SIMULATION WITH ARENA

THIRD EDITION

THE McGRAW-HILL COMPANIES
FOR DONATION ONLY
NOT FOR RESALE
HIGHER EDUCATION
23-ASA-006

Simulation with Arena

Third Edition

W. David Kelton
Professor
Department of Quantitative Analysis and Operations Management
University of Cincinnati

Randall P. Sadowski
Product Manager
Application Programs
Rockwell Software

David T. Sturrock
Director
Simulation Development
Rockwell Software

McGraw Hill Higher Education

Boston Burr Ridge, IL Dubuque, IA Madison, WI New York San Francisco St. Louis
Bangkok Bogotá Caracas Kuala Lumpur Lisbon London Madrid Mexico City
Milan Montreal New Delhi Santiago Seoul Singapore Sydney Taipei Toronto

The McGraw-Hill Companies

Mc Graw Hill **Higher Education**

SIMULATION WITH ARENA, THIRD EDITION

Published by McGraw-Hill, a business unit of The McGraw-Hill Companies, Inc., 1221 Avenue of the Americas, New York, NY 10020. Copyright © 2004, 2002, 1998 by The McGraw-Hill Companies, Inc. All rights reserved. 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 The McGraw-Hill Companies, Inc., including, but not limited to, in any network or other electronic storage or transmission, or broadcast for distance learning.

Some ancillaries, including electronic and print components, may not be available to customers outside the United States.

This book is printed on acid-free paper.

International 2 3 4 5 6 7 8 9 0 DOC/DOC 0 9 8 7 6 5 4
Domestic 3 4 5 6 7 8 9 0 DOC/DOC 0 9 8 7 6 5

ISBN 0–07–285694–7
ISBN 0–07–121933–1 (ISE)

Publisher: *Elizabeth A. Jones*
Senior sponsoring editor: *Suzanne Jeans*
Developmental editor: *Amanda J. Green*
Marketing manager: *Sarah Martin*
Senior project manager: *Kay J. Brimeyer*
Production supervisor: *Sherry L. Kane*
Lead media project manager: *Audrey A. Reiter*
Senior media technology producer: *Phillip Meek*
Designer: *David W. Hash*
Cover designer: *Peter Alan Kauffman*
Printer: *R. R. Donnelley Crawfordsville, IN*

Library of Congress Cataloging-in-Publication Data

Kelton, W. David.
Simulation with Arena / W. David Kelton, Randall P. Sadowski, David T. Sturrock. — 3rd ed.
p. cm.
Includes bibliographical references and index.
ISBN 0–07–285694–7
1. Computer simulation. 2. Arena (Computer file). I. Sadowski, Randall P. II. Sturrock, David T. III. Title.

QA76.9.C65K45 2004
003'.35369—dc21 2003052652
CIP

INTERNATIONAL EDITION ISBN 0–07–121933–1
Copyright © 2004. Exclusive rights by The McGraw-Hill Companies, Inc., for manufacture and export. This book cannot be re-exported from the country to which it is sold by McGraw-Hill. The International Edition is not available in North America.

www.mhhe.com

About the Authors

W. David Kelton is Professor and CBA Research Fellow in the Department of Quantitative Analysis and Operations Management at the University of Cincinnati. He received a B.A. in mathematics from the University of Wisconsin-Madison, an M.S. in mathematics from Ohio University, and M.S. and Ph.D. degrees in industrial engineering from Wisconsin.

His research interests and publications are in the probabilistic and statistical aspects of simulation, applications of simulation, and stochastic models. His papers have appeared in *Operations Research*, *Management Science*, the *INFORMS Journal on Computing*, *IIE Transactions*, *Naval Research Logistics*, and the *Journal of the American Statistical Association*, among others. He is co-author, with Averill M. Law, of *Simulation Modeling and Analysis*, currently in its third edition for McGraw-Hill.

