheet that is well organized. The goal of the design is to select the combination of beams to be used, and the intensity of each one, to generate the best possible dose distribution. Take a 16.50 percent share of the hotel project. (Each produced in batches of 20, so the hil23453 ch03 025-092.qxd 1/31/70 11:19 AM Final PDF to printer Page 27 An Application Vignette Swift & Company is a diversified protein-producing business based in Greeley, Colorado. Consequently, this assumption rules out any exponent other than 1 for any variable in any term of any function (whether the objective function or the function or the function or the function (Z 3x1 5x2) for the Wyndor Glass Co. problem., a cost C(Xt, Dtm) is incurred at time t, for t 0, 1, 2, How much cash would the company have left at the end of 2015? of boots in inventory at the end of 2015? of boots in inventory at the end of a quarter incurs \$8 in storage What are the decisions that need to be made? All these tests work correctly for the spreadsheet in Fig. A random walk is a Markov chain with the property that if the system is in a state i, then in a single transition the system either remains at i or moves to one of the two states immediately adjacent to i., 6, each representing the use of one of the two types of furnaces, expressed as a fraction of the abatement capacity (so xj cannot exceed 1). 3.1, namely, 3x1 for product 1 and 5x2 for product 2. The interest rate for these short-term loans currently is projected to be 7 percent per year. Postoptimality analysis includes the investigation of such trade-offs. Mamon, R. Staff in the manufacturing division provided the data in the first category above. In contrast to textbook problems where the numbers are given to you, determining parameter values for real problems requires gathering relevant data. An OR study seeks solutions that are optimal for the overall organization rather than suboptimal solutions that are best for only one component. (The form of the functional constraints made this outcome a likely one.) If some of the variables had turned out to be noninteger, the easiest approach would have been to round up to integer values. In concluding this discussion of the major phases of an OR study, it should be emphasized that there are many exceptions to the "rules" prescribed in this chapter. • Data files for various cases to enable students to focus on analysis rather than inputting large data sets. (b) Describe the purpose of each of the three general types of models formulated during this study. For example, a good survey of the field can be obtained from Chaps. As a teaching assistant, she analyzed operations research problems into classroom case studies. The hospital proposes a policy of receiving 1 pinted during this study. at each delivery and using the oldest blood first. 20.6. Recall that one of the most popular newspapers that Freddie the newsboy sells from his newsstand is the daily Financial Journal. Because tumor cells, the radiation dosage throughout the tumor region must be large enough to kill the malignant cells, which are slightly more radiosensitive, yet small enough to spare the healthy cells. In this case, the slope of the profit function for product 1 (given by the solid curve in Fig. M. L. Reading is no longer a passive and linear experience but an engaging and dynamic one, where students are more likely to master and retain important concepts, coming to class better prepared. 3 6 4 7 (b) Suppose that Pine Furniture were to produce three end tables 4 24 4 5 and three dining room tables. 0.28 Thus, if the weather is in state 0 (dry) on a particular day, the probability of being in state 0 (dry) on a particular day, the probability of being in state 0 (dry) on a particular day. hil23453 ch03 025-092.qxd 54 1/30/70 7:57 AM Final PDF to printer Page 54 CHAPTER 3 INTRODUCTION TO LINEAR PROGRAMMING TABLE 3.16 Product data for Save-It Co. Grade Specification Material 1: Not more than 30% of total Material 3: Not more than 50% of total Material 4: Exactly 20% of total Material 1: Not more than 30% of total Material 3: Not more than 30% of total Material 3: Not more than 50% of total Material 4: Exactly 20% of total Material 4: Exactly 20 A Amalgamation Cost per Pound (\$) Selling Price per Pound (\$) Selling Price per Pound (\$) 3.00 8.50 B Material 1: Not more than 70% of total 2.00 5.50 product grade. 20.6. This model includes the uncertain variable cell Demand (C12). The values at the dots are given by the Case 3 column in Table 3.4. Contribution of x1 to Z 12 9 Satisfies proportionality assumption 6 Violates proportionality assumption 6 Violates proportionality assumption 3 0 1 2 3 4 x1 hil23453 ch03 025-092.qxd 1/30/70 7:57 AM 3.3 Final PDF to printer Page 41 ASSUMPTIONS OF LINEAR PROGRAMMING 41 is whether, after all the components of profit have been accumulated, proportionality is a reasonable approximation for practical modeling purposes. Finally, since production rates cannot be negative; x1 0 and x2 0. Suppose that extra cash is kept in an interest-bearing of the first two quarters. Allen, "Raw Material Management at Welch's, Inc.," Interfaces, 28(5): 13-24, Sept.-Oct. 3.10) keeps decreasing as x1 is increased. hil23453\_ch28\_001-047.qxd 1/22/1970 10:51 PM Page 35 Confirming Pages 28.6 CHOOSING THE RIGHT DISTRIBUTION 35 IFIGURE 28.23 The characteristics and dialog boxes for two distributions that involve the number of trials until events occur Fortunately, Julie had set up the spreadsheet properly (providing a data cell for the cash flow in each of the next 10 years) to enable performing sensitivity analysis immediately by simply trying different numbers in some of these data cells. (Section 17.9) Queue The waiting line in a queueing system. If you do not like this choice, it will even identify which of the distributions provides the second best fit, the third best fit, and so on. The Transcontinental Airlines Overbooking Problem Transcontinental Airlines (Section
17.9) And so on. The Transcontine (Section 17.9) And so on. The Transcontinenta mainly used by business travelers. Hutton, C. In most cases, you will file a claim with the state where you most recently relocated from another state, that may not be the case. 6. We always will mention whenever a supplementary example on the current topic is included in the Solved Examples section of the book's website The additivity satisfied column shows the case where this function value is obtained simply by adding the first two rows (3 5 8), so that Z 3x1 5x2 as previously assumed. In the values box, any number of values between the minimum and hil23453\_ch28\_001-047.qxd 1/22/1970 10:51 PM Page 37 Confirming Pages 28.6 CHOOSING THE RIGHT DISTRIBUTION 37 IFIGURE 28.24 This dialog box illustrates how ASPE's custom discrete distribution can enable you to custom-design your own distribution by entering a set of discrete values and their weights. The fact that the slope is fixed at 53 means that all lines constructed in this way are parallel. (Section 14.2) Sub-tour reversal A method for adjusting the sequence of cities visited in the current trial solution for a traveling salesman problem by selecting a subsequence of the cities is visited. In full recognition of these practical realities, the OR team now is ready to evaluate the validity of the model more critically (to be continued in Sec. Oh: "Pricing Analysis for Merrill Lynch Integrated Choice," Interfaces, 32(1): 5-19, January-February 2002. The lightly shaded portion of the trials with losses involved losses up to about \$10 million, but that quite a few trials had losses that ranged from \$10 million to nearly \$30 million. After defining this problem, the analyst can then undertake the sometimes lengthy process of gathering the relevant data for analyzing the problem.  $n \rightarrow n t1$  Note that an alternative measure to the (long-run) expected average cost per unit time is the (long-run) expected average cost per unit time. increases the value of the objective function at the fastest possible rate. The agricultural output of each kibbutz is limited by both the amount of available irrigable land and the quantity of water allocated for irrigation by the Water Commissioner (a national government official). When evaluating the various alternative plans, what should be the measure of performance for choosing the best plan? Unprofitable products are being discontinued, releasing production capacity to launch two new product 1: An 8-foot glass door with aluminum framing Product 2: A 4 6 foot double-hung wood-framed window Product 1: An 8-foot glass door with aluminum framing Product 1: An 8-foot glass door with aluminum framing Product 2: A 4 6 foot double-hung wood-framed window Product 1: An 8-foot glass door with aluminum framing Product 2: A 4 6 foot double-hung wood-framed window Product 1: An 8-foot glass door with aluminum framing Product 2: A 4 6 foot double-hung wood-framed window Product 1: An 8-foot glass door with aluminum framing Product 2: A 4 6 foot double-hung wood-framed window Product 1: An 8-foot glass door with aluminum framing Product 2: A 4 6 foot double-hung wood-framed window Product 1: An 8-foot glass door with aluminum framing Product 2: A 4 6 foot double-hung wood-framed window Product 1: An 8-foot glass door with aluminum framing Product 2: A 4 6 foot double-hung wood-framed window Product 1: An 8-foot glass door with aluminum framing Product 2: A 4 6 foot double-hung wood-framed window Product 1: An 8-foot glass door with aluminum framing Product 2: A 4 6 foot double-hung wood-framed window Product 1: An 8-foot glass door with aluminum framed window Product 2: A 4 6 foot double-hung wood-framed window Product 1: An 8-foot glass door with aluminum framed window Product 2: A 4 6 foot double-hung wood-framed window Product 1: An 8-foot glass door with aluminum framed window Product 2: A 4 6 foot double-hung wood-framed window Product 2: A 4 6 foot double-hung wood-framed window Product 2: A 4 6 foot double-hung wood-framed window Product 2: A 4 6 foot double-hung wood-framed window Product 2: A 4 6 foot double-hung wood-framed window Product 2: A 4 6 foot double-hung wood-framed window Product 2: A 4 6 foot double-hung wood-framed window Product 2: A 4 6 foot double-hung wood-framed window Product 2: A 4 6 foot double-hung wood-framed window Product 2: A 4 in Plants 1 and 3, but none in Plant 2. 29.3-3. 8.3 and 9.2 is helpful (but not essential) in Sec. 28.16, the decision variable is ReservationsToAccept (C13) and the results cell is Profit (F23). Ragsdale, C. What is the actual situation? Therefore, the development of electronic digital computers, with their ability to perform arithmetic calculations millions of times faster than a human being can, was a tremendous boon to OR. If you have any difficulty locating your local center, contact your state unemployment agency for assistance. (Section 11.3) Optimal policy The optimal specification of the policy decisions at the respective stages of a dynamic programming problem. (Section 10.5) Spanning tree A connected network for all n nodes of the original network that contains no undirected cycles. 2.2-3. What numbers will Al require? This is what has just happened regarding the daily flight from San Francisco to Chicago. The state of the system on day t can be either State 0 Day t is dry or State 1 Day t has rain. This process has four major steps: (1) plan the spreadsheet model, (2) build the model, (3) test the model, and (4) analyze the model and its results. By substituting, the following two equations are obtained: f13 p10 f03 p11 f13 p12 f23 p23 f33. Beam 2 1 3 2 3 Beam 1 1. (b) Outline the system developed to track and test each needle and syringe in order to gather the needed data. Restrictions on amounts treated (right side of Table 3.17): xA1 xA2 xA3 xA4 xB1 xC1 xB2 xC2 xB3 xC3 xB4 xC4 1,500 1,000 2,000 500 1material 1 2 1material 3 2 1material 4 2. 21.5 are only estimates. The book, unfortunately, seems to talk about the nice mathematical models and theoretical side. Our example below involves overbooking by an airline company. In effect, the random variable is memoryless; the process forgets its history. (This approximation was used in cells C10:C11 of the spreadsheet model in Fig. (A class may consist of a single state.) If there is only one class, i.e., all the states communicate, the Markov chain is said to be irreducible. Kamber, and J. After a solution procedure (another program) is applied to the model, additional computer programs may trigger the implementation of the long-run behavior of finite-state Markov chains do, in fact, hold under relatively general conditions, as summarized below. Furthermore, the strengths of the analytics approach are likely to be increasingly incorporated into the OR approach as time goes on, so it will be instructive to describe analytics a little further. However, it will equip you with a useful language and set of ideas. (Sections 19.1 and 19.2) Deterministic policy A policy that always remains the same over time. Section 3.5 describes how to use Excel to formulate and solve linear programming models in a spreadsheet format with either Solver or Analytical Solver Platform for Education. For example, if you wish to emphasize spreadsheet modeling and applications, we would recommend including some chapters from the Hillier-Hillier textbook, Introduction to Management Science: A Modeling and Case Studies Approach with Spreadsheets. 3.1 for the Wyndor Glass Co. problem. You might think that this must be the major part of the study, but actually it is noted. in most cases. Additional Features Te text website (www.mhhe.com/hillier) contains many other software options, including: • Student versions of the MPL Modeling System and its elite solvers, as well as an MPL tutorial and formulation examples from the text • Student versions of the MPL Modeling System and its elite solvers, as well as an MPL tutorial and formulation examples from the text • Student versions of the MPL Modeling System and its elite solvers, as well as an MPL tutorial and formulation examples from the text • Student versions of the MPL modeling System and its elite solvers, as well as an MPL tutorial and formulation examples from the text • Student versions of the MPL modeling System and its elite solvers, as well as an MPL tutorial and formulation examples from the text • Student versions of the MPL modeling System and its elite solvers, as well as an MPL tutorial and formulation examples from the text • Student versions of the MPL modeling System and its elite solvers, as well as an MPL tutorial and formulation examples from the text • Student versions of the MPL modeling System and its elite solvers, as well as an MPL tutorial and formulation examples from the text • Student versions of the MPL modeling System and its elite solvers, as well as an MPL tutorial and formulation examples from the text • Student versions of the MPL modeling System and its elite solvers, as well as an MPL tutorial and formulation examples from the text • Student versions of the MPL modeling System and its elite solvers, as well as an MPL tutorial and formulation examples from the text • Student versions of the MPL modeling System and its elite solvers, as well as an MPL tutorial and formulation examples from the text • Student versions of the MPL modeling System and text • Student versions of the MPL modeling System and text • Student versions of the MPL modeling System and text • Student versions of text • S OR Tutor and IOR Tutorial for efciently learning various algorithms • Excel spreadsheet formulations, using either the standard Excel Solver or the Analytic Solver or the Analytic Solver Platform for Education, for the examples in the text • Many Excel templates for automatically solving a variety of models Digital supplements ConnectPlus (125917400X) and LearnSmart (1259173992) have been added
to this textbook package to make it convenient for students to learn the material and easier for instructors to assign and grade their work. Reconsider Prob. 28.26 for Freddie's problem, (2) only continuous distributions will be allowed, (4) a sample independence test will be run, and (5) which ranking method will be used (the chi-square test) to evaluate how well each of the distributions fit the data. 3.5 for the Wyndor Glass Co. problem. 2.3-1. (c) Find the ij (the expected first passage time from state i to state j) for all i and j. (This kind of extension of linear programming to what is called mixed-integer programming will be discussed in Chap. A continuous time stochastic process {X(t); t 0} is a continuous time Markov chain if it has the Markov chain if it has the Markov chain if it has the benefits of developing software to support problem solving speedily? (Section 18.2) Ordering cost The total cost of ordering (either through purchasing or producing) some amount to replenish inventory. (Recall that is just the conditional probability of being in state j after n steps, starting in state j being accessible from state i means that it is possible for the system to enter state j eventually when it starts from state i. Address given at the 1971 annual conference of the Canadian Operational Research Society. Additional Examples of Markov Chains A Stock Example. (Section 12.9) new constraints. The short-term loan is repaid one year later, so the FIGURE 21.3 A small version (years 2014 and 2015 only) of the spreadsheet for the Everglade cash flow management problem. For example, instead of jumping right into a 10-year planning problem, you can start with the simpler problem of just looking at a couple of years. (Section 14.4) Heuristic method A procedure that is likely to discover a very good feasible solution, but not necessarily an optimal solution, for the specific problem being considered. Braklow, J. 29.5-6. For example, a random walk often is used as a model for situations involving gambling. One important technique for doing this is called data mining (as described in Selected Reference 8). ... (Section 17.2) Glossaries - 45 Glossary for Chapter 18 Assembly system A multiechelon inventory system A multiple immediate predecessors in the preceding echelon. He will continue to play until he goes broke or nets a fortune of T dollars. For each of these broader phases, list the detailed phases that fall partially or primarily within the broader phase. (c) Summarize the initial results from this tracking and testing system. Lin: "SLIM: Short Cycle Time and Low Inventory in Manufacturing at Samsung Electronics," Interfaces, 32(1): 61-77, January-February 2002. Simulation, the divisibility assumption does not hold because some of or all the decision variables must be restricted to integer values. The first step is to identify the values of (x1, x2) that are permitted by the restrictions. Resist this urge. 28.15 shows the results of applying simulation to the spreadsheet model in Fig. 4 Customers who are fully paid (in state 0) and then subsequently fall into arrears on new purchases are viewed as "new" customers who start in state 1. Tekerian: "Optimizer: IBM's Multi-Echelon Inventory System for Managing Service Logistics," Interfaces, 20(1): 65–82, January-February 1990. H. The team also needs to have the necessary experience and variety of skills to give appropriate consideration to the many ramifications of the problem throughout the organization. The other set of decisions is the mix of materials for each product grade. 0 | 0 ] (a) What is the probability that the unit will be inoperable (because both components are down) after n periods, for n 2, 5, 10, 20? Restriction on treatment cost (right side of Table 3.17): 31xA1 xB1 xC1 2 61xA2 xB2 xC2 2 41xA3 xB3 xC3 2 51xA4 xB4 xC4 2 30,000. .} is a stochastic process where the random variable Xt represents the state of the system at time t, namely, State at time t number of cameras on hand at the end of week t. Pruneau, M. (Now that the range of numbers that need to be considered has been narrowed down this far, Problem 28.10 asks you to continue that analysis by generating a parameter analysis report that considers all integer Uniform Distribution Uniform Distribution: • Fixed lower and upper limit • All values equally likely Integer Uniform Distribution: • Fixed lower and upper limit • All integer values equally likely hil23453 ch28 001-047.qxd 1/22/1970 10:51 PM Page 32 Confirming Pages 32 CHAPTER 28 EXAMPLES OF PERFORMING SIMULATIONS ON SPREADSHEETS Either of these distributions is a particularly convenient one because it has only two parameters (lower and upper limit) and both are very intuitive. Nonnegativity: xj 0, for j 1, 2, p, 9. vii hil23453 fm i-xxx.qxd viii 1/30/70 7:58 AM Page viii Final PDF to printer ABOUT THE AUTHORS In addition to Introduction to Stochastic Models in Operations Research (1990), his books are The Evaluation of Risky Interrelated Investments (North-Holland, 1969), Queueing Tables and Graphs (Elsevier North-Holland, 1981, co-authored by O. 28.3. Consider the historical data contained in the Excel File "Sales Data 2" on this website. However, there also are costs incurred if the number of arriving customers exceeds the number of available seats. (Section 14.4) Population The set of trial solutions under consideration during an iteration of a genetic algorithm. 1 to 15 (introduction, linear programming) require no mathematical programming) require no mathematical programming) require no mathematical programming and mathematical programming) require no mathematical programming and mathematical programming) require no mathematical programming and programming and programming and mathematical programming and programming nonnegativity constraints (or nonnegativity conditions). A common theme in OR is the search for an optimal, or best, solution. (Section 10.2) Undirected path An undirected path from node j is a sequence of connecting arcs whose direction (if any) can be either toward or away from node j. Read Selected Reference 8. quarters and make a recommendation. Finally, if the stock decreased today and yesterday, it will increase tomorrow with probability 4. For each transmission after the first one, the digit entered for transmission is the one that was recorded at the end of the preceding transmission. Therefore, management wants risk analysis to be performed in the usual way (with simulation) to obtain a risk profile of what the total NPV might actually turn out to be with this proposal. Thus, for each product grade, the profit per pound is obtained by subtracting the amalgamation cost given in the third column. (This is the only constraint involving both products.) This is the only constraint involving both products.) constraint concerns the production capacity of Plant 3, where 18 hours of production time per week is available for the two new products, and the function on the left-hand side (3x1 2x2) represents the number of hours of production time per week is available for the two new products. displayed earlier in Fig. The key characteristic of such problems is that it seeks the best trade-off between some cost and some benefit(s). 2.2-1. Similarly, given that there will be three cameras in stock 4 weeks later, that is, (4) p23 0.171. 28.28 identifies the best fitting distributions, ranked according to the Chi-Square test. It is particularly concerned about its major competitor (labeled B). Use the results to answer the following questions. (Section 13.7) Newton's method A traditional type of search procedure that uses a quadratic approximation of the objective function to solve unconstrained optimization problems where the objective function (assuming maximization) is a concave function. {Xt} {X0, X1, X2, . The fact that the mean of 142.273 is so close to 150 shows that a policy of accepting 190 reservations would do an excellent job of filling seats. 21.1, the next section will describe this plan-build-test-analyze process in some detail and illustrate the process in the context of the case study. Source: E. (c) Describe the role of sensitivity analysis in testing the operational validity of a model. Consider the inventory example presented in Sec. For example, choosing Trace Precedents for the ST Interest cell for 2015 (G12) displays the arrows shown in Fig. This brings us to the question of how to identify which distribution is best for a particular uncertain variable cell. Selected Reference 6 focuses on applications in finance and Selected Reference 3 describes applications in finance and Selected Reference 6 focuses on applications in finance and Selected Reference 6 focuses on applications in finance and Selected Reference 3 describes applications in finance and Selected Reference 6 focuses on applications in finance and Selected Reference 6 focuses on applications in finance and Selected Reference 6 focuses on applications in finance and Selected Reference 6 focuses on applications in finance and Selected Reference 6 focuses on applications in finance and Selected Reference 6 focuses on applications in finance and Selected Reference 6 focuses on applications in finance and Selected Reference 6 focuses on applications in finance and Selected Reference 6 focuses on applications in finance and Selected Reference 6 focuses on applications in finance and Selected Reference 6 focuses on applications in finance and Selected Reference 6 focuses on applications in finance and Selected Reference 6 focuses on applications in finance and Selected Reference 6 focuses on applications in finance and Selected Reference 6 focuses on applications in finance and Selected Reference 6 focuses on applications in finance and Selected Reference 6 focuses on applications in finance and Selected Reference 6 focuses on applications in finance and Selected Reference 6 focuses on applications in finance and Selected Reference 8 focuses on
applications in finance and Selected Reference 8 focuses on applications in finance and Selected Reference 8 focuses on applications in finance and Selected Reference 8 focuses on applications in finance and Selected Reference 8 focuses on applications in finance and Selected Reference 8 focuses on applications in finance and Selected Reference 8 focuses on applications in finance and Selected Reference 8 focuses on applications in finance 8 focuses on applications in finance 8 focuses on appl A policy that always remains the same over time. These examples are scaled-down versions of actual applications. How is all this possible? The two products are believed to have an equal chance of reaching itself This continued until the seventh edition had become considerably larger than is desirable for an introductory survey textbook. 17.6). At the same time, the aggregate dose to critical tissues must not exceed established tolerance levels, in order to prevent complications that can be more serious than the disease itself. The rapid spread of OR soon followed. As was true for Table 3.5, the difference lies in the last row, which now gives the total function value for produced jointly. kj This equation recognizes that the first transition from state i can be to either state j or to some other state k. Based on past experience, Susan has predicted the probability of absorption into state 4. The main features of a linear programming model, including all its parameters, can be easily entered onto a spreadsheet. The objective is to maximize the total net return to the Southern Confederation of Kibbutzim as a whole. For example, consider the first specification for product grade A in Table 3.16 (the proportion of material 1 should not exceed 30 percent). hil23453 ch28 001-047.qxd 1/22/1970 10:51 PM Page 38 Confirming Pages 38 CHAPTER 28 EXAMPLES OF PERFORMING SIMULATIONS ON SPREADSHEETS FIGURE 28.25 This dialog box illustrates how ASPE's custom general distribution can enable you to custom-design your own continuous distribution. 163-167 of Selected Reference A8 that describes an OR study done for Yellow Freight System, Inc., and the resulting computer system SYSNET. 18-20 of Selected Reference A8 that describes an OR study done for Yellow Freight System, Inc., and the resulting computer system SYSNET. 18-20 of Selected Reference A8 that describes an OR study done for the Rijkswaterstaat of the Netherlands. hil23453 ch28\_001-047.qxd 1/22/1970 10:51 PM Page 34 Confirming Pages 34 CHAPTER 28 EXAMPLES OF PERFORMING SIMULATIONS ON SPREADSHEETS Distribution: • Describes and event occurs in a fixed number of trials (e.g., number of heads in 10 flips of a coin) • For each trial, only two outcomes possible • Trials independent • Probability remains same for each trial = FIGURE 28.22 The characteristics and dialog boxes for the Bernoulli and binomial distributions in ASPE's Distributions menu. Formulating the Weather Example as a Markov Chain For the weather example introduced in the preceding section, recall that the evolution of the weather in Centerville from day to day has been formulated as a stochastic process {Xt} (t 0, 1, 2, . The final restriction, 3x1 2x2 18, requires plotting the points (x1, x2) such that 3x1 2x2 18 (another line) to complete the boundary. Page ix Final PDF to printer ABOUT THE CASE WRITERS Karl Schmedders is professor at the Kellogg Graduate School of Management (Northwestern University). We will intersperse snippets from some of these examples throughout the chapter. This is inevitable, given the difficulty of communicating and understanding all the aspects and subtleties of a complex operational problem as well as the difficulty of collecting reliable data. 29.2. Whether the stock goes up tomorrow depends upon whether it increased today and yesterday. For example, consider the situation where a normal distribution was entered into an uncertain variable cell in Fig. Liberatore, M. However, those presentations being considered in those chapters. 29.3 because five transitions proved enough to make the state probabilities essentially independent of the initial state. As before, no order is placed if there are any cameras in stock. An output cell that is used to forecast a measure of performance is called a results cell. A stochastic process {Xt} (t 0, 1, . (e) Cite the page in the article that lists basic validation steps. This is a different skillset. hil23453\_ch29\_001-036.qxd 1/22/1970 10:53 PM Page 11 Confirming Pages 29.3 CHAPMAN-KOLMOGOROV EQUATIONS P(3) P3 P P2 0.8 0.6 0.2 0.4 P(4) P4 P P3 0.6 0.2 0.4 P(5) P5 P P4 0.6 0.2 0.4 P(5) P5 P P4 0.6 0.2 0.4 0.8 0.72 0.76 11 0.24 0.752 0.28 0.744 0.248 0.256 0.749 0.250 0.75 0.251 0.75 0.251 0.75 0.752 0.75 0.251 0.75 0.251 0.75 0.251 0.75 0.251 0.75 0.251 0.75 0.251 0.75 0.251 0.251 0.25 0.251 0.25 0.251 0.25 0.251 0.25 0.251 0.2 transition matrix has the interesting feature that the two rows have identical entries (after rounding to three significant digits). The left-hand side (j qj) is the rate at which the process is in state j. 21.1 to illustrate the difference between appropriate formulations and poor formulations of a model. Section 28.6 will describe the characteristics of various distributions. If Zn is zero or positive, no orders are backlogged. After this chapter introduces the general features of linear programming, Chaps. The use of metaheuristics (the subject of Chap. The equations entered into cells D28:D35 (see the bottom of Fig. The recently released Analytic Solver Platform (a powerful spreadsheet optimizer that includes five solvers for linear, mixed-integer, nonlinear, non-smooth, and global optimization), (2) Risk Solver Pro (for simulation and risk analysis), and (3) XLMiner (an Excel-based tool for data mining and forecasting). 13) and LGO for global optimization (Sec. When n 1, we drop the superscript n and simply refer to this as the transition matrix. (Note that wasting time switching between products leads to a positive crossproduct term here, where the total function is measuring production time used, whereas it led to a negative cross-product term for Case 4 in Table 3.6, the function for production time used is 3x1 2x2 0.1x 21x2, so the function value for (x1, x2) (2, 3) is 6 6 1.2 10.8. This case could arise in the following way. 28.6), and cash flows (in Fig. Leachman, R. 1, 2, 3, 4, 16, 17, 18, and 20, along with parts of Chaps. www.mcgrawhillconnect.com Introduction to • A chapter on linear programming under uncertainty that includes topics such as robust optimization, chance constraints, and stochastic programming with recourse • A section on the recent rise of analytics together with operations research • Analytic Solver Platform for Education - exciting new software that provides an all-in-one package for formulating and solving many OR models in spreadsheets Operations Research has been the classic text on operations research. SELECTED REFERENCES 1. Han, J., M. Section 10.6 assumes an acquaintance with the problem formulations in Secs. Don't bother with numbers at this point. This procedure involves constructing a twodimensional graph with x1 and x2 as the axes. We devote this chapter instead to the general art of formulating spreadsheet models to fit any application. It is often desirable to also make probability statements about the number of transitions made by the process in going from state i to state j for the first time. 3, specific linear programming models are constructed to fit such diverse problems as determining (1) the hil23453\_ch02\_010-024.qxd 14 1/15/70 7:34 AM CHAPTER 2 Page 14 Final PDF to printer OVERVIEW OF THE OPERATIONS RESEARCH MODELING APPROACH mix of products that maximizes total net return, (2) the design of radiation therapy that effectively attacks a tumor while minimizing the damage to nearby healthy tissue, (3) the allocation of acreage to crops that maximizes total net return, and (4) the combination of pollution abatement methods that achieves air quality standards at minimum cost. To ensure equity between the three kibbutz will plant the same proportion of its available irrigable land. Owen), Engineering Statistics, (2nd ed., Prentice-Hall, 1972, co-authored by A. 2.1 for a more detailed discussion of this process of defining the problem and gathering the data.) As
a member of Everglade's top management, Julie Lee was able to undertake a major part of this process of defining the company's cash flow problem by herself. Most of the supplements to chapters also have problems. Resnick, S. With a keen eye, you might have noticed that the third constraint, x1 x2 65, actually is not necessary because the second constraint, x1 x2 79, ensures that x1 x2 will be larger than 65. In major OR studies, several months (or longer) may be required to develop, test, and install this computer system. Ng, and T.-K. Consequently, it is not necessary to include unimportant details or factors that have approximately the same effect for all the alternative courses of action considered. (Section 20.5) Congruential methods for generating a sequence of random numbers over some range. flow problem. (Section 16.2) Payoff table A table giving the payoff for each combination of a decision alternative and a state of nature. Volume 2 is scheduled for publication in 2015. Jackson, D. 29.2. The four possible states for the number of cameras on hand at the end of a week are represented by the four nodes (circles) in the diagram. Select three of the applications of operations research listed in Table 1.1. For each one, read the article that is referenced in the solution for the joint probability of the number of customers at the respective facilities of a queueing network that is just the product of the probabilities of the number at each facility considered independently of the others. To access this site, visit www.mhhe.com/hillier. (Section 13.6) Linear complementarity problem with feasible solutions and a bounded feasible region. The crucial question is whether the past is truly representative of the future. Note that P{X(t s) jX(s) i} is a transition probability, just like the transition probability is a transition probability of the future. The conclusion was that proportionality could indeed be assumed without serious distortion. Powell: "Interactive Optimization Improves Service and Performance for Yellow Freight System," Interfaces, 22(1): 147-172, January-February 1992. Although this rule may vary by state at times due to special circumstances (like a global pandemic), the general rule of thumb is that you're expected to pursue work leads every week and report your work search efforts in your weekly claim. Do you have COVID-19-specific questions about unemployment benefits and stimulus checks? Thus, the apparent weaknesses in the initial solution are used to suggest improvements in the model, its input data, and perhaps the solution procedure. The exponential distribution has a single parameter, call it q, where the mean is 1/q and the cumulative distribution function is P{Ti t} 1 eqt, for t 0. Once the data are in place, the layout for the rest of the model quickly falls into place around the structure of the data. number of customers requesting reservations has a normal distribution with a mean of 195 and a standard deviation of 30, this information has been entered into cells D10:F10. The binomial distribution assumes that the event will occur. (Section 15.2) Stable solution A solution for a two-person, zero-sum game where neither player has any motive to consider changing strategies, either to take advantage of his opponent or to prevent the opponent of taking advantage of him. It even is possible to provide great flexibility on the kind of software (if any) that instructors want their students to use, as described below in the section on software options. 20.6. Columns B and C come from the simulation model for this example in Fig. (Even when constraints already are displayed in the spreadsheet, as in columns J, K, and L of this figure, Excel allows these contraints to be violated unless they also are specified by Solver.) Everglade management wants to find a combination of loans that will keep the company solvent throughout the next 10 years (2014-2023) and then will leave as large a cash balance as possible in 2024 after paying off all the loans. (c) Identify the type of data that the management science group obtained for each client. 28.9. Consider the Everglade cash flow problem analyzed in Sec. This problem does not fit into any of the categories of linear programming problems introduced so far. ainxn bi for some values of i. It is difficult to extract a "right" answer from the "wrong" problem! The first thing to recognize is that an OR team normally works in an advisory capacity. Describe an important lesson that was gained from model validation in this study. If you want to work in OR then it is expected that you are familiar with the topics in the book including some theory behind LP, MIP, and so on. In its first year of use (mainly in 2001), the model was applied four times to recover from major schedule disruptions (two snowstorms, a flood, and the September 11 terrorist attacks). Application to the Inventory Example. The website also includes a glossary for each chapter. Read Selected Reference A9 that describes an awardwinning OR study done for Swift & Company. Read Selected Reference A3 that describes an OR study done for Swift attacks). for another (one-quarter) course in other deterministic models. Developing a spreadsheet model without proper planning inevitably leads to a model that is poorly organized and difficult to interpret. The field of operations around the world. Read Selected Reference A7 that describes an OR study done for TNT Express that won the 2012 Franz Edelman Award for Achievement in Operations Research and the Management Sciences. To optimize the model, Solver is used as shown in Fig. (The reason is that states 0 and 1 are mutually exclusive and the only possible states, so the probabilities of the two states must sum to 1.) Therefore, the stochastic process has the Markovian property, so the process is a Markov chain. Table 3.1 summarizes the data gathered. More precisely, this problem involves selecting the level of certain activities that compete for scarce resources that are necessary to perform those activities. Thus, the inventory level fluctuates between a minimum of zero cameras and a maximum of three cameras, so the possible states 0, 1, 2, or 3 cameras on hand. The simple version was used to gain basic insights, including trade-off analyses. Similarly, Plant 2 imposes the restriction that 2x2 12. It provides strong capability for dealing with the types of OR models considered in most of the chapters considered in most of the chapters considered in this book, including linear programming, decision analysis, simulation, and forecasting. Let Xn denote the amount of stock on hand after ordering at the end of period n (where X0 2), so that Xn1 Dn 1 if Xn1 Dn 1 (n 1, 2, . This process is referred to as sensitivity analysis, as discussed further in the next section (and much of Chap. For example, pick some loan amounts for Everglade, and then calculate the company's resulting cash balance at the end of the first couple years. A transition matrix P is said to be doubly stochastic if the sum over each column equals 1; that is, M p ij 1, for all j. (Section 15.6) Two-person zero-sum game A game with two players where one player wins whatever the other one loses, so that the sum of their net winnings is zero. By contrast, the next three columns show different hypothetical cases where the proportionality assumption would be violated. In some cases, people who were fired, suspended or asked to take a leave of absence don't qualify for unemployment. O. After completing all of this, you are ready for the analysis step, which involves applying the model to evaluate proposed solutions and perhaps using Solver to optimize the model. Databases and management information systems may provide up-to-date input for the model each time it is used, in which case interface programs are needed. 13. hil23453\_ch29\_001-036.qxd 1/22/1970 10:53 PM Page 24 CHAPTER 29 MARKOV CHAINS Absorption probabilities are important in random walks. (a) Referring to pp. 29.7, find f10, f1T, f20, f2T. The selected references at the end of the chapter include some award-winning, queueing of how to execute these phases well. Test the model and refine it as needed. Many of the standard tools of OR, such as linear programming, dynamic programming, queueing theory, and inventory theory, were relatively well developed before the end of the 1950s. 7 0.184 0.080 0.368 0.1 0.632 0.368 0.264 0.264
0.264 probability of A winning a single bet is 31, so B wins the bet with probability 32. To illustrate this process of formulating and solving linear programming models on a spreadsheet, we now return to the Wyndor example introduced in Sec. dev.) 494.378 Uniform 160 615 (lower, upper) Think-Big's Simulated Cash Flow (\$millions) 27 28 Year 0 Year 1 Year 2 29 30 31 -24.999 -18.594 -15.239 -19.221 32 33 Year 3 Year 3 Year 3 Year 5 34 35 Year 6 Year 7 130.029 36 37 38 Net Present Value (\$millions) 13.879 39 MeanNPV (\$millions) 13.879 =HotelShare\*D7+ShoppingCenterShare\*D17 Year 2 =HotelShare\*D8+ShoppingCenterShare\*D18 Year 3 =HotelShare\*D10+ShoppingCenterShar =HotelShare\*D13+ShoppingCenterShare\*D23 Net Present Value (\$millions) =CashFlowYear0+NPV(CostOfCapital,CashFlowYear1To7) +PsiOutput() Mean NPV (\$millions) Cash Flow Year 0 -80 Year 1 =PsiNormal(F7,G7) Year 2 =PsiNormal(F8,G8) Year 3 =PsiNormal(F9,G9) Year 4 =PsiNormal(F10,G10) Year 5 =PsiNormal(F11,G11) 7 8 9 10 11 12 Year 6 =PsiNormal(F12,G12) Year 7 =PsiNo =PsiNormal(F22,G22) =PsiUniform(F23,G23) Share 16.50% 13.11% 10% 5.194 6.235 15.364 Think Big's 25 26 27 28 29 Hotel Shopping Center D 3 4 Range Name Cells CashFlowYear1To7 CostOfCapital HotelShare MeanNPV NetPresentValue ShoppingCenter D 3 4 Range Name Cells CashFlowYear1To7 CostOfCapital HotelShare MeanNPV NetPresentValue ShoppingCenter D 3 4 Range Name Cells CashFlowYear1To7 CostOfCapital HotelShare MeanNPV NetPresentValue ShoppingCenter D 3 4 Range Name Cells CashFlowYear1To7 CostOfCapital HotelShare MeanNPV NetPresentValue ShoppingCenter D 3 4 Range Name Cells CashFlowYear1To7 CostOfCapital HotelShare MeanNPV NetPresentValue ShoppingCenter D 3 4 Range Name Cells CashFlowYear1To7 CostOfCapital HotelShare MeanNPV NetPresentValue ShoppingCenter D 3 4 Range Name Cells CashFlowYear1To7 CostOfCapital HotelShare MeanNPV NetPresentValue ShoppingCenter D 3 4 Range Name Cells CashFlowYear1To7 CostOfCapital HotelShare MeanNPV NetPresentValue ShoppingCenter D 3 4 Range Name Cells CashFlowYear1To7 CostOfCapital HotelShare MeanNPV NetPresentValue ShoppingCenter D 3 4 Range Name Cells CashFlowYear1To7 CostOfCapital HotelShare MeanNPV NetPresentValue ShoppingCenter D 3 4 Range Name Cells CashFlowYear1To7 CostOfCapital HotelShare MeanNPV NetPresentValue ShoppingCenter D 3 4 Range Name Cells CashFlowYear1To7 CostOfCapital HotelShare MeanNPV NetPresentValue ShoppingCenter D 3 4 Range Name Cells CashFlowYear1To7 CostOfCapital HotelShare MeanNPV NetPresentValue ShoppingCenter D 3 4 Range Name Cells CashFlowYear1To7 CostOfCapital HotelShare MeanNPV NetPresentValue ShoppingCenter D 3 4 Range Name Cells CashFlowYear1To7 CostOfCapital HotelShare MeanNPV NetPresentValue ShoppingCenter D 3 4 Range Name Cells CashFlowYear1To7 CostOfCapital HotelShare MeanNPV NetPresentValue ShoppingCenter D 3 4 Range Name Cells CashFlowYear1To7 CostOfCapital HotelShare MeanNPV NetPresentValue ShoppingCenter D 3 4 Range Name Cells CashFlowYear1To7 CostOfCapital HotelShare MeanVells CashFlowYear1To7 CostOfCapital HotelShare MeanVells CashFlowYear1To7 C spreadsheet model for applying simulation to the Think-Big Development Co. financial risk analysis problem. It consists of many demonstration examples that display and explain the algorithms in action. Within the restrictions specified in Tables 3.16 and 3.17, management wants to determine the amount of each product grade to produce and the exact mix of materials to be used for each grade. Howard, R. This fact also is implied by the slope-intercept form of the objective function, which indicates that the intercept with the x1 axis 1 15 Z2 increases when the value chosen for Z is increased. 4) Close any Excel windows you have open. (Sections 15.2 and 15.3) Mixed strategy A plan for using a probability distribution to determine which of the original strategies will be used. (Section 10.6) Tree A connected network) that contains no undirected cycles. In particular, the average dosage absorption for the hil23453\_ch03\_025-092.qxd 1/30/70 7:57 AM Final PDF to printer Page 46 An Application Vignette Prostate cancer is the most common form of cancer diagnosed in men. This analysis led to the total annual cost estimates (in millions of dollars) given in Table 3.14 for using the methods at their full abatement capacities. When considering the number of events that occur within a certain period of time, the mean to be entered into the one parameter field in the dialog box should be the average number of events that occur within that period of time. Because the text provides great flexibility for what to emphasize, an instructor can easily pick and choose just certain portions of the book to cover. To test the spreadsheet, try entering values in the changing cells for which you know what the values of the output cells should be, and then see if the spreadsheet gives the results that you expect. Another program may generate management) that interpret the output of the model and its implications for application. For purposes of analysis, it is assumed that each method also can be used less fully to achieve any fraction of the emission-rate reductions shown in this table. It is possible for a Markov chain to have both a recurrent class of states and a transient class of states where the two classes have different periods greater than 1. Linus Schrage of the University of Chicago and LINDO Systems (and who took an introductory operations research course from me 50 years ago) provided LINGO and LINDO for the book's website. Fleuren, H., et al.: "Supply Chain-Wide Optimization at TNT Express," Interfaces, 43(1): 5-20, January-February 2013. This office currently is planning agricultural production for the coming year. hil23453 ch02\_010-024.qxd 1/15/70 7:34 AM Page 23 PROBLEMS Final PDF to printer 23 PROBLEMS 2.1-1. In a similar fashion, the restriction 2x2 12 (or, equivalently, x2 6) implies that the line 2x2 12 should be added to the boundary of the permissible region. (Section 12.8) Descendant A descendant of a subproblem is a new smaller subproblem that is created by branching on this subproblem and then perhaps branching further through subsequent "generations." (Section 12.6) Domain reduction The process used by constraint programming for eliminating possible values for individual variables. Neither of us could have imagined that this extensive worldwide demand would continue at such a high level for such an extended period of time This system usually is computer-based. 29.8. Suppose now that a third machine, identical to the first two, has been added to the shop. For example, if two OR teams were to be given exactly the same problem to analyze with a spreadsheet, their spreadsheet models will likely look quite different. An operating component breaks down in a given period with probability 0.2. When this occurs, the parallel component takes over, if it is operational, at the beginning of the next period. See below for more on these products. Williams, H. (b) If the costs of being in states 0, 1, 2, 3, are 0, \$1,000, \$3,000, and \$6,000, respectively, what is the long-run expected average cost per day? Similarly, the (long-run) actual average cost per unit time is given by M 1 n lim C(Xt1, Dt) k(j). Once again, all the examples that can be solved with this package are detailed in MPL/Solvers files for the corresponding chapters in your OR Courseware. I will be forever indebted to Jerry for giving me this opportunity. However, we believe that many instructors and students will welcome the great power and versatility of ASPE. A continuous time stochastic process 
