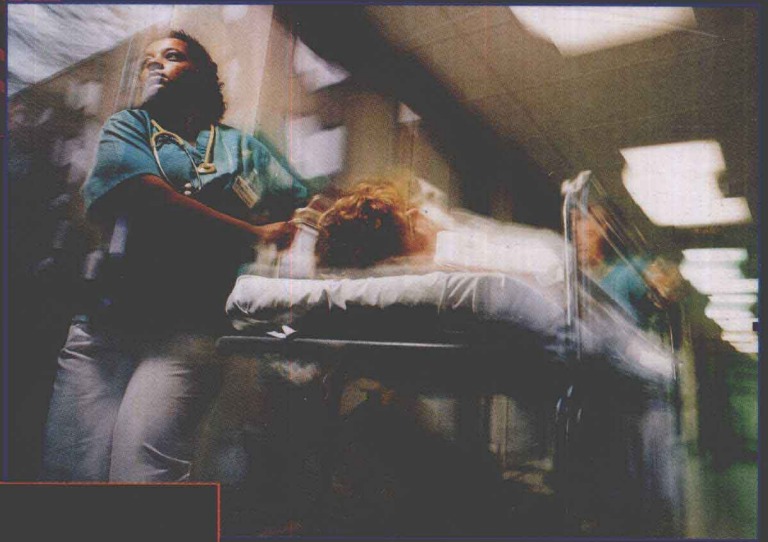
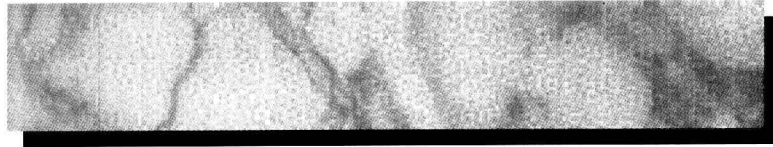


PRODUCTION AND OPERATIONS MANAGEMENT

AN APPLIED MODERN APPROACH



JOSEPH S.
MARTINICH



PRODUCTION AND OPERATIONS MANAGEMENT

AN APPLIED MODERN APPROACH

JOSEPH S. MARTINICH

University of Missouri-St. Louis



John Wiley & Sons, Inc.

New York • Chichester • Brisbane • Toronto • Singapore • Weinheim

| | |
|--|-------------------------------------|
| <i>Acquisitions Editor</i> | Beth Lang Golub |
| <i>Senior Developmental Editor</i> | Nancy Perry |
| <i>Marketing Manager</i> | Leslie Hines |
| <i>Production Manager</i> | Charlotte Hyland |
| <i>Outside Production Management</i> | Suzanne Ingrao of Ingrao Associates |
| <i>Senior Designer</i> | Laura Nicholls |
| <i>Manufacturing Manager</i> | Mark Cirillo |
| <i>Photo Editor</i> | Hilary Newman |
| <i>Senior Illustration Coordinator</i> | Anna Melhorn |

Cover Photos by: (top) Paul Chesley/Tony Stone Images, New York, Inc.
 (center) Mark Joseph/Tony Stone Images, New York, Inc.
 (bottom) Charles Thatcher/Tony Stone Images, New York, Inc.

This book was set in 10/12 pt Noverese by Ruttle, Shaw, and Wetherill and printed and bound by Von Hoffmann Press. The cover was printed by Phoenix Color.

Recognizing the importance of preserving what has been written, it is a policy of John Wiley & Sons, Inc. to have books of enduring value published in the United States printed on acid-free paper, and we exert our best efforts to that end.

Copyright ©1997, by John Wiley & Sons, Inc.

All rights reserved. Published simultaneously in Canada.

Reproduction or translation of any part of this work beyond that permitted by Sections 107 and 108 of the 1976 United States Copyright Act without the permission of the copyright owner is unlawful. Requests for permission or further information should be addressed to the Permissions Department, John Wiley & Sons, Inc.

Library of Congress Cataloging in Publication Data

Martinich, Joseph Stanislaus, 1950–

Production and operations management : an applied modern approach / by Joseph S. Martinich.
 p. cm.

Includes bibliographical references and index.

ISBN 0-471-54632-1 (cloth : alk. paper)

1. Production management. 2. Industrial engineering. I. Title.

TS155.M3345 1997

658.5—dc20

96-28170

CIP

Printed in the United States of America

10 9 8 7 6 5 4 3 2 1

P R E F A C E

No one undertakes a five-year writing project without compelling personal reasons. In my case I had taught production and operations management for 12 years to over a thousand students, 98% of whom were not operations management majors but rather were majoring in accounting, marketing, finance, MIS, and several other fields. Few students had any idea what operations management was, and their quantitative skills were quite varied, with many of them exhibiting severe math anxiety. These factors presented several special challenges in teaching this course: how to demonstrate the relevance of operations management to this wide variety of non-majors; how to teach the thought processes and analytical reasoning required in operations management in a mathematically accessible and interesting way that reduces math anxiety; how to eliminate artificial separations between quantitative and qualitative/behavioral material; and how to make the discussion and examples realistic, and familiarize students with the richness and importance of operations, without overwhelming them.