He is Editor-in-Chief for the *INFORMS Journal on Computing* and has served as Simulation Area Editor for *Operations Research*, the *INFORMS Journal on Computing*, and *IIE Transactions*; Associate Editor of *Operations Research*, the *Journal of Manufacturing Systems*, and *Simulation*; and was Guest Co-Editor for a special simulation issue of *IIE Transactions*. Awards include the TIMS College on Simulation award for best simulation paper in *Management Science*, the IIE Operations Research Division Award, a Meritorious Service Award from *Operations Research*, the INFORMS College on Simulation Distinguished Service Award, and the INFORMS College on Simulation Outstanding Simulation Publication Award. He was President of the TIMS College on Simulation, and was the INFORMS co-representative to the Winter Simulation Conference Board of Directors from 1991 through 1999, serving as Board Chair for 1998. In 1987 he was Program Chair for the WSC, and in 1991 was General Chair. He has worked on grants and consulting contracts from a number of corporations, foundations, and agencies. He keeps up on current events via Chuck Shepherd's syndicated newspaper column *News of the Weird* and personally knows at least one person who has been named there.

Randall P. Sadowski is currently Product Manager for scheduling and data-tracking applications for Rockwell Software. He was previously director of university relations, chief applications officer, vice president of consulting services and user education at Systems Modeling Corporation.

Before joining Systems Modeling, he was on the faculty at Purdue University in the School of Industrial Engineering and at the University of Massachusetts. He received his bachelor's and master's degrees in industrial engineering from Ohio University and his Ph.D. in industrial engineering from Purdue.

He has authored over 50 technical articles and papers, served as chair of the Third International Conference on Production Research and was the general chair of the 1990 Winter Simulation Conference. He is on the visiting committee for the IE

departments at Lehigh University, the University of Pittsburgh, and Ohio University. He is co-author, with C. Dennis Pegden and Robert E. Shannon, of *Introduction to Simulation Using SIMAN*, now in its second edition with McGraw-Hill.

He is a Fellow of the Institute of Industrial Engineers and served as editor of a two-year series on Computer Integrated Manufacturing Systems for *IE Magazine* that received the 1987 IIE Outstanding Publication award. He has served in several positions at IIE, including president at the chapter and division levels, and vice president of Systems Integration at the international level. He founded and continues to organize the annual IIE/RS Student Simulation Contest. He collects tools and is the proud owner of a new tractor named Dutch and a recently enlarged and stocked farm pond.

David T. Sturrock is Director of Simulation Development at Rockwell Software. He is responsible for design, development, and support of simulation products in such varied markets as manufacturing, high-speed processing, contact centers, business processes, and real-time control. Dave has applied simulation techniques in the areas of transportation systems, scheduling, plant layout, contact centers, capacity analysis, process design, health care, and real-time control.

Dave received his bachelor's degree in industrial engineering from The Pennsylvania State University with concentrations in manufacturing and automation. During ten years at Inland Steel Company, he worked as a plant industrial engineer and subsequently formed and led a simulation group. He started using SIMAN just after it was first released in 1983. He joined Systems Modeling as a consultant in 1988. His first assignment was to "help out with the next release," and he has been doing that ever since.

He was General Chair for the international 1999 Winter Simulation Conference (WSC) and has participated in several funded research projects, written a handful of papers, and is an active member of the Institute of Industrial Engineers (IIE).

In his leisure time, Dave enjoys camping, hiking, canoeing, skiing, woodworking, and traveling with his wife and three daughters. So far, his travels have taken him to four continents, 17 countries, and all 50 U.S. states.

此为试读,需要完整PDF请访问: www.ertongbook.com

To those in the truly important arena of our lives:

Albert, Anna, Anne, Christie, and Molly;

Aidan, Charity, Emma, Jenny, Michael, Noah, Sammy, Sean, Shelley, and Tierney;

Melanie, Kathy, Victoria, and Diana.

Preface

This third edition of *Simulation with Arena* has the same goal as the first two editions: to provide an introduction to simulation using Arena. It is intended to be used as an entry-level simulation text, most likely in a first course on simulation at the undergraduate or beginning graduate level. However, material from the later chapters could be incorporated into a second, graduate-level course. The book can also be used to learn simulation independent of a formal course (more specifically, by Arena users). The objective is to present the concepts and methods of simulation using Arena as a vehicle to help the reader reach the point of being able to carry out effective simulation modeling, analysis, and projects using the Arena simulation system. While we'll cover most of the capabilities of Arena, the book is not meant to be an exhaustive reference on the software, which is fully documented in its extensive online reference and help system.