$\{X(t); t 0\}$  has the Markovian property if  $P\{X(t s) jX(s) i\}$ , for all i, j 0, 1, . cnxn, subject to the restrictions a11x1 a12x2 . 7). This also makes it difficult to develop meaningful estimates of the bounds. These advantages have made the triangular distribution a popular choice for simulations. 8.2 also draw upon Chap. The term also can be applied to a group of servers collectively. Bennett, R. For example, a potential solution can be checked to see if it is feasible and what Z value (profit or cost) it achieves. To start, its one-step transition matrix P obtained in Sec. Because of the uncertainty about the true value of the parameter, it is important to analyze how the solution derived from the model would change (if at all) if the values. 29.1 except that demand now has the following probability distribution: 1 P{D 0}, 4 1 P{D 2}, 4 P{D 3} 0. Because a repair takes two periods, V 1 if U 0 (since then one nonoperational component is waiting to begin repair while the other one is entering its second period of repair) or if U 1 and the nonoperational component is waiting to begin repair while the other one is entering its second period of repair) or if U 1 and the nonoperational component is entering its second period of repair) or if U 1 and the nonoperational component is waiting to begin repair while the other one is entering its second period of repair) or if U 1 and the nonoperational component is waiting to begin repair while the other one is entering its second period of repair) or if U 1 and the nonoperational component is waiting to begin repair while the other one is entering its second period of repair) or if U 1 and the nonoperational component is waiting to begin repair while the other one is entering its second period of repair) or if U 1 and the nonoperational component is entering its second period of repair. expensive version of the book that is customized to meet your needs. The Poisson Distribution, as shown in the bottom half of Fig. 29.7. Recurrence is a class property. Altschuler, S., D. Calculate by hand the ending inventory, savings account. The actual profit from producing product 1 (or any other product) is derived from the sales revenue minus various direct variable for the first transition, leads directly to this equation. Water allocation for each kibbutz: 3x1 2x4 x7 600 3x2 2x5 x8 800 3x3 2x6 x9 375 TABLE 3.10 Decision variables for the Southern Confederation of Kibbutzim problem Allocation (Acres) Kibbutz Crop 1 2 3 Sugar beets Cotton Sorghum x1 x4 x7 x2 x5 x8 x3 x6 x9 hil23453\_ch03\_025-092.qxd 50 1/30/70 7:57 AM CHAPTER 3 Final PDF to printer Page 50 INTRODUCTION TO LINEAR PROGRAMMING 3. 17) where a continuous time parameter (call it t) is required, because the evolution of the process is being observed continuously over time. In some cases, these shipments can be guaranteed overnight delivery by 10:30 A.M. the next morning. Another key difference is that all its parameters— min (the minimum value), likely (the most likely value) and max (the maximum value)— are intuitive ones, so they are relatively easy to estimate. Most of Chaps. Except perhaps for the divisibility assumption, minor disparities are to be expected. For each value in this list, a corresponding weight needs to be entered into the weights box. Lieberman, late, of Stanford University.—Tenth edition. The fixed interest rate on this long-term loan is a favorable 5 percent per year. (Section 18.3) Reorder-point, order-quantity policy A policy for a stochastic continuous-review inventory level drops to the reorder point. k0 hil23453 ch29\_001-036.qxd 1/22/1970 10:53 PM Page 29 Confirming Pages 29.8 CONTINUOUS TIME MARKOV CHAINS 29 A pair of states i and j are said to communicate if there are times t1 and t2 such that pij (t1) 0 and pji (t2) 0. Soumis: "Bombardier Flexjet Significantly Improves Its Fractional Aircraft Ownership Operations," Interfaces, 35(1): 49-60, January-February 2005. 29.1, Xt1 max{3 Dt1, 0} Xt 0. Product 2 needs only Plants 2 and 3. State 1: The stock decreased on this day. n → n t1 j0 Now let us assign numerical values to the two components of C(Xt1, Dt) in this example, namely, the ordering cost and the penalty cost for unsatisfied demand. The decision is made to test 11 values of ReservationsToAccept (C13), so sim will be run for values in intervals of five between 150 and 200. In the gambling example, state 2 also has period 2 because it is in the same class as state 1 and we noted above that state 1 has period 2.) is a Markov chain. A negative number would make no sense in this case, but this was no problem since the mean (195) was much larger than three standard deviations (3 3 30 5 90) so a negative value essentially could never occur. The feasible region in the example is the entire shaded area in Fig. The test bank for this new edition, so many new test guestions now are available to instructors. These "demos" supplement the examples in the book. Based on the first answer, the products are placed in cells. The inclusion of a website does not indicate an endorsement by the authors or McGraw-Hill Education, and McGraw-Hill Education does not guarantee the accuracy of the information presented at these sites. In addition to having the usual continuous variables that fit linear programming, the model also has some binary variables (variables whose only possible values are 0 and 1). The current data surge is coming from sophisticated computer tracking of shipments, sales, suppliers, and customers, as well as email, Web traffic, and social networks. (a) Formulate the evolution of the status of the machine as a Markov chain by identifying three possible states at the end of each day, and then constructing the (one-step) transition matrix. Looking to the future, the two approaches should tend to merge over time. Having seen the trial-and-error procedure for finding the optimal point (2, 6), you now can streamline this approach for other problems. Thus, the mean is a very intuitive quantity that can be readily estimated, but the standard deviation is not. I.: "Model World: Danger, Beware the User as Modeler," Interfaces, 20(3): 60-64, May-June 1990. 28.21. Once the process is in state 2, it remains in state 2. The objective cell EndBalance (J21) indicates that the ending balance in 2024 will be \$5.39 million. This mean value of \$482,000 in cell B5 should be a close estimate of the expected profit from using this bid. You then should go back a step or two and make sure that you have thoroughly completed those preceding steps. S. In both cases the engineers have decided that the most effective types of abatement methods are (1) increasing the height of the smokestacks, 6 (2) using filter devices (including gas traps) in the smokestacks, and (3) including cleaner, high-grade materials among the fuels for the fuel of the enough that there will not be many occasions when a significant number of customers need to be bumped from the flight because the number of arrivals exceeds the number of arrivals exceeds the number of seats available. 3 and perhaps in Chap. In the Everglade problem (see Fig. In contrast to the spreadsheet model for the Wyndor Glass Co. product-mix problem shown in Fig. When the simulation run is completed, ASPE provides the results in a variety of useful forms, including a frequency distribution, a statistics table, and a cumulative chart. (Section 16.2) Decision conferencing A process used for group decision making You should find these interactive procedures a very efficient and enlightening way of doing many of your homework problems. Without a doubt, the ongoing pandemic throws a bit of a wrench into the process of actively seeking work, so that component may vary from state to state and could change at any time. The Save-It Co. problem is an example of a blending problem. 3.3 ASSUMPTIONS OF LINEAR PROGRAMMING All the assumptions of linear programming actually are implicit in the model formulation method for generating random observations from a probability distribution. We assume that 1 if j lim pij (t) t→0 0 if i j. 28.32. To see this, observe from P that if the process starts in either of hil23453 ch29 001-036.qxd 1/22/1970 10:53 PM Page 15 Confirming Pages 29.5 LONG-RUN PROPERTIES OF MARKOV CHAINS 15 these states, it can never leave these two states. 29.1, we now will use the above formulas to calculate various n-step transition matrices from the (one-step) transition matrix P that was obtained in Sec. Chapters 9 and 10 will focus on linear programming problems that fall into this new category of fixed requirements problems. (Section 18.5) Economic order quantity model A standard deterministic continuous-review inventory model with a constant demand rate so that an economic guantity is ordered periodically to replenish inventory. Total acreage for each crop: x1 x2 x3 600 x4 x5 x6 500 x7 x8 x9 325 4. C 29.5-7. We feel that it is important to acquaint students with the nature of these packages that they will be using after graduation. This spreadsheet model is repeated here as Fig. 1.3 THE RISE OF ANALYTICS TOGETHER WITH OPERATIONS RESEARCH There has been great buzz throughout the business world in recent years about something called analytics into managerial decision making. He and Dr. Lieberman also received the honorable mention award for the 1995 Lanchester Prize (best English-language publication of any kind in the field of operations research), which was awarded by the Institute of Operations Research and the Management Sciences (INFORMS) for the 6th edition of this book. (Section 20.3) Glossaries - 54 Warm-up period The initial period waiting to essentially reach a steady-state condition before collecting data during a simulation run. This approach has considerable merit. This is a nonrefundable fare, so no-shows forfeit the entire fare. This preeminent professional OR society is enabling this by providing a link to the articles in Interfaces that
describe the applications of OR that are summarized in the application vignettes and other selected references of award winning OR applications provided in the book. ASPE is an especially powerful add-in of this kind. If so, essentially the same spreadsheet model as in Fig. An elementary survey course covering linear programming, mathematical programming, mathematica semester by selectively drawing from material throughout the book. The period of state i is defined to be the integer t (t 1) such that p(n) ii 0 for all values of n other than t, 2t, 3t, . McGraw-Hill LearnSmart® is an adaptive learning system designed to help students learn faster, study more efficiently, and retain more knowledge for greater success. Consider the following inventory policy for the certain product. (Section 12.6) LP relaxation The linear programming problem the constraints that require variables to have integer values. 4 enables you to still find an optimal solution immediately. C., J. The ending balance for 2015 is therefore: Ending Balance (2015) Starting Balance (2015) ST Loan (2015) LT Interest Payment ST Loan Payback (2014) \$1 million \$5 million (5%)(\$6 million) (7%)(\$2 million) \$2 million \$5 million (5%)(\$6 million) (7%)(\$2 million \$5 million (5%)(\$6 million) (7%)(\$6 million) (7%)(\$6 million (5%)(\$6 million (5%)(\$6 million) (7%)(\$6 million) (7%)(\$6 million (5%)(\$6 million) (7%)(\$6 million) (7%)(\$6 million (5%)(\$6 million) (7%)(\$6 million) (7%)(\$6 million) (7%)(\$6 million (5%)(\$6 million) (7%)(\$6 million) (7% actual value in Trials for the binomial distribution will vary from simulation trial because it depends on the number of tickets purchased which is random. Visit www.CourseSmart.com to learn more and to try a sample chapter. This then enters the chosen distribution into the uncertain variable cell. (Section 20.1) Glossaries - 55 hil61217 ch21.gxd 4/29/04 03:40 PM Page 21-1 21 C H A P T E R The Art of Modeling with Spreadsheets A key step in nearly any OR study is to formulate a mathematical model to represent the problem of interest. 3.3, we note that the line giving a larger value of Z (Z 20) is farther up and away from the origin than the other line (Z 10). If so, try to arrange the blocks in consistent rows or columns so they can utilize a single set of headings. Links to Many Articles Describing Dramatic OR Applications. Refer to the scenario described in Prob. To do this, we need to determine all the transition rates, i.e., the qi and qij for i, j 0, 1, 2. When this happens, the repair is done the next day and completed at the end of that day. 29.5. These rates now can be used to calculate the total transition rate out of each state. (Introduction) Just-in-time (JIT) inventory system that places great emphasis on reducing inventory system that places great emphasis on reducing inventory system. are needed. (Selected References 4 and 5 have 17 articles describing the application of analytics in various sports.) These and numerous other success stories about the power of analytics and OR together should lead to their ever-increasing use in the future. E\* (d) Build a spreadsheet model for years 1 through 3, and then thoroughly test the model. If desired, you also can view an enlightening trend chart, which can provide additional details about the results. Try to arrange the spreadsheet so that it starts with the data at the top and progresses logically toward the objective cell (the output cell that contains the value of the objective function) at the bottom. This can be done fairly easily with trial-and-error. 29.6 to find the ij (the expected first passage time from state i to state j) for all i and j. The reason for this assumption is that, in most such situations, the arrivals of customers are random events and the exponential distribution is that it and j. The reason for this assumption is that, in most such situations, the arrivals of customers are random events and the exponential distribution is the probability distribution is the probability distribution is the probability distribution of the time between random events and the exponential distribution is the probability distributi model fits the very general format for the linear programming model is a linear programming mode (Section 10.5) Glossaries - 20 Cut value The sum of the arc capacities of the arcs (in the specified direction) of the cut. And you will know what it can be reasonable represented in vairous formed, like LP, MDP, parameteric black box function, etc. Classical Optimization Methods 959 4. Harris: Competing on Analytics: The New Science of Winning, Harvard Business School Press, Cambridge, MA, 2007. All the units produced at the factories to the distribution center should be forwarded to the warehouses. Like the radiation therapy problem, this is another example of a cost-benefit-trade-off problem. Chapters 9 and 10 consider some special types of linear programming problems whose importance warrants individual study. The material in Chaps. The first three categories of constraints. This does not imply that the study of each problem must give explicit consideration to all aspects of the organization; rather, the objectives being sought must be consistent with those of the overall organization. 0 2 4 6 8 10 x1 next try a larger arbitrary value of Z, say, Z 20 3x1 5x2. During times when both machines are operational, breakdowns occur at the rate of 1 1 2 per day, so q01 2. Equal proportion of land planted: x2 x5 x8 x1 x4 x7 400 600 x3 x6 x9 x2 x5 x8 600 300 x3 x6 x9 x1 x4 x7 300 400 5. He subsequently earned tenure at the age of 28 and the rank of full professor at 32. 28.3. The spreadsheet model is available on this website. Although we refer to "the" mathematical model of a business problem, real problems normally don't have just a single "right" model. (Section 18.5) Echelon A stage at which inventory is held in the progression of units through a multistage inventory system. 28.5 with the ticket demand in cell C11 of Fig. Meini: Numerical Methods for Structured Markov Chains, Oxford University Press, New York, 2005. 3.13, where F1 and F2 are the two factories, W1 and W2 are the two warehouses, and DC is a distribution center. This is particularly advantageous when the mean is less than three standard deviations and the normal distribution should not be used. McGraw-Hill Connect, a web-based assignment and assessment platform that can help students to perform better in their coursework and to master important concepts. (d) What does the author say about whether there is a validation methodology that is appropriate for all models? (Section 20.6) Uniform random number A random observation from a (continuous) uniform distribution over some interval [a, b], commonly where a = 0 and b = 1. (Sections 13.3 and 13.8) Sequential-approximation algorithms that replace the nonlinear objective function by a succession of linear or quadratic approximations. Note that no spaces are allowed in a range name so each new word begins with a capital letter. This reflects the fact that the probability of the weather being in a particular state is essentially independent of the state of the weather five days before. Today it is a standard tool that has saved many thousands or millions of dollars for many companies or businesses of even moderate size in the various industrialized countries of the world, and its use in other sectors of society has been spreading rapidly. The algebra of the model is still there, but it is hidden away in the formulas entered into certain cells of the spreadsheet. The characteristics of each of these distributions are listed on the bidding example mentioned above and use a parameter cell to run multiple simulations. Availability of materials (second column of Table 3.17): xA1 xA2 xA3 xA4 xB1 xC1 xB2 xC2 xB3 xC3 xB4 xC4 3,000 2,000 4,000 1,000 Page 7 Confirming Pages 29.2 MARKOV CHAINS FIGURE 29.2 The state transition diagram for the inventory example. (Section 13.2) Convex programming problems where the objective functions (assuming a < form) are convex functions. State 0 1 (a) P 2 3 0 [0 1 | 0 | 0 1 0 0 1 1 2 3 1 3 2 3 0 0 0 ] 0 | 0 | 0 | bil23453 ch29 001-036.gxd 1/22/1970 10:53 PM Page 33 Confirming Pages PROBLEMS State 0 (b) P 1 2 3 0 1 2 (a) Determine the classes of this Markov chain and, for each class, determine the classes of this Markov chain and, for each class, determine the classes of this Markov chain and, for each class, determine the classes of this Markov chain and for each class, determine
the classes of this Markov chain and for each class, determine the classes of this Markov chain and for each class, determine the classes of this Markov chain and for each class, determine the classes of this Markov chain and for each class. operating and maintenance expenses as well as reduced revenue due to any loss in the efficiency of the production process caused by using the method. The parameter analysis report on the left side of the figure reveals that the mean of the production process caused by using the method. increases until the mean reaches a peak of \$11,912 at 185 reservations, after which it starts to drop. An optimal solution for this model is shown in Table 3.18, and then these xij values are used to calculate the other quantities of interest given in the table. Label these states as X(s) i and X(r) x(r). There is only one (continuous) probability distribution that possesses this property—the exponential distribution. 21 and 28 on the book's website. Plan: Define the Problem and Gather the Data Before sitting down to start planning how to organize the spreadsheet model, it is necessary to thoroughly understand what the problem is. This result follows from the definition of a class. If you have previously used parameter cells with the Solver in ASPE to generate parameter analysis reports for performing sensitivity analysis systematically (as was done in Chap. Each time, he has a probability p of winning and probability p of vinning and p of INTRODUCTION TO LINEAR PROGRAMMING The example has exactly one optimal solution, (x1, x2) (2, 6), which is a CPF solution. (This is property 4 of the exponential distribution described in Sec. This tends to make the overall structure of the problem more comprehensible, and it helps to reveal important cause-and-effect relationships Otherwise, no order is placed. We have added our own automatic procedures to IOR Tutorial in a few cases where these packages are not applicable. (Section 14.4) Gene One of the binary digits that defines a trial solution in base 2 for a genetic algorithm. Another key part of your OR Courseware is a program called IOR Tutorial. Because of the need

to carefully balance all these factors, the design of radiation therapy is a very delicate process. Subsequent applications extended to many daily minor disruptions as well. The geometric distribution of the number of trials until the event occurs for the first time. Frequently, much of the needed data will not be available when the study begins, either because the information never has been kept or because what was kept is outdated or in the wrong form. 10 to 14. 19. (Section 20.5) Applications-oriented simulator A software package designed for simulating a fairly specific type of stochastic system. You will see numerous examples of mathematical models throughout the remainder of this book. (For this reason, a linear programming problem and its model often are referred to interchangeably as simply a linear program, or even as 25 hil23453 ch03 025-092.qxd 26 1/30/70 7:57 AM CHAPTER 3 Page 26 Final PDF to printer INTRODUCTION TO LINEAR PROGRAMMING just an LP.) Furthermore, a remarkably efficient solution procedure, called the simplex method, is available for solving linear programming problems of even enormous size. Otherwise, no ordering will take place. Radiation through the patient's body, damaging both cancerous and healthy tissues. B. ASPE provides the following procedure for fitting the best distribution to data: 1. hil23453 ch29 001-036.qxd 1/22/1970 10:53 PM Page 32 Confirming Pages 32 CHAPTER 29 MARKOV CHAINS PROBLEMS The symbol to the left of some of the problems (or their parts) has the following meaning. Organize and clearly identify the data. By developing effective methods of using the new tool of radar, these teams were instrumental in winning the Air Battle of Britain. Student versions of several elite MPL solvers for linear programming, entry entr a tenured Associate Professor of Quantitative Methods at the University of Washington) provided both the spreadsheets and the Excel files (including many Excel templates) once again for this edition. A Second Stock Example. 3.3) and to perform sensitivity analysis on the effect of the estimates in Table 3.1 being different because of inaccurate estimation, changes of circumstances, etc. Plan: Do Some Calculations by Hand When building a model, another presents probability models for processes that evolve over time in a probabilistic manner. The special cases of m 1 and m n 1 lead to the expressions M (n1) p(n) ij pik k0 and M (n1) p(n) ij pik k0 and M (n1) p(n) ij pik k0 and M (n1) p(n) ji pik k0 and M (n1) NumberThatShow (C17) in Fig. Furthermore, if the assumption is violated only because of start-up costs, there is an extension of linear programming) that can be used, as discussed in Sec.12.3 (the fixed-charge problem). 21-5. W., L. The custom distributions actually are not probability distributions until you make them one. At the same time, we have integrated ASPE in such a way that it can readily be skipped over without loss of continuity for those who do not wish to use spreadsheets. This can be very illuminating. Therefore, an OR team has been formed to study this question. Thus, this problem involves finding the best mix of shift sizes. Each of the other two cases is considered about three times as likely as both products reaching the market at the same time. This term represents the profit generated per week. The loan payments are calculated in columns H and I. We also will assume that we know the initial probabilities P{X0 i} for all i. We begin this chapter by developing a miniature prototype example of a linear programming problem. Denote these four states by 0, 1, 2, 3, respectively. The feasible region is the collection of all feasible solutions. Denardo, E. Dr. Hillier's research has extended into a variety of areas, including integer programming, queueing theory. and its application, statistical quality control, and the application of production systems and to capital budgeting. 16 to 20, there is considerable flexibility of coverage, although some integration of the material is available. Some instructors will focus on the deterministic models of OR, while others will emphasize stochastic models. This case can arise in exactly the same way as described for Case 2 in Table 3.5; namely, extra time is wasted switching the products.  $n \rightarrow$  Furthermore, lim p(n) ij 0,  $n \rightarrow$  where the j uniquely satisfy the following steady-state equations hil23453 ch29 001-036.qxd 1/22/1970 10:53 PM Page 16 Confirming Pages 16 CHAPTER 29 MARKOV CHAINS M j i pij, for j 0, 1, . Elsevier/Morgan Kaufmann, Waltham, MA, 2011. (Section 12.1) Cut An alternative name for cutting plane, defined below. Each pair of boots sold generates a profit of \$20 per pair. See tabs below to explore options and pricing. . W., W. The prerequisites for a course using this book can be relatively modest. If state j is accessible from state i and state i and j are said to communicate. Your assignment is to will need to carry inventory to meet demand in the later quarters. 28.15 for option 1 along with the corresponding results obtained for the other two options as the basis for a managerial decision on which of the three options to choose. Such laws of physics as F = ma and E = mc2 are familiar examples. State 0 1 P 2 3 4 29.5-1. (d) List the four steps in the collaborative-planning process that resulted from this study. The postoptimality analysis done earlier (as described in Sec. One of the newer tools of OR teams is a technique called data mining that addresses this problem. (In the spreadsheet files contained in OR Courseware, the changing cells hil23453 ch03\_025-092.qxd 1/30/70 64 7:57 AM CHAPTER 3 A FIGURE 3.15 The complete spreadsheet for the Wyndor problem with an initial trial solution (both production rates equal to zero) entered into the changing cells (C12 and D12). Peck, and W. hil23453 ch02 010-024.gxd 1/15/70 7:34 AM 2.3 Page 17 Final PDF to printer DERIVING SOLUTIONS FROM THE MODEL 17 optimal solution for the original model may be far from ideal for the real problem, so additional analysis is needed. (Section 17.4) Poisson process A process where the number of events (e.g., arrivals) that have occurred has a Poisson distribution with a mean that is proportional to the elapsed time. Each of the transition probabilities is given next to the corresponding arrow. 20.1 and 20.4, the standard Excel package sometimes is sufficient to do this. In particular, the peak is at 0 but there is a long tail to the right. Sales will always be integer, so discrete might seem the more logical choice. MARY has just been diagnosed as having a cancer at a fairly advanced stage. For Fig. The adjective long-run indicates that this objective provides the flexibility to consider activities that do not translate into profits immediately (e.g., research and development projects) but need to do so eventually in order to be worthwhile. Samsung Electronics Corp. Costy, R. At CourseSmart you can take advantage of significant savings off the cost of a print textbook, reduce their impact on the environment, and gain access to powerful web tools for learning. hil23453\_ch01\_001-009.qxd 8 1/15/70 7:40 AM CHAPTER 1 Page 8 Final PDF to printer INTRODUCTION A very popular approach now is to use today's premier spread sheet package, Microsoft Excel, to formulate small OR models in a spread sheet format. The small claims were spread uniformly between 0 and \$2,000, whereas the large claims were spread uniformly between 40 are roughly 3 times as likely to occur as values near 20 or 30. With the custom cumulative distribution, you enter several values. (b) Find the long-run expected average storage cost per week. There now are a few dozen member countries in the International Federation of Operational Research Societies (IFORS), with each country having a national OR society. You will be introduced to how these algorithms work and what makes them so efficient. A New Section on Robust Optimization. 2.1-2. However, the following limit always exists for an irreducible (finite-state) Markov chain: 1 n limit always exists for an irreducible (finite-state) Markov chain: 1 n limit always exists for an irreducible (finite-state) Markov chain: 1 n limit always exists for an irreducible (finite-state) Markov chain: 1 n limit always exists for an irreducible (finite-state) Markov chain: 1 n limit always exists for an irreducible (finite-state) Markov chain: 1 n limit always exists for an irreducible (finite-state) Markov chain: 1 n limit always exists for an irreducible (finite-state) Markov chain: 1 n limit always exists for an irreducible (finite-state) Markov chain: 1 n limit always exists for an irreducible (finite-state) Markov chain: 1 n limit always exists for an irreducible (finite-state) Markov chain: 1 n limit always exists for an irreducible (finite-state) Markov chain: 1 n limit always exists for an irreducible (finite-state) Markov chain: 1 n limit always exists for an irreducible (finite-state) Markov chain: 1 n limit always exists for an irreducible (finite-state) Markov chain: 1 n limit always exists for an irreducible (finite-state) Markov chain: 1 n limit always exists for an irreducible (finite-state) Markov chain: 1 n limit always exists for an irreducible (finite-state) Markov chain: 1 n limit always exists for an irreducible (finite-state) Markov chain: 1 n limit always exists for an irreducible (finite-state) Markov chain: 1 n limit always exists for an irreducible (finite-state) Markov chain: 1 n limit always exists for an irreducible (finite-state) Markov chain: 1 n limit always exists for an irreducible (finite-state) Markov chain: 1 n limit always exists for an irreducible (finite-state) Markov chain: 1 n limit always exists for an irreducible (finite-s p(k) j, ij  $n \rightarrow n k1$  where the j satisfy the steady-state equations given in the preceding subsection. Without these constraints, the optimal solution given above turned out to have integer values anyway,
so no harm was done by not including the constraints. Now we are ready to define the continuous time Markov chains to be considered in this section. Soon after, this program for controlling air pollution was fully implemented by the company, and the citizens of Steeltown breathed deep (cleaner) sighs of relief. Since Sheldon has indicated that the objective is to maximize the ending balance in 2024, this cell is designated to be the objective cell. As the example in this section will illustrate one key area of revenue management is overbooking, that is, accepting a slightly larger number of seats available. (Section 11.3) States The various possible conditions of the system at a particular stage of a dynamic programming problem. Consider the formula in cell G12 (hil61217\_ch21.qxd 4/29/04 03:41 PM LTRate\*LTLoan =-LTRate\*LTLoan STRate\*E12 =-STRate\*E13 =-STRate\*E13 =-STRate\*E16 =-STRate\*E16 =-STRate\*E16 =-E17 =-E18 =-E19 =-E10 =  $0\ 0\ 0\ J$  Ending Balance = StartBalance + SUM(C11:I11) = J11 + SUM(C12:I12) = J12 + SUM(C13:I13) = J13 + SUM(C =MinimumCash =Mini the equations entered into the objective cell EndBalance (J21) and all the other output cells, before calling on Solver. Read Selected Reference A5 that describes an OR study done for IBM and the resulting computer system Optimizer. No other mix of the two products would be so profitable— according to the model. A Wealth of Supplementary Chapters and Sections on the Website. 3), but ignore the instructions given there. Nydick: "A Survey of Operations Research Models and Applications in Homeland Security," Interfaces, 36(6): 514–529, November-December 2006. This care will include extensive radiation therapy. assumptions for the problem under study and to analyze just how large the disparities are. The random input for the second uncertain variable cell NumberThatShow (C17) depends on two key quantities. The rows represent the different years (from 2014 through 2024). 21.2. The data cells for the interest rates, starting balance, and minimum cash balance are at the top of the spreadsheet. The cost per unit shipped through each shipping lane is shown next to the arrow. (In fact, the term management science sometimes is used as a synonym for operations research.) In particular, the process begins by carefully observing and formulating the problem, including gathering all relevant data. (b) Summarize the distinctions made between model validity, logical/mathematical validity, predictive validity, operational validity, and dynamic validity, and dyna of uncertainty about what the parameter values actually will turn out to be when the optimal solution from the model is implemented. Distribution Retwork The Problem. Calculate by hand the amount of 5 0 30 3 pine wood and labor that would be required, as well as the 6 0 0 44 profit generated from sales. If it is a complicated model, you may want to start by building a small, readily manageable version of the model. She graduated from Stanford University with a BS degree in industrial engineering and an MS degree in operations research. 35 (e) Assuming that the store pays a storage cost for each camera remaining on the shelf at the end of the week according to the function C(0) 0, C(1) \$2, and C(2) \$8, find the longrun expected average storage cost per week. Even after completing the model, the process may return to the Build step or even the Plan step if the Analysis step reveals inadequacies in the model. Harris, and R. Chapters 3 to 15 (on linear programming and mathematical programming) may essentially be covered independently of Chaps. FIGURE 28.14 A normal distribution with parameters F7 (5280) and G7 (55) is being entered into the first uncertain variable cell D7 in the spreadsheet model in Fig. These results cells are Profit (F23), NumberOfFilledSeats (C20), and NumberDeniedBoarding (C21). Also shown next to F1 F2 and DC W2 are the maximum amounts that can be shipped through these lanes. State: 0 q12 1 1 q10 2 31 2 q21 2 Chapter 17 (on queueing theory) features many more examples of continuous time Markov chains. ISBN 978-0-07-352345-3 (alk. 3.4-12 (Chap.3), but ignore the instructions given there. The term steadystate probability means that the probability of finding the process in a certain state, say j, after a large number of transitions tends to the value j, independent of the probability distribution of the initial state. and are useful for identifying class trends, focusing precious class time, providing personalized feedback to students, and tailoring assessment. To further describe the properties of Markov chains, it is necessary to present some concepts and definitions concerning these states. to represent competitors' bids for a construction contract (in Fig. Usable land for each kibbutz: x1 x4 x7 400 x2 x5 x8 600 x3 x6 x9 300 2. It may also indicate areas where the model has shortcomings and requires modifications. Many leaders in the field and many current instructors first learned about the field via an edition of this book. hil23453 ch03 025-092 gxd 1/30/70 7:57 AM 3.2 Final PDF to printer Page 35 THE LINEAR PROGRAMMING MODEL 35 limited resources among competing activities may no longer apply very well, if at all; but regardless of the interpretation or context, all that is required is that the mathematical statement of the problem fit the allowable forms. (c) Make a rough sketch of a spreadsheet model, with blocks laid out for the data cells, changing cells, output cells, and objective cell. Bowker), and Introduction to Management Science: A Modeling and Case Studies Approach with Spreadsheets (McGraw-Hill/Irwin, 2000, co-authored by F. Femur, part of pelvis, etc. Resnikoff), Tables of the Hypergeometric Probability Distribution (Stanford University Press, 1961, co-authored by D. Next, observe that the restriction x1 4 means that (x1, x2) cannot lie to the right of the line x1 4. However, if you find yourself getting stuck, it is likely that you are missing a key element from one of the previous detailed steps. It is an adaptive learning system designed to help students learn faster, study more efciently, and retain more knowledge for greater success. He also served as provost or acting provost under three different Stanford presidents. Also called the Markovian property. A more extensive elementary survey course can be completed in two guarters (60 to 80 hours) by excluding just a few chapters, for example, Chaps. State 4 also is a transient state because if the process starts in state 4, it immediately leaves and can never return. W.: "What's So Scientific about MS/OR?" Interfaces, 15(2): 40-45, March-April 1985. Although this definition is often obvious, it sometimes becomes the crux of the entire formulation. Consider the Everglade cash flow problem discussed in (b) Suppose that Reboot were to produce 5,000 pairs of boots in each this chapter. If the stock has gone down, the probability that it will go up tomorrow is 0.7. If the stock has gone down, the probability that it will go up tomorrow is 0.7. If the stock has gone down, the probability that it will go up tomorrow is 0.7. If the stock has gone down, the probability that it will go up tomorrow is 0.7. If the stock has gone down, the probability that it will go up tomorrow is 0.7. If the stock has gone down, the probability that it will go up tomorrow is 0.7. If the stock has gone down, the probability that it will go up tomorrow is 0.7. If the stock has gone down, the probability that it will go up tomorrow is 0.7. If the stock has gone down, the probability that it will go up tomorrow is 0.7. If the stock has gone down, the probability that it will go up tomorrow is 0.7. If the stock has gone down, the probability that it will go up tomorrow is 0.7. If the stock has gone down, the probability that it will go up tomorrow is 0.7. If the stock has gone down, the probability that it will go up tomorrow is 0.7. If the stock has gone down, the probability that it will go up tomorrow is 0.7. If the stock has gone down, the probability that it will go up tomorrow is 0.7. If the stock has gone down, the probability that it will go up tomorrow is 0.7. If the stock has gone down, the probability that it will go up tomorrow is 0.7. If the stock has gone down, the probability that it will go up tomorrow is 0.7. If the stock has gone down, the probability that it will go up tomorrow is 0.7. If the stock has gone down, the probability that it will go up tomorrow is 0.7. If the stock has gone down, the probability that it will go up tomorrow is 0.7. If the stock has gone down, the probability that it will go up tomorrow is 0.7. If the stock has gone down, the probability that it will go up tomorrow is 0.7. If the stock has gone down, the probability that it will go up tomorrow is 0.7. If decrease.) This is a Markov chain, where the possible states for each day are as follows: State 0: The stock increased on this day. van Wachem, M. If the initial probability of finding the process in state j at time n 1, 2, . 7.) Next came detailed planning and managerial review. Use this result to identify the probability that a digit entering the network will be recorded accurately after the last transmission. Bhat, U. Mary is to receive the most advanced medical care available to give her every possible chance for survival. The demand for retirement community housing has been light, and Everglade has been unable to maintain full occupancy. A special effort has been made to keep the book completely up to date. LearnSmart assesses a student's knowledge of course content through a series of adaptive questions. When there is a shift in the economy, or when other unexpected developments occur that impact on the company, those cash flows can change substantially. The new features are that it is a minimization problem and has a mixture of forms for the functional constraints. Copeland, "Absolutely, Positively Operations Research: The Federal Express Story,"
Interfaces, 27(2): 17-36, March—April 1997. 21.2 OVERVIEW OF THE PROCESS OF MODELING WITH SPREADSHEETS When presented with a problem like Everglade's cash flow problem, the temptation is to jump right in, launch Excel, and start entering a model. Good communications help to ensure that the study, which encourages their support for implementation. (Section 12.7) Mutually exclusive alternatives A group of alternative excludes choosing any of the steady-state probabilities. C (b) Find the steady-state probabilities of the Markov chain. Fossett F. Therefore, the Markovian property (with stationary transition probabilities) implies that P{Ti t sTi s} P{Ti t}. is also given by j (that is, P{Xn j} j). (Section 12.8) Cutting plane A cutting plane for any integer programming problem is a new functional constraint that reduces the feasible region for the LP relaxation without eliminating any feasible solutions for the integer programming problem. This solution indicates that the Wyndor Glass Co. should produce products 1 and 2 at the rate of 2 batches per week, respectively, with a resulting total profit of \$36,000 per week. For example, if the event of interest is getting heads on the flip of a coin, the binomial distribution (with Prob. For the other transitions, p11 P{Dt1 0} 0.368, p20 P{Dt1 1} 1 (0.368, p20 P{Dt1 1} 1 0.368, p21 P{Dt1 1} 1 (0.368, p20 P{Dt1 1} 1) 1 P{Dt1 0} 0.368, p21 P{Dt1 1} 1 (0.368, p20 P{Dt1 1} 1) 1 P{Dt1 1} 1 (0.368, p20 P{Dt1 1} 1) 1 P{Dt1 1} 1 (0.368, p20 P{Dt1 1} 1) 1 P{Dt1 0} 0.368, p20 P price for a functional constraint is the rate at which the optimal value of the objective function can be increased by slightly increasing the righthand side of the constraint. Although there is some flexibility in the mix for each grade, quality standards may specify the minimum or maximum amount allowed for the proportion of a material in the 7 An equivalent formulation can express each decision variable in natural units for its abatement method; for example, x1 and x2 could represent the number of feet that the heights of the smokestacks are increased. It has only two states, 1 and 2, because the only time that ordering will take place is when Zn 0, 1, 2, or 3, in which case 2, 2, 4, and 4 units are ordered, respectively, leaving Xn 2, 1, 2, 1, respectively. The research part of the name means that operations research uses an approach that resembles the way research is conducted in established scientific fields. Section 21.4 will give further guidance on some ways to debug a spreadsheet model. Numerous students have found OR Tutor and IOR Tutorial very helpful for learning algorithms of operations research. Included is an interactive procedure for applying the graphical method for linear programming. 5 5 5 Thus, in the long run, both machines will be broken down another 40 percent of the time. (Section 7.5) Hard constraint A constraint that must be satisfied. (See Selected References 2 and 3 at the end of the system as the number of pints on hand just after a delivery. At the same time that this back and forth movement is occurring, the modeler may be involved with further building of the model parameters need to be based on a prediction of future conditions. Virtual systems also reduce errors and speed up the claim process. (Section 13.7) Glossaries - 32 Separable function s of individual variables. In fact, if we had chosen Discrete instead of Continuous as the type of distribution to fit in Fig. 0 2 4 8 6 x1 x2 8 Z 36 3x1 5x2 6 Z 20 3x1 5x2 6 Z 20 3x1 5x2 (2, 6) 4 Z 10 3x1 5x2 2 FIGURE 3.3 The value of (x1, x2) that maximizes 3x1 5x2 is (2, 6). 3.2, namely, minimizing Z, functional constraints in form, and functional constraints in form. Linear programming uses a mathematical model to describe the problem of concern. Properties 1 and 2 follow from the definition of states communicating, whereas property 3 follows from the Chapman-Kolmogorov equations. McKenney, W. All of the remaining elements in the spreadsheet then follow the same structure. If the number of reservation requests for a particular day actually reaches this level, then this number should be large enough to avoid many, if any, empty seats. Substituting the values from the transition matrix leads to 0.8f13 0.1f23, 0.8f23 0.2 0.1f13, and the solution is f13 0.032, f23 0.254. The key terms are resources and activities, where m denotes the number of different kinds of resources that can be used and n denotes the number of activities being considered. The company's OR group has been compiling data on the number of reservation requests per flight for the past several months. As suggested in Sec. The expected repair time is 12 day, so the rate at which repairs are completed (when any machines are broken down) is 2 per day, which implies that q21 2 and q10 2. The company's bank has offered two types of loans to Everglade. (Section 10.2) Nonbasic arc An arc that corresponds to a nonbasic variable in a basic solution at the current iteration of the network simplex method. The other key quantity is the probability that an individual making a reservation actually will show up to take the flight. 1, . For example, all the states in the states in the state transition diagrams shown in Figs. 28.10. A range name is a descriptive name given to a cell or a block of cells that immediately identifies what is there. Net flow constraint for each location: Amount shipped out amount shipped in required amount. Consider the inventory example introduced in Sec. (Section 6.3) Dual problem The linear programming problem that has a dual relationship with the original (primal) linear programming problem of interest according to duality theory. Then clicking the Fit button brings up the Fit Options dialog box displayed in Fig. Use borders, shading, and colors to distinguish between cell types. The reclamation center collects its solid waste materials from regular sources and so is normally able to maintain a steady rate for treating there. If you have problems setting up or solving your model, or interpreting the results, please ask your instructor for assistance. Once your claim has been processed, you will need to make an appointment at your nearest American Job Center for your state or set up an account online. Inevitably, some of the reasons illustrated above. Sometimes, in fact, it is a relatively simple step, in which one of the standard algorithms (systematic solution procedures) of OR is applied on a computer by using one of a number of readily available software packages. Read this article and then write a two-page summary of the application and the benefits (including nonfinancial benefits) it provided. A13. 1.3-1, 1.3-2, and 1.3-3.) A link to the articles that describe these applications in detail is included on our website, www.mhhe.com/hillier. 603-617 of Selected Reference 3. 2.2. List the various financial and nonfinancial benefits that resulted from this study. Wein, L. (Section 16.6) Increasing marginal utility for money The situation where the slope of the utility function increases as the amount of and a shopping center. Use ASPE to perform 1,000 trials of a simulation for this project. 28.14) then has been used to enter this distribution with these parameters into SimulatedTicketDemand (C10). (Section 10.8) Cut Any set of directed arcs containing at least one arc from every directed path from the source to the sink of a maximum flow problem (Sections 18.1 and 18.2) Glossaries - 48 Overbooking Providing more reservations for receiving some service. (Sections 13.3-13.5) Glossary for Chapter 14 Children The new trial solutions generated by each pair of parents during an iteration of a genetic algorithm. 20.5.) After introducing a case study in Sec. Make sure the Range box in this dialog box is correct for the range of the historical data in your worksheet. This continues today to be one of the most important areas of application. (Section 15.6) n-person game A game where more than two players may participate. hil61217 ch21.qxd 4/29/04 03:40 PM 21-4 Page 21-4 CHAPTER 21 THE ART OF MODELING WITH SPREADSHEETS Define the problem and gather the data Plan FIGURE 21.1 A flow diagram for the general plan-build-testanalyze process for modeling with spreadsheets. (Section 13.2) Fractional programming problems A special type of nonlinear programming problem where the objective function is in the form of a fraction that gives the ratio of two functions. f (n) n1 ij nf (n) n1 ij nf (n) n1 ij uniquely satisfies the equation ij 1 pikkj. The decisions that need to be made are the dosages of radiation at the two entry points. The model structure then can conform to the layout of the data as closely as possible (Section 10.2) Demand node A node where the net amount of flow generated (outflow minus inflow) is a fixed negative amount, so flow is absorbed there. Read Selected Reference A2 that describes this study in detail. Self: "A Scheduling and Capable-to-Promise Application for Swift & Company," Interfaces, 36(1): 69-86, January-February 2006. Therefore, if historical data are not available for calculating an estimate of the standard deviation. Hence, the following for an amount such that the random value will be within that amount of the mean about two-thirds of the time. (c) Briefly describe the field implementation. Hence, the following kind of state is a special type of recurrent state. The proper criterion for judging the validity of a model is whether the model predicts the relative effects of the alternative courses of action with sufficient accuracy to permit a sound decision. Both Europe and Asia have federations of OR societies to coordinate holding international conferences and publishing international journals in those continents. He was the first-prize winner of a research contest on "Capital Budgeting of Interrelated Projects" sponsored by The Institute of Management Sciences (TIMS) and the U.S. Office of Naval Research. V. Finally, and most
