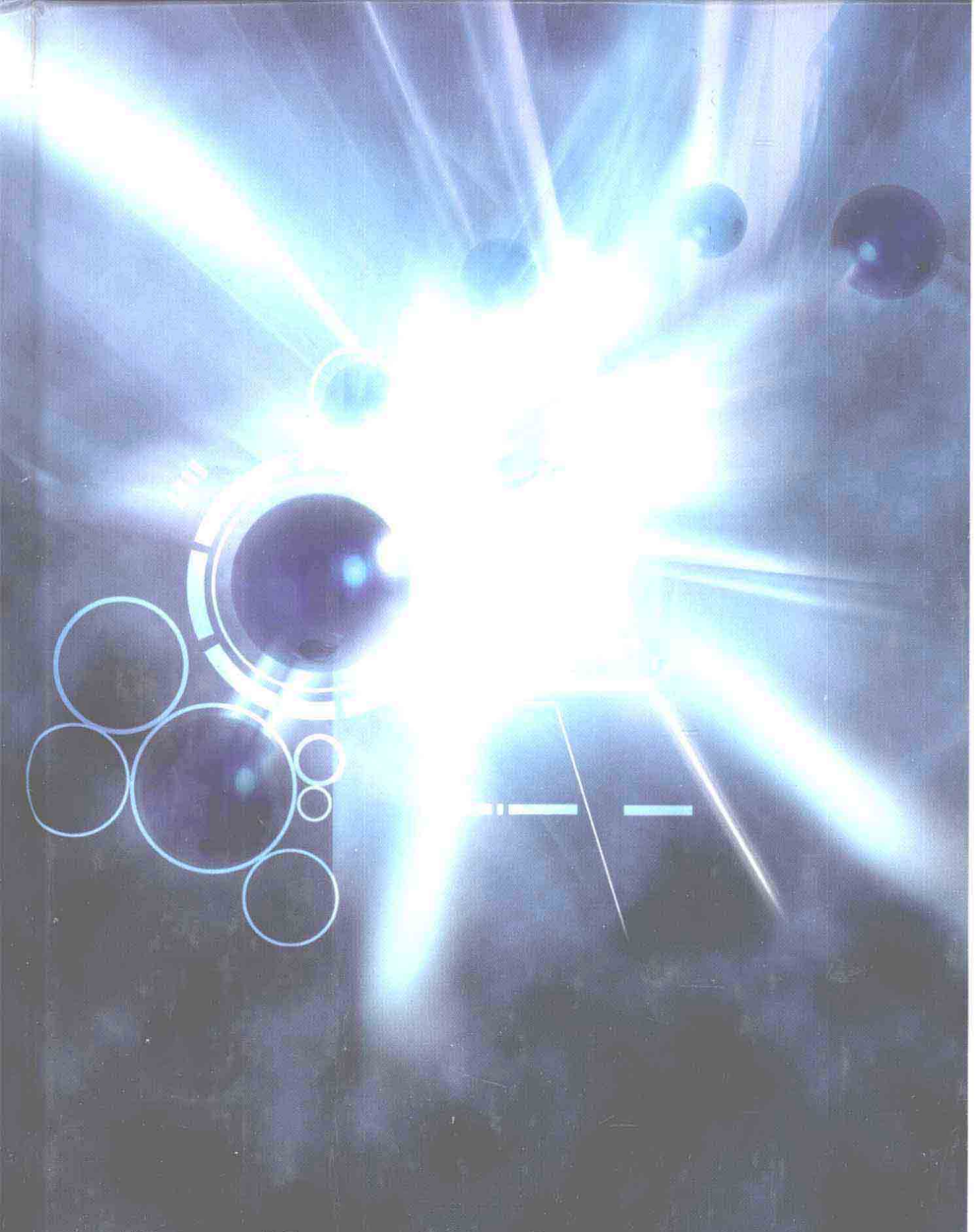

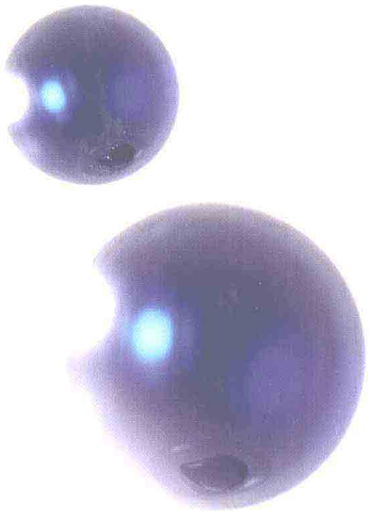

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SIMULATION

USING PROMODEL

second edition

S E C O N D E D I T I O N

SIMULATION USING PROMODEL

Dr. Charles Harrell
Professor, Brigham Young University, Provo, Utah
Director, PROMODEL Corporation, Orem, Utah

Dr. Biman K. Ghosh, Project Leader
Professor, California State Polytechnic University, Pomona, California

Dr. Royce O. Bowden, Jr.
Professor, Mississippi State University, Mississippi State, Mississippi

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To Paula, Raja, and Pritha
B.K.G.