Included is a CD with the Arena 7.01 academic software and all the examples in the text. A Web site for the book can be found at http://www.arenasimulation.com/academicprograms/. We encourage all readers to visit this site to learn of any updates or errata for the book or example files supplied, possible additional exercises, and other items of interest. The site also contains material to support instructors who have adopted the book for use in class, including downloadable lecture slides and solutions to exercises; university instructors who have adopted the book should contact the local McGraw-Hill representative for authorization (see http://www.mhhe.com/catalogs/sem/engineering to locate representatives in the U.S., or call 1-609-426-5793 to locate representatives outside the U.S.).

We've adopted an informal, tutorial writing style centered around carefully crafted examples to aid the beginner in understanding the ideas and topics presented. Ideally, readers would build simulation models as they read through the chapters. We start by having the reader develop simple, well-animated, high-level models, and then progress to advanced modeling and analysis. Statistical analysis is not treated as a separate topic, but is integrated into many of the modeling chapters, reflecting the joint nature of these activities in good simulation studies. We've also devoted more advanced chapters to statistical issues and project planning to cover more advanced issues not treated in our modeling chapters. We believe that this approach greatly enhances the learning process by placing it in a more realistic and (frankly) less boring setting.

We assume neither prior knowledge of simulation nor computer-programming experience. We do assume basic familiarity with computing in general (files, folders, basic editing operations, etc.), but nothing advanced. A fundamental understanding of probability and statistics is needed, though we provide a self-contained refresher of these subjects in Appendices C and D.

Here's a quick overview of the topics and organization. We start in Chapter 1 with a general introduction, a brief history of simulation, and modeling concepts. Chapter 2 addresses the simulation process using a simple simulation executed by hand.

In Chapter 3, we acquaint readers with Arena by examining a completed simulation model of the problem simulated by hand in Chapter 2, rebuilding it from scratch, going over the Arena user interface, and providing an overview of Arena's capabilities.

Chapters 4 and 5 advance the reader's modeling skills by considering one "core" example per chapter, in increasingly complex versions to illustrate a variety of modeling and animation features; the statistical issue of selecting input probability distributions is also covered in Chapter 4 using the Arena Input Analyzer.

Chapter 6 uses the model in Chapter 5 to illustrate the basic Arena capabilities of statistical analysis of output, including single-system analysis, comparing multiple scenarios (configurations of a model), and searching for an optimal scenario; this material uses the Arena Output and Process Analyzers, as well as OptQuest for Arena.

In Chapter 7, we introduce another "core" model, again in increasingly complex versions, and then use it to illustrate statistical analysis of long-run (steady-state) simulations. Alternate ways in which simulated entities can move around is the subject of Chapter 8, including material-handling capabilities, building on the models in Chapter 7. Chapter 9 digs deeper into Arena's extensive modeling constructs, using a sequence of small, focused models to present a wide variety of special-purpose capabilities; this is for more advanced simulation users and would probably not be covered in a beginning course.

In Chapter 10, we describe a number of topics in the area of customizing Arena and integrating it with other applications like spreadsheets and databases; this includes using VBA (Visual Basic for Applications) with Arena. Chapter 11 shows how Arena can handle continuous and combined discrete/continuous models, such as fluid flow. Chapter 12 covers more advanced statistical concepts underlying and applied to simulation analysis, including random-number generators, variate and process generation, variance-reduction techniques, sequential sampling, and designing simulation experiments. Chapter 13 provides a broad overview of the simulation process and discusses more specifically the issues of managing and disseminating a simulation project.

Appendix A describes a complete modeling specification from a project for *The Washington Post* newspaper. In Appendix B, we give problem statements for the Arena modeling contest held annually by the Institute of Industrial Engineers (IIE) and Rockwell Software. Appendix C gives a complete but concise review of the basics of probability and statistics couched in the framework of their role in simulation modeling and analysis. The probability distributions supported by Arena are detailed in Appendix D. Installation instructions for the Arena academic software can be found in Appendix E. All references are collected in a single References section at the end of the book. The index is extensive, to aid readers in locating topics and seeing how they relate to each other; the index includes authors cited.