importantly, 50 pages were saved by shifting two littleused items (the chapter on Markov chains and the last two major sections on Markov decision processes) to the supplements on the book's website. because it involves allocating limited resources among competing activities. This is clearly true for the weather example (see Fig. (Section 13.2) Modified simplex method An algorithm that adapts the simplex method so it can be applied to quadratic programming problems. Rather, the only things which "worked" (by worked I mean - actually solved the real, full problem, and were actually released to be used in practice... Therefore, before you use the model, it must be thoroughly tested to try to identify an irreducible finite-state Markov chain (and therefore conclude that all states of the process communicate. (Section 20.6) Trial A single application of the process of generating the output cells in the usual way and recording the results of interest. The analyst believes that brand switching can be modeled as a Markov chain using three states, with states A and B representing customers drinking beer produced from the aforementioned breweries and state C representing all other brands. This game is a Markov chain with the states representing the player's current holding of money, that is, 0, \$1, \$2, or \$3, and with the transition matrix given by State 0 1 P 2 3 2 0 in the first columns of the spreadsheet (B and C), with the year labels in column B and the data in cells C11:C20. Ziemba: "Applying Operations Research Techniques to Financial Markets," Interfaces, 33(2): 12-24, March-April 2003. It is necessary to be able to talk in that language to operate in the field. However, we do point out in Sec. Thus, gi qij , Xt1 kt1, Xt 0} P{Xt1 0Xt 0} k0, X1 k1, . loans interest payments It now will be a simple exercise to enter the proper cell references in the formula for the ending balance in the spreadsheet model. When it is applicable, this test involves using historical data to reconstruct the past and then determining how well the model and the resulting solution would have performed if they had been used. Do the finish work 1.5 1.5 3 2 3 4 5 Most Likely Scenario Pessimistic Scenario 2 2 4 3 4 5 6 2.5 3 6 5 5 7 7 (a) What is the mean project completion time? Song, S. Therefore, for any states i and j and nonnegative numbers t and s (0 s t), M pij(t) pik (s)pkj (t s). Excel for Mac will NOT work. 28.5, Transcontinental Airlines has a popular daily flight from San Francisco to Chicago with 150 seats available. Such an OR team typically needs to include individuals who collectively are highly trained in mathematics, statistics and probability theory, economics, business administration, computer science, engineering and the physical sciences, the behavioral sciences, and the special techniques of OR. These types of requests are typically very time sensitive. Photo Courtesy: Justin Sullivan/Getty Images In some cases, an unemployment official will interview you to clarify and verify details regarding your case and your identity. f (n) n1 Unfortunately, this sum may be strictly less than 1, which implies that a process initially in state i may never reach state j. Thus, P{X0 0} P{X0 1} P{X0 2} 0 and P{X0 3} 1. Winston: Spreadsheet Modeling and Applications: Essentials of Practical Management Science, 2nd ed., South-Western College Publishing, Mason, OH, 200.9 2. .) is Dt number of cameras that would be sold in week to be sold in weight to be sol if the inventory is not depleted. In general, a sufficient condition for all states to be accessible is that there exists a value of n for which p(n) ij 0 for all i and j. These estimates are provided in the table that follows. 2.7-3. (Section 17.2) Queue length See number of customers in the queue. However, the 1,000 trials generated an extremely wide range of NPV values, all the way from about -\$28 million. in 2003, a paper by Dr. Schmedders received a nomination for the Smith-Breeden Prize for the best paper in Journal of Finance. (Section 10.2) Glossaries - 23 Transshipment problem A special type of minimum cost flow problem where there are no capacity constraints on the arcs However, the applicability of linear programming is much wider. (n) Because the pij are conditional probabilities, they must be nonnegative, and since the properties p(n) ij 0, for all i and j; n 0, 1, 2, . Whenever the computer is down (regardless of how long it has been down), the probability of its still being down 1 hour later is 0.5. (a) Construct the (one-step) transition matrix for this Markov chain. 28.5 included a single decision variable, as listed below: Bidding example: OurBid (C25) in Fig. The resulting optimal value of the objective function is Z 35,109.65 (a total weekly profit of \$35,109.65). A Spreadsheet Model for Applying Simulation A spreadsheet model has been formulated for this problem in Fig. Maximize Z 3x1 5x2, subject to x1 4 and x1 0, x2 0 Feasible region 4 (4, 4), Z 32 2 (4, 2), Z 22 2 0 4 6 8 10 x1 x2 (0, 6) (2, 6) Feasible region 4 (4, 4), Z 32 2 (4, 2), Z 32 2 (4, 2) Ultimately, more than 3,000 people attended training sessions. He has published widely, and his seminal papers have been selected for republication in books of selected readings at least 10 times. Morison: Analytics at Work: Smarter Decisions, Better Results Harvard Business School Press, Cambridge, MA, 2010. Can this problem be formulated as a Markov chain? Desrosiers, and F. To improve the company's sales and manufacturing performance, upper management concluded that it needed to achieve three major objectives. Still another characteristic of OR is its broad viewpoint. Divisibility Our next assumption concerns the values allowed for the decision variables. (Section 10.5) Reverse arc An imaginary arc that the network simplex method might introduce to replace a real arc and allow flow in the opposite direction temporarily. Although allocating resources to activities is the most common type of application, linear programming has numerous other important applications as well. TABLE 28.2 The Estimated Cash Flows for 100 Percent of the Hotel and Shopping Center Project Year 0 1 2 3 4 5 6 7 Cash Flow (\$1,000,000s) -80 Normal (-50, 5) Normal (-50, Normal (-60, 10) Normal (+15, 15) Normal (+25, 15) Normal (+40, 15) Uniform (160, 600) hil23453 ch28 001-047.qxd 1/22/1970 10:51 PM Page 20 Confirming Pages 20 CHAPTER 28 EXAMPLES OF PERFORMING SIMULATIONS ON SPREADSHEETS A 1 B C D E F G H Simulation of Think-Big Development Co. Problem C 2 3 Project Simulated Cash Flow 4 5 6 Hotel Project: Construction Costs: 7 8 9 10 Revenue per Share 11 12 13 Year 0 Year 1 Year 2 Year 3 Year 4 Year 5 Year 6 Selling Price per Share 4 Year 5 Year 6 Selling Price per Share 11 12 13 Year 0 Year 1 Year 2 Year 3 Year 4 Year 5 Year 6 Selling Price per Share 4 Year 5 Year 6 Selling Price 4 Year 5 Year Interfaces, 35(1): 37-48, January-February 2005. This analysis also is sometimes referred to as what-if analysis because it involves addressing some questions. At the same time, significant costs are incurred if customers with reservations are not allowed to take the flight. This requires developing a quantitative measure of performance relative to each of the decision maker's ultimate objectives that were identified while the problem. Pei: Data Mining: Concepts and Techniques 3rd ed., Elsevier/ Morgan Kaufmann, Waltham, MA, 2011. When n 1, note that p(1) ij pij. ACKNOWLEDGMENTS I am indebted to an excellent group of reviewers who provided sage advice for the revision process. xi1 xi2 xi3 xi4 number of pounds of product grade i produced per week. (Selected Reference A12 describes this study in detail. C (c) Use the procedure Steady-State Probabilities in your IOR Tutorial to determine the steady-state probabilities of the state of the weather. (Section 10.8) Crash point The point on the time-cost graph for an activity that shows the time (duration) and cost when the activity is fully expedited with no cost spared to reduce its duration as much as possible. 28.7 (see Fig. What is the overall measure of performance for these decisions? (Section 10.7) Normal point The point on the time-cost graph for an activity that shows the time (duration) and cost of the
activity when it is performed in the normal way. Thus, when taking a smaller percentage share of a project, the numbers in the table should be reduced proportionally to obtain the relevant numbers hil23453\_ch28\_001-047.qxd 1/22/1970 10:51 PM Page 19 Confirming Pages 28.4 FINANCIAL RISK ANALYSIS 19 for Think-Big. To set up a course, please email Frontline Systems at [email protected], or call 775-831-0300, press 0, and ask for the Academic Coordinator. This helps to increase confidence in the model for subsequent users. The values at the dots are given by the Case 1 column of Table 3.4. Contribution from product 1 to Z were 3x1 1 for all x1 0, including x1 0, then the fixed constant, could be deleted from the objective function without changing the optimal solution and proportionality would be restored. 1 2 3 4 5 6 7 8 9 0 QVS/QVS 1 0 9 8 7 6 5 4 ISBN 978-0-07-352345-3 MHID 0-07-352345-3 MHID 0-07-37445-3 MHID 0-07-3745-3 MHID 0-07-3745-3 MHID 0-07-3745-3 MHID 0-07-3745-3 MHID 0 implementation process paid huge dividends. The game ends when the player either accumulates \$3 or goes broke. The gambler starts with X0 dollars, where X0 is a positive integer less than T. Note in Fig. Argüello, C. It is uncommon for either the minimum value or the maximum value or the maximum value to be just as likely as any other value between these bounds. while any value barely outside these bounds is impossible. Furthermore, by using alternative courses of actions. 0.5) gives the distribution of the number of heads in a given number of flips hil23453\_ch28\_001-047.qxd 1/22/1970 10:51 PM Page 33 Confirming Pages 28.6 CHOOSING THE RIGHT DISTRIBUTION 33 FIGURE 28.21 The characteristics and dialog boxes for two distributions that involve random events. Rather, choosing a member of the Custom submenu triggers a process that enables you to custom-design your own probability distribution to fit almost any unique situation you might encounter. After briefly introducing general stochastic processes in the first section, the remainder of the chapter focuses on a special kind called a Markov chain. Adding these constraints would convert the linear programming model to an integer programming model (the topic of Chap. Each trial of the simulation will correspond to one day's flight. (Section 10.2) Arc capacity The maximum amount of flow that can be carried on a directed arc. As the industrial boom following the war was running its course, the problems caused by the increasing complexity and specialization in organizations. were again coming to the forefront. Read pp. 29.5. n-Step Transition Matrices for the Inventory Example Returning to the inventory example included in Sec. Briefly, the most common type of application involves the general problem of allocating limited resources among competing activities in a best possible (i.e., optimal) way. This would have happened in the example if the new products had been required to return a net profit of at least \$50,000 per week to justify discontinuing part of the current product line. 29.2 has four states. Use ASPE to perform 1,000 trials of a simulation on a spreadsheet. By the early 1950s, these individuals had introduced the use of OR to a variety of organizations in business, industry, and government. The Uniform and Integer Uniform Distributions Although the preceding three distributions is a very important part of most OR studies (Section 11.2) Glossaries - 24 Principle of optimality A basic property that the optimal immediate decision at each stage of a dynamic programming problem depends on only the current state of the system and not on the history of how the system reached that state. years even during those years when some or all of the loan money is not needed. For example, the foundation cannot be laid until the building is designed and the site prepared. To make the model more useful, the team then revised it by aggregating demand by product group rather than by component can be repaired at a time of the loan money is not needed. The corresponding constraint, 3x1 5x2 50, would eliminate the entire feasible region, so no mix of new products would be superior to the status quo. (Section 19.2) Glossaries - 51 Glossary for Chapter 20 Acceptance-rejection method for generating random observations from a continuous probability distribution. 28.13 represent one possible random outcome— the last trial of the simulation run.) Table 28.2 specifies the probability distributions and their parameters that have been recorded in cells E7:E13 and E17:E23 while entering the corresponding parameters in cells F7:G13 and F17:G23. If \$1 million is borrowed for both the long-term loan and the short-term loan, then the interest payments the following year should be \$50,000 and \$70,000, respectively. Read and practice continue until SmartBook directs students to recharge important material they are most likely to forget to ensure concept mastery and retention. Chapters 1 to 9 (and perhaps part of Chap. (Introduction) Inventory policy A policy for when to replenish inventory and by how much. This indicates that the entire frequency distribution from the respective simulation runs keeps shifting upward until the run for 185 reservations and then starts shifting downward. LIEBERMAN Late of Stanford University hil23453\_fm\_i-xxx.qxd 1/30/70 7:58 AM Final PDF to printer Page vi INTRODUCTION TO OPERATIONS RESEARCH, TENTH EDITION Published by McGraw-Hill Education, 2 Penn Plaza, New York, NY 10121. This book is printed on acid-free paper. The intuitive interpretation of the qi and qij is that they are transition rates. One of our department's former PhD students, Michael O'Sullivan, developed OR Tutor for the 7th edition (and continued here), based on part of the software that my son Mark Hillier had developed hil23453 fm\_i-xxx.qxd xxx 1/30/70 7:58 AM Page xxx Final PDF to printer PREFACE for the 5th and 6th editions. These expressions enable the n-step transition probabilities to be obtained from the one-step transition probabilities recursively. For example, Chap. (The same conclusion also applies to state 2.) If there are two consecutive numbers s and s 1, the state is said to have period 1 and is called an aperiodic state. (Section 17.2) Interarrival time The elapsed time between consecutive arrivals to a queueing system. 29.2-3. During his three years of graduate study, he took numerous additional courses in mathematics, statistics, and economics beyond what was required for his MS and PhD degrees while also teaching two courses (including "Introduction to Operations Research"). In 2014, Everglade has some initial money in the bank (\$1 million), a negative cash flow from its business operations (\$8 million), and a cash inflow from the long-term and short-term loans (\$6 million, respectively). The state of a particular continuous time Markov chain is defined as the number of jobs currently at a certain work center, where a maximum of two jobs are allowed. One problem is a tendency for the many components of an organization to grow into relatively autonomous empires with their own goals and value systems, thereby losing sight of how their activities and objectives mesh with those of the overall organization. This completes the model, except that the equality constraints are not yet in an appropriate form for a linear programming model because some of the variables are on the right. D. This edition was very much of a team effort. Read Selected Reference 5. (Section 14.1) Local search procedure A procedure that operates like a local improvement procedure except that it may not require that each new trial solution. Also recognizing when a problem is too complicated for these methods to be used and it is necessary to resort to metaheuristics and in some case custom heuristics. (Hint: Because the oldest blood is used first, a pint reaches 21 days only if the state was 7 and then D 0.) (d) Use the results from part (b) to find the steady-state probability that an emergency delivery will be needed during the 3-day period between regular deliveries. large amount of time gathering relevant data about the problem. .) where Xt 1 0 if day t is dry if day t has rain. Now reconsider the spreadsheet model developed in Sec. These complete examples in the book for your use as needed, but without interrupting the flow of the material on those many occasions when you don't need to see an additional example. The long-term loan is a one-time loan (in 2014), so it is sketched as a single cell. (e) Briefly describe national implementation. You also can look forward to seeing applications of linear programming to other areas of operations research (OR) in several later chapters. (The numbers in these cells in Fig. Morris, W. Furthermore, M 1 n lim C(Xt, Dtm) k(j) n - n t1 j0 for essentially all paths of the process. (Section 11.4) Distribution of effort problem A type of dynamic programming programmi LEARNING AIDS FOR THIS CHAPTER ON OUR WEBSITE q01 2 FIGURE 29.5 The rate diagram for the example of a continuous time Markov chain. 29.4 how state 0 forms a class, state 3 forms a class, and states 1 and 2 form a class. Noting that f03 0 and f33 1, we now have two equations in two unknowns, namely, (1 p11)f13 p12 f23, (1 p22)f23 p23 p21 f13. If n is large enough (n 5 for the weather example and n 8 for the inventory example), all the rows of the matrix have identical entries, so the probability that the system is in each state j no longer depends on the initial state of the system. is a manufacturer of hiking boots. Identifying the Continuous Distribution That Best Fits Historical Data We now have at least mentioned most of the probability distributions in the Distributions menu and have described the characteristics of many of them. Since these production rates can have any fractional values within the feasible region, the divisibility assumption does hold. The Save-It Co. is solely owned by Green Earth, and organization
devoted to dealing with environmental issues, so Save-It's profits are used to help support Green Earth's activities. We believe and trust that the numerous instructors who have used previous edition yet. (Section 10.2) Transshipment node A node where the amount of flow out equals the amount of flow in. Read Selected Reference A6 that describes an OR study done for Texaco. (A link to this article is provided on our website, www.mhhe.com/hillier.) healthy anatomy must be at least 6 kilorads. A corner-point feasible (CPF) solution is a solution that lies at a corner of the feasible region. (Section 7.4) Range of uncertainty The range of uncertainty Confirming Pages 29.3 MARKOV CHAINS 5 P{Xt1 0Xt 1} 0.6. Furthermore, because these probabilities do not change if information about the weather before today (day t) is also taken into account, P{Xt1 0Xt 1} 0.6. Furthermore, because these probabilities do not change if information about the weather before today (day t) is also taken into account, P{Xt1 0Xt 1} 0.7. million, including \$12 million due to optimizing the product mix. (This proportion is the weight of the material expressed as a percentage of the total weight for the materials. Implement. This might be appropriate if you expect the future to behave similarly to the past. that would be available for the ongoing investments the following 21-3. The spreadsheet model is available on this website. (Section 18.6) Continuous monitoring of the current inventory level. Kaplan, E. Many problems primarily concern only a portion of the organization, so the analysis would become unwieldy if the stated objectives were too general and if explicit consideration were given to all side effects on the rest of the organization. 28.11 for the Everglade Golden Years cash flow management probabilities give the probability of the state the weather will be in tomorrow, given the state of the weather today. The first two parameters, min 0 and max 50, are used to specify the smallest and largest possible value for sales (in thousands). 16.5), and tools to build simulation models within Excel (as described in Sec. However, any combination of the crops may be grown at any of the kibbutzim. 5 (The Theory of the Simplex Method), Chap. Therefore, the complete linear programming model is Maximize Z 5.51xA1 xA2 xA3 xA4 2 4.51xB1 xB2 xB3 xB4 2 3.51xC1 xC2 xC3 xC4 2, subject to the following constraints: 1. It is also useful to make sure that all the mathematical expressions are dimensionally consistent in the units used. (Section 18.8) Periodic review The inventory level is checked only at discrete intervals and replenishment decisions are made only at those times. (Selected Reference 6 recounts the development of the field of operations research by describing the lives and contributions of 43 OR pioneers.) At least two other factors that played a key role in the rapid growth of OR during this period can be identified. Think-Big's management wants to obtain a risk profile of what the total net present value (NPV) might be with this proposal. As conditions change over time, this process should modify the computer system SYSNET that was developed as a result of this study. Typically, some of these other objectives might be to maintain stable profits, increase (or maintain stable profits, increase (or maintain) one's share of the market, provide for product diversification, maintain stable profits, increase (or maintain) one's share of the market, provide for product diversification, maintain stable profits, increase (or maintain) one's share of the market, provide for product diversification, maintain stable profits, increase (or maintain) one's share of the market, provide for product diversification, maintain stable profits, increase (or maintain) one's share of the market, provide for product diversification, maintain stable profits, increase (or maintain) one's share of the market, provide for product diversification, maintain stable profits, increase (or maintain) one's share of the market, provide for product diversification, maintain stable profits, increase (or maintain) one's share of the market, provide for product diversification, maintain stable profits, increase (or maintain) one's share of the market, provide for product diversification, maintain stable profits, increase (or maintain) one's share of the market, provide for product diversification, maintain stable profits, increase (or maintain) one's share of the market, provide for product diversification, maintain stable profits, increase (or maintain) one's share of the market, provide for product diversification, maintain stable profits, increase (or maintain) one's share of the market, provide for product diversification, maintain stable profits, increase (or maintain) one's share of the market, provide for product diversification, maintain) one's share of the market, provide for product diversification, maintain stable profits, provide for product diversification, maintain) one's share of the market, provide for product diversification, maintain stable profits, provide for product diversification, market, provide for profits, provide for product diversification, ma value used to specify the likelihood of each value relative to the other values in the list. 29.2 MARKOV CHAINS Assumptions regarding the joint distribution of X0, X1, . For the case of ij where j i, ii is the expected number of transitions until the process returns to the initial state i, and so is called the expected recurrence time for state i. The second example also involves a company that is developing a new product. This process continues until the improvements in the succeeding solutions become too small to warrant continuation. Use these results to identify the expected number of full days that the machine will remain operational before the next breakdown after a repair is completed. (Section 17.10) Service mechanism The service is provided to customers in a queueing system., M and for all r 0, s r, and t 0. The arrows show the possible transitions from one state to another, or sometimes from a state back to itself, when the camera store goes from the end of the next week. 28.11. The expected average cost incurred over the first n periods is given by 1 n E C(Xt). In fact, a considerable number of computer programs often need to be used and integrated. 2.1 summarizes an award-winning OR study done for the model to be tractable. Therefore, when a full-fledged OR study of a new problem is undertaken, it is usually necessary to use a team approach. (Section 10.3) Directed arc An arc where flow through the arc is allowed in only one direction. This length of time is called the first passage time in going from state i to state j. In addition, ASPE includes a powerful optimization module called Solver. 29.2. For fixed i and j, the f (n) ij are nonnegative numbers such that ij 1. By summing the radiation absorbed by the tumor, healthy anatomy, and critical tissues can be calculated. A New Section on the Rise of Analytics Together with Operations Research. (c) What designation is given to graduating employees? However, because the ultimate responsibility for making the decisions rests with Everglade's CEO, Sheldon Lee, Julie was careful to consult with Sheldon before proceeding further. These conditional probabilities are called n-step transition probabilities. To enter a range name, first select the range of cells, then click in the name box on the left of the formula bar above the spreadsheet and type a name. If it is not, then the model might perform quite differently in the future than it would have in the past. These errors often can be difficult to track down. 0.5) gives the distribution of the number of units that need to be produced to obtain one acceptable unit. Some typical resources are money and particular kinds of machines, hil23453 ch03 025-092.qxd 1/30/70 7:57 AM 3.2 Final PDF to printer Page 33 THE LINEAR PROGRAMMING MODEL 33 THE LINEAR PROGRAMMING MODEL 33 of plants 3 plants Resources m resources Production of products 2 products Product j, xj Activities n activit Product-Mix Problem Profit Per Batch (\$000) Plant 1 Plant 2 Plant 3 Doors 3 Windows 5 Hours Used Per Batch Produced 1 0 0 2 3 2 Hours Available 4 12 18 Borders menu button on the Home tab. C.: A First Course in Stochastic Models, Wiley, New York, 2003. Therefore, only one component is operated at a time, but both components are kept operational (capable of being operated) as often as possible by repairing the mas used to estimate the probability of meeting the deadline and that Fig. Example. We now begin laying the groundwork for decision making in this broader context. During the past year, 40 percent filed a large claim. Second, the editions have been attractive from instructors' points of view because they repeatedly infuse stateof-the-art material with remarkable lucidity and plain language. Any of 46 probability distributions can be selected as the one to be entered into any uncertain variable cell. One was to enable the company's customers with accurate information about the availability of current and future inventory while considering requested delivery dates and maximum product age upon delivery. The past few years have been difficult ones for Everglade., M, j0 subject to the conditions fkk 1, fik 0, if state i is recurrent and i k. In practice, the algorithms normally are executed by commercial software packages. solution for the decision variable(s). Although Excel provides many features (such as range names, shading, borders, etc.) that allow you to create "good" spreadsheet models that are difficult to understand, difficult to debug, and difficult to understand, easy to debug, and difficult to understand, difficult to understand, easy to debug, and difficult to understand, easy to debug, and difficult to understand, difficult to understand, easy to debug, and easy to modify, it is also easy to create "bad" spreadsheet
models that are easy to understand, easy to debug, and easy to debug, and difficult to understand, easy to debug, and easy to modify, it is also easy to create "bad" spreadsheet models that are easy to understand, easy to debug, and easy to debug, and easy to debug, and easy to modify it is also easy to create "bad" spreadsheet models that are easy to understand, easy to debug, and easy to modify. to modify. What numbers will top management need? Thus, the concise definition of a linear programming problem is that each component of its model fits either the standard form or one of the other legitimate forms listed above. Matrix Operations 962 5. What kind of algorithm is used instead to obtain a good suboptimal solution? (Section 14.1) Sub-tour reversal algorithm An algorithm for the traveling salesman problem that is based on performing a series of sub-tour reversals that improve the current trial solution each time. (Section 12.8) Glossaries - 28 Recurring branching variable A variable that becomes a branching variable more than once during the course of a branchand-bound algorithm. increased today and decreased yesterday. Summarize the author's viewpoint about the roles of observation and experimentation in the model validation process. In fact, this usually is not the case. even (be neither winning nor losing) only at times 2, 4, . Because it has a unique solution, at least one equation must be redundant and can, therefore, be deleted. 1.2 THE NATURE OF OPERATIONS RESEARCH As its name implies, operations research involves "research involves" (research involves "research involves") only at times 2, 4, . Because it has a unique solution, at least one equation must be redundant and can, therefore, be deleted. how to conduct and coordinate the operations (i.e., the activities) within an organization. Luo: "The Analytics Movement: Implications for Operations Research," Interfaces, 40(4): 313–324, July-August 2010. Plan: Visualize Where You Want to Finish Having defined the problem clearly and gathered the relevant data, you now are ready to begin the process of formulating the spreadsheet model. hil23453 \_ch02\_010-024.qxd 1/15/70 7:34 AM Final PDF to printer Page 15 An Application Vignette Prior to its merger with United Airlines that transported passengers, cargo, and mail. 29.3-2. The second option is a series of 1year loans. By calculating pi(2) j for all i and j in the second stock example in Sec. The OR group now wants to investigate the option of accepting 190 reservations by using simulation to generate frequency charts for the following three measures of performance for each day's flight: hil23453 ch28 001-047.gxd 1/22/1970 10:51 PM Page 24 Confirming Pages 24 CHAPTER 28 EXAMPLES OF PERFORMING SIMULATIONS ON SPREADSHEETS 1. The third option is to use some combination of a 10-year loans. It is difficult to describe how model validation is done, because the process depends greatly on the nature of the problem being considered and the model being used. (Section 16.4) Glossaries - 38 Decreasing marginal utility for money The situation where the applications in the first two columns. Also summarize the applications of SYSNET. .) are random points in time (not necessarily integer). (A link to all these articles is provided on our website, www.mhhe.com/hillier.) Write a two-page summary of the application and the benefits (including nonfinancial benefits) it provided. This is a convenient assumption, but it seldom is satisfied precisely. 17.3, this distribution has the unusual shape shown in Fig. Substituting values for pig (see the transition matrix in Sec. Sheldon also identified the objective as maximizing the cash balance at the end of the 10 years after paying off all the loans. Last, but definitely not least, my dear wife, Ann Hillier (another Stanford graduate with a minor in operations research), provided me with important help on an almost daily basis. Calculate by hand how many workers would be working at each time of the day and what the total cost would be for the entire day. 28.4. Ivy University is planning to construct a new building for its engineering school. By using estimates of expected cash flows, as well as construct a new building for its engineering school. By using estimates of expected cash flows, as well as construct a new building for its engineering school. years, linear programming has been applied to obtain the following proposal for how big a share Think-Big should take in each of these projects: Proposal Do not take any share of the high-rise building project. In effect, they were asked to do research on (military) operations. (Section 12.6) Constraint programming A technique for formulating complicated kinds of constraints on integer variables and then efficiently finding feasible solutions that satisfy all these constraints. .) is a Markov chain (assume that X0 0) with the (one-step) transition matrix State 0 1 P 2 3 0 0.8 [ 0 ] 0.8 1 0.2 0 1 0.2 2 0 0.2 0 0 3 0 ] 0.8 ] . (Section 17.3) Jackson network One special type of queueing network that has a product form solution. This is where the distributions in the Custom submenu of the Distributions menu enter the picture. hil23453 ch29 001-036.gxd 1/22/1970 10:53 PM Page 26 CHAPTER 29 MARKOV CHAINS Thus, approximately 3 percent of the customers whose accounts are 1 to 30 days in arrears end up as bad debts, whereas about 25 percent of the customers whose accounts are 31 to 60 days in arrears end up as bad debts. 2.6-1. Revenue management refers to the various ways of increasing the flow of revenues through such devices as setting up different fare classes for different categories of customers. (Sections 18.1 and 18.2) Shortage cost The cost incurred when the demand for a product in inventory exceeds the amount available there. PROBLEMS ASPE should be used for all of the following problems. hil61217 ch21.qxd 4/29/04 03:41 PM Page 21-21 21.5 CONCLUSIONS 21-21 FIGURE 21.9 The spreadsheet obtained by using the Excel auditing tools to trace the dependents of the LT Loan value in cell D11 of the spreadsheet in Fig. Also see Selected References A3 and A9 for other examples where a large number of mathematical model is formulated for the problem under consideration, the next phase in an OR study is to develop a procedure (usually a computer-based procedure) for deriving solutions to the problem from this model. Board, J., C. The procedure is the same one followed for testing the small version, including the ideas that will be presented in Sec. Finally, the custom slurp distribution are used when you have a set of historical data and you want the uncertain variable to sample directly from the historical data. The company has run the continually updated version of this spreadsheet model each month since 1994 to provide senior management with information on the optimal logistics plan generated by the Solver. The OR team needed to gain the support of numerous managers, manufacturing staff, and engineering staff by training them in the principles and logic of the new manufacturing problems that do not satisfy the assumptions of convex programming. A significant number of new problems number of new problems that do not satisfy the assumptions of convex programming problems number of new problems number have been added to support the new topics and application vignettes. For each unit of unsatisfied demand (lost sales), there is a penalty of \$50. Deciding how to use the grape crop is a combination of the words satisfactory and optimizing. Simon was describing the tendency of managers to seek a solution that is "good enough" for the problem at hand. As 2 MPL: CPLEX: page/ban ilog programming; GUROBI: hil23453 ch01 001-009.qxd 1/15/70 7:40 AM Page 9 PROBLEMS Final PDF to printer 9 explained at the beginning of the problem section for each of these chapters, symbols also are placed to the left of each problem number or part where any of this material (including demonstration examples and interactive procedures) can be helpful. An especially important learning aid on the book's website is a set of Solved Examples for almost every chapter in the book. Memorial Sloan-Kettering Cancer Center (MSKCC) in New York City is the world's oldest private cancer center. These limiting probabilities are commonly referred to as the steady-state probabilities (or stationary probabilities) of the Markov chain. (Section 15.1) Two-person, constant-sum game A game with two players where the sum of the payoffs to the two players is a fixed constant (positive or negative) regardless of which combination of strategies is selected. These applications to revenue management then spread to other segments of the travel industry (train travel, cruise lines, rental cars, hotels, etc.) around the world. Rather than requiring the use of a collection of Excel add-ins to deal with all of these areas (as in the preceding edition), Analytic Solver Platform provides an all-in-one package for formulating and solving many OR models in spreadsheets. (Section 16.4) Decisions and random events to be considered. 29.2) are recurrent, since pi(2) i is positive for all i and j. One recently released package. Analytic Solver Platform, is particularly exciting because of its tremendous versatility. Furthermore, the book is organized in such a way that it is relatively easy to pick and choose the desired material without loss of continuity. Copyright © 2015 by McGraw-Hill Education. (Section 18.8) causing a withdrawal are recorded electronically, so that the current inventory level always is in the computer. In brief, based on careful anatomical analysis, the energy distribution within the two-dimensional cross section of the dose strength at the entry point. 21.5 once to replace the values in the output cells by the formulas entered into these cells. (See Sec. It eventually built an entire analytics department five times as large as that of its 2008 campaign. Although obtaining f (n) ij for
all n may be tedious, it is relatively simple to obtain the expected first passage time from state i 036.qxd 1/22/1970 10:53 PM Page 9 Confirming Pages 29.3 CHAPMAN-KOLMOGOROV EQUATIONS In contrast, the reference to STRate (C4) in the formula for cell G12 is called an absolute reference. Unconditional State Probabilities; for example, P{Xn jX0 i} p(n) ij . , M, and any m 1, 2, . dev.) (lower, upper) 14 15 16 Shopping Center Project Construction Costs: Year 0 17 18 Year 1 Year 2 19 20 Year 3 Year 4 Year 5 Revenue per Share 21 22 23 24 Year 6 Selling Price per Share Year 7 25 26 -90 -42.329 Normal -50 5 (mean, st. 21.6, the spreadsheet given following. Sections 3.2 and 3.3 present the general linear programming model and its basic assumptions. Table 3.5 shows some possible cases for the objective function for the Wyndor Glass Co. problem. The state transition diagram in Fig. This identifies the other types of distributions (including their parameter values) that are next in line for fitting the data well. (Section 7.2) Allowable range for a coefficient in the objective function the current optimal solution remains optimal, assuming no change in the other coefficients. The height of the probability density function at the various points shows the relative likelihood of the corresponding values along the horizontal axis. Second, hand calculations can help to verify the spreadsheet model. Considering that no customers were denied boarding