Over the years, I prepared in-class notes, transparencies, and exercises that addressed these issues in the course, but I found no textbook that adequately assisted the students (and me) in doing so. Many students encouraged me to turn my notes into a book because they found them more readable and interesting than the text. Little did I know that this "conversion" of notes would take five years of my life, but I believe the result has been a book that will help instructors teach, and students learn, about the extent, substance, and excitement of operations management.

GOALS AND CORRESPONDING FEATURES

In writing this book I had the following goals:

1. **To demonstrate the importance of operations management to non-majors.** Anyone seeking a supervisory or managerial career in marketing,

accounting, finance, engineering, MIS, medicine, law, and most other professions, will find that a large part of their jobs will be devoted to operational issues.

- Opening each chapter is an **On the Job** box, which briefly describes the featured person's operations management activities. Many of the people profiled work outside the operations function of their companies; they include accounting managers, financial officers, customer service and sales personnel, purchasing managers, engineers, and entrepreneurs. Few had extensive formal training in operations management, but most have found that their formal exposure to operations management, though limited, has been invaluable.
 - **Over 200 companies** are used to illustrate the applicability and importance of operations management to a wide variety of organizations, as well as a variety of jobs.
 - Each chapter contains an **In Good Company** box, which describes how the profiled organization has addressed the operations management issues in that chapter to improve its performance.
2. **To familiarize students with real production systems.** Although many of my students hold part- or full-time jobs, most of them are familiar with very few production systems and frequently with only a small part of their own companies, such as the accounts receivable department. Accountants, sales representatives, and computer systems analysts who understand the general nature and activities of production systems are better able to work with and communicate with customers, suppliers, and co-workers and be more effective in their jobs.
- **Chapter 3**, therefore, provides **tours of four production systems**. These tours, which include both manufacturing and service operations, describe the main activities involved in producing the compa-

nies' products, whether it be a roll of liner-board or a title insurance policy. More importantly, the chapter identifies operational problems and issues important to the success of the company. These discussions preview and motivate the topics to be covered in the remainder of the book.

- The end-of-chapter **Cases** and some in-text **examples** have also been designed to provide descriptions of real production systems or parts of systems.
3. **To make the topics realistic and applicable.** Because of their work experiences, students want to see how the topic applies to their jobs. They have also encountered the ambiguities, "messiness," and unanticipated consequences of real situations, so they will not accept tools that work only in idealized worlds.
- I have used real examples extensively to show how companies and workers are confronting P/OM issues and problems. Over 100 photos make the people, companies, and situations more tangible.
 - Many of the illustrative examples are a bit longer and "messier" than the "toy" problems commonly used in texts. Typically, a single example will grow in complexity and realism as the discussion progresses and additional factors are introduced. For example, Chapter 7 first presents the rationale, thought-process, and mechanics of a standard heuristic for designing a single repetitive flow process (assembly line). Unlike many P/OM texts, however, this chapter then discusses methods for improving the design, including switching heuristics and nonquantitative considerations involving staffing, technology, and task synergies. More advanced topics, such as the use of parallel work-stations, parallel production lines, and the effects of randomness and variation on the production system, are presented for instructors who wish to cover the topic in greater depth. Without being smothered in mathematical calculations, students can see the complexity of operational problems and possible approaches to resolving them and become familiar with available tools.
 - The end-of-chapter **Cases** provide detailed and realistic examples of how quan-

titative and qualitative aspects of P/OM must be integrated to solve real problems and bring together the topics of the chapter and related chapters. With two exceptions (Walt Disney World and Southwest Airlines), the companies used are fictitious, but the problems underlying most of the cases are a synthesis of actual situations from my experiences and those of colleagues or from written reports. The cases are quite different from those in other books in that they tell a story of the problem and how it was solved. They demonstrate the problems that occur in implementation; the unexpected events that can occur; and how behavioral and quantitative tools can be combined to obtain better solutions than either one alone can achieve. Although the cases are not designed for "solution," discussion questions are provided with each one.