As mentioned above, the presentation is in "tutorial style," built around a sequence of carefully crafted examples illustrating concepts and applications, rather than in the conventional style of stating concepts first and then citing examples as an

afterthought. So it probably makes sense to read (or teach) the material essentially in the order presented. A one-semester or one-quarter first course in simulation could cover all the material in Chapters 1–8, including the statistical material. Time permitting, selected modeling and computing topics from Chapters 9–11 could be included, or some of the more advanced statistical issues from Chapter 12, or the project-management material from Chapter 13, according to the instructor's tastes. A second course in simulation could assume most of the material in Chapters 1–8, then cover the more advanced modeling ideas in Chapters 9–11, followed by topics from Chapters 12 and 13. For self-study, we'd suggest going through Chapters 1–6 to understand the basics, getting at least familiar with Chapters 7 and 8, then regarding the rest of the book as a source for more advanced topics and reference. Regardless of what's covered, and whether the book is used in a course or independently, it will be helpful to follow along in Arena on a computer while reading this book.

The CD included contains the academic version of Arena (see Appendix E for installation instructions), which has all the modeling and analysis capabilities of the complete commercial version but limits model size. All the examples in the book, as well as all the exercises at the ends of the chapters, will run with this educational version of Arena. The CD also contains files for all the example models in the book, as well as other support materials. This software can be installed on any university computer as well as on students' computers. It is intended for use in conjunction with this book for the purpose of learning simulation and Arena. It is not authorized for use in commercial environments.

If you were familiar with the second edition, here are the main changes:

- All the examples have been updated to conform to the current Arena version (7.01). The software is largely consistent with what was discussed in the second edition, but there are several new features and capabilities that we illustrate, including model documentation, enhanced plots, file reading and writing, printing, and animation symbols.
- Chapter 4 has been expanded to include what was Model 6-1.
- A new automotive maintenance and repair shop model has replaced the former call-center model, a new inventory model has been included in Chapter 5, and the statistical-analysis material has been moved out to Chapter 6.
- Chapter 6 is new and contains essentially what was in the statistical-analysis section of the former Chapter 5, using the new automotive maintenance and repair shop model of the updated Chapter 5.
- The new Chapters 7 through 13 cover the same material as in the former Chapters 6 through 12, respectively, except for updates.
- Two new IIE/RS modeling-contest problems have been added to Appendix B.
- The support materials on the Web site (slides and solutions) have all been updated.

As with any labor like this, there are a lot of people and institutions that supported us in a lot of different ways. First and foremost, Lynn Barrett at Rockwell Software really made this all happen by reading (and re-reading and re-re-reading, and then fixing) our semi-literate drafts, orchestrating the composing and production, reminding us of what month (and year) it was, and tolerating our tardiness and fussiness and quirky personal-hyphenation habits; her husband Doug also deserves our thanks for putting up with her putting up with us. Rockwell Software provided resources in the form of time, software, hardware, technical assistance, and moral encouragement; we'd particularly like to thank the Arena development team—Norene Collins, Cory Crooks, Glenn Drake, Tim Haston, Cynthia Kasales, Judy Kirby, Frank Palmieri, Chris Snyder, Dave Takus, and Vytas Urbonavicius—as well as Nicky Bleiel, Steve Frank, Judy Jordan, Gavan Hood, Scott Miller, Dennis Pegden, Jon Phillips, Darryl Starks, and Nancy Swets. And a special note of thanks goes to Deb Sadowski for her writing and influence as a co-author of the first two editions. The Department of Quantitative Analysis and Operations Management at the University of Cincinnati was also quite supportive.