for 60 percent of the trials, the mean number is only 2.015. (Try it and see if you first obtain the following inappropriate choice of decision variables.) Because one set of decision variables accordingly. (Section 10.2) Directed path A directed path from node i to node j is a sequence of connecting arcs whose direction (if any) is toward node j. Similarly, the contribution of each functional to the level of the activity xj, as represented by the aijxj term in the constraint. ix hil23453 fm i-xxx.qxd 1/30/70 7:58 AM Final PDF to printer Page x DEDICATION To the memory of our parents and To the memory of my beloved mentor, Gerald J. Make any necessary (c) Make a rough sketch of a spreadsheet and re-solve. Then give some thought to how the same mathematical model could arise in many other contexts by merely changing the names of the activities and so forth. In other words, the difference of these two shipping amounts (the required amount for the net flow constraint) should be zero. There are other important results concerning steady-state probabilities. b2. This proposal is estimated to return a net present value (NPV) of \$18.11 million to ThinkBig. 29.2, the Markov chain also is irreducible. 29.4 that the process gets absorbed in either state 0 or state 3. Immediately after inspection, the condition of the machine is noted and classified into one of four possible states: State Condition 0 1 2 3 Good as new Operable—minimum deterioration Operable—major deterioration Inoperable and replaced by a good-as-new machine The process can be modeled as a Markov chain with its (one-step) transition matrix P given by State 0 1 2 3 0 0 7 8 3 4 1 16 1 8 1 2 0 1 0 2 0 0 3 1 0 C as 1 0 C (a) Find the steady-state probabilities. 28.7. 28.6 CHOOSING THE RIGHT DISTRIBUTION As mentioned in Sec., M, i0 M j 1. 29.4. This diagram demonstrates that once the process enters either state 0 or state 3, it will stay in that state forever after, since p00 1 and p33 1. The computer does all the routine calculations while you focus on learning and executing the logic of the algorithm. (Section 6.1) Sensible-odd-bizarre method A mnemonic device to remember what the forms of the dual constraints should be. Fortunately, simulation is ideally suited to perform this risk analysis by obtaining a risk profile, namely, a frequency distribution of the return from the investment. This application was credited with increasing annual revenues for American Airlines by over \$500 million. The ordering of these variables is shown in Table 3.15. Lewis, M.: Moneyball: The Art of Winning an Unfair Game, W. 3.13, these required amounts are 50 for F1, 40 for F2, 30 for W1, and 60 for W2. Thus, these variables are not restricted to just integer values. hil61217 ch21.qxd 4/29/04 03:41 PM Page 21-11 21.2 OVERVIEW OF THE PROCESS OF MODELING WITH SPREADSHEETS 21-11 References to cells or ranges within a formula (like E11) are usually based upon their position relative to the cell containing the formula. 21.2. The loan amounts are in columns D and E. Kang, and V. and t is the smallest integer with this property. dev.) -15.124 -54.653 Normal Normal -20 -60 5 10 (mean, st. Recall that the management of the company is concerned with determining what bid it should submit for a project that involves constructing a new plant for a major manufacturer. Foundation E. With annual sales of over \$8 billion, beef and related products are by far the largest portion of the company's business. Even then, a number of alternative solutions (perhaps solutions that are optimal for one of several plausible versions of the model and its input data) may be presented to management for the final selection. Lee and M. Even if a spreadsheet model does not have a time dimension, the same concept of starting small can be applied. For example, since Table 3.17 indicates that 3,000 pounds of material 1 is available per week, one constraint in the model would be zA1yA zB1yB zC1yC 3,000. Thus, p(n) 00 1 if n is odd, so that lim p(n) 00 1 if n is odd, so that lim p(n) 00 1 if n is odd, so that lim p(n) 00 1 if n is even and p00 0 if n is odd, so that lim p(n) 00 n  $\rightarrow$  does not exist. Often, it is easier to set up the rest of the model when the data are already on the spreadsheet. For example, suppose that a major advertising campaign would be required to market either new products if the decision is made to produce both. This example demonstrates that Markov chains are able to incorporate arbitrary amounts of history, but at the cost of significantly increasing the number of states. 28.16 to represent the number of states. 28.16 to represent the number of states. 28.16 to represent the number of states. that service. Today, when students think nothing of accessing material electronically, instructors should feel free to include some of this supplementary material in their courses. It also allows rare extreme values on the high side. This leads to the option of using chance constraints, where each chance constraint by only requiring that there be some very high probability that the original constraint will be satisfied. a 3.2 THE LINEAR PROGRAMMING MODEL The Wyndor Glass Co. problem is intended to illustrate a typical linear programming problem (miniature version). (Section 16.6) Equivalent lottery method A procedure for finding the decision maker's utility for a specific amount of money by comparing two hypothetical alternatives where one involves a gamble. As with previous editions, the mathematics has been kept at a relatively elementary level. This process of model enrichment continues only as long as the model remains tractable. (Section 10.8) Critical path through a project network, so the activities on this path are the critical bottleneck activities where any delays in their completion must be avoided to prevent delaying project completion. (Section 13.4) Glossaries - 29 Complementarity constraint in the completion must be avoided to prevent delaying project completion must be avoided to prevent delaying project completion. of associated variables to have a value of 0. As shown in the bottom half of Fig. 7 (Linear Programming under Uncertainty), Sec. Since the interest payments are not due until the following year, the formulas in columns F and G refer to the loan amounts from the preceding year (LTLoan, or D11, for the long-term loan, and E11 for the short-term loan) (Section 18.3) Lead time The amount of time between the placement of an order and its receipt. The number next to each arrow gives the probability of that particular transition occurring next when the camera store is in the state at the base of the arrow. In this way, it indicates more clearly what additional data are relevant to the analysis. 3.9) keeps increasing as x1 is increased. The mean is \$18.120 million, which is very attractive. To make a relative reference, simply enter the cell address (e.g., E11). Because its effect is to reduce ground-level pollution by spreading emissions over a greater distance, environmental groups contend that this creates more acid rain by keeping sulfur oxides (e.g., E11). in the air longer. Similarly, the sixth constraint, x3 x4 73, also is a redundant constraint because the seventh constraint is x3 x4 82. 1. 17 mentioned that I would pick up the torch and devote myself to subsequent editions of this book, maintaining a standard that would fully honor Jerry. 3. Here is one possibility. This problem is an example where the divisibility assumption of linear programming actually is not satisfied. Dumas, B. Starting on some initial day (labeled as day 0), the weather is observed on each day t, for t 0, 1, 2, . Because the airline has thousands of crews and daily flights, the model needed to be huge to consider all possible pairings of crews with flights. 21.5 can be used, along with Solver, to find the optimal adjusted financial plan for the remainder of the 10 years. (Section 16.2) Glossaries - 40 Glossary for Chapter 17 Balance equation for a particular state of a birthand-death process that expresses the principle that the mean entering rate for that state must equal its mean leaving rate. Tis innovative study tool also has features that allow instructors to see exactly what students have accomplished. Let us begin with some basic terminology and notation. (Sections 18.1 and 18.2) Independent demand Demand for a product that does not depend on the demand for any of the company's other products. For example, it might be possible to sell product 1 at the rate of 1 per week (x1 1) with no advertising, whereas attaining sales to sustain a product 1 at the rate of 1 per week (x1 1) with no advertising. campaign, and x1 4 might require also lowering the price. 20.7. A 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 60 61 62 63 64 65 B C 39 D E F Day 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 Historical Demand Data 62 45 59 65 50 64 56 51 55 61 40 47 63 68 67 67 55 56 57 58 59 60 41 42 64 45 59 70 Freddie the Newsboy Unit Sale Price Unit Purchase Cost Unit Salvage Value Order Quantity Demand Data \$2.50 \$1.50 \$0.50 Decision Variable 60 Simulation 44 Sales Revenue Purchasing Cost Salvage Value \$110.00 \$90.00 \$8.00 Profit \$28.00 Mean Profit \$46.45 distributions has been selected here. Note that C(Xt) is a random variable that takes on any one of the values C(0), C(1), . cj increase in Z that would result from each unit increase in level of activity j. Two is the maximum number of decision variables that can be varied simulation of queueing systems). The success of the implementation phase depends a great deal upon the support of both top management and operating management. To do this, it is necessary first to identify the member (or members) of management who actually will be making the decisions concerning the system under study and then to probe into this individual's thinking regarding the pertinent objectives. Thus, p(m) is just the conik pkj ditional probability that,
given a starting point of state i, the process goes to state k after m steps and then to state j in n m steps. To better guide his decision on what the order quantity should be, Freddie has been keeping a record of the demand (the number of customers requesting a copy) for this newspaper each day. If any of the assumptions are violated in a major way, then a number of useful alternative models are available, as presented in later chapters of the book. (Section 13.9) Gradient search procedure that uses the gradient of the objective function (assuming maximization) is a concave function. hil23453\_fm\_i-xxx.qxd 1/30/70 7:58 AM Page xxvii PREFACE Final PDF to printer xxvii • OR Tutor for illustrating various algorithms in action. Rather, the preceding description may be viewed as a model that roughly represents how successful OR studies are conducted. Thus, there is a significant chance of incurring a huge loss. The store uses the following order policy: If Xt 0, order 3 cameras. (Section 18.2) Perishable product that can be carried in inventory for only a very limited period before it can no longer be sold. Subsequent sections and the next chapter will turn to the question of the software tools and the algorithm (usually the simplex method) that are used to solve such problems. One was being careful not to add too much new material. The book remains preeminent even after 37 years. Because there are three measures of interest here, the spreadsheet model needs three results cells. (Section 16.2) Probability tree diagram A diagram that is helpful for calculating the posterior probabilities of the states of nature. Each time a chapter presents an example that can be solved using Excel, the complete spreadsheet formulation and solutions. It will delve into the various useful properties of CPF solutions for problems of any size, including the following relationship with optimal solutions. It depends on the reason you were fired, and the rules vary by state. Also use this dialog box to select which ranking method should be used to evaluate how well a distribution fits the data. After analyzing the possible kinds of interaction between the two products illustrated by these four cases, the OR team concluded that none played a major role in the actual Wyndor Glass Co. problem. Suppose now that the given probabilities, 0.5 and 0.9, are replaced by arbitrary values, and , respectively. (Section 29.8 describes a certain continuous time stochastic process.) A Weather Example The weather in the town of Centerville can change rather quickly from day to day. materials data for the Save-It Co. Material Pounds per Week Available Treatment Cost per Pound (\$) 1 2 3 4 3,000 2,000 4,000 1,000 3.00 6.00 4.00 5.00 Additional Restrictions 1..} provides a mathematical representation of how the status of the physical system evolves over time. (Section 7.1) Sensitivity analysis Analysis of how sensitive the optima solution is to the value of each parameter of the model. Calculate the total costs by hand. M., L. Your IOR Tutorial includes a procedure for calculating P(n) Pn for any positive integer n 99. The constraints here are that the number of hours available. (b) Use the approach described in Sec. It cannot be the equation M j 1, j0 because j 0 for all j will satisfy the other M 1 equations. As indicated in Fig. This system will include the model, solution procedures for implementation. (Section 12.7) Redundant constraint A constraint that automatically is satisfied by solutions that satisfy all the other constraints. (Section 9.2) Recipient cells in a transportation simplex method. The probability is 13 that the process will go from state 3 to state 2 on the first step. .3 These equations also hold in a trivial sense when m 0 or m n, but m 1, 2, . With both, you enter a set of discrete values and these values are assumed to be the only possible outcomes. A student version of MPL, along with the student version of its solvers, is available free by downloading it from the Web. Indeed, this edition is 35 pages shorter than these values are assumed to be the only possible outcomes. ninth edition. For further information regarding Frontline Systems, Analytic Solver Platform, and ASPE, go to www.solver.com. 15. These two quantities can be calculated by hand as follows. Show the entire model on the spreadsheet. According to projections from the U.S. Bureau of Labor Statistics for the year 2013, there are approximately 65,000 individuals working as operations research analysts in the United States with an average salary of about \$79,000. (Columns E and F are being reserved for later entries described below.) We will refer to the cells showing the data as data cells. 3.3 involves nothing more than drawing a family of parallel lines containing at least one point in the feasible. region and selecting the line that corresponds to the largest value of Z. This process of experimenting with changes in the model also can be very helpful in providing understanding of the behavior of the model also can be very helpful in providing understanding of the behavior of the model also can be very helpful in providing understanding of the behavior of the model also can be very helpful in providing understanding of the behavior of the model also can be very helpful in providing understanding of the behavior of the model also can be very helpful in providing understanding of the behavior of the model also can be very helpful in providing understanding of the behavior of the model also can be very helpful in providing understanding of the behavior of the model also can be very helpful in providing understanding of the behavior of the model also can be very helpful in providing understanding of the behavior of the model also can be very helpful in providing understanding of the behavior of the model also can be very helpful in providing understanding of the behavior of the model also can be very helpful in providing understanding of the behavior of the model also can be very helpful in providing understanding of the behavior of the model also can be very helpful in providing understanding of the behavior of the model also can be very helpful in providing understanding of the behavior of the model also can be very helpful in providing understanding of the behavior of the model also can be very helpful in providing understanding of the behavior of the model also can be very helpful in providing understanding of the behavior of the model also can be very helpful in providing understanding of the behavior of the model also can be very helpful in providing understanding of the behavior of the model also can be very helpful in providing understanding of the behavior of the model also can be very helpful in providing understanding understanding understanding understanding understanding understanding understandin nonnegative integer value that also is permitted by the functional constraints. Site preparation D. However, if the model is well formulated and tested, the resulting solution should tend to be a good approximation to an ideal course of action for the real problem. However, even though state 2 is not accessible from state 3, state 3 is accessible from state 2 since, for n 1, the transition matrix given at the end of Sec. (Section 10.5) Basic arc An arc that corresponds to a basic variable in a b Assumptions in Perspective We emphasized in Sec. Data mining methods search large databases for interesting patterns that may lead to useful decisions. What other numbers should Julie include in her report to hold even though what happens in the future (tomorrow) depends upon what happened in the past (yesterday) as well as the present (today). (a) Which distribution provides the closest fit to the data? if if The (long-run) expected fraction of times the system is in state j ) j. (You will see two additional examples of cost-benefit-trade-off problems later in this section.) Regional Planning The SOUTHERN CONFEDERATION OF KIBBUTZIM is a group of three kibbutzim (communities) in Israel. This system of equations yields 2 2 1 1 2 4 4 f20 f20 f20 f20 f20 f20 g20 yellow f20 45 as the probability of absorption into state 0. (Section 20.6) State of the system The key information that defines the current status of the system. 28.1 and the overbooking example in Sec. Because of the system the system that satisfies the requirements with the smallest possible cost, an OR team was formed to solve the problem. In addition to the starting balance left over from 2014 (\$1 million), negative cash flow from business operations for 2015 (\$2 million), and a new short-term loan for 2015 (\$2 million), the company will need to make interest payments on its 2014 loans as well as pay back the shortterm loan from 2014. The Fairwinds Development Corporation is considering taking part in one or more of three different development projects— bles requires 8, 15, and 80 pounds of pine wood, respectively. A "GO Academy" then was established to train the key employees who would implement the program. hil23453 ch28 001-047.qxd 1/22/1970 10:51 PM Page 45 Confirming Pages 28.8 PROBLEMS 45 When using ASPE, each input cell that has a random value is referred to as an uncertain variable cell. However, if its experience with a particular flight is much different from this, then an exception is made and the OR group is called in to analyze what the overbooking policy should be for that particular flight. This treatment can be applied through either external beam radiation therapy (as illustrated by the first example in this section) or brachytherapy, which involves placing approximately 100 radioactive "seeds" within the tumor region. Rather than covering nearly all of the 1,000 pages in the book, perhaps you wish to use only a much smaller portion of the text. (You can see the first of these application vignettes in this section.) The last column indicates that these applications typically resulted in
annual savings in the many millions of dollars. In general, credit is not extended and customers are expected to pay their bills promptly. Furthermore, p00 p01 1, p10 p11 1, so so p01 1 - 0.8 0.2, p11 1 - 0.6 0.4. Therefore, the (one-step) transition matrix is State 0 1 State 0 0 p00 p01 0 0.8 P 1 p10 p11 1 0.6 1 0.2 0.4 where these transition probabilities are for the transition from the row state to the column state. (Section 9.3) Cost table that displays all the alternative costs of assigning assignees to tasks in an assignment problem, so the table provides a complete formulation of the problem. 9.1 and 9.3, while prior exposure to Secs. This profit function, 3 which is given by the solid curve in Fig. 28.1. The spreadsheet model is available on this website. In particular, if the stock has increased for the past two days, it will increase tomorrow with probability 0.9. If the stock increased today but decreased yesterday, then it will increase tomorrow with probability 0.5. Finally, if the stock decreased for the past two days, then it will increase tomorrow with probability 0.3. If we define the state as representing whether the stock goes up or down today, the system is no longer a Markov chain. However, assessing the risk is relatively difficult. (b) Describe the author's viewpoint about how basic precepts of using models to do research in the natural sciences can also be used to guide research on operations (OR). For this reason it is usually important to conduct sensitivity analysis after a solution is found that is optimal under the assumed parameter values. Figure 28.31 shows the resulting parameter analysis report. Click the cell where you want the uncertain variable cell to be. What this same problem. 20) also can be useful. The mean coincides with the most likely value because this is a hil23453\_ch28\_001-047.qxd 1/22/1970 10:51 PM Page 30 Confirming Pages 30 CHAPTER 28 EXAMPLES OF PERFORMING SIMULATIONS ON SPREADSHEETS symmetric distribution. Tenth Edition hil23453 fm i-xxx.qxd 1/30/70 7:58 AM Page i Final PDF to printer INSTALLING ANALYTIC SOLVER PLATFORM FOR EDUCATION Instructors: A course code will enable your students to download and install Analytic Solver Platform for Education with a semester-long (140 day) license, and will enable Frontline Systems to assist students with installation, and provide technical support to you during the course. (b) The probability that it will rain today is 0.5. Use the results from part (a) to determine the probability that it will rain no days from now, for n 2, 5, 10, 20. A common definition of sensitive parameter (used throughout this book) is the following. In contrast to the Wyndor problem. The transition intensities are 1 pii(t) d qi pii(0) lim, t→0 t dt for i 0, 1, 2, . However, because of the uncertainty for years 1–7, cells D7:D13 and the transition intensities are 1 pii(t) d qi pii(0) lim, t→0 t dt for i 0, 1, 2, . However, because of the uncertainty for years 1–7, cells D7:D13 and the transition intensities are 1 pii(t) d qi pii(0) lim, t→0 t dt for i 0, 1, 2, . However, because of the uncertainty for years 1–7, cells D7:D13 and the transition intensities are 1 pii(t) d qi pii(0) lim, t→0 t dt for i 0, 1, 2, . However, because of the uncertainty for years 1–7, cells D7:D13 and the transition intensities are 1 pii(t) d qi pii(0) lim, t→0 t dt for i 0, 1, 2, . However, because of the uncertainty for years 1–7, cells D7:D13 and the transition intensities are 1 pii(t) d qi pii(0) lim, t→0 t dt for i 0, 1, 2, . However, because of the uncertainty for years 1–7, cells D7:D13 and the transition intensities are 1 pii(t) d qi pii(0) lim, t→0 t dt for i 0, 1, 2, . However, because of the uncertainty for years 1–7, cells D7:D13 and the transition intensities are 1 pii(t) d qi pii(0) lim, t→0 t dt for i 0, 1, 2, . However, because of the uncertainty for years 1–7, cells D7:D13 and the transition intensities are 1 pii(t) d qi pii(t) d q D17:D23 containing the simulated cash flows for these years need to be uncertain variable cells. 29.5, the (long-run) expected average cost per week (based on just ordering costs and unsatisfied demand costs) is calculated for the inventory example of Sec. www.mhlearnsmart.com Tenth Edition Operations Research Ann Hillier Lieberman Powered by the intelligent and adaptive LearnSmart engine, SmartBook<sup>™</sup> is the frst and only continuously adaptive reading experience available today. Operations research analysts also often deal with the last one. Expected Average Cost per Unit Time for Complex Cost Functions In the preceding subsection, the cost function was based solely on the state that the process is in at time t. CrewSolver enables a crew coordinator to input data about the schedule disruption and then to use a graphical user interface to request an immediate solution for how to reassign crews to flights. Section 3.6 illustrates how a massive model can arise and how it can still be formulated successfully with the help of a special modeling language such as MPL (its formulation is described in this section) or LINGO (its formulation of this model is presented in Supplement 2 to this chapter on the book's website). problem discussed in Sec. With the custom general distribution, you also enter several values in between the minimum and maximum, but instead of cumulative probabilities, you enter relative to outcomes near the list. 21.6 does and the list. much morning shift, two for the afternoon shift, and four for the better job of following the guideline. (Section 17.9) Queueing system A place where customers receive some kind of service from a server, perhaps after waiting in a queue. Tis edition provides more coverage of dramatic real-world applications than ever before. These directors are determined to follow socially responsible policies, and they have been discussing with Steeltown city officials and citizens' groups what to do about the air pollutions menu includes many other distributions as well, such as beta, gamma, Weibull, Pert, Pareto, Erlang, and many more. Burns, T. However, the beginning of the activity called operations research has generally been attributed to the military services early in World War II. 28.27, ASPE would have found the integer uniform distribution to be the best fit. Mason, J. A7. Alternatively, integer programming techniques described in Chap. L., and S. What 2 6 8 7 should the objective be? This makes it easy to identify at least an approximation of an optimal solution for problems with only one or two decision variables. The third equation simply expresses the fact that the probabilities of these mutually exclusive states must sum to 1. However, even though the fare is nonrefundable, an average of only 80 percent of the customers who make reservations actually show up to take the flight, so it seems appropriate to accept more reservations than can be flown. In 1996, INFORMS also awarded him the prestigious Kimball Medal for his exceptional contributions to the field of operations than can be flown. breaks down is 1 day, so the rate at which it breaks down (when operational) is 1 per day, which implies that q12 1..) represents the state of the system at the end of week t, its only possible values are 0, 1, 2, or 3., the random variable Xt takes on the values, Xt 01 if day t is dry if day t has rain., and M p(n) ij 1 j0 for all i; n 0, 1, 2, ..., be the demand for the product in periods 1, 2, . Overall planning for this group is done in its 4 This model is much smaller than normally would be needed for actual applications. The advent of powerful spreadsheets a central role in conducting postoptimality analysis. At each step it has probability 0.5 of moving one point clockwise (0 follows 4) and 0.5 of moving one point counterclockwise. Focus instead on using spreadsheet modeling to address Web Mercantile's problem by doing the following. This example illustrates how a successful implementation phase might need to involve thousands of employees before undertaking the new procedures. 17.4 (lack of memory and the minimum of exponential), since these properties imply that the Tij random variables introduced earlier do indeed have exponential distributions. 8, 15, and 19. (Profit per batch produced was chosen as an appropriate measure after the team concluded that the incremental profit from each additional batch produced would be roughly constant regardless of the total number of batches produced. 3.2. (The demo called Graphical Method in your OR Tutor provides a more detailed example of constructing a feasible region.) The final step is to pick out the point in this feasible region that maximizes the value of Z 3x1 5x2. Therefore, by using money units of in this objective function, the complete linear programming model is hil23453 ch03 025-092.gxd 1/30/70 7:57 AM 3.4 Final PDF to printer Page 61 ADDITIONAL EXAMPLES 50 units produced 61 \$900/unit F1 W1 30 units needed assistance of various other key individuals in the organization, including information technology (IT) specialists, to track down all the vital data. As a result of these three properties of communicate with each other are in the same class. xj levelation, the states may be partitioned into one or more separate classes such that those states that communicate with each other are in the same class. xj levelation, including information technology (IT) specialists, to track down all the vital data. of activity j 1for j 1, 2, p, n2. Sensitivity analysis plays an important role in the analysis of the Wyndor Glass Co. problem, as you will see in Sec. A gambler bets \$1 on each play of a game. (Section 15.1) Pure strategy One of the original strategies (as opposed to a mixed strategy) in the formulation of a two-person, zero-sum game. 29.1, where Xt is the number of cameras on hand at the end of week t, where we start with X0 3. The late Gerald J. 21.3 shows the "range names" given to certain cells. The company's average cost
for doing this is \$150. After 35 years on the Stanford faculty, he took early retirement from his faculty responsibilities in order to focus full time on textbook writing, and now is Professor Emeritus of Operations Research at Stanford. While you may be breathing an initial sigh of relief once your initial claim is processed, be sure to maintain your job search as directed. Step 6: File Your Weekly Payment Request and Keep Up the Job SearchOnce you start receiving unemployment benefits, you have to file weekly or biweekly (varies by state) payment requests online to be paid — no exceptions. Additivity Although the product terms (terms involving the product of two or more variables). Similarly, given that there are two cameras left in stock at the end of a week, the probability is 0.097 that there will be three cameras in stock 2 weeks later, that is, (2) p23 0.097. {Xn} is a Markov chain. (Rounding up is feasible for this example because all the functional constraints are in form with nonnegative coefficients.) Rounding up does not ensure obtaining an optimal solution for the integer programming model, but the error introduced by rounding up such hil23453 ch03 025-092.qxd 60 1/30/70 7:57 AM CHAPTER 3 Page 60 Final PDF to printer INTRODUCTION TO LINEAR PROGRAMMING large numbers would be negligible for most practical situations. Figure 3.15 shows how these answers can be incorporated into the spreadsheet. The cost in this case is a monetary cost and the benefits are the various types of pollution abatement. Therefore, the British and then the U.S. military management called upon a large number of scientists to apply a scientific approach to dealing with this and other strategic and tactical problems. (Section 16.4) Glossaries - 39 Payoff A quantitative measure of the outcome from a decision alternative and a state of nature. However, it is difficult to tell from these numbers which distributions menu best fits these data. Due to attenuation, each beam delivers more radiation to the tissue near the exit point. (Section 18.6) Salvage value The value of an item if it is left over when no further inventory is desired. (Section 10.7) Supply node A node where the amount of flow generated (outflow minus inflow) is a fixed positive amount. Thus, it attempts to resolve the conflicts of interest among the components of the organization as a whole. (Section 6.1) Primal-dual table A table that highlights the correspondence between the primal and dual problems. In the inventory example, the probability distribution of the first passage time in going from state 3 to state 0 is obtained from these recursive relationships as follows: f (1) 30 p30 0.080, (1) (1) (1) f (2) 30 p31 f 10 p32 f 20 p33 f 30 0.184(0.632) 0.368(0.264) 0.368(0.080) 0.243, where the p3k and f (1) k0 pk0 are obtained from the (one-step) transition matrix given in Sec. If the requirement that the states be aperiodic is relaxed, then the limit lim p(n) ij n  $\rightarrow$  may not exist. (Section 10.3) Path A path between two nodes is a sequence of distinct arcs connecting these nodes when the direction (if any) of the arcs is ignored. .). It is estimated that there were nearly 240,000 new cases and nearly 30,000 deaths in just the United States alone in 2013. (Section 11.2) Policy decision as a function of the possible states that the system can be in at that stage. Having previously worked in software engineering, then trained in mathematics (stats & OR), and since worked in OR for ~3 years, I have a strong opinion on this. The bands in this chart trend upward until the number of reservations to accept reaches approximately hil23453 ch28\_001-047.qxd 1/22/1970 10:51 PM Page 44 Confirming Pages 44 CHAPTER 28 EXAMPLES OF PERFORMING SIMULATIONS ON SPREADSHEETS FIGURE 28.32 The parameter analysis report for this overbooking problem that considers all integer values for the number of reservations to accept between 180 and 190. For example, if kibbutz 2 must plants 200 of its available 400 acres, while kibbutz 2 must plants 200 of its available 400 acres, while kibbutz 2 must plant 300 of its available 400 acres, while kibbutz 1 plants 200 of its available 400 acres, while kibbutz 2 must plant 300 of its available 400 acres, while kibbutz 2 must plant 300 of its available 400 acres, while kibbutz 3 plants 150 acres of its 300 acres. obtained by varying the values of the parameters and/or the decision variables and checking to see whether the output from the model behaves in a random walk, consider a gambling example similar to that presented in Sec. This is especially true for the certainty assumption, so sensitivity analysis normally is a must to compensate for the violation of this assumption. represent the demand for this camera (the number of units that would be sold if the inventory is not depleted) during the first week, second week, . The other entries in this table reflect one of the provisions in the company's current contract with the union that represents the customer service agents. Given this information, it now would be natural to seek the probability distribution of the system at time t s t. Also, to protect against uncertainty, company policy dictates maintaining a balance of at least \$500,000 in cash reserves at all times. The short-term loan can be taken in any or all of the 10 years, so the "answer" should include 10 numbers indicating how much to borrow at the short-term rate in each given year. The Netherlands government agency responsible for water control and public works, the Rijkswaterstaat, commissioned a major OR study to guide the development of a new national water management policy. At first glance, it might appear that Case 2 in Table 3.4 is quite similar to Case 1. The results are shown in Fig. This enables you to test the small version first to get all the logic straightened out correctly before expanding to a full-scale model and undertaking a final test. The third column identifies the section where an "application vignette" devotes several paragraphs to describing the application and also references an article that provides full details. All these formulas are summarized below the spreadsheet in Fig. 2) Fill out the registration form on the page visited is step 1, supplying your name, school, email address (key information will be sent to this address), course code (obtain this from your instructor), and textbook code (enter HLIOR10). To illustrate this point, consider the two-state transition matrix State 0 P 1 0 0 1 1 1. For n 1, this first passage time from state k to state j is n 1. Kempf: "Product Line Design and Scheduling at Intel," Interfaces, 42(5): 425-436, September-October 2012. Madrid, C. You then will use these algorithms to solve a variety of problems on a computer. T57.6.H53 2015 658.4'032--dc23 2013035901 The Internet addresses listed in the text were accurate at the time of publication. 29.3 dealt with finding n-step transition probabilities from state i to state j. uniform distribution into the uncertain variable cell Demand (C12) was reasonable. This was accomplished through a variety of means. For example, what information should Julie provide in her report to Sheldon? Linear programming problems always involve finding the best mix of activity levels. Therefore, I took early retirement from my faculty responsibilities at Stanford in order to work full time on textbook writing for the foreseeable future. hil23453\_ch28\_001-047.qxd 1/22/1970 10:51 PM Page 47 Confirming Pages ACKNOWLEDGMENT (c) Suppose you were the CEO of the Think-Big Development Co. Use the results in Fig. We will focus on analyzing absorbing states in Sec. This problem will demonstrate this fact and investigate the impact of the number of trials per simulation on this randomness. Kleindorfer, H. hil23453\_ch01\_001-009.qxd 1/31/70 11:14 AM Final PDF to printer Page 6 An Application Vignette FedEx Corporation is the world's largest courier delivery services company. To obtain a close estimate of the average cost of insurance experience.  $n \rightarrow n \rightarrow n t1$  Similarly, j can also be interpreted as the (long-run) actual fraction of times that the system is in state j. (Section 20.3) Continuous simulation The type of simulation where changes in the state of the system occur continuously over time. This continuously over time of sec. (Thus, qi iscuric) and the airline overbooking example of Sec. (Thus, qi iscuric) and the airline
overbooking example of Sec. (Thus, qi iscuric) and the airline overbooking example of Sec. (Thus, qi iscuric) and the airline overbooking example of Sec. (Thus, qi iscuric) and the airline overbooking example of Sec. (Thus, qi iscuric) and the airline overbooking examp the reciprocal of the expected time that the process spends in state i per visit to state i; that is, qi 1/E[Ti].) Similarly, qij is the transition rate from state i to state j per unit of time spent in state i. A variety of examples in this chapter illustrate some of the many possibilities for important applications of simulation. Fulfilling these objectives might achieve long-run profit maximization, but the relationship may be sufficiently obscure that it may not be convenient to incorporate them all into this one objective. In the early years, these generally were mainframe computers, but now personal computers and workstations are being widely used to solve OR models. To make this definition more concrete and clarify why we need to worry about this assumption, let us look at some examples. The OR team immediately recognized that this was a linear programming problem of the classic product mix type, and the team next undertook the formulation of the corresponding mathematical model. While discussing the three types of loan options, Julia asks two questions. (Section 15.4) Infinite game A game where the players have an infinite number of pure strategies available to them. 16 to 20 covers the probabilistic (stochastic) models of operations research suitable for presentation in a (one-quarter) course. This new model does not fit this same standard form, but it does incorporate three other legitimate forms described in Sec. Reclaiming Solid Wastes The SAVE-IT COMPANY operates a reclamation center that collects four types of solid waste materials and treats them so that they can be amalgamated into a salable product. In our examples of performing simulations on a spreadsheet, the integer uniform distribution was used to represent the demand for a newspaper (in Fig. This yields Z 30,610, that is, a total daily personnel cost of \$30,610. Brenner, and S. Recurrent States and Transient States are will ever return to this state. The long-term loan is paid back 10 years later (2024). LT Rate ST Rate ST Rate Start Balance Minimum Cash Flow LT Loan ST Loan LT Interest ST SPREADSHEETS interest payments, and loan paybacks are all part of the calculation for the ending balance, the columns are arranged this way, with the ending balance, the columns are arranged this way, with the ending balance directly to the right of all these other elements. (b) Quote the one-sentence statement of the general mission of the OR group (called the management science group) that conducted this study. (The proportionality assumption still is satisfied since after the value of one variable.) This case would arise if the two products were complementary in some way that increases profit. .), when {Xn} (n 0, 1, . However, if the only possible values are integer numbers over a relatively broad range, a continuous distribution may be used as an approximation by rounding any fractional value to the nearest integer. Therefore, care must be taken to ensure that the model remains a valid representation of the problem. The left-hand side of each of these constraints represents the benefit of having that number of agents working during that time period and the right-hand side represents the minimum acceptable level of that benefit. What are the constraints on these decisions? Fu (eds.): Encyclopedia of Operations Research and Management Science, 3rd ed., Springer, New York, 2014. Enter the Data First Any spreadsheet model is driven by the data in the spreadsheet. The marketing division has concluded that the company could sell as much of either product as could be produced by these plants. (Section 16.4) Expected value of experimentation (EVE) The maximum increase in the expected payoff that could be obtained from performing experimentation). As a matter of fact, the mathematical analysis often represents only a relatively small part of the total effort required. Although it must be interpreted carefully in terms of the practical needs of management, this "search for to printer OVERVIEW OF THE OPERATIONS RESEARCH MODELING APPROACH 9. Case 16.4 University Toys and the Engineering Professor Action Figures Case 18.2 TNT: Tackling Newsboy's Teachings Case 18.3 Jettisoning Surplus Stock Case 20.3 Planning Planers Case 20.4 Pricing under Pressure SUPPLEMENT 1 TO CHAPTER 3 The LINGO Modeling Language SUPPLEMENT 2 TO CHAPTER 3 More about LINGO SUPPLEMENT TO CHAPTER 8 Linear Goal Programming and Its Solution Procedures Problems xviii SUPPLEMENT TO CHAPTER 16 Using TreePlan Software for Decision Trees Final PDF to printer hil23453 fm i-xxx.qxd 1/30/70 7:58 AM Page xix Final PDF to printer SUPPLEMENT 1 TO CHAPTER 18 Derivation of the Optimal Policy for the Stochastic Single-Period Model for Perishable Products Problems SUPPLEMENT 2 TO CHAPTER 19 A Policy Improvement Algorithm for Finding Optimal Policies Problems SUPPLEMENT 1 TO CHAPTER 19 A Discounted Cost Criterion Problems SUPPLEMENT 1 TO CHAPTER 20 Variance-Reducing Techniques Problems SUPPLEMENT 2 TO CHAPTER 20 Regenerative Method of Statistical Analysis Problems CHAPTER 21 The Art of Modeling with Spreadsheets 21.1 A Case Study: The Everglade Golden Years Company Cash Flow Problem 21.2 Overview of the Process of Modeling with Spreadsheets 21.3 Some Guidelines for Building "Good" Spreadsheet Models 21.4 Debugging a Spreadsheet Model 21.5 Conclusions Selected References Learning Aids for This Chapter on Our Website Problems Case 21.1 Prudent Provisions for Pensions CHAPTER 22 Project Management with PERT/CPM 22.1 A Prototype Example—The Reliable Construction Co. Project 22.2 Using a Network to Visually Display a Project 22.3 Scheduling a Project with PERT/CPM 22.4 Dealing with Uncertain Activity Durations 22.5 Considering Time-Cost Trade-Offs 22.6 Scheduling and Controlling Project Costs 22.7 An Evaluation of PERT/CPM 22.8 Conclusions Selected References Learning Aids for This Chapter on Our Website Problems Case 22.1 "School's out forever (Section 20.6) Uncertain variable cell An input cell that has a random value so that a probability distribution must be entered into the cell instead of permanently entering a single number. Sections 7.4-7.6 describe other remaining scheduled flights. 2.6-3. Each table sold generates \$50, \$100, and \$220 a significant investment over the next few years, and then would profit, respectively. Assume that any cash left at the end of a year profit from sales, and inventory costs for quarters 1 and 2. Read Selected Reference A10 that describes an OR study done for the Health Department of New Haven, Connecticut. He also received visiting appointments at Cornell University, Carnegie-Mellon University of Cambridge (England). The mathematical model might then say that the problem is to choose the values of the decision variables so as to maximize the objective function, subject to the specified constraints. The board of directors of Green Earth has instructed the management of Save-It to divide this money among the material is actually collected and treated. For each shift, the daily collected and treated the management of Save-It to divide this money among the material is actually collected and treated. compensation (including benefits) for each agent is shown in the bottom row. After examining data over the past several years on the month by month progression of individual customers from state to state, the store has developed the following transition matrix: 4 State State 0: fully paid 1: 1 to 30 days in arrears 2: 31 to 60 days in arrears 3: bad debt 0: Fully Paid 1: 1 to 30 Days in Arrears 2: 31 to 60 Days in Arrears 3: Bad Debt 1 0.7 0 0.2 0 0.1 0 0 0.5 0.1 0.2 0.2 0 0 1 Although each customer will end up as a bad debt given that the account belongs to the 1 to 30 days in arrears state, and similarly, given that the account belongs to the 31 to 60 days in arrears state. An unfortunate trend with early editions of this book was that each new edition of stochastic processes in general and Markov chains in particular. Landscaping Predecessors - A A B, C D D E F, G H H 28.2. Consider the historical data contained in the Excel File "Sales Data 1" on this website. What are the constraints on what can be done? 2.2-2. Thus, p(n) ij 0 for n 2, 3, . 3.6 (MPL and LINGO), Supplements 1 and 2 to this chapter on the book's website (LINGO), Sec. They have a fixed minimum value and a fixed maximum value. Problem 28.8 asks you to refine this analysis by generating a parameter analysis report that considers all bids between \$5.2 million and \$5.6 million in multiples of \$0.05 million. The interactive simulation mode in ASPE makes this especially easy, since the results in the statistic cells are available immediately after changing the value of a decision variable. T.: "On the Art of Modeling," Management Science, 13: B707-717, 1967. Section 29.2 further defines the particular type of stochastic process considered in this chapter. 4. n-Step Transition Matrices for the Weather Example For the weather example introduced in Sec. This often provides a convenient and intuitive way of representing the problem. There are a lot of factors that enter into this calculation, so it is easy to get overwhelmed. A 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 11 B D E F Normal Mean 195 Standard Dev. Julie has projected Everglade's net cash flows over the next 10 years as shown in Table 21.1. With less money currently currently a factor of factors that enter into this calculation, so it is easy to get overwhelmed. A 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 11 B D E F Normal Mean 195 Standard Dev. Julie has projected Everglade's net cash flows over the next 10 years as shown in Table 21.1. With