To Yvonne, Emily, Elizabeth, Richard, Ryan, and Polly
C.H.

To CeCelia, Taylor, and Robert
R.O.B.

Charles Harrell
Charles Harrell is an associate professor of engineering and technology at Brigham Young University and founder of PROMODEL Corporation. He received his B.S. from Brigham Young University, M.S. in industrial engineering from the University of Utah, and Ph.D. in manufacturing engineering from the Technical University of Denmark. His area of interest and expertise is in manufacturing system design and simulation. He has worked in manufacturing and systems engineering positions for Ford Motor Company and the Eaton Corporation. At BYU he teaches courses in manufacturing systems, manufacturing simulation, and manufacturing information systems. He is the author or coauthor of several simulation books and has given numerous presentations on manufacturing system design and simulation. He serves on the board of directors of PROMODEL Corporation and continues to architect their simulation and modeling tools. He is a senior member of IIE and SME. He enjoys sports and playing with his grandchildren.

Biman K. Ghosh
Biman K. Ghosh is a professor of industrial and manufacturing engineering at the California State Polytechnic University, Pomona. He has been teaching and consulting all over the United States for the past 17 years. Prior to that Dr. Ghosh worked for such multinational companies as Tata, Mercedes Benz, Sandvik, and Siemens. Dr. Ghosh has been a consultant to Northrop Grumman, McDonnell Douglas, Boeing, Rockwell, Loral, Visteon, UPS, Sikorsky, Baxter, Paccar, Johnson Controls, Powersim, and Galorath. Dr. Ghosh has published extensively. His teaching and consulting interests are in the areas of simulation, supply chain management, lean manufacturing, flexible manufacturing, cellular manufacturing, computer-aided manufacturing, design for manufacturing, design of experiments, total quality management, and work measurement. His passion is still and video photography.

Royce O. Bowden
Royce O. Bowden, Jr., is a professor of industrial engineering at Mississippi State University (MSU), where he teaches courses in simulation, statistics, production control, and artificial intelligence. Professor Bowden's degrees include a Ph.D. and M.S. in industrial engineering. Prior to joining MSU, he served in engineering positions at Texas Instruments in Dallas, Texas, and Martin Marietta Aerospace in New Orleans, Louisiana. Professor Bowden's research program centers on the use, development, and integration of simulation and artificial intelligence techniques for solving systems engineering problems and is focused on simulation output analysis for decision support. His research on combining simulation with modern optimization techniques provided the foundation for the first widely used commercial simulation optimization software. Dr. Bowden's research program has been funded by several organizations including the U.S. Department of Transportation, National Science Foundation, U.S. Department of Agriculture, National Aeronautics and Space Administration, Whirlpool Corporation, and Litton-Ingalls Shipbuilding. Professor Bowden is author (or coauthor) of numerous research papers and two simulation books and serves as an associate editor for *International Journal of Modeling and Simulation*. Dr. Bowden is a Hearin Distinguished Professor of Engineering at MSU. He is a licensed private airplane pilot and an accomplished unicyclist (rumored to have been seen riding and juggling at the same time).

F O R E W O R D

Simulation is a modeling and analysis technique used to evaluate and improve dynamic systems of all types. It has grown from a relatively obscure technology used by only a few specialists to a widely accepted tool used by decision makers at all levels in an organization. Imagine being in a highly competitive industry and managing a manufacturing or service facility that is burdened by outdated technologies and inefficient management practices. In order to stay competitive, you know that changes must be made, but you are not exactly sure what changes would work best, or if certain changes will work at all. You would like to be able to try out a few different ideas, but you recognize that this would be very time-consuming, expensive, and disruptive to the current operation. Now, suppose that there was some magical way you could make a duplicate of your system and have unlimited freedom to rearrange activities, reallocate resources, or change any operating procedures. What if you could even try out completely new technologies and radical new innovations all within just a matter of minutes or hours? Suppose, further, that all of this experimentation could be done in compressed time with automatic tracking and reporting of key performance measures. Not only would you discover ways to improve your operation, but it could all be achieved risk free—without committing any capital, wasting any time, or disrupting the current system. This is precisely the kind of capability that simulation provides. Simulation lets you experiment with a computer model of your system in compressed time, giving you decision-making capability that is unattainable in any other way.