We are also grateful to Gary Lucke and Olivier Girod of *The Washington Post* for allowing us to include a simulation specification that was developed for them by Rockwell Software as part of a larger project. Special thanks go to Pete Kauffman for his cover design and production assistance, and to Jim McClure for his cartoon and illustration design. And we appreciate the skillful motivation and gentle nudging by our editors at McGraw-Hill, Suzanne Jeans and, earlier, Eric Munson. The reviewers, Mansooreh Mollaghasemi, Barry Nelson, Ed Watson, and King Preston White, Jr., provided extremely valuable input and help, ranging from overall organization and content all the way to the downright subatomic. Thanks are also due to the many individuals who have used part or all of the early material in classes (as well as to their students who were subjected to early drafts), as well as a host of other folks who provided all kinds of input, feedback and help: Christos Alexopoulos, Ken Bauer, Diane Bischak, Sherri Blaszkiewicz, Eberhard Blümel, Mike Branson, Jeff Camm, Colin Campbell, John Charnes, Chun-Hung Chen, Hong Chen, Jack Chen, Russell Cheng, Christopher Chung, Frank Ciarallo, John J. Clifford, Mary Court, Tom Crowe, Halim Damerdji, Pat Delaney, Mike Dellinger, Darrell Donahue, Ken Ebeling, Neil Eisner, Gerald Evans, Steve Fisk, Michael Fu, Shannon Funk, Fred Glover, Dave Goldsman, Byron Gottfried, Frank Grange, Don Gross, John Gum, Tom Gurgiolo, Jorge Haddock, Bill Harper, Joe Heim, Michael Howard, Arthur Hsu, Eric Johnson, Elena Joshi, Keebom Kang, Elena Katok, Jim Kelly, Teri King, Gary Kochenberger, Patrick Koelling, David Kohler, Wendy Krah, Bradley Kramer, Michael Kwinn, Jr., Averill Law, Larry Leemis, Marty Levy, Bob Lipset, Gerald Mackulak, Nancy Markovitch, Deb Mederios, Brian Melloy, Mansooreh Mollaghasemi, Ed Mooney, Jack Morris, Jim Morris, Charles Mosier, Marvin Nakayama, Dick Nance, Barry Nelson, James Patell, Cecil Peterson, Dave Pratt, Mike Proctor, Madhu Rao, James Reeve, Steve Roberts, Paul Rogers, Ralph Rogers, Tom Rohleder, Jerzy Rozenblit, Salim Salloum, G. Sathyanarayanan, Bruce Schmeiser, Carl Schultz, Thomas Schulze, Marv Seppanen, Michael Setzer, David Sieger, Robert

Signorile, Julie Ann Stuart, Jim Swain, Mike Taaffe, Laurie Travis, Reha Tutuncu, Wayne Wakeland, Ed Watson, Michael Weng, King Preston White, Jr., Jim Wilson, Irv Winters, Chih-Hang (John) Wu, James Wynne, Susan Xu, and Stefanos Zenios.

W. David Kelton
University of Cincinnati
david.kelton@uc.edu

Randall P. Sadowski
Rockwell Software
rpsadowski@software.rockwell.com

David T. Sturrock
Rockwell Software
dtsturrock@software.rockwell.com

此为试读,需要完整PDF请访问: www.ertongbook.com

Arena, SIMAN, Cinema, and Arena Factory Analyzer are either registered trademarks or trademarks of Rockwell Software, Inc. AutoCAD is a registered trademark of Autodesk. Microsoft, ActiveX, Outlook, PowerPoint, Windows, Windows NT, Visio, and Visual Basic are either registered trademarks or trademarks of Microsoft Corporation in the United States and/or other countries. OptQuest is a registered trademark of OptTek Systems, Inc. Oracle is a registered trademark of Oracle Corporation. Crystal Reports is a registered trademark of Crystal Decisions. All other trademarks and registered trademarks are acknowledged as being the property of their respective owners.

This Rockwell Software product is warranted in accord with the product license. The product's performance will be affected by system configuration, the application being performed, operator control, and other related factors.

This product's implementation may vary among users.

This textbook is as up-to-date as possible at the time of printing. Rockwell Software reserves the right to change any information contained in this book or the software at any time without prior notice.

The instructions in this book do not claim to cover all the details or variations in the equipment, procedure, or process described, nor to provide directions for meeting every possible contingency during installation, operation, or maintenance.

Contents

Chapter 1: What Is Simulation? 1

1.1 Modeling 3
1.1.1 What's Being Modeled? 4
1.1.2 How About Just Playing with the System? 5
1.1.3 Sometimes You Can't (or Shouldn't) Play with the System 5
1.1.4 Physical Models 6
1.1.5 Logical (or Mathematical) Models 6
1.1.6 What Do You Do with a Logical Model? 6
1.2 Computer Simulation 7
1.2.1 Popularity and Advantages 7
1.2.2 The Bad News 8
1.2.3 Different Kinds of Simulations 9
1.3 How Simulations Get Done 10
1.3.1 By Hand 10
1.3.2 Programming in General-Purpose Languages 11
1.3.3 Simulation Languages 12
1.3.4 High-Level Simulators 12
1.3.5 Where Arena Fits In 12
1.4 When Simulations Are Used 14
1.4.1 The Early Years 14
1.4.2 The Formative Years 14
1.4.3 The Recent Past 15
1.4.4 The Present 15
1.4.5 The Future 15