less money currently a factor of the factor of coming in than would be provided by full occupancy and with all the construction costs for the new retirement community, Everglade will have negative cash flow for the next few years. For example, see H. Having gained perspective by trying this arbitrarily chosen value of Z 10, you should FIGURE 3.1 Shaded area shows values of (x1, x2) allowed by x1 0, x2 0, x1 4. To do so, let C(Xt) 10 Xt j Xt j. Section 21.4 presents some helpful ways to debug a spreadsheet model and to root out such errors. Her research grant from Stanford to continue her work and was invited to speak at an INFORMS conference to present her conclusions regarding successful classroom case studies. 0 If the process starts in state 0 at time 0, it will be in state 0 at times 2, 4, 6, . Thus, the two uncertain variable cells in this model are SimulatedTicketDemand (C10) and NumberThatShow (C17). 21.5. FIGURE 21.10 The spreadsheet obtained by using the Excel auditing tools to trace the precedents of the ST Interest (2004) calculation in cell G12 of the spreadsheet in Fig. The OR team used this model7 to find a minimum-cost plan 1x1, x2, x3, x4, x5, x6 2 11, 0.623, 0.343, 1, 0.048, 12, with Z 32.16 (total annual cost of \$32.16 million). Still another disadvantage is that a curve with a gradually changing slope, such as the bellshaped curve for the normal distribution, usually describes the true distribution more accurately than the straight line segments in the triangular distribution. The implementation phase involves several steps. (Section 9.2) Glossary for Chapter 10 Activity A distinct task that needs to be performed as part of a project. 28.6, the binomial distribution gives the distribution of the number of times a particular event occurs out of a certain number of opportunities. Suppose now that the stock's going up tomorrow depends upon whether it increased today and yesterday. When you are done, choose Remove Arrows. 3.2. In particular, from a mathematical viewpoint, the assumptions simply are that the model must have a linear objective function subject to linear constraints. (Section 10.2) Feasible spanning tree A spanning tree A spanning tree as a constraints and arc capacity constraints for the flows through the arcs. If z 0 cameras are ordered the cost incurred is (10 25z) dollars., 6. These teams of scientists were the first OR teams. With the custom discrete distribution, each value (or outcome) is assigned its own probability, whereas the custom discrete uniform distribution assumes that all the discrete values have the same probability. Describe how the probabilities in the n-step transition matrices obtained in part (b) compare to these steady-state probabilities as n grows large. 0.097 | 0.165 | 0.080 | 0.632 | 0.264 | 0.080 | 0.632 | 0.264 | 0.080 | 0.368 0.368 0.368 0.368 0.368 ] 0 | 0 | 0 | 0.368 ] For example, given that there is one camera left in stock at the end of a week, the probability is 0.283 that there will be no cameras in stock 2 weeks later, that is, p(2) 10 0.283. Consequently, a whole range of computers from mainframes to laptops now are being routinely used to solve OR problems, including some of enormous size. I also am excited about the partnership with INFORMS that began with the 9th edition. Reboot, Inc. For other problems, what happens when the proportionality assumption does not hold even as a reasonable approximation? Suppose that a cost (or other penalty function) C(Xt) is incurred when the process is in state Xt at time t, for t 0, 1, 2, . The DISTRIBUTION UNLIMITED CO. Section 17.4 describes this property of the exponential distribution in some detail. (Section 10.7) Sink The node for a maximum flow problem at which all flow through the network terminates. (b) As described on pages 53 and 58-59 of this reference, this OR study is remarkable for combining a wide range of mathematical models. The first m constraints (those with a function of all the variables ai1x1 ai2x2 ··· ainxn on the left-hand side) are sometimes called functional constraints). This goal is pursued in four ways. After witnessing the impact of analytics, many major league baseball teams now have hired analytics, many major league baseball teams now have hired analytics professionals. 3.4, you will find it good practice to analyze how well each of the four assumptions of linear programming applies. Brown, G. There also are great differences in the kind of software (if any) that instructors want their students to use. After many years, LINDO (and its companion modeling language LINGO) continues to be a popular OR software package. To analyze the impact of individual client behavior in response to different options, the team needed to assemble a comprehensive 200 gigabyte client database involving 5 million clients, 10 million accounts, 100 million trade records, and 250 million trade records, and 250 million trade records. (a) Construct the (one-step) transition matrix. Therefore, the total amount shipped from the factories to the distribution center. For all three columns, the individual contributions from the products toward using the capacity of Plant 3 are just as assumed previously, namely, 3x1 for product 2, or 3(2) 6 for x1 2 and 2(3) 6 for x2 3. FIGURE 3.8 The solid curve violates the proportionality assumption because of the start-up cost that is incurred when x1 is increased from 0., xn so as to Maximize Z c1x1 c2x2 . (f) List the various tangible and intangible benefits that resulted from the study. Just as in many other developed countries, OR is an important profession in the United States. Ms. Stephens taught public speaking in Stanford's School of Engineering and served as a teaching assistant for a case studies course in operations research. If the model is to be used repeatedly, the next step is to install a well-documented system for applying the model as prescribed by management., M and j i. 29.1 for the next state is Xt1 max {Xt Dt1, 0} if Xt 1. The amount available of each resource is limited, so a careful allocation of resources to activities must be made. TABLE 3.11 Optimal solution for the Southern Confederation of Kibbutz Crop Sugar beets Cotton Sorghum 5 1 1 1333 100 0 2 3 100 250 0 25 150 0 Actually, any one of these equations is redundant and can be deleted if desired. Refer to pp. These revisions make the book even more suitable for use in a modern course that reflects contemporary practice in the field. Markov chains are a central topic of probability theory and stochastic processes that have been borrowed as a tool of operations research, so this chapter better fits as a reference in the supplements. Thus, E11 is two cells to the left and one cell up. Introduction to operations research / Frederick S. Bowker), Tables of the Non-Central t-Distribution (Stanford University Press, 1957, co-authored by G., M? {Xt} is an irreducible (finite-state) Markov chain, Fortunately, it can give negative values with significant frequency only if the mean is less than three standard deviations. Additivit assumption: Every function in a linear programming model (whether the objective function or the function or the function or the respective activities. Following the merger under the name of United Airlines, the combined airline has a fleet of over 700 aircraft serving up to 370 destinations. The problem must possess CPF solutions and at least one optimal solution. (c) OMEGA is constantly being updated and extended to reflect changes in the operating environment. The Normal Distribution dialog box (shown earlier in Fig. Use the results given in Prob. Finally, the landscaper has guaranteed that his work will be completed in five months. Photo Courtesy: Witthaya Prasongsin/Moment/Getty Images Due to the COVID-19 pandemic, unemployment rates rose sharply in the United States in the spring of 2020. Like the other procedures are designed specifically to provide you with an efficient, enjoyable, and enlightening learning experience while you do your homework. The particle starts at point 0. What kinds of numbers need to be included in the recommendation? Assume that there is one camera in stock at the time (the end of a week) the policy is instituted. In recent years, great progress has been made in developing efficient and effective metaheuristics that provide both a general structure and strategy guidelines for designing a specific heuristic procedure to fit a particular kind of problem. The additivity satisfied column of Table 3.6 shows this case as is, whereas the next two columns display cases where the function has an extra approach to circumventing the problem of suboptimization is to use long-run profit maximization (considering the time value of money) as the sole objective. This point is the desired optimal solution. (Section 16.2) Prior probabilities The estimated probabilities of the states of nature prior to obtaining additional information through a test or survey. Therefore, the attitude of the townspeople always has been, What's good for Nori & Leets is good for the town. Whenever the number up to 3. (Section 12.8) Relaxation A relaxation of a problem is obtained by deleting a set of constraints from the problem. To get started, a discrete uniform distribution between 40 and 70 has been entered into this uncertain variable cell. Mathematical symbols and expressions. Assad: An Annotated Timeline of Operations Research: An Informal History, Kluwer Academic Publishers (now Springer), Boston, 2005. 22 begins with the company having just won the contract by submitting this bid. (Section 18.8) Material requirements of a final product. Even for the gambling example, states 0 and 3 are recurrent states because the process will keep returning immediately to one of these states forever once the process enters that state. The new standards require that the company reduce its annual emission of these pollutants by the amounts shown in Table 3.12. When producing, this is
the cost incurred in setting up to start a production run. 28.22. j0 If you prefer to work with a system of equations in matrix form, this system (excluding the sum = 1 equation) also can be expressed as P, where = (0, 1, . Organizing the elements with a consistent structure, like in Fig. Furthermore, gi as defined here turns out to still be the parameter of the exponential distribution for Ti as well (see property 1 of the preceding paragraph). Hillier played in developing this chapter. For example, the formula copied to G13 refers to cell E12, the one in G14 refers to cell E13, and so on. It also provides a Certified Analytics Professional credential for those individuals who satisfy certain criteria and pass an examination. It also lets instructors see exactly what students have accomplished, and it features a built-in assessment tool for graded assignments. Identifying the sensitive parameters is important, because this identifies the parameters is important, because this identifying the sensitive parameters whose value must be assigned with special care to avoid distorting the output of the model. (heads) to occur with a fixed probability (0.5). (Section 7.4) Recourse The opportunity to set the values of some of the decision variables at a later time to adjust to what transpired earlier when other decision variables at a later time to adjust to what transpired earlier when other decision variables at a later time to adjust to what transpired earlier when other decision variables at a later time to adjust to what transpired earlier when other decision variables at a later time to adjust to what transpired earlier when other decision variables at a later time to adjust to what transpired earlier when other decision variables at a later time to adjust to what transpired earlier when other decision variables at a later time to adjust to what transpired earlier when other decision variables at a later time to adjust to what transpired earlier when other decision variables at a later time to adjust to what transpired earlier when other decision variables at a later time to adjust to what transpired earlier when other decision variables at a later time to adjust to what transpired earlier when other decision variables at a later time to adjust to what transpired earlier when other decision variables at a later time to adjust to what transpired earlier when other decision variables at a later time to adjust to what transpired earlier when other decision variables at a later time to adjust to what transpired earlier when other decision variables at a later time to adjust to what transpired earlier when other decision variables at a later time to adjust to what transpired earlier when other decision variables at a later time to adjust to what transpired earlier when other decision variables at a later time to adjust to what transpired earlier when other decision variables at a later time to adjust to what transpired earlier when other decision variables at a later time to adjust to what transpired earlier when other decision variables at a later time to adjust to what transpired earlier when other decision variabl \$1 at a time until one player is broke. hil23453 ch29 001-036.qxd 1/22/1970 10:52 PM Page 3 Confirming Pages 29.2 MARKOV CHAINS 3 Assume that X0 3, so that week 1 begins with three cameras on hand. Arrange your book to fit your teaching style. Several other helpful features are available from Excel's auditing tools. Therefore, management is wondering whether it would be more prudent to go ahead with just one of the two projects. The equation of this line is 3x1 5x2 3(2) 5(6) 36 Z, indicating that the optimization techniques of operations research described in many of the chapters of this book generally are what are used here. 28.20 definitely are not., M. However, the (nonnumerical) results still hold for other problems as long as the following conditions are satisfied: 1. Chapters 1 and 2 give an introduction to the subject of operations research. (Notice how the layout of the coefficients of x1 and x2 in this linear programming model essentially duplicates the information summarized in Table 3.1.) hil23453\_ch03\_025-092.qxd 1/30/70 7:57 AM 3.1 Final PDF to printer Page 29 PROTOTYPE EXAMPLE 29 This problem is a classic example of a resource-allocation problem, the most common type of linear programming problem. (Section 12.3) Element constraint A global constraint that constraint programming uses to look up a cost or profit associated with an integer variable. Suppose the camera remaining on the shelf at the end of the week. I also adopted the goal of avoiding any growth in subsequent editions. (Section 17.8) Number of customers in the queue The number of customers who are waiting for service to begin. Similarly, each term on the right-hand side (i qij) is the transition rate from state i, since qij is the transition rate from state i. Hillier, Introduction to Management Science: A Modeling and Case Studies Approach with Spreadsheets, 5th ed., McGraw-Hill/Irwin, Burr Ridge, IL, 2014. If you want five heads, the negative binomial distribution (with Prob. In addition to Stochastic Models in Operations Research (1990), his books are Handbook of Industrial Statistics (PrenticeHall, 1955, co-authored by A. Previous editions © 2010, 2005, and 2001. The Bernoulli and Binomial Distribution The Bernoulli distribution is a very simple discrete distribution with only two possible values (1 or 0) as shown in the top half of Fig. This plan specifies which types of abatement methods will be used and at what fractions of their abatement capacities for (1) the blast furnaces. Two statistics are causing particular concern. (Section 17.2) Queue discipline The rule for determining the order in which members of the queue are selected to begin service. (Section 10.5) Source The node for a maximum flow problem at which all flow through the network originates. Therefore, the goal of an OR study should be to conduct the study in an optimal manner, regardless of whether this involves finding an optimal solution for the model. cells. Therefore, your OR Courseware includes a wealth of material to introduce you to four particularly popular software packages described next. When the original problem is a linear programming constraint, (c) Find the expected recurrence time for state 0 (i.e., the expected length of time a machine can be used before it must be replaced). The study continued for over five years, culminating in June 2001, largely because of the extensive effort required for the implementation phase. You can put the signs on the sketch to remind yourself that these will be constraints. Another Stanford PhD graduate, William Sun (CEO of the software company Accelet Corporation), and his team did a brilliant job of starting with much of Mark Hillier's earlier software and implementing it anew in Java 2 as IOR Tutorial for the 7th edition. Other items to check include whether range names refer to the appropriate cells and whether formulas have been entered into output cells correctly. E\* (e) Expand the model to full scale and then solve it., xn are called the decision variables. (Section 18.7) Quantity discounts Discounts that are provided when sufficiently large orders are placed. The first is a 10-year loan with interest-only payments made annually and then the entire principal repaid in a single balloon payment after 10 years. As illustrated in Secs. (d) Briefly describe the field implementation test. The Obama campaign management hired a multi-disciplinary team of statisticians, predictive modelers, data-mining experts, mathematicians, software experts and the second experts are second experts. programmers, and OR analysts. Suppose that a communications network transmits binary digits, 0 or 1, where each digit is transmitted 10 times in succession. The other legitimate forms are the following: 1. A state is said to be a transient state if, upon entering this state, the process might never return to this state again. To discover how to perform this step efficiently, begin by trial and error. Therefore, the first order of business is to study the relevant system and develop a well-defined statement of the problem to be considered. hil23453 ch28 001-047.qxd 1/22/1970 10:51 PM Page 23 Confirming Pages 28.5 REVENUE MANAGEMENT IN THE TRAVEL INDUSTRY 23 Following this breakthrough at American Airlines, other airlines quickly stepped up their use of operations research in similar ways. Section 18.6) Revenue management Managing the demand for a company's product with the goal of maximizing expected revenue when dealing with a perishable product whose entire inventory must be made available to customers at a designated point in time or be lost forever. After thorough analysis of this type, the medical team has carefully estimated the data needed to design Mary's treatment, as summarized in Table 3.7. The first column lists the areas of the body that must be considered, and then the next two columns give the fraction of the radiation dose at the entry point for each beam that is absorbed by the respective areas on average. 21.3. The bottom of Fig. Long story short, where you're currently residing might not be the state that will pay you unemployment benefits if you haven't lived there long. A trend chart also provides additional insights to aid in decision making. The binomial distribution is equivalent to the Bernoulli distributions for Random Events (e.g., time between random events (e.g., time between arrivals) • Events are independent • Mean = average time until the next event occurs Poisson Distribution: • Describes the number of times an event occurs during a given period of time (e.g., arrivals per hour), assumed constant over time of the coin. The simultaneous solution to this system of equations is 10 1.58 weeks, 20 2.51 weeks, 30 3.50 weeks, so that the expected time until the cameras are out of stock is 3.50 weeks.
He also gave important help on the textual material involving ASPE and contributed greatly to Chaps. A considerable number of books and articles present some of these applications. Eilon, "Goals and Constraints in Decision-making," Operational Research Quarterly, 23: 3-15, 1972. The late Herbert Simon (an eminent management scientist and a Nobel Laureate in economics) pointed out that satisficing is much more prevalent than optimizing in actual practice. If the demand during a period exceeds the number of items available, this unsatisfied demand is backlogged; i.e., it is filled when the next order is received. 27 (on the book's website), are prominently used here. 1.4. List the various financial and nonfinancial benefits that resulted from this study. For most of these activities, a set of predecessor activities must be completed before the activity begins. Avis, L. Hillier was born and raised in Aberdeen, Washington, where he was an award winner in statewide high school contests in essay writing, mathematics, debate, and music. Much data usually are needed both to gain an accurate understanding of the problem and to provide the needed input for the mathematical model being formulated in the next phase of study. A recent stockholders' revolt resulted in the election of a new enlightened board of directors for the company. The Think-Big Financial Risk Analysis Problem The Think-B details of the algorithms needed to solve these models. Highly respected as a senior statesman of the field of operations research, Dr. Lieberman served in numerous leadership roles, including as the elected president of the second of the various values of NPV, including those where NPV is negative. To perform this risk analysis, Think-Big staff now has devoted considerable time to estimating the amount of uncertainty in the cash flows for each project over the next seven years. Student versions of MPL (a leading algebraic modeling language) along with an MPL Tutorial and MPL formulations and solutions for all relevant examples throughout the book. A sketch of a potential spreadsheet layout for the Everglade problem is shown in Fig. 20.6, our focus here is on summarizing the results. Since Fig. Other Forms We now hasten to add that the preceding model does not actually fit the natural form of some linear programming problems. 29.1 and formulated in Sec. If this occurs when the balance is between 31 and 60 days in arrears, the store views the customer as being in state 2. In this case, the first passage time in going from state 3 to state 1 is 2 weeks, the first passage time in going from state 3 to state 0 is 3 weeks, and the recurrence time for state 3 is 4 weeks. There are two random inputs associated with each flight, namely, the number of customers requesting reservations (abbreviated as Ticket Demand in cell B10) and the number of customers who actually arrive to take the flight (abbreviated as Number That Show in cell B17). The overall OR study directly involved over 125 person-years of effort (more than one-third in data gathering), created several dozen computer programs, and structured an enormous amount of data. When using the fill commands, it is important to understand the difference between STRate\*E11). 21.3, the formulas in columns F, G, I, J, and L can be copied using the Fill Down command in the Editing Group of the Home tab to obtain all the formulas shown in Fig. Use range names. This mix is identified by the proportion of material in the product grade, which would suggest defining the other set of decision variables as zij proportion of material in the product grade i 1 A, B, C; j 1, 2, 3, 42. After a preliminary version of the new system had been developed (based on a multiechelon inventory model), a preimplementation test of the system was conducted. (Section 6.1) Primal feasible for the primal problem. Students: 1) To download and install Analytic Solver Platform for Education from Frontline Systems to work with Excel for Windows, please visit: www.solver.com/student. The system is observed at particular points of time, labeled t 0, 1, 2, . A Spreadsheet Model for Applying Simulation Figure 28.16 shows a spreadsheet model for this problem. This solution is optimal rather than the point (6, 6) because decreasing Z (for positive values of Z) pushes the objective function line toward the origin (where Z 0). Read Selected Reference 4. 0.5) gives the distribution of the number of flips until the first head occurs. Hillier • Gerald J. For this editions of providing enough introduction in the book to enable the basic use of any of the three options without distracting those using

another, while also providing ample supporting material for each option on the book's website. Because Welch's lacked a formal system for optimizing raw material movement and the recipes used for production, an OR team developed a preliminary linear programming model. 47 28.8. Consider the Reliable Construction Co. bidding problem discussed in Sec. However, we can transform the system to a Markov chain by defining the states as follows: 2 State State O: 1: 2: 3: The The The State State O: 1: 2: 3: The The The State State O: 1: 2: 3: The State O: 1: 2: 3: The State State State O: 1: 2: 3: The State State State O: 1: 2: 3: The State State State State State State O: 1: 2: 3: The State State State State State model developed by Everglade's CFO, Julie Lee, is the one shown in Fig. 10.7, we will solve for its optimal solution: xF1-F2 0, xF1-W1 10, xF2-DC 40, xP1-W1 10, xF2-W1 20. He also is a Fellow of INFORMS. As discussed while interpreting this result, the percentage of trials on which the project is completed by the deadline will vary from simulation run to simulation run. Once the repair of a machine is completed by the deadline will vary from simulation run. this point can be calculated algebraically as the simultaneous solution of these two equations. (d) The improved production throughput that resulted from this distribution are the number of trials and the probability of the event occurring on a trial. 1.3-2. (Selected Reference A2 describes this study in detail. Based on this experience, both political parties undoubtedly will make extensive use of analytics in the future in major political campaigns. Except for Sec. First, the OR team gives operating management a careful explanation of the new system to be adopted and how it relates to operating realities. In the inventory example, it was assumed that initially there were 3 units in stock, that is, X0 3. Eventually, after a long succession of improved models, the OR team concludes that the current model now is giving reasonably valid results. applications, the powerful linear programming approach is used for the initial analysis, and then a more complicated model is used to refine this analysis. Based upon compiled data, the company has noted that only 1 percent of its recorders fail during the first year, whereas 5 percent of the recorders that survive the first year will fail during the second year. (Section 17.7) Infinite queue A queue that can hold an essentially unlimited number of customers. Some of the earliest applications of linear programming were for gasoline. Framing F. Learn more at www.solver.com/using-frontline-solversmacintosh. The leading brewery on the West Coast (labeled A) has hired an OR analyze its market position. (Hint: Use the Custom Discrete distribution to simulate the demand for tickets.) (b) Generate a parameter analysis report to consider all nine possible quantities of tickets to purchase between 10 and 18. distribution network for Distribution Unlimited Co. 40 units produced F2 W2 Minimize Z 2xF1-F2 4xF1-DC 9xF1-W1 3xF2-DC xDC-W2 3xW1-W2 2xW2-W1, 60 units needed subject to the following constraints: 1. However, it is possible to have more than one. 29.8, this will be the only kind of stochastic process considered in this chapter. The problem is to determine how many agents should be assigned to the respective shifts each day to minimize the total personnel cost for agents, based on this bottom row, while meeting (or surpassing) the service requirements given in the rightmost column. Common examples include model airplanes, portraits, globes, and so on. (Section 18.3) EOQ model An abbreviation of economic order quantity model. In this airline overbooking example, the events are customers making a reservation actually will arrive to take the flight. To make sure you don't overlook this mention we will boldface the words additional example (or something similar) each time. Think-Big management is quite concerned about the risk profile for the steady-state probabilities of a Markov chain, including how to derive them more directly, at the beginning of Sec. 2.5-2. To provide you with another example of a model for the problem before then applying the graphical method step by step to hil23453 ch03 025-092.qxd 32 1/30/70 7:57 AM CHAPTER 3 Page 32 Final PDF to printer INTRODUCTION TO LINEAR PROGRAMMING solve the model. Hillier, Stanford University, Gerald J. She has spent the last week in front of her computer trying to come to grips with the company's imminent cash flow problem. In the gambling example, states 2 and 3 do not. A Customizable Version of the Text Also is Available. When a customer is bumped from this flight, Transcontinental Airlines arranges to put the customer on the next available flight to Chicago on another airline. At the end of a given day, the price is recorded. de, F. Furthermore, all the other relatively high points are near the peak. Read Selected Reference A8 that describes an OR study done for the Rijkswaterstaat of the Netherlands. Any restrictions on the values that can be assigned to these decision variables are also expressed mathematically, typically by means of inequalities or equations (for example, x1 + 3x1x2 + 2x2 10). 30 Binomial Tickets Purchased 180 Probability to Show Up 80% C Transcontinental Airlines overbooking Available Seats Fixed Cost Avg. Such an assumption is suitable for many problems, but there are certain cases (such as for some queueing models considered in Chap. Occasionally used for either interarrival times or service times. What is the probability that Susan will make at least \$0 profit? 20.6 included still another approach, using the Solver in ASPE to search for an optimal solution for simulation models.) An intuitive approach for searching for an optimal solution is to use trial and error. hil23453 ch28 001-047.gxd 1/22/1970 10:51 PM Page 22 CHAPTER 28 EXAMPLES of PERFORMING SIMULATIONS ON SPREADSHEETS FIGURE 28.15 The frequency chart and statistics table that summarize table ta the results of running the simulation model in Figure 28.13 for the Think-Big Development Co. financial risk analysis problem. By its very nature, OR requires considerable ingenuity and innovation, so it is impossible to write down any standard procedure that should always be followed by OR teams. Strand Vice President, General Manager, Products & Markets: Marty Lange Vice President, Content Production & Technology Services: Kimberly Meriwether David Global Publisher: Raghothaman Srinivasan Development Editor: Vincent Bradshaw Marketing Manager: Nick McFadden Director, Content Production: Terri Schiesl Content Production: Terri Schiesl Content Production & Technology Services: Kimberly Meriwether David Global Publisher: Raghothaman Srinivasan Development Editor: Vincent Bradshaw Marketing Manager: Nick McFadden Director, Content Production: Terri Schiesl Content Production & Technology Services: Kimberly Meriwether David Global Publisher: Raghothaman Srinivasan Development Editor: Vincent Bradshaw Marketing Manager: Nick McFadden Director, Content Production: Terri Schiesl Content Production & Technology Services: Kimberly Meriwether David Global Publisher: Raghothaman Srinivasan Development Editor: Vincent Bradshaw Marketing Manager: Nick McFadden Director, Content Production: Terri Schiesl Content Production & Technology Services: Kimberly Meriwether David Global Publisher: Raghothaman Srinivasan Development Editor: Vincent Bradshaw Marketing Manager: Nick McFadden Director, Content Production: Terri Schiesl Content Designer: Studio Montage, St. Louis, MO Compositor: Laserwords Private Limited Typeface: 10/12 Times Roman Printer: Quad/Graphics All credits appearing on page or at the end of the book are considered to be an extension of the copyright page. Product-mix problems are one type of resource-allocation problem, but you will see examples of resource-allocations problems of other types in Sec. Therefore, the "answer" should include a single number indicating how much money to borrow now at the long-term rate. In general, the first passage times are random variables. 28.28. (b) Summarize the author's viewpoint about the complementary roles of modeling, evaluating information from the model, and then applying the decision maker's judgment when deciding on a course of action. One then seeks a solution that remains a particularly good one for all the various combinations of likely values of the sensitive parameters. (Section 10.2) Destination The node at which travel through the network is assumed to end for a shortest-path problem. (Section 17.2) Phase-type distributions. One of the great strengths of a spreadsheet is the ease with which it can be used interactively by anyone, including managers, to see what happens to the optimal solution (according to the current version of the model) when changes are made to the model. To show the mean NPV over the simulation run, MeanNPV (D39) is defined as a statistic cell. These discussions led to developing the following definition of the problem: Determine what the production rates should be for the two products in order to maximize their total profit, subject to the restrictions imposed by the limited production capacities available in the three plants. When deciding which type of distributions should be considered for fitting, the default option of continuous hil23453\_ch28\_001-047.qxd 1/22/1970 10:51 PM Page 39 Confirming Pages 28.6 CHOOSING THE RIGHT DISTRIBUTION FIGURE 28.26 Cells F4:F63 contain the historical demand data that have been collected for the example involving Freddie the newsboy that was introduced in Sec. McGraw-Hill LearnSmart® is available as a standalone product or an integrated feature of McGraw-Hill Connect Engineering. In the words of one of England's pioneering OR leaders, Samuel Eilon, "Optimizing is the science of the ultimate; as possible to the decision-making process. Excel provides a number of useful features to aid
in the debugging process. Excel provides a number of useful features to aid in the debugging process. the precision of the data and then will make do with the best that can be obtained. 20.7 that was presented in Sec. (Section 14.1) Tabu list A record of the moves that currently are forbidden by a tabu search algorithm. Therefore, given the ordering policy described in Sec. (Section 14.1) Tabu list A record of the moves that currently are forbidden by a tabu search algorithm. could impact your claim. Step 2: Determine Your EligibilityAs stated earlier, you need to meet certain criteria in order to be eligible for unemployment benefits. These observations imply that our trial-and-error procedure for constructing lines in Fig. Sensitivity analysis played a major role in this study. (Section 15.3) Saddle point An entry in a payoff table that is both the minimum in its row and the maximum of its column. If any values in this range are possible, including even fractional values, then the uniform distribution. (c) Use ASPE's Solver to search for the number of reservations to accept that maximizes the airline's mean profit. Management evaluates the study and its recommendations, takes into account a variety of intangible factors, and makes the final decision based on its best judgment. These tissues include critical organs (e.g., the rectum) as well as bony structures (e. occur because the marketing costs need to go up more than proportionally to attain increases in the level of sales. Combining the xij in different ways yields the following quantities needed in the model (for i = A, B, C; j = 1, 2, 3, 4). tion. Our interpretation of the words allocating 1 This is called our standard form rather than the standard form because some textbooks adopt other forms. (Section 13.9) Sequential unconstrained minimization technique A classic algorithm within the category of sequential-approximation algorithms. The four-step transition matrix can also be obtained as follows: P(4) P(2) 0.249 0.286 0.283 0.252 0.286 0.289 0.286 0.289 0.282 0.284 0.289 0.286 0.285 0.283 0.286 0.300 0.233 0.233 0.300 0.165 0.233 0.200 0.165 0.261 0.268 0.263 0.261 0.164 0.166 0.263 0.261 0.164 0.166 0.263 0.261 0.268 0.263 0.261 0.164 0.166 0.263 0.261 0.268 0.263 0.261 0.268 0.263 0.261 0.164 0.166 0.263 0.261 0.268 0.263 0.261 0.268 0.263 0.261 0.268 0.263 0.261 0.164 0.166 0.268 0.263 0.261 0.268 0.263 0.261 0.268 0.263 0.261 0.164 0.166 0.268 0.263 0.261 0.268 0.261 0.268 0.268 0.268 0.268 improved service to customers and better managerial control) sometimes were considered to be even more important than these financial benefits. Therefore, these distributions are referred as central-tendency distributions backed by great service and a team that cares about your success. The one concern that Sheldon raises is that the cash flows in the coming years shown in column C of Fig. This reduced its size to 324 decision variables and 361 functional constraints. (Introduction and Section 15.1) Unstable solution A solution for a two-person, zero-sum game where each player has a motive to consider changing his strategy once he deduces his opponent's strategy. The team adopted a linear programming approach, formulating the model summarized next. During a repair day, the spare machine has a probability of 0.1 of breaking down, in which case it is repaired the next day. Initially, when dealing with a fairly complicated problem, it is helpful to take some time to perform each of these detailed steps manually one at a time. After the overall measure as a mathematical function of the decision variables. 29.5-3. Because the TABLE 3.14 Total annual cost from the maximum feasible use of an abatement method for Nori & Leets Co. (\$ millions) Abatement Method Taller smokestacks Filters Better fuels Blast Furnaces 8 7 11 Open-Hearth Furnaces feasible use of an abatement method) for Nori & Leets Co. Abatement Method Blast Furnaces X1 x3 x5 x2 x4 x6 Taller smokestacks Filters Better fuels objective is to minimize total cost while satisfying the emission reduction requirements, the data in Tables 3.12, 3.13, and 3.14 yield the following model: Minimize Z 8x1 10x2 7x3 6x4 11x5 9x6, subject to the following constraints: 1. Some other kinds of sports teams also are beginning to use analytics. Profit per batch produced of each new product. 29.6-2. Specifically, OR is also concerned with the practical management of the organization. Thus, the probabilities in either row of this five-step transition matrix are referred to as the steady-state probabilities of this Markov chain. The constants (namely, the coefficients and righthand sides) in the constraints and the objective function are called the parameters of the model. The state (number of machines broken down) increases by 1 when a repair occurs. Labe, B. In addition, Solver can quickly apply the simplex method to find an optimal solution for the model. (Section 13.3) Complementary variables (either one) can be nonzero. Since each random variable Xt (t 0, 1, 2, . These millions of daily shipments must be individually sorted and routed to the correct general location (usually by aircraft) and then delivered to the exact destination (usually by motorized vehicle) in an amazingly short period of time. Management feels that the bid should be in the range between \$4.8 million, so these are the numbers (in units of millions of dollars) that are entered into the entry boxes for Bounds in this dialog box. If k is an absorbing state, and the probability of ever going to state k is called the probability of absorption into state k, given that the system throughout its future use. Separate data from formulas. Get the simple model working, and then move on to tackle the difficult constraints. (Because of its importance, Appendix 5 provides a hil23453\_ch28\_001-047.qxd 1/22/1970 10:51 PM Page 29 Confirming Pages 28.6 CHOOSING THE RIGHT DISTRIBUTION 29 tendency distributions in ASPE's Common submenu of the Distribution, (2) the triangular distribution, (2) the triangular distribution, and (3) the lognormal distribution, and (3) the lognormal distribution, and (3) the lognormal distribution and (3) the lognorm packages for doing OR. For example, suppose that both products need to use the same machinery and equipment. Build: Start with a Small Version of the Spreadsheet, it is finally time to open a new worksheet in Excel and start building the model. I.: "Decision-Aiding Models: Validation, Assessment, and Related Issues for Policy Analysis," Operations Research, 31: 603-631, 1983. (b) Generate a trend chart for the five long-term loan amounts considered in part a. This brought the use of OR within the easy reach of much larger numbers of people, and this progress further accelerated in the 1990s and into the 21st century. With all this analytics input, the Obama team launched a full-scale and allfront campaign, leveraging massive amounts of data from various sources to directly micro-target potential voters and donors with tailored messages. We believe that we have provided enough material to meet the needs of all of these kinds of instructors. , M) as described in the preceding section, these expected recurrence times can be calculated immediately as 1 ii , i for i 0, 1, . Common terminology for the linear programming model can now be summarized. Hillier, F. Thus, in addition to pursuing the science of the ultimate, the team should also consider the cost of the study and the disadvantages of delaying its completion, and then attempt to maximize the net benefits resulting from the study. Then (n) (n) P{Xn j} P{X0 0} p(n) 0 P{X0 1} p1 P{X0 Programming). Now suppose that the manufacturer keeps a spare machine that only is used when the primary machine is being repaired. (a) What does the author say about whether a model can be completely validated? A 1 2 3 4 5 6 7 8 9 10 11 12 B D LT Rate ST Rate 5% 7% Start Balance MinimumCash 1 0.5 Year 2014 2015 Cash Flow -8 -2 F 9 10 11 12 C E F G H I J ST Payback Ending Balance 1.00 1.56 K L Everglade Cash Flow Management Problem (Years 2014 and 2015) LT Interest (all cash figures in millions of dollars) G ST Interest =-LTRate\*E11 Range Name LTLoan =-STRate\*E11 Range Name LTLoan 5 I LT ST Payback Payback =-E11 LT Interest ST Interest -0.30 -0.14 J LT Payback -2.00 K L Ending Minimum Balance =StartBalance+SUM(C11:I11) >=
=MinimumCash =J11+SUM(C12:I12) Minimum Balance >= 0.50 >= 0.50 hil61217 ch21.qxd 4/29/04 03:41 PM Page 21-9 21.2 OVERVIEW OF THE PROCESS OF MODELING WITH SPREADSHEETS 21-9 formula in cell I12 refers to the short-term loan taken the preceding year (cell E11). (Section 20.1) General-purpose simulation model. Title. Some of these algorithms are amazingly efficient and are routinely used on problems cells, and statistic cells.) The Simulation Results Using the Simulation Options dialog box to specify 1,000 trials, Fig. It pinpoints concepts the student does not understand and maps out a personalized study plan for success. hil23453 ch29 001-036.qxd 1/22/1970 10:53 PM Page 13 Confirming Pages 29.4 CLASSIFICATION OF STATES OF A MARKOV CHAIN 13 State j is said to be accessible from state i if p(n) ij 0 for some n 0. This student version also is provided in your OR Courseware. In fact, we could even find analytics eventually replacing operations research as the common name for this integrated discipline. 28.24. In the latter case, the task of developing this measure tends to be a complex one requiring a careful comparison of the objectives and their relative importance. (e) List the various financial and nonfinancial benefits that resulted from this study. Student versions of LINDO (a traditional optimizer) and LINGO (a popular algebraic modeling language), along with formulations and solutions for all relevant examples throughout the book. (Also see Selected References A11 and A13 for other examples where quickly deriving the appropriate kinds of solutions were a key part of an award-winning OR application.) 2.4 TESTING THE MODEL Developing a large mathematical model is analogous in some ways to developing a large computer program. The new procedures then were phased in gradually to build confidence. (Section 12.6) Branch-and-cut algorithm for integer programming that combines automatic problem preprocessing, the generation of cutting planes, and clever branchand-bound techniques. After post-doctoral research at the Hoover Institution, a think tank on the Stanford campus, he became assistant professor of managerial economics and decision sciences at the Kellogg School. The reason is that a small number of trials had profits far below the mean, including even a few that incurred losses, which dragged the mean down somewhat. maker who may be uncomfortable with algebra. (b) Write the steady-state equations. Because they are equality constraints, each of these constraints, each of these constraints, each of these constraints, each of these constraints imposes the fixed requirement that the net flow out of that location is required to equal a certain fixed amount. (Section 9.2) Sources The supply center for a transportation problem. The random variables Xt are dependent and may be evaluated iteratively by the expression max{3 Dt1, 0} Xt1 max{X D, 0} tt1 if if Xt 0 Xt 1, for t 0, 1, 2, . (Section 16.2) Posterior probabilities. However, this market has picked up recently, and the future is looking brighter. To make this one-time cost commensurable with the ongoing annual costs, the time value of money was used to calculate the annual expenditure (over the expected life of the method) that would be equivalent in value to this start-up cost. In addition, the Institute of Operations Research and the Management Sciences (INFORMS) awarded him and Dr. Hillier the honorable mention award for the 1995 Lanchester Prize for the 6th edition of this book. (Section 17.2) Nonpreemptive priorities for selecting the next customer to begin service when a server becomes free, without affecting customers who already have begun service. Thus, this equation is analogous to the conservation of flow equations encountered in many engineering and science courses. a 3.1 PROTOTYPE EXAMPLE The WYNDOR GLASS CO. However, there are pitfalls to be avoided when you use mathematical models. If you want to make sure your claim isn't delayed, be sure to complete all the sections fully and accurately. It is evident that no single individual should be expected to be an expert on all the many aspects of OR work or the problems typically considered; this would require a group of individuals having diverse backgrounds and skills. 28.15. , M). Develop a computer-based procedure for deriving solutions to the problem from the model. Following publication, it was unclear how well this particular goal was met, but what did become clear was that the demand for the book was far larger than either of us had anticipated. You also can trace backward to see which cells provide the data for any given cell. The Pine Furniture Company makes fine country furniture. Repeat part (b) to find the new probability that a digit entering the network will be recorded accurately after the last transmission. Since the decision variables always are the levels of the activities, the five decision variables here are xj number of agents assigned to shift j, for j 1, 2, 3, 4, 5. 29.5 LONG-RUN PROPERTIES OF MARKOV CHAINS Steady-State Probabilities While calculating the nstep transition probabilities for both the weather and inventory examples in Sec. (b) What is the probability that the probabilities in any row are the steady-state probabilities for this Markov chain, i.e., the probabilities of the state of the system after enough time has elapsed that the initial state is no longer relevant. 12 could be used to solve exactly for an optimal solution with integer values. 29.2. Its state transition diagram shown in Fig. The stochastic process {Xt} {X0, X1, X2, . (Section 17.5) Balking An arriving customer who refuses to enter a queueing system because the solve exactly for an optimal solution with integer values. queue is too long is said to be balking. In Mary's case, the size and location of her treatment an even more delicate process than usual. Furthermore, we still need to see why the OR team for the problem. This case, the size and location of the problem. implies that Xt1 Xt, so p12 0, p13 0, and p23 0. We shall restrict our consideration to continuous time Markov chains with the following properties: 1. Therefore, even though NumberThatShow (C17) would be expected to be fairly close to the product of cells E17 and F17, there will be some variation according to some probability distribution. Thus, (1)ne1 P{Dt1 n}, n! so (to three significant digits) for n 0, 1, . You may refer to Appendix 1 for documentation of the software. 2.2-5. 20.7. These data indicate a lot of variation in sales from day to day—ranging from about 40 copies. In this case, if the unconditional probability P{Xn j} is desired, it is necessary to specify the probability distribution of the initial state, namely, P{X0 i} for i 0, 1, . (c) Use the results from part (b) to find the steady-state probability that a pint of blood will need to be discarded during a 3-day period. 28.7. Susan is a ticket scalper. 29.1 graphically depicts the same information provided by the transition matrix. Therefore, these probabilities satisfy the following recursive relationships: (1) f (1) ij pij pij, (1) f (2) ij pik f (n) ij months. 29.4 CLASSIFICATION OF STATES OF A MARKOV CHAIN We have just seen near the end of the preceding section that the n-step transition probabilities after a sufficient number of steps. The OR group wants to consider integer values of the decision variable over the range between 150 and 200, so the parameter cell dialog box is used in the usual way to specify these bounds on the variable. The proposal being analyzed is to take the shares shown in cells H28:H29. When dealing with large and challenging OR problems, it is common to also use a modeling system to efficiently formulate the mathematical model and enter it into the computer. Solve for the steady-state probabilities of the state of the weather in terms of and . 3.3 reveals that a segment of the line 3x1 5x2 20 lies within the region, so that the maximum permissible value of Z must be at least 20., then {Xn} is a Markov chain. This is the most important constraint, but the other two functional constraints impose additional restrictions as well. Similarly, both the weather example and the first stock example contain only recurrent states, since p i j is positive for all i and j. 28.16.) ASPE's Distributions menu includes both continuous and discrete distributions. Some ancillaries, including electronic and print components, may not be available to customers outside the United States. 21.1. As suggested by this figure, the four major steps in this process are to (1) plan, (2) build, (3) test, and (4) analyze the spreadsheet model. Consequently, we can use the steady-state equations given in the preceding subsection to find the steady-state equations given in the preceding subsection to find the steady-state equations given in the preceding subsection to find the steady-state equations given in the preceding subsection to find the steady-state equations given in the preceding subsection to find the steady-state equations given in the preceding subsection to find the steady-state equations given in the preceding subsection to find the steady-state equations given in the preceding subsection to find the steady-state equations given in the preceding subsection to find the steady-state equations given in the preceding subsection to find the steady-state equations given in the preceding subsection to find the steady-state equations given in the preceding subsection to find the steady-state equations given in the preceding subsection to find the steady-state equations given in the preceding subsection to find the steady-state equations given in the preceding subsection to find the steady-state equations given in the preceding subsection to find the steady-state equations given in the preceding subsection to find the steady-state equations given in the preceding subsection to find the steady-state equations given in the preceding subsection to find the steady-state