4. **To provide a state-of-the art treatment of topics.** In the past 20 years, businesses have radically changed the way they design and produce goods and services; they have redesigned jobs and work systems, quality management systems, and material management and inventory systems, and they have changed the technologies they use at a dizzying pace. Terms such as *lean production*, *just-in-time production*, *electronic data interchange*, *total quality management*, *concurrent engineering*, and *cellular production* have entered the vernacular of the business press.
- These approaches and methodologies are not simply tacked onto this book as a separate "new methods" section resembling a glossary. They are discussed extensively throughout the book in an integrated fashion. For example, not only is Chapter 11 devoted entirely to *quality management*, total quality management principles and techniques are woven into the chapters on operations strategy, product design, process design, job design, and lean production.
 - Entire chapters or substantial sections, not just brief abstracts, are devoted to topics such as *lean and just-in-time production*, *cellular production*, and *vendor relations*.
 - Attention to the *ecological implications* of operations decisions has been increasing, and not

simply because of environmental regulations. Several chapters contain sections that point out, and illustrate with real examples, the opportunities that exist for companies to increase profits by designing products and production processes and managing operations in an environmentally sound manner.

5. To emphasize the strategic role of operations in organizations.

The major changes occurring in business have involved fundamental changes in strategy. Companies such as Hewlett-Packard, Southwest Airlines, Walt Disney, Wal-Mart, Toyota, and Chrysler have become successful not simply because they have marketed their products well, but because they have developed production systems that allow them to excel in various ways: introducing new products more quickly, producing products of higher quality or at lower cost than competitors, or being more responsive and flexible in the timeliness of delivery and variety of products produced.

- Chapter 2, therefore, provides an extensive discussion of the *role of operations in the development and execution of an organization's strategy*. The need for compatibility between the marketing strategy, such as one based on providing customized products, and the operations strategy and production system is emphasized. Numerous real-world examples and numerical illustrations are used to show how companies can, and have, exploited operational strengths.
- Subsequent chapters dealing with *system design issues* reinforce and expand the discussion of operations strategy, such as how capacity and facility location decisions can be used to enhance competitive position.

6. To make the quantitative models and tools accessible.

The proliferation of computers and model-based software has made the use of quantitative models and methods in operations management *more* wide-spread and important rather than less so. However, the form and level of knowledge students need regarding quantitative methods has changed. Every student needs to develop the ability to analyze a situation or problem, identify what information is known, structure the problem, identify what is to be determined, and select a method for finding the solution.

- When presenting quantitative material I have tried to focus on the thought-process of how to approach various types of problems, and *when* and *why* the approach presented is appropriate in practice.
- To a large extent, I have avoided presenting quantitative material in a fashion where assumptions and formulas are stated, followed by a “toy” numerical example where the student simply substitutes numbers for variables. Because my illustrative examples explain *the rationale of the approach and the reasons* for each step, the mathematical steps are more intuitive, less magical, and more likely to be comprehended and retained by students.
- **Solved Problems** are provided at the end of all chapters that contain quantitative material. The solutions for these problems are explained in detail, providing further reinforcement and practice for students.



ORGANIZATION OF THE BOOK

The general organization of the book is consistent with most P/OM courses. It begins with *general background information* on operations management, strategy, and production processes. It then discusses issues related to the *design* of production systems. The final part focuses on shorter-term operations *planning* and *control* decisions. Three features of the organization of the book should also assist instruction.

Topics are integrated and reinforced. Topics such as quality management and lean production permeate so many aspects of operations that it is artificial to segment totally their coverage from other operations management topics. For example, mistake-proofing of jobs (*poka yoke*) is a common tool used in quality management, but not to include it in the job design chapter would be to omit an important job design principle. For this reason, many popular topics are covered in more than one place in the book. Typically, one chapter will provide detailed discussion of the topic, but it will be discussed within other relevant chapters as well. This approach allows instructors to omit chapters from the course and still be able to cover desired topics.

Quantitative and qualitative topics are integrated.

To perform good operational planning and to solve operational problems, a manager must utilize a wide set of skills and knowledge. A theme of this book is that quantitative methods are *tools* to be used as part of the decision-making process, not an end in themselves. Too often operations management topics and problems are divided into mutually exclusive categories—quantitative or qualitative—where one and only one approach is presented. I have organized the book by general topics or problems and have included whatever knowledge or skills are helpful or appropriate. For example, Chapter 9 not only presents mathematical models of queueing systems, it also considers “qualitative” issues, such as the relative advantages of single waiting lines and express servers, the psychology of waiting, and selection of appropriate performance measures.

The book is flexible and usable by a wide audience.

Material in this book has been used at four universities in both undergraduate and graduate business courses and in a senior level engineering management course with success. The topics covered in introductory P/OM courses vary considerably from school to school and instructor to instructor. Therefore, this book contains all the standard P/OM topics, from which an instructor can customize his or her course. Further, almost all chapters are sufficiently self-contained so any set of chapters can be combined for a course.