Chapter 2: Fundamental Simulation Concepts 17

2.1 An Example 19
2.1.1 The System 19
2.1.2 Goals of the Study 21
2.2 Analysis Options 22
2.2.1 Educated Guessing 22
2.2.2 Queueing Theory 23
2.2.3 Mechanistic Simulation 24
2.3 Pieces of a Simulation Model 24
2.3.1 Entities 24
2.3.2 Attributes 25
2.3.3 (Global) Variables 26
2.3.4 Resources 26
2.3.5 Queues 26

2.3.6 Statistical Accumulators 27
2.3.7 Events 27
2.3.8 Simulation Clock 28
2.3.9 Starting and Stopping 28
2.4 Event-Driven Hand Simulation 29
2.4.1 Outline of the Action 29
2.4.2 Keeping Track of Things 30
2.4.3 Carrying It Out 32
2.4.4 Finishing Up 36
2.5 Event- and Process-Oriented Simulation 36
2.6 Randomness in Simulation 38
2.6.1 Random Input, Random Output 38
2.6.2 Replicating the Example 39
2.6.3 Comparing Alternatives 40
2.7 Overview of a Simulation Study 42
2.8 Exercises 43

Chapter 3: A Guided Tour Through Arena 47

3.1 Starting Up 49
3.2 Exploring the Arena Window 51
3.2.1 Opening a Model 51
3.2.2 Basic Interaction and Pieces of the Arena Window 51
3.2.3 Moving Around and Up and Down in the Flowchart View 54
3.2.4 Modules 55
3.2.5 Internal Model Documentation 56
3.3 Browsing Through an Existing Model: Model 3-1 57
3.3.1 The Create Flowchart Module 57
3.3.2 The Entity Data Module 59
3.3.3 The Process Flowchart Module 59
3.3.4 The Resource Data Module 62
3.3.5 The Queue Data Module 62
3.3.6 Animating Resources and Queues 63
3.3.7 The Dispose Flowchart Module 63
3.3.8 Connecting Flowchart Modules 64
3.3.9 Dynamic Plots 65
3.3.10 Dressing Things Up 67
3.3.11 Setting the Run Conditions 67
3.3.12 Running It 69
3.3.13 Viewing the Reports 69
3.4 Building Model 3-1 Yourself 75
3.4.1 New Model Window and Basic Process Panel 75
3.4.2 Place and Connect the Flowchart Modules 76
3.4.3 The Create Flowchart Module 77
3.4.4 Displays 77
3.4.5 The Entity Data Module 78

3.4.6 The Process Flowchart Module 78
3.4.7 The Resource and Queue Data Modules 79
3.4.8 Resource Animation 79
3.4.9 The Dispose Flowchart Module 80
3.4.10 Dynamic Plots 80
3.4.11 Window Dressing 83
3.4.12 The Run > Setup Dialog Boxes 84
3.4.13 Establishing Named Views 84
3.5 More on Menus, Toolbars, Drawing, and Printing 84
3.5.1 Menus 84
3.5.2 Toolbars 88
3.5.3 Drawing 91
3.5.4 Printing 93
3.6 Help! 93
3.7 More on Running Models 94
3.8 Summary and Forecast 95
3.9 Exercises 96

Chapter 4: Modeling Basic Operations and Inputs 101

4.1 Model 4-1: An Electronic Assembly and Test System 103
4.1.1 Developing a Modeling Approach 104
4.1.2 Building the Model 105
4.1.3 Running the Model 116
4.1.4 Viewing the Results 118
4.2 Model 4-2: The Enhanced Electronic Assembly and Test System 120
4.2.1 Expanding Resource Representation: Schedules and States 122
4.2.2 Resource Schedules 122
4.2.3 Resource Failures 126
4.2.4 Frequencies 128
4.2.5 Results of Model 4-2 131
4.3 Model 4-3: Enhancing the Animation 135
4.3.1 Changing Animation Queues 136
4.3.2 Changing Entity Pictures 138
4.3.3 Adding Resource Pictures 140
4.3.4 Adding Variables and Plots 142
4.4 Model 4-4: The Electronic Assembly and Test System with Part Transfers 144
4.4.1 Some New Arena Concepts: Stations and Transfers 144
4.4.2 Adding the Route Logic 146
4.4.3 Altering the Animation 149
4.5 Input Analysis: Specifying Model Parameters and Distributions 152
4.5.1 Deterministic vs. Random Inputs 153
4.5.2 Collecting Data 154
4.5.3 Using Data 155
4.5.4 Fitting Input Distributions via the Input Analyzer 156
4.5.5 No Data? 164