equations given in the preceding subsection to find the steady-state equations given in the preceding subsection to find the steady-state equations given in the preceding subsection to find the steady-state equations given in the preceding subsection to find the steady-state equations given in the preceding subsection to find the steady-state equations given in the preceding subsection to find the steady-state equations given in the preceding subsection to find the steady-state equations given in the p down. In particular, qi is the transition rate out of state i in the sense that qi is the expected number of times state i per unit of time spent in state i. We mentioned in Sec. (Sections 13.3 and 13.7) Complementarity problem A special type of problem where the objective is to find a feasible solution for a certain set of constraints. Another is that the triangular distribution can be asymmetric. The last column gives the restrictions on the total dosage from both beams that is absorbed on average by the respective areas of the body. Thus, linear programming involves the planning of activities to obtain an optimal result, i.e., a result that reaches the specified goal best (according to the mathematical model) among all feasible alternatives. The uncertain variable cells are cells D7:D13 and D17:D23, the results cell is NetPresentValue (D37), the statistic cell is MeanNPV (D39), and the decision variables are HotelShare (H28) and ShoppingCenterShare (H29). 2 that well-conducted OR studies do not simply find one solution for the initial model formulated and then stop. The frequency chart for NumberOfFilledSeats (C20) indicates that almost half of the 1,000 trials resulted in all 150 seats being filled. Conclusions Everglade management is pleased that the simulation results indicate that the proposed financing plan is likely to lead to a favorable outcome at the end of the 10 years. (Section 20.4) Next-event that will occur in the simulated system. 28.32) for this problem suggests that 185 is the best number of reservations to accept in order to maximize profit, but the only numbers considered were a multiple of five. 29.1. The cost of other ordering policies can be evaluated in a similar way to identify the policy that minimizes the expected average cost per week. Just as the one-step transition probabilities played a major role in describing discrete time Markov chains, the analogous role for a continuous time Markov chain is played by the transition intensities. If the solution is implemented on an ongoing basis, any later change in the value of a sensitive parameter immediately signals a need to change the solution. To illustrate these distributions, suppose you are again interested in the event of getting heads on a flip of a coin (a trial). The cj, bi, and aij are also referred to as the parameters of the model. To meet these three challenges, an OR team developed an integrated system of 45 linear programming models based on three model formulations to dynamically schedule its beef-fabrication operations at five plants in real time as it receives orders. Like the Wyndor problem and the demonstration example for the graphical method in OR Tutor, the first of these examples has only two decision variables and so can be solved by the graphical method. To a considerable extent, the scientific method is of these examples has only two decision variables and so can be solved by the graphical method. used to investigate the problem of concern. The function being maximized, c1x1 c2x2 ··· cnxn, is called the objective function. In the last subsection of Sec. The company has 3,000 pounds of pine wood be sold upon completion. Then, after gaining a deeper understanding of mathematical models, we suggest that you plan to return to review this chapter again in order to further sharpen this perspective. i0 If such a chain is irreducible, aperiodic, and consists of M 1 states, show that 1 3 3 1 5 1 4 1 10 4 0 0 | 1 0 1 4 1 2 2 | 0 2 0 5 0 0 0 1 0 | 1 1 1 2 0 3 3 0 for j 0, 1, . This occurs only if (1) it has no feasible solutions or (2) the constraints do not prevent improving the value of the objective function (Z) indefinitely in the favorable direction (positive or negative). Again, comparing the 10 3x1 5x2 and 20 3x1 5x2 lines in Fig. The decision to be made concerns how much to ship through each shipping lane. Adding too much detail and precision to be made concerns how much to ship through each shipping lane. academic users can apply to receive full-sized versions of MPL, CPLEX, and GUROBI by going to their respective websites. 2 This means that any academic users (professors or students) now can obtain professional versions of MPL with CPLEX and GUROBI for use in their coursework. van Doremalen, E. Consider an OR study done for IBM to Results chart in Fig. Using the notation introduced in this section, the (one-step) transition probabilities are p00 P{Xt1 0Xt 0} 0.8, p10 P{Xt1 0Xt 0} 0. where there is no preplay communication between the players. LEARNING AIDS FOR THIS CHAPTER ON THIS WEBSITE Chapter 21 Excel Files: Everglade Case Study hil61217\_ch21.qxd 4/29/04 03:41 PM Page 21-23 PROBLEMS 21-23 Wyndor Example Everglade Problem 21-9 Everglade Problem 21-10 An Excel Add-in: Analytic Solver Platform for Education (ASPE) PROBLEMS We have inserted the symbol E\* (for Excel) to the left of each problem or part where Excel should be used. Then Xn1 Xn 1 n1 X Xn1 Xn, with probability p with probability p in tackling a real world problem is in framing the problem in such a way that those methods can even be used in the first place. These disruptions can cause flight delays and cancellations. This study resulted in a new inventory system that improved customer service while reducing the value of IBM's inventories by over \$250 million and saving an additional \$20 million per year through improved operational efficiency. When the sum does equal 1, f ij(n) (for n 1, 2, . Since PD(4) 0.015, PD(5) 0.003, and PD(6) 0.001, we obtain k(0) 86.2. Also using PD(2) 0.184 and PD(3) 0.061, similar calculations lead to the results k(1)  $E[C(1, Dt)] 50E(max{Dt 1, 0}) 50[PD(2) 2PD(3) 3PD(4) ] 18.4, k(2) <math>E[C(2, Dt)] 50E(max{Dt 2, 0})$ 50[PD(3) 2PD(4) 3PD(5) ] 5.2, and k(3)  $E[C(3, Dt)] 50E(max\{Dt 3, 0\}) 50[PD(4) 2PD(5) 3PD(6) ]$  1.2. Thus, the (long-run) expected average cost per week is given by 3 k(j) 86.2(0.286) 18.4(0.285) 5.2(0.263) 1.2(0.166) \$31.46. (We say a best instead of the best solution because multiple solutions may be tied as best.) Rather than simply improving the status quo, the goal is to identify a best possible course of action. There are many other situations where absorbing states play an important role. The price that would be paid for filling seats so well is that a few customers would need to be bumped from some of the flights. There are seven choices in the Custom submenu: Cumul (short for cumulative), Discrete, DisUniform (short for discrete uniform), General, Histogram, Sip, and Slurp. The OR team also identified the data that needed to be gathered: 1. (This story is continued in Case 7.1 at the end of Chap. The probability distributions associated with them depend upon the transition probabilities of the process. However, it is not clear just how many more should be hired. • A test bank featuring moderately difficult questions that require students to show their • work is being provided to instructors. Management wants to choose the bid that would maximize its expected profit. Airlines like Continental (and now under its reincarnation as part of United Airlines) face schedule disruptions daily because of unexpected events, including inclement weather, aircraft mechanical problems, and crew unavailability. We will describe how this is done in the latter part of this section. The binomial distribution gives the continental (and now under its reincarnation as part of this section). probability distribution of the number of independent opportunities (called trials) for the event to occur, where the probability of the event occurring remains the same from trial to trial. Every working day, it delivers many millions of documents, packages, and other items throughout the United States and hundreds of countries and territories around the world. Source: G. Markov chains also provided the foundation for the study of Markov decision models in Chap. Because of declining earnings, top management has decided to revamp the company's product line. .) can be considered as a probability distribution for the random variable, the first passage time. A range name is a descriptive name given to a block of cells that immediately identifies what is there. In each case, the final decisions regarding the start date for construction and the size of the trends in the demand for this. service. Just as so many individuals made important contributions to this edition, I would like to invite each of you to start contributing to the next edition by using my email address below to send me your comments, suggestions, and errata to help me improve the book in the future. Fairwinds has \$10 million available now and expects to receive \$6 million from other projects by the end of each year (1 through 6) E\* (d) Build a spreadsheet model and then solve it. (Section 12.6) Branching tree A tree (as defined in Sec. However, along with its blessings, this increasing specialization has created new problems, problems that are still occurring in many organizations. Section 3.4 gives some additional examples of linear programming applications. Processing times have an exponential distribution with a mean of 1 day. 20.6 to illustrate another special feature of ASPE. One is the inclusion of many application second had a powerful impact on a company or organization by using techniques like those studied in that portion of the book. Hassler, K. As it turns out, the discipline of analytics is closely related to the to 10 years. Technological
limit: xj 1, for j 1, 2, . In real applications, the certainty assumption is seldom satisfied precisely. It is far easier to fix a problem early, while the spreadsheet is still a manageable size, rather than later after an error has been propagated throughout a much larger spreadsheet. dev.) 14.059 29.746 81.373 395.247 Normal MODELS There are many ways to set up a model on a spreadsheet. When historical data are available, ASPE provides a powerful feature for doing this service are staggering. 28.16 for the Transcontinental Airlines overbooking problem. D., M. The shortage cost per period is 4Zn if Zn 0 and zero otherwise. However, there now is an increasing marginal return; i.e., the slope of the profit function for product 1 (see the solid curve in Fig. Read Selected Reference A13 that describes an OR study done for Intel that won the 2011 Daniel H. (c) Generate a sensitivity chart. (Section 16.2) Decision node A point in a decision tree where a decision needs to be made. Assume that n is small enough that these conditional probabilities are not yet steady-state probabilities. It is unclear which company will be able to bring its product to market first and thereby capture most of the sales. entered as zeroes at this point. A particle moves on a circle through points that have been marked 0, 1, 2, 3, 4 (in a clockwise order). Given the following (one-step) transition matrices of a Markov chain, determine the classes of the Markov chain and whether they are recurrent. (Section 12.5) Fathoming A basic step in a branch-and-bound algorithm that uses fathoming tests to determine if a subproblem can be dismissed from further consideration. These constraints have the following form. The complex version then was used in the final rounds of the analysis or whenever greater accuracy or more detailed outputs were desired. (Section 13.3) Global maximum (or minimum) A feasible solution that maximizes (or minimizes) the value of the objective function over the entire feasible region. Referring to the Case 1 column of Table 3.5, this case corresponds to an objective function of Z 3x1 5x2 x1x2, so that Z 3 5 1 9 for (x1, x2) (1, 1), thereby violating the additivity assumption that Z 3 5. (The data cells are the cells that show the data for the problem.) Concentrate on the layout. The number of requests for reservations usually exceeds the number of seats by a considerable amount. Therefore, while granting that management's prime responsibilities also must be recognized. q0 q01 2 q1 q10 q12 3 q2 q21 2 Plugging all the rates into the steady-state equations given in the preceding subsection then yields Balance equation for state 2: Probabilities sum to 1: 20 21 31 20 22 22 1 0 1 2 1 Any one of the balance equations (say, the second) can be deleted as redundant, and the simultaneous solution of the remaining equations gives the steady-state distribution as 2 2 1 (0, 1, 2) , . Schuster and S. ASPE alone matches or exceeds the capabilities of all these previous packages. Choosing either Continuous or Discrete (or both) would have led to the same type of distribution (uniform). If it is to state j, the first passage time is 1. There is also a logical progression to the spreadsheet. (Section 18.7) Supply chain A network of facilities that procure raw materials, transform them into intermediate goods and then final products, and finally deliver the products to customers through a distribution system that usually includes a multiechelon inventory system. If the stock decreased today and increase tomorrow with probability 3. In any application of linear programming, all the activities may be of one general kind (such as any one of these three examples), and then the individual activities may be of one general kind (such as any one of these three examples), and then the individual activities may be of one general kind (such as any one of these three examples), and then the individual activities may be of one general kind (such as any one of these three examples), and then the individual activities may be of one general kind (such as any one of these three examples), and then the individual activities may be of one general kind (such as any one of these three examples). this general category. For example, the widely used spreadsheet package, Microsoft Excel, provides a Solver that will solve a variety of OR problems. Today, literally millions of individuals have ready access to OR software. After clearly identifying what information is really desired and the most conveying this information by means of decision variables, we can develop the objective function and the constraints on the values of these decision variables. hil23453\_ch03\_025-092.qxd 1/30/70 7:57 AM Final PDF to printer Page 63 An Application Vignette Welch's, Inc., is the world's largest processor of Concord and Niagara grapes, with net sales of \$650 million in 2012. Focus instead on using spreadsheet modeling to address Al Ferris's problem by doing the following. A., and S. There are 150 seats available in the single cabin. Each of these phases will be discussed in turn in the following sections. 29.1). This concept can be most readily conveyed in the context of linear programming because of all the methodology that now has been developed for dealing with linear programming under uncertainty. 28.16). If the process enters a certain state and then stays in this state and then stays in this state at the next step, this is considered a return to this state. Sheskin, T. (Section 17.3) staying the same over time. Since excess copies left over at the end of the day represent a loss for Freddie, he is trying to decide what his order quantity should be in the future. An integral part of this revolutionary change has been a tremendous increase in the division of labor and segmentation of management responsibilities in these organizations for Freddie, he is trying to decide what his order quantity should be in the future. J.: "The Easy Chair: Observation and Experimentation," Interfaces, 19(5): 23-30, September-October 1989. Hillier, McGraw-Hill/Irwin, 2014. ax m \$3 \$300/unit \$1 80 t \$200/unit provides still another way of reformulating a linear programming model (or another type of model) where there is some uncertainty about what the values of the parameters will turn out to be. Sections 8.1 and 8.2 use parts of Chaps. Molly Stephens is a partner in the Los Angeles office of Quinn, Emanuel, Urquhart & Sullivan, LLP. However, there are some differences in their relative emphases. (In fact, three of the nonnegativity constraints- x1 0, x4 0, x5 0-also are redundant constraints: x1 48, x4 43, and x5 15. The eBooks allow readers to do full text searches, add highlighting and notes, and share notes with others. Third, many cases patterned after real applications are included at the end of chapters and on the book's website. Indeed, packaged software for both personal computers has become widely available for solving many mathematical models. Controlling Air Pollution The NORI & LEETS CO., one of the major producers of steel in its part of the world, is located in the city of Steeltown and is the only large employer there. (Section 9.2) Dummy destination An imaginary destination for the sum of the sum of the demands at the destinations (including this dummy destination). (Introduction) Serial multiechelon system A multiechelon inventory system where there is only a single installation at each echelon. hil23453\_ch28\_001-047.qxd 1/22/1970 10:51 PM Page 18 Confirming Pages 18 28.4 CHAPTER 28 EXAMPLES OF PERFORMING SIMULATIONS ON SPREADSHEETS FINANCIAL RISK ANALYSIS One of the system of the system at the system where there is only a single installation at each echelon. the earliest areas of application of simulation, dating back to the 1960s, was financial risk analysis. The entries in the changing cells, LTLoan (D11) and STLoan (D11) and STL the organization. Section 2.4 will describe how the process of testing a model typically leads to a succession of models that provide better and better representations, here are the steps to take next to file an unemployment claim online. Step 1: Contact Your State Unemployment AgencyWhether you were laid off because of the pandemic or lost your job due to other unforeseen circumstances, filing for unemployment benefits is one way to cover a portion of your monthly bills while you're between jobs. Download SolverSetup64 ONLY if you see "64-bit" displayed. Markov chains have the special property that probabilities involving how the process will evolve in the future depend only on the present state of the process, and so are independent of events in the past. initiated a major OR study in March 1996 to develop new methodologies and scheduling applications that would streamline the entire semiconductor manufacturing process and reduce work-inprogress inventories. 3.4 along with examples of other categories of linear programming problems. The first utilizes the custom discrete distribution (Section 20.3) Random number A random observation from some form of a uniform distribution. 3.5), the ability to build decision trees within Excel (as described in Sec. Convexity 954 3. Deriving this conditional probability often is very difficult. (Section 18.5) Backlogging The situation where excess demand is not lost but instead is held until it can be satisfied when the next normal delivery replenishes the inventory. Lasdon, A. The tables are handmade, and require one hour, two hours, and four A, B, and C—that are about to be launched. 168-172, summarize the various benefits that have resulted from using SYSNET. dev.) (mean, st. The transition matrix calculated below. Additional learning aids are Excel files that provide the spreadsheet models for the examples in this chapter, as well as Sales Data 1 and Sales Data 2 for two end-of-chapter problems. Carlson, and D. The application of analytics can be divided into three overlapping categories. In addition,
he recently completed a 20-year tenure as the series editor for Springer's International Series in Operations Research and Management Science, a particularly prominent book series with over 200 published books that he founded in 1993. I., and M. (Section 17.3) Utilization factor The average fraction of time that the servers are being utilized serving customers. There no longer is a start-up cost, and the profit from the first unit of product 1 per week is indeed 3, as originally assumed. All six phases described in Chap. It has already been pointed out that a sufficient condition for all states to be accessible (and therefore communicate with each other) is that there exists a value of n for which pij(n) 0 for all i and j. Then construct the (one-step) transition matrix. (Section 7.2) Chance constraint When an original constraint includes one or more parameters that actually are random variables, the corresponding chance constraint specifies that the original constraint is required to hold with at least a certain minimum acceptable probability. Hicks, R., R. Extensive feedback from the user team led to major improvements in the proposed system. It can be used to evaluate any proposed solution, including quickly determining what interest and loan payments will be required and what the resulting balances will be at the end of each year. You can go to www.mcgrawhillcreate.com and register to experience how McGraw-Hill Create empowers you to teach your way. (Sections 17.4) and 17.6) Glossaries - 41 Finite calling population A calling population whose size is so limited that the mean arrival rate to the queueing system. This distribution always is "positively skewed," meaning that the long tail always is to the right. 2.2. This study did not conclude by recommending just a single solution. This will be easier to understand and follow than if the data cells, changing cells, output cells, and objective cell are all scattered throughout the spreadsheet. Prepare for the ongoing application of the model as prescribed by management. 29.3 CHAPMAN-KOLMOGOROV EQUATIONS Section 29.2 introduced the n-step transition probability p(n) if . S., and M. 6 and 7. Before discussing how to formulate such a models in general and of mathematical models in general and of mathematical models in general and the shopping center project, respectively, so Think-Big's share of these cash flows needs to be reduced proportionally based on its shares in these projects. Lee, and A. and every sequence i, j, k0, k1, . 29.4), state 2 is not accessible from state 3. Although these evaluations often flew in the face of conventional baseball wisdom, both descriptive analytics and predictive analytics were being used to identify overlooked players who could greatly help the team. It also has the ability to solve optimization models involving uncertainty and recourse decisions, perform sensitivity analysis, and construct decision trees. The roots of OR can be traced back many decades, 1 when early attempts were made to use a scientific approach in the management of organizations. Calculate by hand what the ending cash position would be after each year. Kamesam, P. Graphical procedure can be used to solve it. A12. (b) List the complicating factors that these and therefore only two decision variables and therefore only two decision variables. OR team members faced when they started developing a model and a solution algorithm. The j are called the steady-state probabilities of the Markov chains" and their properties. Scatter also causes some delivery of radiation to tissue outside the direct path of the beam. It has three plants. All three cases are hypothetical examples of ways in which the proportionality assumption could be violated. (Section 9.1) Supply from a source to the destinations. (Section 9.1) Supply from a source to the destination to tissue outside the direct path of the beam. It has three plants. All three cases are hypothetical examples of ways in which the proportionality assumption could be violated. criterion for decision making that uses probabilities to calculate the expected payoff. Furthermore, in a finite-state Markov chain, not all states can be transient. Rather than formulating one mathematical model, this OR study developed a comprehensive, integrated system of 50 models! Furthermore, for some of the models, both simple and complex versions were developed. 21.3. This spreadsheet is set up to follow the layout suggested in the sketch of Fig. These state-run agencies give people access to job listings and career training resources, and registration is mandatory to receive your unemployment insurance benefits. No part of this publication may be reproduced or distributed in any form or by any means, or stored in a database or retrieval system, without the prior written consent of McGraw-Hill Education, including, but not limited to, in any network or other electronic storage or transmission, or broadcast for distance learning. Also assume that these probabilities do not change if information is also provided about the weather before today. When a simulation to identify at least an approximation of an optimal solution. As the owner of the store, Dave would like to learn more about how the status of this stochastic process evolves over time while using the current ordering policy described below. This probability has been set at 80 percent in Probability ToShowUp (F17) since this is the average percentage of those who have shown up for the flight in recent months. Denote the state of the system by (x, y), where x and y, respectively, take on the values 1 or 0 depending upon whether the primary machine (x) and the spare machine (y) are operational (value of 1) or not operational (value of 0) at the end of the day. Although we will mention their optimal solutions that are obtained by the simplex method, the focus here is on how to formulate the linear programming model for these larger problems. 0.5x1 0.5x2 6 0 5 10 x1 Coordinating Technical Office. Because the model and a huge in-memory data store representing current operations. The OR team began by having discussions with upper management to identify management of the study. analysis, but some other relatively elementary techniques now have also been well developed, including particularly the ones presented in the three new sections described above. For the other rows of P, the formula at the end of Sec. Using parameter cells allows you to do the same thing in a more systematic way. This possibility is investigated in Problem 28.9. The scenarios that would lead to a negative cash balance at the end of the 10 years are those where the company's retirement communities fail to achieve full occupancy because of overestimating the demand for this service. (d) Briefly describe how management incentives and enforcement were used in implementing SYSNET. Another long-time friend, Bjarni Kristjansson (who heads Maximal Software), did the same thing for the MPL/Solvers files and MPL tutorial material, as well as arranging to provide a student version of MPL and various elite solvers for the book's website. (b) Find the classes of the Markov chain. (Section 10.2) Directed network A network whose arcs are all directed arcs. Furthermore, the fractions can be different for blast furnaces and for open-hearth furnaces. C (c) Use your IOR Tutorial to determine the state of the Markov chain. Huang, M. Certain symbols are commonly used to denote the various components of a linear programming model. The stage now was set to develop the general framework of the company's plan for pollution abatement. m a11 a21 a12 a22 ... Finally, the material in Chaps. However, this is not always convenient. Students can practice important skills at their own pace and on their o gambling examples, the numeric labeling of the states that the process reaches coincides with the physical expression of the system—i.e., actual inventory levels and the player's holding of money, respectively—whereas the numeric labeling of the states in the weather and stock examples has no physical significance. Melhem: "OMEGA: An Improved Gasoline Blending System for Texaco," Interfaces, 19(1): 85-101, January-February 1990. The structure of the model should then follow the structure of the data cells. As discussed in the preceding section, gathering accurate data frequently is difficult. First, it can help clarify what formula should be entered for an output cell. Thus, in making these calculations for 30, we also obtain 20 and 10. Similarly, models play an important role in science and business, as illustrated by models of the atom, models of genetic structure, mathematical equations describing physical laws of motion or chemical reactions, graphs, organizational charts, and industrial accounting systems. (Section 9.1) Dummy source An imaginary source that is introduced into the formulation of a transportation problem to enable the sum of the demands at the destinations. One special feature in your OR Courseware is a program called OR Tutor. A WEALTH OF SOFTWARE OPTIONS A wealth of software options is provided on the book's website www.mhhe.com/hillier as outlined below: • Excel spreadsheets: state-of-the-art sprea sign is not necessary (and so was not used) when copying down column G since the relative location of column E (two columns to the left) always remains the same. Figure 28.17 displays the Binomial Distribution dialog box that enters this distribution into NumberThatShow (C17) by referencing the parameters TicketsPurchased (E17) and ProbabilityToShowUp (F17). It also has enabled me to closely monitor new trends and developments in the field in order to bring this edition completely up to date. Although some minor flaws undoubtedly remain hidden in the model (and may never be detected), the major flaws have been sufficiently eliminated so that the model now can be reliably used. The Everglade Golden Years Company operates upscale
retirement communities in certain parts of southern Florida. 29.2 for this example, these equations become hil23453 ch29 001-036.gxd 1/22/1970 10:53 PM Page 17 Confirming Pages 29.5 LONG-RUN PROPERTIES OF MARKOV CHAINS 0 0.80 0.61, 1 0.20 0.41, 1 0 1. In addition, many of the problems from the ninth edition have been revised. Frederick S. 14) is continuing to grow. Denote this expectation by ij if ij 1 f (n) n1 if ij 1. Figure 3.3 shows that this line passes through the point (2, 6), indicating that the optimal solution is x1 2 and x2 6. Assad, A. Such problems have a wide variety of constraints (some are resource constraints, and some are neither), so blended problems and cost-benefit-trade-off problems) described earlier in this section. 29.2-1. Such processes are called stochastic processes. As just noted, both states 0 and 3 for the gambling example fit this definition, so they both are absorbing states as well as a special type of recurrent state. To obtain this information, the set of equations presented at the beginning of this section must be solved to obtain f13 and f23. 28.16 In both of these cases, you have seen how well simulation with ASPE can evaluate a particular value of the decision variable by providing a wealth of output for the results cell(s). hil23453\_ch03\_025-092.qxd 1/30/70 7:57 AM 3.4 Final PDF to printer Page 55 ADDITIONAL EXAMPLES 55 In this particular problem, the decisions to be made are well defined, but the appropriate means of conveying this information may require some thought. 2.2 described an OR study done for Continental Airlines that led to the formulation of a huge mathematical model for reassigning crews to flights when schedule disruptions occur. E\* (d) Build a spreadsheet model for reassigning crews to flights when schedule disruptions occur. E\* (d) Build a spreadsheet model for reassigning crews to flights when schedule disruptions occur. E\* (d) Build a spreadsheet model for reassigning crews to flights when schedule disruptions occur. E\* (d) Build a spreadsheet model for reassigning crews to flights when schedule disruptions occur. E\* (d) Build a spreadsheet model for reassigning crews to flights when schedule disruptions occur. E\* (d) Build a spreadsheet model for reassigning crews to flights when schedule disruptions occur. E\* (d) Build a spreadsheet model for reassigning crews to flights when schedule disruptions occur. E\* (d) Build a spreadsheet model for reassigning crews to flights when schedule disruptions occur. E\* (d) Build a spreadsheet model for reassigning crews to flights when schedule disruptions occur. E\* (d) Build a spreadsheet model for reassigning crews to flights when schedule disruptions occur. E\* (d) Build a spreadsheet model for reassigning crews to flights when schedule disruptions occur. E\* (d) Build a spreadsheet model for reassigning crews to flights when schedule disruptions occur. E\* (d) Build a spreadsheet model for reassigning crews to flights when schedule disruptions occur. E\* (d) Build a spreadsheet model for reassigning crews to flights when schedule disruptions occur. E\* (d) Build a spreadsheet model for reassigning crews to flights when schedule disruptions occur. E\* (d) Build a spreadsheet model for reassigning crews to flights when schedule disruptions occur. E\* (d) Build a spreadsheet model for reassigning crews to flights a spreadsheet model for reassigning crews to flig Construction Time Estimates (months) Activity Optimistic Scenario C. (Involving the decision maker from the outset also is essential to build her or his support for the implementation of the study.) By its nature, OR is concerned with the welfare of the entire organization rather than that of only certain of its components. His research was in the stochastic areas of operations research, often at the interface of applied probability and statistics. 10-18. All the other restrictions arise from five net flow constraints, one for each of the five locations. 9. Thus, for the inventory example, where 0 0.286, 1 0.285, 2 0.263, and 3 0.166, the corresponding expected recurrence times are 1 00 3.50 weeks,  $0 \equiv 29.7 \ 1 \ 22$  3.80 weeks, 2 ABSORBING STATES It was pointed out in Sec. Kok, T. In other words, what is P{X(s t) jX(s) i and X(r) x(r)}, for j 0, 1, . The next state visited after state i is independent of the time spent in state i. This work won the 1991 Franz Edelman Award as that year's best application of operations research and management science anywhere throughout the world. 1.5 that your OR Courseware introduces you to four particularly popular commercial software packages—Excel with its Solver, a powerful Excel add-in called Analytical Solver Platform, LINGO/LINDO, and MPL/Solvers—for solving a variety of OR models. (Section 17.2) Number of customers in the system. The total number of customers in the queueing system, either waiting for service to begin or currently being served. The only difference is that the transition probabilities in the diagram are slightly different (0.7 replaces 0.8, 0.3 replaces 0.2, and 0.5 replaces 0.2, and 0.5 replaces 0.8, 0.3 replaces 0.8, replaces both 0.6 and 0.4 in Fig. a1n a2n ... Wyndor's overall measure of performance is the total profit per week from the two products, so the objective is to maximize this guantity. The second column then introduces more general terms for these same components that will fit many linear programming problems. C (d) Find the steady-state probabilities of the state of this Markov chain. In each case, the partners in the project would spend three years with the construction, then retain ownership for three years with the construction, then sell the property in the seventh year. model, (2) build the model, (3) test the model, and (4) analyze the model and hil61217 ch21.qxd 21-22 4/29/04 03:41 PM Page 21-22 CHAPTER 21 THE ART OF MODELING WITH SPREADSHEETS its results. 29.4 that a state k is called an absorbing state if pkk 1, so that once the chain visits k it remains there forever. hil23453 ch28 001-047.qxd Page 16 Confirming Pages CHAPTER 28 EXAMPLES OF PERFORMING SIMULATIONS ON SPREADSHEETS hil23453 ch28 001-047.qxd 1/22/1970 10:51 PM Page 17 Confirming Pages 28.3 CASH FLOW MANAGEMENT 17 FIGURE 28.12 The frequency chart and statistics table that summarize the results of running the simulation model in Fig. Of these two quantities, the less difficult one to determine is the return that would be obtained if everything evolves as currently projected. When there are two or more absorbed into one of these states, it is desirable to find these probabilities of absorption. Which long-term loan amount maximizes Everglade's mean ending balance? 21.1 A CASE STUDY: THE EVERGLADE GOLDEN YEARS COMPANY CASH FLOW PROBLEM This case study involves a problem in cash flow management that the Everglade Golden Years Company faced in late 2009. Also see Selected References 1 and 6 for further details about this history. Factory F2 has just one route to W2 (F2 DC W2) and one to W1 (F2 DC W2) values of the corresponding basic variables are obtained by solving the node constraints. Like the many other demonstration examples accompanying other sections of the book, this computer demonstration for the respective states of a Markov decision process. The right-hand side of a resource constraint represents the amount available of some resource, so the left-hand side must be the righthand side. 1 hil23453\_ch29\_001-036.qxd 1/22/1970 10:52 PM Page 2 CONFIRMING Pages 2 CHAPTER 29 MARKOV CHAINS Stochastic processes are of interest for describing the behavior of a system operating over some period of time. Instead, it is a fixed-requirement constraints and tailed technical analysis of the problem and then presents recommendations to management. Let D1, D2, . What formulas need to be entered? Since the objective is to minimize the total shipping costs, the coefficients for the objective is to minimize the total shipping cost. display data. When leaving state i, the process moves to a state j with probability pij, where the pij satisfy the conditions pii 0 and for all i, hil23453 ch29 001-036.qxd 1/22/1970 10:53 PM Page 28 ChAPTER 29 MARKOV CHAINS M pij 1 for all i. The group doing this review preferably should include at least one individual who did not participate in the formulation of the model. (The discussion assumes that Microsoft Excel is being used, but the same principles also will apply when using other commercially available spreadsheets is more an art than a science. (a) Use the procedure Chapman-Kolmogorov Equations in your IOR Tutorial to find the n-step transition matrix P(n) for n 2, 5, 10, 20. (Section 18.3) Marginal analysis Analysis of the incremental effect of increasing a decision variable by a small amount. InterContinental Hotels Bank One Corporation Merrill Lynch Sasol FAA 1.5 Section Annual Savings ALGORITHMS AND OR COURSEWARE An important part of this book is the presentation of the major algorithms (systematic solution procedures) of OR for solving certain types of problems. 28.22, the binomial distribution is an extension of the Bernoulli distribution for when an event might occur a number of times. Although most routine OR studies provide considerably more modest benefits than the applications summarized in Table 1.1, the figures in the rightmost column of this table do accurately reflect the dramatic impact that large, well-designed OR studies occasionally can have. The model poses the problem in terms of making decisions about the levels of the activities, so x1, x2, . A certain shop has two identical machines that are operated continuously except when they are broken down. To make an absolute reference, either use a range name for the cell (e.g., \$E\$11). After spending half an hour trying different numbers, Sheldon and Julie conclude that the plan in Fig. For example, if a reference to \$E11 in a formula is copied to a new location, the \$E will remain constant,
but the row number will adjust. If FIGURE 28.20 The characteristics and dialog boxes for the uniform distributions in ASPE's Distributions menu. (Section 12.6) Branching variable A variable that the current iteration of a branch-and-bound algorithm uses to divide a subproblem into smaller subproblems by assigning alternative values to the variable. Dr. Lieberman was one of Stanford's most eminent leaders in recent decades. In this section we begin broadening our horizons. For example, LTLoan (D11) and STLoan (D11) and ST pij(t) 0, for all t 0 and all states i and j. A11. It appears that the uniform distribution would be a good fit. (Selected Reference 6 at the end of the chapter provides further background about data mining.) Example. G.: Case Studies in Operations Research: Realistic Applications of Optimal Decision Making, Springer, New York, scheduled for publication in 2014. Emission reduction: 12x1 9x2 25x3 20x4 17x5 13x6 60 35x1 42x2 18x3 31x4 56x5 49x6 150 37x1 53x2 28x3 24x4 29x5 20x6 125 2. The online process isn't just helpful for pandemic safety reasons. 14. (Section 17.2) Waiting cost The cost associated with making customers wait in a queueing system. hil23453 ch29 001-036.gxd 1/22/1970 10:53 PM Page 21 Confirming Pages 29.6 FIRST PASSAGE TIMES 21 The results of this subsection were presented only in terms of the inventory example., n) are the input constants for the model. This monitoring has led to the choice of the major additions to the new edition outlined next. The board of directors has instructed

management to have the engineering staff determine how to achieve these reductions in the most economical way. While one of the benefits of spreadsheets is the flexibility also can be dangerous. Note that all of the functional constraints in this problem are benefit constraints. The extra cross-product term (0.5x1x2) would give the production time wasted in this way. (A link to all these articles is provided on our website, www.mhhe.com/hillier.) For each one, write a one-page summary of the application and the benefits) it provided. Zaider, "Operations Research Advances Cancer Therapeutics," Interfaces, 38(1): 5-25, Jan.-Feb. You then can print out your work and results for your homework. An additional characteristic is that OR frequently attempts to search for a best solution) for the model that represents the problem under consideration. (Section 14.1) Glossaries - 35 Glossary for Chapter 15 Cooperative game A nonzero-sum game where preplay discussions and binding agreements are permitted. What numbers will Web Mercantile require? (b) Find the expected recurrence time for the state (1, 0). {Xt} (t 0, 1, . These additional restrictions are listed in Table 3.17. hil23453 ch03 025-092.qxd 1/30/70 7:57 AM 3.4 Final PDF to printer Page 57 ADDITIONAL EXAMPLES 57 TABLE 3.18 Optimal solution for the Save-It Co. problem Pounds Used per Week Material Grade A 1 412.3 (19.2%) 2587.7 (50%) 0 B C Total 3000 2 859.6 (40%) 517.5 (10%) 0 2149 5175 0 947 This formulation completes the model, except that the constraints for the mixture specifications need to be rewritten in the proper form for a linear programming model by bringing all variables to the left-hand side and combining terms, as follows: Mixture specifications: 0.7xA1 0.3xA2 0.3xA4 0 0.4xA3 0.4xA4 0 0.5xA1 0.5xA2 0.5xA1 0.5xA2 0.2xA3 0.2xA1 0.2xA2 0.2xA3 0.8xA4 0 0.5xB1 0.5xB2 0.5xB3 0.5xB4 0 0.1xB1 0.9xB2 0.1xB3 0.1xB3 0.1xB1 0.1xB1 0.1xB2 0.1xB3 0.1xB3 0.1xB3 0.9xB4 0 0.3xC1 0.7xC2 0.7xC3 0.7xC4 0 1 grade A, material 32 1 grade A, m Glossaries - 22 Project network A network used to visually display a project. To provide you with some structure as you begin learning the art of modeling process depicted in Fig. 3 0.5 1 1-r 0 0.7 1 r r 1-2 r 3 1 The state transition diagram for this example is shown in Fig. This also gives the bad news that there is roughly a 19 percent chance of incurring a loss of some size. What is the required amount for DC? .) has the Markov chain. Each course outlined has been presented at either the undergraduate or graduate level at Stanford University, and this text has been used in basically the manner suggested 0.2 0.8 0 1 0.6 0.4 hil23453 ch29 001-036.qxd 1/22/1970 10:53 PM Page 6 Confirming Pages 6 CHAPTER 29 MARKOV CHAINS Formulating the Inventory example as a Markov Chain Returning to the inventory example as a Markov Chain Returning to the inventory example as a Markov Chain Returning to the inventory example as a Markov Chain Returning to the inventory example developed in the preceding section, recall that Xt is the number of cameras in stock at the end of week t (before ordering any more), so Xt represents the state of the system at time t (the end of week t). Sensitivity analysis then was conducted to explore the effect of any inaccuracies in the cost data given in Table 3.14. What is the nature of this remarkable tool, and what kinds of problems does it address? x2 5 4 3 2 1 0 1 2 3 4 5 6 7 x1 hil23453\_ch03\_025-092.qxd 1/30/70 30 7:57 AM CHAPTER 3 Final PDF to printer Page 30 INTRODUCTION TO LINEAR PROGRAMMING x2 10 3x1 2x2 18 8 x1 4 2x2 12 6 4 Feasible region 2 FIGURE 3.2 Shaded area shows the set of permissible values of (x1, x2), called the feasible region. On nearly all of hil23453\_ch28\_001-047.qxd 1/22/1970 10:51 PM Page 27 Confirming Pages 28.5 REVENUE MANAGEMENT IN THE TRAVEL INDUSTRY FIGURE 28.18 The frequency charts and statistics tables that summarize the results for the respective results cells—Profit (F23), NumberOfFilledSeats (C20), and NumberDeniedBoarding (C21)—from running the simulation model in Fig. (a) Refine the search by generating a parameter analysis report for this bidding problem that considers all bids between \$5.2 million. He received several teaching awards at Stanford, including the university's prestigious Walter J These equations also must hold if Xt1 0 is replaced by Xt1 1. (Section 10.7) Node A junction point of a network, shown as a labeled circle. The six values automatically are distributed evenly over the range specified in Fig. As you work through the examples in Sec. The definition of a Markov chain given in Sec. If successful, the new system may be used for years to come. In particular, this model is to select the values for x1, x2, . Taylor, P. R. The Likelihood box in the first statistics table reveals that 98.6 percent of the trials resulted in a positive profit. The latter case is referred to as having an unbounded Z or an unbounded Z or an unbounded by a streamlined version of the simplex method for solving minimum cost flow problems very efficiently. J.: Markov Chains and Decision Processes for Engineers and Managers, CRC Press, Boca Raton, 2011. He was both an engineer (having received an undergraduate degree in mechanical engineers) and an operations research statistician (with a engineer statistic) and the engineer (having received an undergraduate degree in mechanical engineers) and Decision Processes for Engineers and Managers, CRC Press, Boca Raton, 2011. He was both an engineer (having received an undergraduate degree) and the engineers and Managers (having received an undergraduate degree) and the engineers and Managers (having received an undergraduate degree) and the engineers (having received an undergraduate degree) are the engineers (having received an undegree) are the engineers (h an AM from Columbia University in mathematical statistics, and a PhD from Stanford University in statistics)., Xt1 kt1, Xt 1} P{Xt1 0Xt 1} for t 0, 1, . MPL is a user-friendly modeling system that includes a considerable number of elite solvers for solving such problems very efficiently. These are some of the reasons for the tremendous impact of linear programming in recent decades. Operations research (OR) is the technological engine that drives this company. Therefore, the objective cell to be maximized is EndBalance (J21), and the changing cells are the loan amounts LTLoan(D11)andSTLoan(E11:E20). Occasionally, the degree of uncertainty in the parameters is too great to be amenable to sensitivity analysis alone. For example, if the dose level at the entry point for beam 1 is 1 kilorad, then an average of 0.4 kilorad will be absorbed by the entire healthy anatomy in the two-dimensional plane, an average of 0.3 kilorad will be absorbed by the various parts of the tumor, and 0.6 kilorad will be absorbed by the center of the tumor. hil23453 ch03 025-092.qxd 28 1/30/70 7:57 AM Final PDF to printer Page 28 CHAPTER 3 INTRODUCTION TO LINEAR PROGRAMMING TABLE 3.1 Data for the Wyndor Glass Co. problem Production Time per Batch, Hours Product Plant 1 2 Production Time Available per Week, Hours 1 2 3 1 0 3 0 2 2 4 12 18 Profit per batch \$3,000 \$5,000 Formulation as a Linear Programming Problem The definition of the respective products to be made are the number of batches of the respective products to be made are the number of batches of the respective products to be made are the number of batches of the respective products to be made are the number of batches of the respective products to be made are the number of batches of the respective products to be made are the number of batches of the respective products to be made are the number of batches of the respective products to be made are the number of batches of the respective products to be made are the number of batches of the respective products to be made are the number of batches of the respective products to be made are the number of batches of the respective products to be made are the number of batches of the respective products to be made are the number of batches of the respective products to be made are the number of batches of the respective products to be made are the number of batches of the respective products to be made are the number of batches of the respective products to be made are the number of batches of the respective products to be made are the number of batches of the respective products to be produced per weak so as to maximize their total profit. Continental Airlines," Interfaces, 33(1): 5-22, Jan.-Feb. Plotting a frequency chart for these data suggests that they roughly follow a bellshaped curve. ij and M j 1. Since each decision variable represents the level of some activity, it is being assumed that the activities can be run at fractional levels. (Section 20.6) Fixed-time incrementing A time advance method that always advances the simulation clock by a fixed amount. Green Earth has raised contributions and grants, amounting to \$30,000 per week, to be used exclusively to cover the entire treatment cost for the solid waste materials. procedures just listed (or other equivalent routines) to solve the problem. Hillier Stanford University ([email protected]) May 2013 hil23453 ch01 001-009.qxd 1/15/70 7:40 AM Final PDF to printer Page 1 1 C H A P T E R Introduction 1.1 THE ORIGINS OF OPERATIONS RESEARCH Since the advent of the industrial revolution, the world has seen a remarkable growth in the size and complexity of organizations. Let's say Everglade takes a long-term loan of \$6 million, and then adds short-term loans of \$2 million in 2015. Make sure that the Monte Carlo sampling method is chosen in Simulation Options. (Section 13.7) Concave function that is always "curving downward" (or not curving at all), as defined further in Appendix 2. (Section 17.2) Waiting time in the system both before service begins and during service. The answers to these questions can quickly lead you to the heart of the problem and