This text is geared toward simulation courses taught at either a graduate or an undergraduate level. It contains an ideal blend of theory and practice and covers the use of simulation in both manufacturing and service systems. This makes it well suited for use in courses in either an engineering or a business curriculum. It is also suitable for simulation courses taught in statistics and computer science programs. The strong focus on the practical aspects of simulation also makes it a book that any practitioner of simulation would want to have on hand.

This text is designed to be used in conjunction with ProModel simulation software, which accompanies the book. ProModel is one of the most powerful and popular simulation packages used today for its ease of use and flexibility. ProModel was the first fully commercial, Windows-based simulation package and the first to introduce simulation optimization. ProModel is already being used in thousands of organizations and taught in hundreds of universities and colleges throughout the world. While many teaching aids have been developed to train individuals in the use of ProModel, this is the first full-fledged textbook written for teaching simulation using ProModel.

Simulation is definitely a learn-by-doing activity. The goal of this text is not simply to introduce students to the topic of simulation, but to actually develop competence in the use of simulation. To this end, the book contains plenty of real-life examples, case studies, and lab exercises to give students actual experience in the use of simulation. Simulation texts often place too much emphasis on the theory behind simulation and not enough emphasis on how it is used in actual problem-solving situations. In simulation courses we have taught over the years, the

strongest feedback we have received from students is that they wish they had more hands-on time with simulation beginning from the very first week of the semester.

This text is divided into three parts: a section on the general science and practice of simulation, a lab section to train students in the use of ProModel, and a section containing cases to assign as student projects. While the book is intended for use with ProModel, the division of the book into these three distinct parts permits a modular use of the book, allowing any part to be used independently of any other part. For example, the lab section based on ProModel could be replaced with training on some other simulation product. If you already have a background in simulation and want to use the book as a primer on ProModel, the labs can be completed independently of Parts I and III.

Part I consists of study chapters covering the science and technology of simulation. The first four chapters introduce the topic of simulation, its application to system design and improvement, and how simulation works. Chapters 5 through 11 present both the practical and theoretical aspects of conducting a simulation project and applying simulation optimization. Chapters 12 through 14 cover specific applications of simulation to manufacturing, material handling, and service systems.

Part II is the lab portion of the book containing exercises for developing simulation skills using ProModel. The labs are correlated with the reading chapters in Part I so that Lab 1 should be completed along with Chapter 1 and so on. There are 14 chapters and 14 labs. The labs are designed to be self-teaching. Students are walked through the steps of modeling a particular situation and then are given exercises to complete on their own.

Part III is a series of case studies taken mostly from actual scenarios that can be assigned as simulation projects. They are intended as capstone experiences to give students an opportunity to bring together what they have learned in the course to solve a real-life problem.

This text focuses on the use of simulation to solve problems in the two most common types of systems today: manufacturing and service systems. Nearly 15 percent of the U.S. workforce is employed in manufacturing. In 1955, about one-half of the U.S. workforce worked in the service sector. Today nearly 80 percent of the American workforce can be found in service-related occupations. Manufacturing and service systems share much in common. They both consist of activities, resources, and controls for processing incoming entities. The performance objectives in both instances relate to quality, efficiency, cost reduction, process time reduction, and customer satisfaction. In addition to having common elements and objectives, they are also often interrelated. Manufacturing systems are supported by service activities such as product design, order management, or maintenance. Service systems receive support from production activities such as food production, check processing, or printing. Regardless of the industry in which one ends up, an understanding of the modeling issues underlying both systems will be helpful.

Acknowledgments

No work of this magnitude is performed in a vacuum, independently of the help and assistance of others. We are indebted to many colleagues, associates, and other individuals who had a hand in this project. John Mauer (Geer Mountain Software) provided valuable information on input modeling and the use of Stat::Fit. Dr. John D. Hall (APT Research, Inc.) and Dr. Allen G. Greenwood (Mississippi State University) helped to develop and refine the ANOVA material in Chapter 10. Kerim Tumay provided valuable input on the issues associated with service system simulation.

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BRIEF CONTENTS

C O N T E N T S

PART I

STUDY CHAPTERS