4.5.6 Nonstationary Arrival Processes 166
4.5.7 Multivariate and Correlated Input Data 167
4.6 Summary and Forecast 168
4.7 Exercises 168

Chapter 5: Modeling Detailed Operations 175

5.1 Model 5-1: An Automotive Maintenance and Repair Shop 178
5.2 New Modeling Issues 179
5.2.1 Multiple-Way Decisions 179
5.2.2 Sets 180
5.2.3 Variables and Expressions 180
5.2.4 Submodels 181
5.2.5 Duplicating Entities 182
5.2.6 Holding Entities 182
5.2.7 Statistics and Animation 182
5.2.8 Terminating or Steady-State 183
5.3 Modeling Approach 184
5.4 Building the Model 185
5.4.1 Defining the Data 186
5.4.2 Submodel Creation 192
5.4.3 Generate Appointment Calls 193
5.4.4 Make Appointment 198
5.4.5 Service Activity 201
5.4.6 Update Performance Variables 205
5.4.7 Control Logic 208
5.5 Finding and Fixing Model Errors 209
5.6 Animating the Automotive Shop Model 218
5.7 Model 5-2: Enhancing the Automotive Shop Model 223
5.8 New Modeling Issues for Model 5-2 223
5.8.1 Sets and Resource Logic 223
5.8.2 Nonstationary Arrival Process 225
5.9 Building Model 5-2 226
5.9.1 Modeling the Service Bays 226
5.9.2 Modeling the Customer Arrivals 228
5.10 Model 5-3: An (*s*, *S*) Inventory Simulation 233
5.10.1 System Description 233
5.10.2 Simulation Model 235
5.11 Summary and Forecast 247
5.12 Exercises 247

Chapter 6: Statistical Analysis of Output from Terminating Simulations 255

6.1 Time Frame of Simulations 258
6.2 Strategy for Data Collection and Analysis 258
6.3 Confidence Intervals for Terminating Systems 260

6.4 Comparing Two Alternatives 265
6.5 Evaluating Many Alternatives with the Process Analyzer (PAN) 268
6.6 Searching for an Optimal Alternative with OptQuest 275
6.7 Summary and Forecast 278
6.8 Exercises 279

Chapter 7: Intermediate Modeling and Steady-State Statistical Analysis 283

7.1 Model 7-1: A Small Manufacturing System 285
7.1.1 New Arena Concepts 286
7.1.2 The Modeling Approach 288
7.1.3 The Data Modules 289
7.1.4 The Logic Modules 291
7.1.5 Animation 298
7.1.6 Verification 300
7.2 Statistical Analysis of Output from Steady-State Simulations 304
7.2.1 Warm-Up and Run Length 304
7.2.2 Truncated Replications 308
7.2.3 Batching in a Single Run 309
7.2.4 What To Do? 312
7.2.5 Other Methods and Goals for Steady-State Statistical Analysis 313
7.3 Summary and Forecast 313
7.4 Exercises 313

Chapter 8: Entity Transfer 319

8.1 Types of Entity Transfers 321
8.2 Model 8-1: The Small Manufacturing System with Resource-Constrained Transfers 323
8.3 The Small Manufacturing System with Transporters 327
8.3.1 Model 8-2: The Modified Model 8-1 for Transporters 328
8.3.2 Model 8-3: Refining the Animation for Transporters 335
8.4 Conveyors 341
8.4.1 Model 8-4: The Small Manufacturing System with Nonaccumulating Conveyors 344
8.4.2 Model 8-5: The Small Manufacturing System with Accumulating Conveyors 349
8.5 Summary and Forecast 350
8.6 Exercises 350

Chapter 9: A Sampler of Further Modeling Issues and Techniques 353

9.1 Modeling Conveyors Using the Advanced Transfer Panel 355
9.1.1 Model 9-1: Finite Buffers at Stations 356
9.1.2 Model 9-2: Parts Stay on Conveyor During Processing 360
9.2 More on Transporters 361

此为试读，需要完整PDF请访问：www.ertongbook.com