help get the modeling process started. Then, since the cash flow, loan amounts, FIGURE 21.2 Sketch of the spreadsheet for Everglade's cash flow problem. A number of Excel templates for solving basic models. The disadvantage of this distribution is that it usually is only a rough approximation of the true distribution. Net flow constraints: xF1-F2 xF1-DC xF1-W1 xF1-F2 xF1-DC 50 1factory 12 xF2-DC xF2-DC xF2-DC xF2-W1 40 1factory 22 0 1distribution center 2 xW1-W2 xW2-W1 30 1warehouse 1 2 xDC-W2 xW1-W2 xW2-W1 60 1warehouse 22 2. The number of filled seats. Because some shifts are less desirable than others, the wages specified in the contract differ by shift. In the late 1990s, full-service financial services firms came under assault from electronic brokerage firms offering extremely low trading costs. When purchasing, this is the administrative cost of ordering. Therefore, the objectives that are formulated ideally should be those of the entire organization. In particular, if i and j are recurrent states belonging to different classes, then p(n) ij 0, for all n. The Likelihood box in the statistics table reveals that 81 percent of the trials resulted in a positive net present value. Each pair (a) Visualize where you want to finish. If you have this textbook but you aren't enrolled in a course, call 775-831-0300 and press 0 for assistance with the software. Using this plan-build-test-analyze process should yield a spreadsheet model, but it doesn't guarantee that you will obtain a good one. Proportionality is an assumption about both the objective function and the functional constraints, as summarized below. (c) Now use the result given in Prob. (Section 7.4) Stochastic programming model A model that includes one or more random variables among its parameters and then seeks a solution that will perform well on the average. C (b) Find the probability distribution of the state of this Markov chain n weeks after the new inventory policy is instituted, for n 2, 5, 10. 29.2-2. The reduced cost for a basic variable automatically is 0. The objective for a blending problem is to find the best blend of ingredients into final products to meet certain specifications. McGowan, and A. Nearly half of these increased revenues came from the use of a new overbooking model. An 1 S. Calculus is used only in Chap. (Section 12.8) MIP An abbreviation for mixed integer programming, defined below. One way of summarizing the usual (overlapping) phases of an OR study is the following: 1. This edition continues to provide the option • • • • of using Excel and its Solver (a product of Frontline Systems, Inc.) to formulate and solve some operations research (OR) models. The main restrictions on the values of these decision variables are that the number of agents working during each time period must satisfy the minimum requirement given in TABLE 3.19 Data for the Union Airways personnel scheduling problem Time Periods Covered Shift Time Periods 1 6:00 P.M. to 4:00 P.M. to 8:00 P.M. to 8:00 P.M. to 10:00 A.M. to 10:00 P.M. to 8:00 P.M. to 8:00 P.M. to 8:00 P.M. to 10:00 A.M. P.M. 10:00 P.M. to midnight Midnight to 6:00 A.M. < < < Daily cost per agent \$170 2 < < < \$160 3 < < < \$180 5 Minimum Number of Agents Needed < \$180 5 Minimum Number of Agents Needed < \$180 5 Minimum Number of Agents \$195 hil23453 ch03 025-092.qxd 1/30/70 7:57 AM 3.4 Final PDF to printer Page 59 ADDITIONAL EXAMPLES 59 the rightmost column of Agents Needed < < \$180 5 Minimum Number of Agents Needed < < \$180 5 Minimum Number of Agents Needed < < \$180 5 Minimum Number of Agents Needed < < \$180 5 Minimum Number of Agents Needed < < \$180 5 Minimum Number of Agents Needed < < \$180 5 Minimum Number of Agents Needed < < \$180 5 Minimum Number of Agents Needed < < \$180 5 Minimum Number of Agents Needed < < \$180 5 Minimum Number of Agents Needed < < \$180 5 Minimum Number of Agents Needed < < \$180 5 Minimum Number of Agents Needed < < \$180 5 Minimum Number of Agents Needed < < \$180 5 Minimum Number of Agents Needed < < \$180 5 Minimum Number of Agents Needed < < \$180 5 Minimum Number of Agents Needed < < \$180 5 Minimum Number of Agents Needed < < \$180 5 Minimum Number of Agents Needed < < \$180 5 Minimum Number of Agents Needed < < \$180 5 Minimum Number of Agents Needed < < \$180 5 Minimum Number of Agents Needed < < \$180 5 Minimum Number of Agents Needed < < \$180 5 Minimum Number of Agents Needed < < \$180 5 Minimum Number of Agents Needed < < \$180 5 Minimum Number of Agents Needed < < \$180 5 Minimum Number of Agents Needed < < \$180 5 Minimum Number of Agents Needed < < \$180 5 Minimum Number of Agents Needed < < \$180 5 Minimum Number of Agents Needed < < \$180 5 Minimum Number of Agents Needed < < \$180 5 Minimum Number of \$180 5 Minim Table 3.19. Each arrow represents a feasible shipping lane. (Section 16.2) Backward induction procedure for solving a decision analysis problem by working backward through its decision tree. At any point, Julie also will have the option of returning to the company's bank to try to arrange another long-term loan for the remainder of the 10 years at a lower interest rate than for short-term loans. Briefly describe the various kinds of changes involved. Plumbing H. (Section 14.2) Metaheuristic A general solution method to fit a particular kind of problem. 7. D. However, the triangular distribution also has certain disadvantages. The McGraw-Hill editorial team and I think that the net effect of the revision has been to make this edition even more of a "student's book"—clear, interesting, and well-organized with lots of helpful examples and illustrations, good motivation and perspective, easy-to-find important material, and enjoyable homework, without too much notation, terminology, and dense mathematics. for all i and j. The overall equation thereby states that the rate at which the process leaves state j must equal the rate at which the process leaves state j. (c) Briefly describe the preimplementation test of Optimizer. (Section 16.6) Risk-neutral individual An individual whose utility function for money is proportional to the amount of money involved. Upon receiving his PhD degree, he joined the faculty of Stanford University and began work on the 1st edition of this textbook two years later. The chi-square test also has been selected for the ranking method. State 0 1 2 3 1 1 1 0 0 3 3 3 1 1 1 1 1 31 009.qxd 2 1/15/70 7:40 AM CHAPTER 1 Page 2 Final PDF to printer INTRODUCTION When the war effort spurred interest in applying OR outside the military as well. (Section 12.6) Set covering problem A type of pure BIP problem A type of pure collectively possess each of a number of characteristics at least once. By the end of April, a staggering 30 million Americans had filed for unemployment benefits. The subsequent examples become progressively more challenging. It also included carefully updating both the application vignettes and selected references for each chapter. n t1 By using the result that 1 n lim p(k) j, ij n - n k1 it can be shown that the (long-run) expected average cost per unit time is given by M 1 n lim E C(Xt) jC(j). However, it does not imply that practical OR studies are primarily mathematical exercises. DeWitt, C. (Section 14.3) Glossaries - 34 Steepest ascent/mildest descent approach An algorithmic approach that seeks the greatest possible improvement at each iteration but also accepts the best available. Pidd, M.: "Just Modeling," Interfaces, 29(2):118-132, March-April 1999. The adjective linear means that all the mathematical functions in this model are required to be linear functions. (Section 10.8) Activity-on-arc (AOA) project network A project network A project network A project network a model in OR. The chief operating officer (COO) has asked you to do some spreadsheet modeling with these data to analyze what the product Year Project A Project B Project C mix should be for the coming week and make a recommendation. However, both models have only two variables, so this new problem also can be solved by the graphical method illustrated in Sec. The only possible values are nonnegative integers: 0, 1, 2. (Section 17.10) Waiting time in the queue The elapsed time that an individual customer spends in the queue waiting for service to begin. In 2008, he joined the University of Zurich, where he currently teaches courses in management science, spreadsheet modeling, and computational economics and finance. 6 (Duality Theory), Chap. The new Section 7.4 introduces the robust optimization approach when dealing with linear programming problems. In particular, the demand in the next year ticipate in each project either fully, fractionally (with other develis expected to be 3,000, 4,000, 8,000, and 7,000 pairs of boots in opment partners), or not at all. Dr. Hillier has held many leadership positions with the professional societies in his field. Integrate grade reports easily with Learning Management Systems (LMS), such as WebCT and Blackboard—and much more. For example, just how does Julie keep track of the cash balances in the Everglade cash flow problem? Starting at time 0 and letting the time parameter t run continuously for t 0, we let the random variable X(t) be the state of the system at time t. The equations entered into all the output cells, results cells, and statistic cells are given at the bottom of Fig. (b) Referring to p. Thus, the ending Balance (2014) ST Loan year 2015 are a little more complicated. The next step is to construct a scientific (typically mathematical) model that attempts to abstract the essence of the real problem. A large amount of computation is usually required to deal most effectively with the complex problems typically considered by OR. In a finite-state Markov chain, recurrent states that are aperiodic are called ergodic states. 29.5. C (a) Find the steady-state probabilities of the state of this Markov chain. 1.4 THE IMPACT OF OPERATIONS RESEARCH Operations research has had an
impressive impact on improving the efficiency of numerous organizations around the world. States 0 and 3 are examples of what are called an absorbing state (a state that is never left once the process enters that state). These crops differ primarily in their expected net return per acre and their consumption of water. In the gambling example (end of Section 29.2), starting in state 1, it is possible for the process to enter state 1 only at times 2, 4, . It is even possible that two or more completely different types of models may be developed to help analyze the same problem. New with this edition of the textbook is a powerful software package from Frontline Systems called Analytic Solver Platform for Education (ASPE), which is fully compatible with Excel and Excel's Solver. A continuous distribution is used if any values are possible, including both integer and fractional numbers, over the entire range of possible values. Furthermore, if concerns arise in the future about the model, this documentation will be helpful in diagnosing where problems may lie. (Section 10.7) Glossaries - 19 Connected if the network contains at least one undirected path between them. formulate a spreadsheet model to analyze the problem. When we began work on the book 50 years ago, Jerry already was a prominent member of the field, a successful textbook writer, and the chairman of a renowned operations research program at Stanford University. Determining the appropriate values to assign to the parameters of the model (one value per parameter) is both a critical and a challenging part of the model-building process. The dark figure in each dialog box displays a typical probability density function for that distribution. Now that the data have been gathered, the OR group decides to begin its analysis by investigating the option of increasing the number of reservations to accept for this flight to 190, since 80 percent of 190 152, which is very close to the number of seats of available (150). 29.4 indicates that both states 1 and 2 are transient states sooner or later to enter either state 0 or state 3 and then will remain in that state forever. Others want an even more applied course, with emphasis on applications and the role of OR in managerial decision making. In particular, let f (n) ij denote the probability that the first passage time from state i to j is equal to n. A computer is inspected at the end of every hour. This quadratic function also is normally assumed to be a concave function (when maximizing) or a convex function (when minimizing). Additionally, if your application is denied for any reason, you have the right to file an appeal to try to overturn the denial. Step 3: Verify Your Identity During the initial application process, each state's unemployment division will ask you to verify and authenticate your identity. emergence of powerful spreadsheet technology in recent years now provides an alternative way of displaying a mathematical model for a problem that is small enough to fit comfortably into a spreadsheet. In this section we discuss the general characteristics of linear programming problems, including the various legitimate forms of the mathematical model for linear programming. relative and absolute references. At the end of period n, if Zn 1, an order is placed for 2m units, where m is the smallest integer such that Zn 2m 1. Please give the course code, plus the instructions below, to your students. This is a rather unusual property for a probability distribution to possess. Thus, the data cells in the Wyndor problem are given the range names UnitProfit (C4:D4), HoursUsedPerBatchProduced (C7:D9), and HoursAvailable (G7:G9). Electrical G. The distribution network available for shipping this product is shown in Fig. After choosing Parameter Analysis from the Reports>Simulation menu on the ASPE ribbon, the corresponding dialog box in Fig. Determine the period of each of the states in the Markov chain that has the following (one-step) transition matrix. Table 3.17 gives the quantities available for collection and treatment, for each type of material. Using the toggle feature in Excel once more will restore the view of the spreadsheet shown in Fig. This indicates that the most likely times are short ones well below the mean but that very long times also are possible. Mathematical models have many advantages over a verbal description of the problem. For each one, read this article and write a one-page summary of the application and the benefits (including nonfinancial benefits) it provided. 17 on queueing theory, you hopefully will recall that the most commonly used queueing models assume that the time between consecutive arrivals of customers to receive a particular service has an exponential distribution. 10.2) that records the progress of a branchand-bound algorithm in partitioning an integer programming problem into smaller and smaller subproblems. The time required to repair a machine has an exponential distribution with a mean of 1 day. The third functional constraint, where the right-hand side represents the benefit achieved. Before attempting to construct a linear programming model, we must give careful consideration to the proper definition of the decision variables. Earl, "An Optimization Framework for Conformal Radiation Treatment Planning," INFORMS Journal on Computing, 19(3): 366-380, Summer 2007. Because of this close and growing tie between the two disciplines, it has become important to describe this relationship and to put it into perspective in an introductory OR course. (Section 10.8) CPM method of time-cost trade-off between the total cost of a project and its duration when various levels of crashing are used to reduce the duration. The data from Table 3.7 can then be used directly to formulate the following linear programming model.4 Minimize Z 0.4x1 0.5x2 , subject to 0.3x1 0.1x2 2.7 0.5x1 0.5x2 6 o.6x1 0.4x2 6 and x1 0, x2 0. One is that the triangular distribution has a fixed minimum value, whereas the normal distribution allows rare extreme values far into the tails. Then, when you are ready to undertake the building step, it is a good idea to start by building a small, readily manageable version of the model to full-scale size. Since sales between 20 thousand, the weights for the values  $\{10, 20, 30, 40\}$  are entered as  $\{3, 1, 1, 3\}$ . (Section 16.2) Node A junction point in a decision tree. hil23453 ch03\_025-092.qxd 1/30/70 7:57 AM 3.2 Final PDF to printer Page 37 THE LINEAR PROGRAMMING MODEL 37 (4, 1), Z x2 10 (4, 10), Z 52 (4, 6), Z 42 6 FIGURE 3.6 The Wyndor Glass Co. problem would have no optimal solutions if the only functional constraint were x1  $\leq$  4, because x2 then could be increased indefinitely in the feasible region without ever reaching the maximum value of Z 3x1 5x2. 29.4-1. This overall measure might be abstract (e.g., utility). A variety of scenarios (e.g., an extremely dry year or an extremely wet year) also were analyzed, with appropriate probabilities assigned. 7.2). Any situation whose mathematical formulation fits this model is a linear programming problem. Wright, P. Our case writers, Karl Schmedders and Molly Stephens (both graduates of our department), wrote 24 elaborate cases for the 7th edition, and all of these cases continue to accompany this new edition. 0.5 and suc 5) gives the distribution of the number of flips until heads have occurred five times. These references do not change when they are filled into other cells. (Section 14.4) Random number A random observation from a uniform distribution between 0 and 1. This study led to a worldwide global optimization (GO) program for the company. Section 7.5 describes how this important idea is implemented. 1 Selected Reference 7 provides an entertaining history of operations from the company. 1564 to 2004 that influenced the subsequent development of OR. There are a wide variety of other applications. For example, he has served as treasurer of the Operations Research Society of America (ORSA), vice president for meetings of TIMS, co-general chairman of the 1989 TIMS International Meeting in Osaka, Japan, chair of the TIMS Publications Committee, chair of the ORSA Resources Planning Committee, chair of the ORSA/TIMS Combined Meetings Committee, and chair of the John vor Committee for INFORMS. In each case, the individual contributions from the products are just as assumed in Sec. Consider the following blood inventory problem facing a hospital. Spreadsheet models also were formulated in several other chapters. 28.19 shows the dialog box for three products are just as assumed in Sec. distributions from the Common submenu of the Distributions menu. Instead, a number of attractive alternatives were identified, analyzed, and compared. Some fads come and go, but this appears to be a permanent shift in the direction of OR in the coming years. IOR Tutorial also includes a number of other helpful procedures, including some of the provide graphical displays of how the solution provided by an algorithms automatically and several procedures that provide displays of how the solution provided by an algorithm varies with the data of the problem. Miller: Elements of Applied Stochastic Processes, 3rd ed., Wiley, New York, 2002. Case 2 in Table 3.5 also violates the additivity assumption because of the extra term in the corresponding objective function, Z 3x1 5x2 x1x2, so that Z 3 5 1 7 for (x1, x2) (1, 1). Through their research on how to better manage convoy and antisubmarine operations, they also played a major role in winning the Battle of the North Atlantic. 21.5. Her next step is to submit to her CEO, Sheldon Lee, a report that recommends the plan obtained by this model. Often T is taken to be the set of nonnegative integers, and Xt represents a measurable characteristic of interest at time t. Batavia, J. Steady-State Probabilities for a discrete time Markov chain satisfy the ChapmanKolmogorov equations, the
continuous time transition probability function also satisfies these equations. However, this is not true for all Markov chains. A production process contains a machine that deteriorates rapidly in both quality and output under heavy usage, so that it is inspected at the end of each day. Therefore, this leading OR society now includes an annual Conference on Business Analytics and Operations Research among its major conferences. paper) 1. We then return to the example analyzed in Sec. A video cassette recorder fails within 2 years. 2.3). An Inventory Example Dave's Photography Store has the following inventory problem. To circumvent this disadvantage of retrospective testing, it is sometimes useful to further test the model by continuing the status quo temporarily. We recommend to instructors that they point out this important learning aid to their students. He also won the Outstanding Sophomore testing, it is sometimes useful to further test the model by continuing the status quo temporarily. Debater award, played in the Stanford Woodwind Quintet and Stanford Symphony Orchestra, and won the Hamilton Award for combining excellences. For the Everglade problem, these would include some data cells (interest rates, starting balance, minimum balances, and cash flows), some changing cells (loan amounts), and a number of output cells (interest payments, loan paybacks, and ending balances). Introduction to ive sar r Frederick S. For example, Xt might represent the inventory level of a particularly important type that is studied in the next several chapters is the linear programming model, where the mathematical functions appearing in both the objective function and the constraints are all linear functions. Freddie purchases copies from his distributor early each morning. Click the Downloaded file (SolverSetup.exe or SolverSetup.exe) are necessary to obtain analytical results. The interest payments start one year after the loans. ) denote the amount of inventory on hand minus the number of units backlogged before ordering at the end of period n (Z0 0). hil23453\_ch03\_025-092.qxd 1/30/70 48 7:57 AM CHAPTER 3 Final PDF to printer Page 48 INTRODUCTION TO LINEAR PROGRAMMING x2 15 0.6x1 0.4x2 6 10 (6, 6) 5 (7.5, 4.5) Z 5.25 0.4x1 0.5x2 0.3x1 0.1x2 2.7 E FIGURE 3.12 Graphical solution for the design of Mary's radiation therapy. 2.3, one purpose is to identify the sensitive parameters (those whose value cannot be changed without changing the optimal solution), since any later change in the value of a sensitive parameter immediately signals a need to change the solution being used., M, and p (t) d qij pij(0) lim ij qi pij, t→0 dt t for all j i, where pij (t) is the continuous time transition probability described in property 2 of the preceding paragraph. (Section 18.2) Discount rate The rate at which future income over time loses its current value because of the time value of money. Davenport, T. As summarized in Table 3.3, the TABLE 3.3 Data needed for a linear programming model involving the allocation of resources to activities Resource Usage per Unit of Activity Resource 1 2 ... (Section 18.7) No backlogging The situation where excess demand either must be met through a priority replenishment of inventory or it will be lost. Many students also might find these additional examples helpful when preparing for an examination. The random variable Ti has an exponential distribution with a mean of 1/qi. maximum can be entered as a list inside of curly brackets. Through a hil23453\_fm\_i-xxx.qxd xxviii 1/30/70 7:58 AM Page xxviii Final PDF to printer PREFACE series of adaptive questions, LearnSmart pinpoints concepts the student does not understand and maps out a personalized study plan for success. However, the complication in this case is that our company's management has learned that another firm is developing a competitive product. 3-20 and 30-32.) (a) Summarize the background that led to undertaking this study. (Section 17.2) Service time The elapsed time from the beginning to the end of a customer's service. These are the kinds of questions that need to be addressed by the members of management who are responsible for making the decisions. A second factor that gave great impetus to the growth of the computer revolution. They might want to emphasize the mathematical models throughout this book. (Section 12.4) Subproblem A portion of another problem that is obtained by eliminating a portion of the feasible region, perhaps by fixing the value of one of the variables. (Section 11.2) Stages A dynamic programming problem is divided into stages, where each stage involves making one decisions that comprise the overall problem. For Excel 2007, always download SolverSetup. (c) Referring to pp. Ahuja, J. Fortunately, ASPE provides a way to systematically perform multiple simulations by using parameter cells. Y.: The Science of Decision Making: A Problem-Based Approach Using Excel, Wiley, New York, 2002. The company's current product lines consist of end tables, coffee \* tables, and dining room tables. In other words, the probability is 0.005 that the digit being transmitted will be recorded with the opposite value at the end of the transmission. A disadvantage of these other models is that the algorithms available for solving them are not nearly as powerful as those for linear programming, but this gap has been closing in some cases. (Section 18.2) Demand The demand for a product in inventory is the number of units that will need to be withdrawn from inventory for some use (e.g., sales) during a specific period. (a) Construct the (one-step) transition matrix of the Markov chain. (Section 9.4) Parameter table A table that displays all the parameters of a transportation problem, so the table provides a complete formulation of the problem. Two features account for this success. We begin by surveying the characteristics of many of the 46 distributions and how these characteristics help to identify the best choice. 7), the parameter analysis reports in simulation models work in much the same way. Now, sadly, Jerry is no longer with us. Consider the Markov chain that has hil23453 ch03 025-092.qxd 56 1/30/70 7:57 AM Final PDF to printer Page 56 CHAPTER 3 INTRODUCTION TO LINEAR PROGRAMMING so 0.7xA1 0.3xA2 0.3xA4 0, which is a legitimate linear programming constraint. FIGURE 29.1 The state transition diagram for the weather example. , xn) is called a solution, regardless of whether it is a desirable or even an allowable choice. If the transition probabilities are independent of s, so that P{X(t) jX(s) i} P{X(t) receive a complimentary print review copy in 3-5 business days or a complimentary electronic review copy (eComp) via e-mail in minutes. Student versions of LINDO and LINGO now can be downloaded free from the Web at www.lindo.com. Therefore, the group estimates that the number of reservation requests per flight has a normal distribution with a mean of 195. Kumar, "A New Linear Programming Approach to Radiation Therapy Treatment Planning Problems," Operations Research, 54(2): 201-216, March-April 2006. (Section 10.5) Residual network that shows the remaining arc capacities for assigning additional flows after some flows have been assigned to the arcs by the augmenting path algorithm for a maximum flow problem. i0 However, the following steady-state equations provide a more useful system of equations for solving for the steady-state equations for solving for j 0, 1, . Suppose that this amortization were done and that the total start-up cost amounted to reducing Z by 1, but that the profit without considering the start-up cost would be 3x1. A9. pages cm Includes bibliographical references and indexes. Certainty Our last assumption concerns the parameters of the model, namely, the coefficients in the objective functional constraints bi. 21.4 for debugging a spreadsheet model. Formulation as a Linear Programming Problem. The goal of this section is to provide some guidelines that will help you create "good" spreadsheet models. Management recognizes the need for cost control while also consistently providing a satisfactory level of service to customers. It was a wonderful opportunity for me to work with and to learn from the master. Furthermore, whenever the process moves from one of these states to the other one, it always will return to the original state eventually. The one maintenance person still must maintain all the machines. (Section 20.6) Pseudo-random numbers A term sometimes applied to random numbers generated by a computer because such numbers are predictable and reproducible. n → n t1 j0 Application to the Inventory Example. In both the weather and inventory examples, all states communicate. All four packages include the simplex method for solving linear programming models. (one-step) transition matrix for this Markov chain. However, producing both products would require switching the production of one product and setting up for the other. These distributions are not as widely used in simulations, so they will not be discussed further. However, it needs to be recognized that these solutions are optimal only with respect to the model being used. Column H is blank because the long-term loan does not need to be repaid until 2024. (Section 12.5) Minimum cover of a constraint refers to a group of binary variables that satisfy certain conditions with respect to the constraint during a procedure for generating cutting planes. (Section 16.7) Maximum likelihood criterion A criterion for decision making with probabilities that focuses on the most likely state of nature. Each new loan can be used to help repay the loan for the preceding year if needed. hil23453 ch29\_001-036.qxd 1/22/1970 10:53 PM Page 14 Confirming Pages 14 CHAPTER 29 MARKOV CHAINS A state is said to be a recurrent state if, upon entering this state, the process definitely will return to this state again. By plugging in a long-term loan of \$6 million, along with
short-term loans of \$2 million in 2014 and \$5 million in 2015, into a completed spreadsheet the ending balances should be the same as calculated above. Unfortunately, despite its helpful logical approach, there is no guarantee that the planbuild-test-analyze process will lead to a "good" spreadsheet model. We will illustrate this feature next by returning to the example involving Freddie the newsboy that was presented in Sec. Select one of the applications of operations research listed in Table 1.1. Read the article that is referenced in the application vignette presented in the problem in its entirety and considering all its interrelationships simultaneously. 28.13). hil23453 ch29 001-036.qxd 1/22/1970 10:53 PM Page 18 Confirming Pages 18 CHAPTER 29 MARKOV CHAINS Thus, the probability of finding the process in a transient state after a large number of transitions tends to zero. Kanaley, Y. (Section 17.9) Lack of memory property When referring to arrivals, this property is that the remaining time until the next arrival is completely uninfluenced by when the last arrival occurred. 10.6, where we focus on linear programming problems of this type (called the minimum cost flow problem). I.: Adventures in Stochastic Processes, Birkhäuser, Boston, 1992. (Section 13.10) Gradient algorithms that modify the gradient search procedure to keep the search procedure from penetrating any constraint boundary. If the time between consecutive events has an exponential distribution. However, the cash balances are a result of how much is borrowed, how much is paid, and all of the other cash flows , xn 0. This kind of process is referred to as being a discrete time stochastic process with a finite state space. For your convenience, we also have included this student version (including the six solvers just mentioned) in your OR Courseware. (b) Formulate the evolution of the weather as a Markov chain by defining its states and giving its (one-step) transition matrix. Suppose that the process enters state i at time t s. Refer first to the Case 1 column in Table 3.4. This case would arise if there were start-up costs associated with initiating the product 1. You also might find these supplementary examples helpful when preparing for an examination. (Section 10.8) Arc A channel through which flow may occur from one node to another. (Sections 10.3 and 10.4) Length of a path through a project network The sum of the (estimated) durations of the activities on the path. By contrast, the next two columns show hypothetical cases where the additivity assumption). Hillier and Mark S. This process of problem definition is a crucial one because it greatly affects how relevant the conclusions of the study will be. On the other hand, combining all three methods at full capacity on both types of furnaces (which would be prohibitively expensive if the company's TABLE 3.12 Clean air standards for the Nori & Leets Co. Pollutant Particulates Sulfur oxides Hydrocarbons 6 Required Reduction in Annual Emission Rate (Million Pounds) 60 150 125 This particular abatement method has become a controversial one. If either produced by itself, this machinery and equipment would be dedicated to this one use. , respectively. Let X0 represent the number of cameras on hand at the outset, X1 the number of cameras on hand at the end of week 1, X2 the number of cameras on hand at the end of week 2, and so on, so the random variable Xt (for t 0, 1, 2, . 18.8, one of the most prominent areas for the application of operations research in recent years has been in improving revenue management in the travel industry. 13 (Nonlinear Programming) and in one example in Chap. (d) Build a spreadsheet model and then solve it. 28.13. Fortunately, there is another way of defining the decision variables that will fit the linear programming format. If the linear programming format. to more fully meet the needs of today's students. Then move the ruler with fixed slope through the feasible region in the direction of improving Z. 11. This project will require completing all of the activities in the above table. decision variables (so the graphical method cannot be used), the simplex method described in Chap. Given that the first transition is to some state k (k j) instead, which occurs with probability pik, the conditional expected first passage time from state i to state j is 1 kj. Ask your McGraw-Hill Representative for more detail and check it out at www.mcgrawhillconnect.com/engineering. Thus, the stochastic process {Xt} {X0, X1, X2, . (e) What was the resulting impact on Merrill Lynch's competitive position? hil23453\_ch02\_010-024.qxd 1/15/70 7:34 AM Final PDF to printer Page 10 2 C H A P T E R Overview of the Operations Research Modeling Approach T he bulk of this book is devoted to the mathematical methods of operations research (OR). For either type of furnace, the emission reduction achieved by each method is not substantially affected by whether the other methods also are used. Therefore, the state space consists of the four states (2, 0), (1, 0), (0, 1), and (1, 1). (Section 10.2) Connected network A network where every pair of nodes is connected. Therefore, the engineers concluded that they would have to use some combination of the methods, perhaps with fractional capacities, based upon the relative costs. We will discuss absorbing states further in Sec. Think about what output cells LTLoan should impact directly. (See Selected Reference 3 for a detailed discussion.) Since the OR team may spend months developing all the detailed pieces of the model, it is easy to "lose the forest for the trees." Therefore, after the details ("the trees") of the initial version of the model are completed, a good way to begin model validation is to take a fresh look at the overall model ("the forest") to check for obvious errors or oversights. This asymmetry provides additional flexibility to the triangular distribution. (Section 15.2) Graphical method of solving a two-person, zero-sum game with mixed strategies such that, after dominated strategies are eliminated, one of the two players has only two pure strategies. (Section 13.3) Glossaries - 31 Linearly constrained optimization problems Nonlinear programming problems where all the constraint functions (but not the second equation is the same, except in terms of state 1. (Section 12.9) Incumbent The best feasible solution found so far by a branch-and-bound algorithm Some functional constraints with a greater-than-or-equal-to inequality: ai1x1 ai2x2 . P.: Model Building in Mathematical Programming, 5th ed., Wiley, Hoboken, NJ, 2013. A Markov chain is said to be ergodic if all its states are ergodic states. hil61217 ch21.qxd 4/29/04 03:41 PM Page 21-13 21.3 SOME GUIDELINES FOR BUILDING "GOOD' SPREADSHEET MODELS 21-13 After running Solver, the optimal solution is shown in Fig. (Introduction) Local improvement procedure A procedure that searches in the neighborhood of the current trial solution. (a) What is the problem being addressed? McGraw-Hill SmartBook<sup>™</sup> Powered by the intelligent and adaptive LearnSmart engine, SmartBook is the first and only continuously adaptive reading experience available today. If state i communicates with state k, then state i communicates with state i communicates with state i communicates with state i communicates with state k. chooses the decision criterion that provides the best guarantee for its minimum possible payoff. 1998. O'Keefe: "Let the Needles Do the Talking! Evaluating the New Haven Needle Exchange," Interfaces, 23(1): 7-26, January-February 1993. 29.5-2 to find the steadystate probabilities. Therefore, the model has millions of decision variables and many thousands of constraints. The parameter analysis report generated in Sec. for real... These results are shown in Fig. 730 Case 16.4 University Toys and the Engineering Professor Action Figures CHAPTER 17 Queueing Theory 731 17.1 Prototype Example 732 17.2 Basic Structure of Queueing Models 732 17.3 Examples of Real Queueing Systems 737 17.4 The Role of the Exponential Distribution 739 17.5 The Birth-and-Death Process 745 17.6 Queueing Models Based on the Birth-and-Death Process 750 17.7 Queueing Models Involving Nonexponential Distributions 762 17.8 Priority-Discipline Queueing Models 770 17.9 Queueing Models 770 17.9 Queueing Models 17.0 The Application of Queueing Theory 779 17.11 Conclusions 784 Selected References 784 Learning Aids for This Chapter on Our Website 785 Problems 786 Case 17.1 Reducing In-Process Inventory 799 CHAPTER 18 Inventory 799 CHAPTER 18 Inventory 799 Case 17.2 Queueing Quandary 799 CHAPTER 18 Inventory 798 Preview of an Added Case on Our Website 785 Problems 786 Case 17.1 Reducing In-Process Inventory 799 CHAPTER 18 Inventory 799 CHAPTER 18 Inventory 799 Chapter on Our Website 785 Problems 786 Case 17.1 Reducing In-Process Inventory 799 Chapter on Our Website 785 Problems 786 Case 17.1 Reducing In-Process Inventory 799 Chapter 18 Inventory 79 Deterministic Continuous-Review Model 805 18.4 A Deterministic Continuous-Review Model 815 18.5 Deterministic Continuous-Review Model 815 18.5 Deterministic Continuous-Review Model 815 18.6 A Stochastic Continuous-Review Model 815 18.7 A Stochastic Con Selected References 862 Learning Aids for This Chapter on Our Website 863 Problems 864 Case 18.1 Brushing Up on Inventory Control 874 Previews of Added Cases on Our Website 863 Prototype Example 878 19.2 A Model for Markov Decision Processes 880 842 730 hil23453\_fm\_i-xxx.qxd 1/30/70 7:58 AM Final PDF to printer Page xvii CONTENTS xvii 19.3 Linear Programming and Optimal Policies 883 19.4 Conclusions 887 Selected References 888 Learning Aids for This Chapter on Our Website 888 Problems 889 CHAPTER 20 Simulation 892 20.1 The Essence of Simulation 892 20.2 Some Common Types of Applications of Simulation 904 20.3 Generation of Random Numbers 908 20.4 Generation of Ra Learning Aids for This Chapter on Our Website 942 Problems 943
Case 20.1 Reducing In-Process Inventory, Revisited 950 Case 20.2 Action Adventures 951 Case 20.3 Planning Planers 951 Case 20.4 Pricing under Pressure 951 Case 20.2 Action Adventures 950 Previews of Added Cases on Our Website 951 Case 20.3 Planning Planers 951 Case 20.4 Pricing under Pressure 951 Case 20.3 Planning Planers 951 Case 20.4 Pricing under Pressure 951 Case 20 31(6): 69-82, November-December 2001. However, Case 2 actually arises in a very different way. What is the appropriate distribution for this uncertain variable. What should the "answer" look like when presenting the recommended approach to the problem? Goals may be set to establish minimum satisfactory levels of performance in various areas, based perhaps on past levels of performance or on what the competition is achieving. H., and E. Because the name analytics) is more meaningful to most people than the term operations research, we might find that analytics may eventually replace operations research as the common name for this integrated discipline. Blood is hil23453\_ch29\_001-036.qxd 1/22/1970 10:53 PM Page 34 Confirming Pages 34 CHAPTER 29 MARKOV CHAINS discarded if it is still on the shelf after 21 days. There usually are a small number of no-shows, so overbooking will increase revenue by essentially filling the available seating. It was becoming apparent to a growing number of people, including business consultants who had served on or with the OR teams during the war, that these were basically the same problems that is incorporated into the spreadsheet model in Fig. Therefore, the breadth of application is unusually wide. Therefore, the complete linear programming model is  $48 \times 1 \times 279 \times 1 \times 265 \times 1 \times 279 \times 1 \times 2$ P.M.) (2-4 P.M.) (4-6 P.M.) (6-8 P.M.) (6-8 P.M.) (10 P.M.-midnight) (Midnight-6 A.M.) and xj 0, for j 1, 2, 3, 4, 5. However, as you become more experienced with modeling in spreadsheets, you may find yourself merging some of the detailed steps and quickly performing them mentally. 3.4-10 (Chap. Table for a Normal Distribution 967 PARTIAL ANSWERS TO SELECTED PROBLEMS INDEXES Author Index 983 Subject Index 983 Subject Index 983 Subject Index 983 fm i-xxx.gxd 1/30/70 7:58 AM Page xviii SUPPLEMENTS AVAILABLE ON THE TEXT WEBSITE www.mhhe.com/hillier ADDITIONAL CASES Case 3.2 Cutting Cafeteria Costs Case 3.3 Staffing a Call Center Case 3.4 Promoting a Breakfast Cereal Case 4.2 New Frontiers Case 4.3 Assigning Students to Schools Case 7.2 Farm Management Case 7.2 Farm Management Case 7.3 Assigning Art Case 12.2 Assigning Art Case 12.3 Assigning Students to Schools Case 7.4 Writing a Nontechnical Memo Case 9.2 Continuation of the Texago Case 5.2 Farm Management Case 7.3 Assigning Art Case 12.3 Assigning Art Case 12.3 Assigning Students to Schools Case 7.4 Writing a Nontechnical Memo Case 9.3 Project Pickings Case 10.3 Steps to Success Case 12.2 Assigning Art Case 12.3 Assigning Art Case 12.3 Assigning Art Case 12.3 Assigning Students to Schools Case 7.4 Writing a Nontechnical Memo Case 9.3 Project Pickings Case 10.3 Steps to Success Case 12.2 Assigning Art Case 12.3 Assigning Art Ca Stocking Sets Case 12.4 Assigning Students to Schools, Revisited Again Case 13.2 International Investments Case 13.3 Promoting a Breakfast Cereal, Revisited Again Case 16.3 Who Wants to be a Millionaire? Therefore, I worked hard to substantially reduce the size of the eighth edition and then further reduced the size of the ninth edition slightly. All rights reserved., m and j 1, 2, . You will gain insight into this topic as you work through subsequent examples. (c) If it costs \$30,000 per period? If you find that you need additional examples of formulating small and relatively straightforward linear programming models before dealing with these more challenging formulation examples in the Solved Examples in the Solved Examples in the book's website. ji Just as qi is the parameter of the exponential distribution for Ti, each qij is the parameter of an exponential distribution for a related random variable described below: Each time it will spend in state i before a transition to state j occurs (if a transition to some other state does not occur first) is a random variable Tij, where i, j 0, 1, . For the first row of P, we are dealing with a transition from state Xt 0 to some state Xt1. How do you begin putting together the spreadsheet? It even has an ultra-high-performance linear mixed-integer optimizer. (Section 12.8) Branching A basic step in a branch-and-bound algorithm that partitions a set of feasible solutions into subsets, perhaps by setting a variable at different values. (Section 17.5) Server An entity that is serving the customers coming to a queueing system. A Parameter Analysis Report and Trend Chart for the Transcontinental Airlines Overbooking Problem As described in Sec. However, the two-headed arrows between Build and Test indicate a recursive process where testing frequently results in returning to the Build step to fix some problems discovered during the Test step. They cannot be chosen independently, but instead are a function of the other numbers in the spreadsheet. The ending balance in 2014 is the starting balance plus the sum of all the various cash flows that occur in 2014 (cells C11:I11). These are very risky projects since it is unclear how well these properties will compete in the marketplace when they go into operation in a few years. These transition rates are summarized in the rate diagram shown in Fig. Click the Fit button on the ASPE ribbon, which brings up the Fit Options dialog box. POWERFUL NEW ONLINE RESOURCES CourseSmart Provides an eBook at www.CourseSmart.com. This is done by drawing each line that borders the range of permissible values for one restriction. hil23453 ch29 001-036.qxd 1/22/1970 10:52 PM Page 1 Confirming Pages 29 C H A P T E R Markov Chains C hapter 16 focused on decision making in the face of uncertainty about one future event (learning the true state of nature). Baker: Management Science 5. To gualify for unemployment, an individual who lost their job must be eligible for work, able to work and actively seeking employment. Alternatively, there also are methods for explicitly considering multiple objectives simultaneously, and one of these (goal programming) is discussed in the supplement to Chap. With the widespread use of databases and the explosive growth in their sizes in recent years, OR teams now frequently find that their biggest data problem is not that too little is available but that there is too much data. OTHER SPECIAL FEATURES OF THIS BOOK • An Emphasis on Real Applications. A New Section on Stochastic Programming with Recourse. The other 20 percent forfeit the fare (or, in most cases, allow their company to do so) because their plans have changed. Section 3.5 introduced spreadsheet modeling in the context of linear programming problems. Owen, M. In both of the stock examples in Sec. 29.2-2 do not. The distinguishing characteristic of changing cells (the loan amounts) is that they do not depend on anything else. displayed in Fig. It is good to highlight these assumptions so you can more easily evaluate how well linear programming applies to any given problem. Therefore, to be successful, OR must also provide positive, understandable conclusions to the decision maker(s) when they are needed. are at the upper edge of what the different market segments are willing to pay and then allocating seats appropriately to the various fare classes. To begin, note that the nonnegativity restrictions x1 0 and x2 0 require (x1, x2) to lie on the positive side of the axes (including actually on either axis), i.e., in the first quadrant. (Section 20.4) Animation A computer display with icons that shows what is happening in a simulation. F., and the PAWN team: "Planning the Netherlands' Water Resources," Interfaces, 15(1): 3-33, January-February 1985. (d) List the various financial and nonfinancial benefits that resulted from this study. In addition, INFORMS publishes many of the leading journals in the field, including one called Analytics, and another, called Interfaces, regularly publishes articles describing major OR studies and the impact they had on their organizations. 28.5. A B 1 2 ReservationsToAccept 150 Mean \$5,789 3 155 \$6,896 4 5 160 \$7,968 165 \$9,001 6 170 175 \$10,880 8 9 180 \$11,592 185 \$11,912 10 190 \$11,712 11 195 \$11,124 12 200 \$10,395 7 \$9,982 185; then they start trending slowly downward. The OR team is much more likely to gain this support if it has kept management well informed and encouraged management well informed and encouraged management well informed and encouraged management. of batches of a product produced per week). Therefore, rather than be deluded into demanding the impossible, you should make the test of the practical success of an OR study hinge on whether it provides a better guide for action than can be obtained by other means. The average number has been 195, but with considerable variation from flight to flight on both sides of this average. C (c) Suppose that the network is redesigned to improve the probability that a single transmission will be accurate from 0.995 to 0.998. Calculate by hand what the endanalyze what the endanalyze what the endanalyze what the production schedule should be for the next four ing cash position would be after year 1 and year 2. (Section 12.7) Global constraint A constraint that succinctly expresses a global pattern in the allowable relationship between multiple variables. Sensitivity analysis also was used to assess the impact of changing the assumptions of the models, e.g., the assumption on the effect of future international treaties on the amount of pollution entering the Netherlands. PROBLEMS 1.3-1. 3.1, namely, that this profit is indeed proportional to x1 so that 3x1 is the appropriate term for the objective function. 3.8, certainly is not proportional to x1. The benefit
constraint for each type of pollutant has the amount of abatement achieved on the right-hand side. 13, but the only background needed for this is presented in Appendix 4. Are there common row or column headings for different blocks of cells? xDC-W2 0, You will see this problem again in Sec. For problems where there is no latitude for violating the constraints even a little bit, a relatively new technique called robust optimization provides a way of obtaining a solution that is virtually guaranteed to be feasible and nearly optimal regardless of reasonable deviations of the parameter values from their estimated values. Reboot has 1,000 pairs of boots in inobjective be? These probabilities can be obtained by solving a system of linear equations that considers all the possibilities for the first transition and then, given the first transition, considers the conditional probability of absorption into state k. Tijms, H. 2.4-3. Similar efforts assisted the Island Campaign in the Pacific. How does SmartBook work? Photo Courtesy: svetikd/E+/Getty Images Finally, it's important to keep in mind that unemployment benefits are usually contingent upon a recipient doing their part to actively look for a new job. Harold, and J. (Section 12.3) Binary variable A variable that is restricted to the values of 0 and 1. This provides new data that were not available when the model was constructed. OR can be thought of as focusing mainly on advanced analytics whereas analytics professionals might get more involved with less advanced aspects of the study. Romeijn, R. Depending on the state you reside in, you will be eligible to apply for unemployment benefits online, in person, on the phone or by mailing in a claim form. A convenient way of showing all the n-step transition probabilities is the n-step transition matrix State 0 1 P(n) 00 (n) p 10 ... | (n) pM0 1 p(n) 01 p(n) 01 p(n) 11 ... p(n) M1 ... ... M p(n) 0M ] p(n) 1M ... M p(n) 0M ] p(n) MM ] Note that the transition from the row state to the column state. The choice of activity levels then dictates how much of each resource will be consumed by each activity. It is not even necessary that the absolute magnitude of the measure of performance be approximately correct for the various alternatives, provided that their relative values (i.e., the differences between their values) are sufficiently precise. (a) Develop the rate diagram for this Markov chain. In this section, we describe this approach and illustrate it by applying it in turn to the two decision variables listed above. (Section 10.2) Augmenting path A directed path from the source to the sink in the residual capacity. Some functional constraints in equation form: ai1x1 ai2x2. Here, any specification of values for the decision variables (x1, x2, . 29.3, we noted an interesting feature of these matrices. This program is intended to be your personal tutor to help you learn the algorithms. Operations research. (Section 8.1) Glossaries - 16 Gradient The gradient of the objective function. The feasible region consists of just the dark line segment between (6, 6) and (7.5, 4.5), because the points on this segment are the only ones that simultaneously satisfy all the constraints. All these characteristics lead quite naturally to still another one. Although the eighth edition just appeared, the seventh edition had 46 percent of the market for books of its kind, and it ranked second in international sales among all McGraw-Hill publications in engineering. E., and S. 2.3) can be helpful in guiding this review process. Specify which type of distributions are being considered for fitting (continuous or discrete). An important unit consists of two components placed in parallel. (Section 19.2) Discounted cost criterion A criterion for measuring the performance of a Markov decision process by using its expected total discounted cost based on the time value of money. (Section 20.1) Glossaries - 53 Simulation model A representation of the system to be simulated that also describes how the simulation will be performed. 3.6. We next introduce a special type of feasible solution that plays the key role when the simplex method searches for an optimal solution. He had been Professor Emeritus of Operations Research. Our peers over at Ask.com have the answers. Test: Test the Small Version of the Model If you do start with a small version of the model first, be sure to test this version thoroughly to make sure that all the logic is correct. The holding cost per period is Zn if Zn 0 and zero otherwise. However, the actual percentage of those who show up on any particular day may vary somewhat on either side of this average percentage. hil61217 ch21.gxd 4/29/04 Page 21-14 CHAPTER 21 21-14 1 2 3 4 5 6 7 8 9 10 11 12 03:41 PM A B THE ART OF MODELING WITH SPREADSHEETS C D Doors \$3,000 Windows \$5,000 Wyndor Glass Co. Produced 1 0 0 2 3 2 Batches Produced Solver Parameters Set both the repair time and the time until a breakdown have exponential distributions, {X(t); t 0} is a continuous time Markov chain5 with states 0, 1, 2. (a) Briefly describe how the OR team gained the support of upper management for implementing SYSNET. Furthermore, its model fits our standard form and its context is the traditional one of improved business planning. In developing the model, a good approach is to begin with a very simple version and then move in evolutionary fashion toward more elaborate models that more nearly reflect the complexity of the real problem. If you decide that you would like to learn more about these award-winning applications of operations research, a link to the articles that describe these OR studies in detail is included on the book's website, www.mhhe.com/hillier. 17.4.) This result leads to an equivalent way of describing a continuous time Markov chain: 1. Number of hours of production time used in each plant for each batch produced of each new product. Everything that happens in a given year is arranged together in a single row., C(M) and that the function C() is independent of t. In conjunction with the study phase discussed in Sec. Therefore, summing these conditional probabilities over all possible k must yield p(n) ij. In addition to the approximately 1,000 pages in this book, another several hundred pages of supplementary material also are provided on this book's website (as outlined in the table of contents). bm hil23453\_ch03\_025-092.qxd 34 1/30/70 7:57 AM CHAPTER 3 Final PDF to printer Page 34 INTRODUCTION TO LINEAR PROGRAMMING values of cj, bi, and aij (for i 1, 2, . Distributions for Number of Trials Until Event Occurs Geometric Distribution: • Describes number of trials until an event occurs (e.g., number of trials until an event occurs n times • Same as geometric when suc = n = 1 • Probability same for each trial • Continue until succeed • Number of trials until an event occurs n times • Same as geometric when suc = n = 1 • Probability same for each trial • Continue until succeed • Number of trials until an event occurs n times • Same as geometric when suc = n = 1 • Probability same for each trial • Continue until succeed • Number of trials until an event occurs n times • Same as geometric when suc = n = 1 • Probability same for each trial • Continue until succeed • Number of trials until an event occurs n times • Same as geometric when suc = n = 1 • Probability same for each trial • Continue until succeed • Number of trials until an event occurs n times • Same as geometric when suc = n = 1 • Probability same for each trial • Continue until succeed • Number of trials until an event occurs n times • Same as geometric when suc = n = 1 • Probability same for each trials until an event occurs n times • Same as geometric when suc = n = 1 • Probability same for each trials until an event occurs n times • Same as geometric when suc = n = 1 • Probability same for each trials until an event occurs n times • Same as geometric when suc = n = 1 • Probability same for each trials until an event occurs n times • Same as geometric when suc = n = 1 • Probability same for each trials until an event occurs n times • Same as geometric when suc = n = 1 • Probability same for each trials until an event occurs n times • Same as geometric when suc = n = 1 • Probability same for each trials until an event occurs n times • Same as geometric when suc = n = 1 • Probability same for each trials until an event occurs n times • Same as geometric when suc = n = 1 • Probability same for each trials until an event occurs n times • Same as geometric when suc = n = 1 • Probability same for each trials until an event occurs n times • Same as geometric when suc = n = 1 • Probability sa each trial • Continue until nth success • Number of trials unlimited There is also a Custom submenu that enables you to design your own distributions. 3.13. Doing this by hand would often be out of the question. Furthermore, the solutions to the other M 1 steady-state equations have a unique solution up to a multiplicative constant, and it is the final equation that forces the solution to be a probability distribution. Documenting the process used for model validation is important. Bukiet, B., E. hil23453\_fm\_i-xxx.qxd 1/30/70 7:58 AM Page ii Final PDF to printer hil23453 fm i-xxx.qxd 1/30/70 7:58 AM Page iii Final PDF to printer INTRODUCTION TO OPERATIONS RESEARCH hil23453 fm i-xxx.gxd 1/30/70 7:58 AM Final PDF to printer hil23453 fm i-xxx.gxd 1/30/70 7:58 AM Final PDF to printer hil23453 fm i-xxx.gxd 1/30/70 7:58 AM Final PDF to printer hil23453 fm i-xxx.gxd 1/30/70 7:58 AM Final PDF to printer hil23453 fm i-xxx.gxd 1/30/70 7:58 AM Final PDF to printer hil23453 fm i-xxx.gxd 1/30/70 7:58 AM Final PDF to printer hil23453 fm i-xxx.gxd 1/30/70 7:58 AM Final PDF to printer hil23453 fm i-xxx.gxd 1/30/70 7:58 AM Final PDF to printer hil23453 fm i-xxx.gxd 1/30/70 7:58 AM Final PDF to printer hil23453 fm i-xxx.gxd 1/30/70 7:58 AM Final PDF to printer hil23453 fm i-xxx.gxd 1/30/70 7:58 AM
Final PDF to printer hil23453 fm i-xxx.gxd 1/30/70 7:58 AM Final PDF to printer hil23453 fm i-xxx.gxd 1/3 incurred by a company each time one of its customers with a reservation for receiving some service (e.g., a seat on an airline flight) is then denied that service. 29.3. Thus, after many weeks the probability of finding zero, one, two, and three cameras in stock at the end of a week tends to 0.286, 0.285, 0.263, and 0.166, respectively. The Lognormal Distribution The lognormal distribution shown at the bottom of Fig. To enter this distribution, first choose General from the custom submenu of the Distributions menu to bring up the dialog box shown in Fig. This would occur in the example if the produced of produced of produced of produced to \$2,000. 3.3 that the two lines just constructed are parallel. 7.2. However, it is necessary to acquire some more background before we finish that story. Bladder and tumor 2. It is very common in real applications of linear programming that almost none of the four assumptions hold completely. company, which now employs nearly 50,000 residents. However, this "fix" does not work here because the 1 constant does not apply when x1 0. (Section 16.3) Risk-averse individual An 2006. A transition from Xt 0 to Xt1 0 implies that the demand for cameras in week t 1 is 3 or more after 3 cameras are added to the depleted inventory at the beginning of the week, so p00 P{Dt1 3} 0.080. 28.2 ReservationsToAccept (C13) in Fig. Simply sketch out blocks on a piece of paper for the various data cells, changing cells, and output cells, and label them. A 1 2 3 4 5 6 7 8 B C Batches of Doors Produced Batches of Windows Produced Hours Used (Plant 2) Hours Used (Plant 3) Total Profit 2 6 2 12 18 \$36,000 Wyndor Glass Co. (Poor Formulation) Solver Parameters Set Objective Cell: C8 To: Max By Changing Variable Cells: C3:C4 Subject to the Constraints: C5 =DFinish HStart >= EFinish IStart >= FFinish  $>=>= 0.50\$ =MAX(MinimumBalance-L19,0) =MAX(MinimumBalance-L16,0) =MAX(MinimumBalance-L16,0) =MAX(MinimumCash = MinimumCash =

=MinimumCash Balance =MinimumCash =MinimumCash Minimum P BalanceBeforeSTLoan CashFlow EndBalance EndingBalance EndingBalance LTLoan LTRate N Cells L12:L22 F12:F21 N22 N12:N22 G12 C3 N24 P12:P22 C7 C6 M12:M22 C4 Range Name Loan =MAX(MinimumBalance-L12,0) =MAX(MinimumBalance-L12,0) =  $0.50 \ 0.50 \$ -2.35 7.78 3.03 ST Loan 3.05 7.25 9.65 M 0.00 0.00 -7.28 -2.53 Balance Before ST Loan -2.55 -6.75 -9.15 L -9.65 -7.78 -3.05 -7.25 LT ST Payback K Payback K Payback K Payback ST K 0 0 0 -0.16 0 -0.21 -0.23 -5 5 1 -6 3 Cash Flow (Triangular Distribution) Simulated Cash Flow Likely Max Min -8.20 -8 -7 -9 -3.76 -2 1 -4 -1.65 -4 0 -7 2.78 3 7 0 1 0.5 5% 7% LT Cash LT Interest Flow Loan =PsiTriangular(C12,D12,E12) 4.65 = -LTRate\*LTLoan =PsiTriangular(C1 2022 Year 2014 2015 2016 2017 2018 2019 Start Balance Minimum Cash LT Rate ST Rate I 10:51 PM 16 14 15 13 C 1/22/1970 11 12 B Everglade Cash Flow Management Problem When Applying Simulation A 16 9 10 7 8 6 5 2 3 4 1 management problem. By the same token, international corporations acquire additional obligations to follow socially responsible practices. (Section 14.3) Simulated annealing A type of metaheuristic that is based on the analogy to a physical annealing process. Some relevant factors or interrelationships undoubtedly have not been incorporated into the model, and some parameters undoubtedly have not been estimated correctly. There is no one right way of modeling any given problem. 28.30 This Parameter Analysis dialog box allows you to specify which parameter cells to vary and which results to show after each simulation run. It also was determined that the cost of a method being used at a lower level is roughly proportional to the fraction of the abatement capacity given in Table 3.13 that is achieved. It can be shown that this latter measure also is given by M 1 n lim C(Xt) j C(j) n 
i n t1 j0 for essentially all paths of the process. If you have a Mac, you'll need to install "dual-boot" or VM software, Microsoft Windows, and Office or Excel for Windows first. An experienced modeler often is able to do some of these steps mentally, without working them out explicitly on paper. For example, the model formulated for both the bidding example in Sec. ignore the instructions given there. The random variable Xt represents the state of the system at time t, so its only possible values are 0, 1, . American Airlines was the pioneer in making extensive use of operations research for improving its revenue management. In the gambling example given at the end of Sec. It also is anticipated that this approach can be extended to other forms of brachytherapy, such as treatment of breast, cervix, esophagus, biliary tract, pancreas, head and neck, and eye. Enter the data into the spreadsheet containing your simulation model. (Section 10.8) PERT/CPM The merger of the two techniques originally know as PERT and CPM. The frequency chart for NumberDeniedBoarding (C21) indicates that this spreadsheet containing your simulation model. occurred about 40 percent of the time. Consider a department store that classifies the balance of a customer's bill as fully paid (state 0), 1 to 30 days in arrears (state 2), or bad debt (state 3). Some Award-Winning Applications of the OR Modeling Approach: (A link to all these articles is provided on our website, www.mhhe.com/hillier.) A1. Each of these methods has a technological limit on how heavily it can be used (e.g., a maximum feasible increase in the height of the smokestacks), but there also is considerable flexibility for using the method at a fraction of its technological limit. Therefore, Everylade management concludes that it should take a more cautious approach in moving forward with its current plans to build more retirement communities over the next 10 years. The word programming does not refer here to computer programming; rather, it is essentially a synonym for planning. Let Xt be a vector consisting of two elements U and V, where U represents the number of components that are operational at the end of period t and V represents the number of periods of repair that have been completed on components that are not yet operational. Assume that the probability of its being clear (no rain) tomorrow is 0.9 if it is raining today, and assume that the probability of its being clear (no rain) tomorrow is 0.9 if it is raining today, and 18.8) Stable product A product which will remain sellable indefinitely so there is no deadline for disposing of its inventory. (Section 18.2) Distribution system A multichelon inventory system where an installation might have multiple immediate successors in the next echelon. Demand for year in projects A, B, and C. The fixed cost for operating the flight is \$30,000, so more than 100 reservations are needed to make a profit on any particular day. (c) Describe how the needed data were gathered. While gathering its data, the OR group has discovered the reason why. This was a large model with 8,000 decision variables that focused on the component level of detail. These questions often are raised by the managers who will be making the ultimate decisions rather than by the OR team. Tickets that Susan is unable to sell on game day have no value. hil23453 ch02 010-024.qxd 24 1/15/70 7:34 AM CHAPTER 2 Page 24 Final PDF to printer OVERVIEW OF THE OPERATIONS RESEARCH MODELING APPROACH (b) Because of the complexity of the problem, it is practically impossible to solve optimally. As described earlier, the powerful Analytic Solver Platform for Education (ASPE) to formulate and solve a wide variety of OR models in an Excel environment. (a) Visualize where you want to finish. 29.7 to find the probability that the manufacturer will have to honor the warranty. This initiative led to Continental winning the prestigious First Prize in the 2002 international competition for the Franz Edelman Award for Achievement in Operations for the ij can be used to compute the expected time until the cameras are out of stock, given that the process is started when three cameras are available. MPL, LINGO, and LINDO tutorials also are provided on the book's website. Thus, all that is required is that there be a high correlation between the prediction by the model and what would actually happen in the real world., kt1., then the (one-step) transition probabilities are said to be stationary. Rash, E. and K. With its current production fa- 100 percent, then all the cash flows associated with that project are cility, the company can produce at most 6,000 pairs of boots in any reduced proportionally. 28.27. This expected first passage time 30., respectively, so the random variable Dt (for t 1, 2, ., P{Dt1 0} e1 0.368, P{Dt1 1} e1 0.368, 1 P{Dt1 2} e1 0.184, 2 P{Dt1 3} 1 P{Dt1 2} 1 (0.368 0.368 0.184) 0.080. At the same time, management feels that it would be prudent to take steps to reduce the 5 percent chance of an unfavorable outcome. These specifications are given in Table 3.16 along with the cost of amalgamation and the selling price for each grade. Company policy requires ending each year quarter. About two-thirds of the distribution lies within one standard deviation, since finding a nonsensical optimal solution signals that you have made a mistake in formulating the model. Consequently, it is vital for the OR team to get on the same wavelength as management, including identifying the "right" problem from management for the support of management for the support for the support of management for the support of managem the elements? in the actual real world) were heuristics, meta-heuristics, simulation based optimisation, and statistical analysis of simulation output. Even worse, months later, many jobless people were still desperately trying to cut through all the red tape and the massive volume of people to file their own unemployment claims. Therefore, it is always a good idea to enter and carefully lay out all the data before you begin to set up the rest of the model. Notice that the model for the Wyndor Glass Co. problem formulated in the preceding section fits our standard form, with m 3 and n 2. The intuition behind the first equation is that, in steady state, the probability of being in state 0 after the next transition must equal (1) the probability of being in state 0 now and then staying in state 0 after the next transition plus (2) the probability of being in state 1 now and next making the transition to state 0. (Section 12.9) Auxiliary binary variable that is introduced into the model, not to represent a yes-or-no decision, but simply to help formulate the model as a (pure or mixed) BIP problem. What are the parameters of the distribution? (d) Let T 3 and p 0.7. Find f10, f1T, f20, f2T. Deleting the nonnegativity constraints for some decision variables: xj unrestricted in sign for some values of j. The sequence X0, X1, X2, . You also can see in Fig. Therefore, an OR team is studying how to schedule the agents to provide satisfactory service with the smallest personnel cost. 21.5. The changing cells, LTLoan (D11) and STLoan (D11) values of these parameters were changed from the current environmental standards to other reasonable values. After these data were developed, it became clear that no single method by itself could achieve all the required reductions. j0 This is the cost associated with the particular ordering policy described in Sec. (Sections 13.10 and 13.4) Glossaries - 30 Geometric programming problems A special type of nonlinear programming problems, among others. If, for example, LTLoan is missing from any of the formulas in column F, the error will be immediately revealed by the missing arrow. This section includes a few examples with complete solutions for almost every chapter as a supplement to the examples in the book and in OR Tutor. S., and R. Saxena, R., and A. He also supervised the further development of LINGO/LINDO files for the various chapters as well as providing tutorial material for the book's website. algebraic format. Consider the second version of the stock market model presented as an example in Sec. am1 am2 ... If Zn is negative, then Zn represents the number of backlogged units and no inventory is on hand. However, the chances of being dry (no rain) tomorrow are somewhat larger if it is dry today than if it rains today. If there are multiple objectives, their respective measures commonly are then transformed and combined into a composite measure, called the overall measure of performance. Thus, OR can be thought of as focusing mainly on advanced analytics—predictive activities—whereas analytics professionals might get more involved than OR analysts with the entire business process, including what precedes the first category (identifying a need) and what follows the last category (implementation). 29.8-2. Therefore, it often is necessary to install a new computer-based management information system to collect the necessary to install a new computer-based management information). placed over the isodose map. The cost is charged as follows: hil23453 ch29 001-036.qxd 1/22/1970 10:53 PM Page 19 Confirming Pages 29.5 LONG-RUN PROPERTIES OF MARKOV CHAINS [0 | 2 C(xt) ] 8 | 18 if if if 19 xt 0 xt 1 xt 2 xt 3 Using the steady-state probabilities found earlier in this section, the long-run expected average storage cost per week can then be obtained from the preceding equation, i.e., 1 n lim E C(Xt) 0.286(0) 0.285(2) 0.263(8) 0.166(18) 5.662. The Bernoulli distribution gives a value of 0 (representing yes) with this probability; otherwise, it gives a value of 0 (representing no). To illustrate, this case would result if the last two functional constraints were mistakenly deleted in the example, as illustrated in Fig. 2.3-3. (Section 17.7) Glossaries - 43 Preemptive priorities for serving customer that include ejecting the lowest priority customer being served back into the queue in order to serve a higher priority customer that has just entered the queueing system. Matrix notation is used in Chap. Finally, a mathematical model forms a bridge to the use of high-powered mathematical techniques and computers to analyze the problem. (Sections 13.3 and 13.7) Quasi-Newton methods Convex programming algorithms that extend an approximation of Newton's method for unconstrained optimization to deal instead with constrained optimization problems. (Section 10.7) Length of a link or an arc The number (typically a distance, a cost, or a time) associated with a link or arc for either a shortest-path problem or a minimum spanning tree problem. The objective is to maximize the net weekly profit (total sales income minus total amalgamation cost), exclusive of the fixed treatment cost of \$30,000 per week that is being covered by gifts and grants. (Introduction) Mixed integer programming The type of integer programming the type of integer programming where only some of the variables are required to have integer programming the type of integer programming the typ (3) {D X, 0} ttt1 if if Xt1 0 Xt1 1, for t 1, 2, . 21.3 that is violated by this poor model. In particular, if the state k is an absorbing state, then the set of absorption probabilities fik satisfies the system of equations M fik pij fjk, for i 0, 1, . Dozens of textbooks have been written about linear programming, and published articles describing important applications now number in the hundreds. A robust set of questions and activities are presented engineering and aligned with the textbook's learning outcomes. (Section 17.4) Little's formula L =  $\lambda W_r$ . (Section 17.2) Glossaries - 42 Mean arrivals to a queueing system per unit time. (Section 17.4) Little's formula L =  $\lambda W_r$ . 16.7) Decision maker The individual or group responsible for making the decision under consideration. This has been done in the new Section 1.3. Many New or Revised Problems. (Section 17.2) Social service system A queueing system which is providing a social service. H.: "ASP, The Art and Science of Practice: Elements of the Practice of Operations Research: A Framework," Interfaces, 35(2): 154-163, March-April 2005. In fact, most of the basic models of queueing theory fall into this category. The general contractor has provided three estimates for each of the construction tasks—an optimistic scenario (minimum time required if the weather is good and all goes well), a most likely scenario, and a pessimistic scenario (maximum time required if there are weather and other problems). If deviations do occur, adjustments will of course need to be made in the short-term loan amounts. (Section 9.1) Donor cells Cells in a transportation simplex tableau that reduce their allocations do occur, adjustments will of course need to be made in the short-term loan amounts. method. However, some decisions need to take into account uncertainty about many future events. 28.31) for this problem suggests that \$5.4 million. How does the expected number of full days hereafter that the machine will remain operational before the next breakdown compare with the corresponding result from part (b) when the repair had just been completed? The objective is to choose the values of x1 and x2 so as to maximize Z 3x1 5x2, subject to the restrictions imposed on their values of x1 and x2 so as to maximize Z 3x1 5x2, subject to the restrictions imposed on their values by the limited production capacities available in the three plants. Everylade has recently broken ground for the construction of a new retirement community and has more new construction planned over the next 10 years. The key characteristic of resource constraints. This is often especially revealing when the parameters or variables are assigned extreme values near their maxima or minima. All of this helps to explain why the book is a relatively large one. 3 1, hil23453\_ch03 025-092.qxd 1/30/70 40 7:57 AM Final PDF to printer Page 40 CHAPTER 3 INTRODUCTION TO LINEAR PROGRAMMING Contribution of x1 to Z 18 15 12 9 (the marginal return from product 1) keeps increasing as x1 is increased. Under the assumptions of this example, it can be shown that the (long-run) expected average cost per unit time is given by M 1 n lim E C(Xt1, Dt) k(j) j,  $n \rightarrow n t1 j0$  hil23453\_ch29\_001-036.qxd 1/22/1970 10:53 PM Page 20 Confirming Pages 20 CHAPTER 29 MARKOV CHAINS where k(j) E[C(j, Dt)], and where this latter (conditional) expectation is taken with respect to the probability distribution of the random variable Dt, given the state j. The three main types of pollutants in this airshed are particulate matter, sulfur oxides, and hydrocarbons. These symbols are listed below, along with their interpretation for the random variable Dt, given the state j. the general problem of allocating resources to activities. In other words, pij 0 for 8 of the 16 entries in the transition matrix. A major proportion of all scientific computation on computers is devoted to the use of linear programming. (Section 10.2) amount of flow into that node. (Section 8.4) Interior-point algorithm An algorithm that generates trial solutions inside the boundary of the feasible region that lead toward an optimal solution. Activities correspond to shifts, where the level of each activity is the number of agents assigned to that shift. (Section 16.6) Risk-seeking individual An individual who has an increasing marginal utility for money. Stationary transition probabilities. Given that the current state is Xt i, the expression at the end of Sec. The current status of the system can fall into any one of M 1 mutually exclusive categories called states. In the inventory example (see Fig. (We will discuss range names and their usefulness) further in Sec. Therefore, the value assigned to a parameter often is, of necessity, only a rough estimate. Indicate whether to allow shifted distributions and whether to allow shifted distributions and whether to allow shifted distributions and whether to run a sample independence test. equations to obtain the steady-state probabilities. 3.1. Formulating the Model on a Spreadsheet Figure 3.14 displays the Wyndor problem by transferring the data from Table 3.1 onto a spreadsheet. He initially introduced the concept of analytics," that now has been named as one of the ten must-read articles in that magazine's 90-year history. However, we make a few general comments, and then we give an example. The frequency chart in Fig. However, the real question **I** FIGURE 3.10 The solid curve violates the proportionality assumption because its slope (the marginal return from product 1) keeps decreasing as x1 is increased. If no cameras are ordered, no ordering cost is incurred. (Section 10.8) Crashing an activity Taking special costly measures to reduce the duration of an activity below its normal value. mathematical model that represents the essence of the problem. Bini, D., G. This phase is a critical one because it is here, and only here, that the benefits of the random factors that affect the payoff that would be obtained from a decision alternative. Instead, the objectives used in the study should be as specific as they can be while still encompassing the main goals of the decision maker and maintaining a reasonable degree of consistency with the higher-level objectives of the organization. This procedure often is referred to as the graphical method for linear programming. Kim, K. j0 3. This is most often the case when the time or cost required to find an optimal solution for an adequate model of the problem would be very large. (Section 12.4) Set partitioning problem A variation of a set covering problem where the selected activities must collectively possess each of a number of characteristics exactly once. Similarly, consider a production process with a 50 percent yield, so each unit produced has an 0.5 probability of being acceptable. Management wants to choose one of the three options. However, this attitude is now changing; uncontrolled air pollution from the company's furnaces is ruining the appearance of the city and endangering the health of its residents. (When normal distributions were entered into uncertain variable cells in Fig. (Section 17.2) Reneging A customer in the queueing system who becomes impatient and leaves before being served is said to be reneging. J. Also note that the width of the entire set of seven bands increases until about the simulation run for 180 reservations and then remains about the same thereafter. Library of Congress Cataloging-in-Publication Data Hillier, Frederick S. Therefore, an instructor who does not wish to assign problems that were assigned in previous classes has a substantial number from which to choose. Self, "A Scheduling and Capableto-Promise Application for Swift & Company," Interfaces, 36(1): 39-50, Jan.-Feb. As the reverse of the first case, Case 2 would arise if the two products were competitive in some way that decreased their joint profit. Since all the states are recurrent, the system of equations leads to the expressions 30 1 p3110 p3220 p3330, hil23453 ch29 001-036.qxd 1/22/1970 10:53 PM Page 23 Confirming Pages 29.7 ABSORBING STATES 23 20 1 p2110 p2220 p2330, 10 1 p1110 p1220 p1330, or 30 1 0.18410 0.36820, 10 1 0.36810. my conclusion is that the clean mathematical methods tend not to fit many real world problems, at least not the really complicated problems, which is what I have faced almost exclusively in my work. Reexamining the definition of the problem and comparing it with the model may help to reveal mistakes. Similarly, you can make the column absolute and the row relative (or vice versa) by putting a \$ sign in front of only the letter (or number) of the cell reference. (ed.) "50th Anniversary Issue," Operations Research (a special issue featuring personalized accounts of some of the key early theoretical and practical developments in the field), 50(1), January-February 2002. The data for the problem are located at the top and left of the spreadsheet. (Section 8.3) Upper bound technique that enables the simplex method (and its variants) to deal efficiently with upper-bound constraints in a linear programming model. (Section 20.3) Simulation clock A variable in the computer program that records how much simulated time has elapsed so far. For the best results, a realistic model might even need many tens of thousands of decision variables and constraints. As illustrated by certain formulas (especially the one in cell F12) below the spreadsheet, writing a formula in terms of range names instead of cell addresses makes the formula interpret. The examples for the current chapter begin with a relatively straightforward problem that involves formulating a small linear programming model and applying the graphical method. Thus, there may a better chance of finding a continuous distribution that is a good fit. Don't try to download from any other page. Second, real applications also are briefly described (especially in Chapters 2 and 12) as part of the presentation of some OR technique to illustrate its use. a1nxr b1 a21x1 a22x2 . Explain why these states give the process the Markovian property where an elaborate implementation strategy was a key to the success of an award-winning OR study.) at he remainder of this book focuses primarily on constructing and solving mathematical models, in this chapter we have tried to emphasize that this constitutes only a portion of the overall process involved in conducting a typical OR study. Printed in the United States of America. Furthermore, lim pij (t) j t -> always exists and is independent of the Markov chain, for 0, 1, . It is found to be either working (up) or failed (down). , xn) whose respective values are to be determined. For example, in Fig. (Section 20.3) Results cell An output cell that is used by simulation to calculate a measure of performance. All the educational resources accompanying the book further enhance the learning experience. However, Table 3.17 gives both the treatment cost and the availability of the materials by quantity (pounds) rather than proportion, so it is this quantity information that needs to be recorded in some of the constraints. The following example illustrates this approach in the context of real estate investments. Some Key Random Variables In the analysis of continuous time Markov chains, one key set of random variables is the following: Each time the process enters state i, the amount of time it spends in that state before moving to a different state is a random variable Ti, where i 0, 1, . decreased both today and yesterday. decisions. For n 0, p(0) ij is just P{X0 jX0 i} and hence is 1 when i j and is 0 when i j. Consider the following gambler's ruin problem. If the stock increased today and decreased today it will increase tomorrow with probability 2. Enter each piece of data into one cell only. What are the decisions that need to be made? (Section 20.1) Simulator A shorthand name for applications-oriented simulator (defined above). This function is called the objective function. One is TicketsPurchased (E17), which is the minimum of Demand (C11) and ReservationsToAccept (C13). 3x1 2x2. He received his doctorate in operations research, including a case studies course in operations research, including a case studies course in operations research. In this case, the first passage time is called the recurrence time for state i. At Kellogg he received several teaching awards including the L. Its impact since just 1950 has been extraordinary. As for Excel, each time an example can be solved with this package, all the details are given in a LINGO/LINDO file for that chapter in your OR Courseware, hil23453 ch29 001-036.gxd 1/22/1970 10:53 PM Page 30 CHAPTER 29 MARKOV CHAINS Define that chapter in your OR courseware, hil23453 ch29 001-036.gxd 1/22/1970 10:53 PM Page 30 CHAPTER 29 MARKOV CHAINS Define that chapter in your OR courseware, hil23453 ch29 001-036.gxd 1/22/1970 10:53 PM Page 30 CHAPTER 29 MARKOV CHAINS Define that chapter in your OR courseware, hil23453 ch29 001-036.gxd 1/22/1970 10:53 PM Page 30 CHAPTER 29 MARKOV CHAINS Define that chapter in your OR courseware, hil23453 ch29 001-036.gxd 1/22/1970 10:53 PM Page 30 CHAPTER 29 MARKOV CHAINS Define that chapter in your OR courseware, hil23453 ch29 001-036.gxd 1/22/1970 10:53 PM Page 30 CHAPTER 29 MARKOV CHAINS Define that chapter in your OR courseware, hil23453 ch29 001-036.gxd 1/22/1970 10:53 PM Page 30 CHAPTER 29 MARKOV CHAINS Define that chapter in your OR courseware, hil23453 ch29 001-036.gxd 1/22/1970 10:53 PM Page 30 CHAPTER 29 MARKOV CHAINS Define that chapter in your OR courseware, hil23453 ch29 001-036.gxd 1/22/1970 10:53 PM Page 30 CHAPTER 29 MARKOV CHAINS Define that chapter in your OR courseware, hil23453 ch29 001-036.gxd 1/22/1970 10:53 PM Page 30 CHAPTER 29 MARKOV CHAINS Define that chapter in your OR courseware, hil23453 ch29 001-036.gxd 1/22/1970 10:53 PM Page 30 CHAPTER 29 MARKOV CHAINS Define that chapter in your OR courseware, hil23453 ch29 001-036.gxd 1/22/1970 10:53 PM Page 30 CHAPTER 29 MARKOV CHAINS Define that chapter in your OR courseware, hil23453 ch29 001-036.gxd 1/22/1970 10:53 PM Page 30 CHAPTER 29 MARKOV CHAINS Define that chapter in your OR courseware, hil23453 ch29 random variable X(t) as X(t) number of machines broken down at time t, so the possible values of X(t) are 0, 1, 2. For example, once the projected cash flows should be structured the same way. (Section 7.6) Glossary for Chapter 8 Dual simplex method An algorithm that deals with a linear programming problem as if the simplex method were being applied simultaneously to its dual problem. This is quite appropriate because these quantitative techniques form the main part of what is known about OR. The Exponential Distribution If you have studied Chap. Assume that the bid may be any value between \$4.8 million and \$5.8 million. These four individuals and their companies—Accelet Corporation, LINDO Systems, Maximal Software, and Frontline Systems—have made an invaluable contribution to this book. Section 21.3 describes in detail the following guidelines for building "good" spreadsheet models. An analysis was conducted to estimate the total annual cost that would be incurred by each abatement method. These opportunities are conventionally referred to as trials (not to be confused with a trial of a simulation). Read Selected Reference A14 that describes an OR study done for the San Francisco Police Department.

About. Using a state-of-the-art data assimilation system and surface pressure observations, the NOAA-CIRES-DOE Twentieth Century Reanalysis (20CR) project has generated a four-dimensional global atmospheric dataset of weather spanning 1836 to 2015 to place current atmospheric circulation patterns into a historical perspective.. 20th Century Reanalysis and PSL Find similar free ebooks. Introduction to Operations Research (9th edition) By Frederick S. Hillier, Gerald J. Lieberman. 2009 | 1088 Pages | ISBN: 0073376299 | PDF | 20 MB. For over four decases, Introduction to Operations research at Stanford University. Dr. Hillier is especially known for his classic ext award-winning text, Introduction to Operations research at Stanford University. Dr. Hillier is especially known for his classic ext award-winning text, Introduction good opening paragraph for essay , family essay brainly essay on the place i would like to Dec 22, 2021 · Dec 06, 2021 · Essay on the articles of confederation hoya answers lhuman study harvey case energy conservation and environmental protection essay ... Undergraduate Courses Lower Division Tentative Schedule Upper Division Tentative Schedule PIC Tentative Schedule CLE Course Sites course descriptions for Mathematics clower & Upper Division, and arctice and and anter grade only! mathematics courses equip conservation and production; refining, marketing and transport; chemicals ... 9/2/2022 · OPERATIONS RESEARCH Tenth Edition FREDERICK S. HILLER Stanford University GCraw Hill Education - 1.1 The Origins of Operations Research 1.1.2 The Nature of Operations Research ... For assistance with Perspective... Visit the Technical Support Online of Stanford University Center (FAQs, articles, self-help resources) Phone; (800) 331-5094 Online: Submit a Support Center (FAQs, articles, self-help resources) Phone; (800) 331-5094 Online: Submit a Support Center on Support Center (FAQs, articles, self-help resources) Phone; (800) 331-5094 Online: Submit a Support Center on Support Center (FAQs, articles,

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