Instructors should find this text very flexible with respect to the degree of mathematical content desired in the course. By choosing to include or omit individual chapter sections, **Chapter Supplements**, or **Tutorials**, instructors can use this book for courses ranging from those with quite modest to very substantial mathematical emphasis. The core of the book only assumes students have prerequisite knowledge of college algebra and basic probability and statistics. For those schools that wish to introduce management science tools, such as linear programming or simulation, as part of the P/OM course, three **Tutorials** provide in-depth introductions with special focus on how these tools can be used for operations management. At those schools where students have more advanced mathematical preparation, such as a prerequisite management science course, the tutorials can either be omitted or sections of them can be used to illustrate the application of these tools to P/OM topics.



OTHER FEATURES

In addition to the features mentioned earlier—**On the Job** and **In Good Company** profiles, **End-of-Chapter Cases**, **Plant Tours**, and **Solved Problems**—the book contains several other features that support the learning process:

- **Chapter Summaries.** The most important issues discussed in the chapter are presented in one- or two-sentence statements at the end of each chapter. These reinforce key ideas and provide a quick reference for the main ideas.
- **Highlighted Formulas and Key Formulas Section.** The most important and frequently needed formulas and equations are highlighted with color in the body of the chapter. They are then printed together at the end of the chapter for easy reference when students are solving numerical problems.
- **Highlighted Key Terms and Key Terms Section.** Key terms are highlighted in bold where they are first defined and then are listed at the end of each chapter with the page number cited where their definition was given.
- **End-of-Chapter Problems.** The book contains approximately 250 end-of-chapter problems. I have intentionally tried to provide a set of problems with a wide range of difficulty from the very direct and simple to relatively complex mini-cases requiring considerable analysis and possibly the use of computer software. (The most difficult ones are designated by an asterisk *.) To a large extent, the problems have been constructed in pairs; problems 1 and 2 address the same topic, and so on. In general, even-numbered problems will only use data from other even-numbered problems and similarly for odd-numbered problems. The answers to almost all odd-numbered problems are given at the end of the book.
- **Discussion and Review Questions.** Over 270 questions are provided at the end of the chapters. These not only help students review the important topics, but many require students to relate the topics to their own experiences and to draw upon several topics together to answer the questions.

SUPPLEMENTARY MATERIALS

Instructor's Guide. The Instructor's Guide was written by the author to make sure it was compatible with the themes and style of the text. For each chapter, the Guide contains: (1) a list of learning objectives, (2) possible in-class exercises to motivate or illustrate the chapter topic, (3) suggested examples or additional comments instructors can use to illustrate topics, (4) solutions to all end-of-chapter problems, (5) answers to review and discussion questions where there is a dominant answer (for many questions, especially those requiring students to use their own experiences no single answer exists), and (6) possible answers to the case questions.

PowerPoint Presentation. These PowerPoint lecture slides contain a combination of key concepts, images, and examples from the text. Developed by Lance Matheson of Virginia Tech, the slides are divided into a thorough presentation file for each chapter, and consist of over 600 instructional images. Designed according to the organization of the material in the text, this series of electronic transparencies can be used for classroom presentation to reinforce P/OM concepts visually and graphically.

Computer Software. Software developed by Y. Chang (developer of QSOM™ Prentice Hall) is available with the book. However, the book is designed so it can be used with any of the standard operations management or management science packages.

Test Bank. Including objective questions and problems, as well as short-answer and essay questions, the Test Bank has been designed to meet the varying testing needs of instructors.

Computerized Test Bank. The entire Test Bank is also available in a computerized form, allowing instructors to create and modify exams. It is available in a Windows format for IBM and IBM compatibles.

Video Tapes. The Wiley/Nightly Business Report Video contains segments from the highly respected Nightly Business Report that have been selected for their applicability to P/OM concepts, their discus-

sion of various companies and industries, and for their reinforcement of key concepts in the text. Each segment is approximately 3-5 minutes long and can be used to introduce topics to students and provide a real-world context for related concepts. Additionally, a selection of plant tour videos are available, related to companies and industries in the text.

Software Animated Simulations. This selection of software simulations of key concepts from the text are designed for use in classroom presentation. The simulations, including queuing and JIT scheduling, allow instructors to demonstrate the effects of key parameters.

Supplement CD-ROM. This CD-ROM contains all of the supplements for this text (excluding video) in computerized form, allowing instructors to print, edit, and project the material as needed. Instructors may print out any of the material for their own use or for distribution to students. Also included on the CD-ROM are the Software Animated Simulations, the PowerPoint Presentations, and the text illustrations. Available for IBM or IBM compatibles.

ACKNOWLEDGMENTS

This book is the result of hard work by many people. First, I would like to thank the hundreds of students who used parts of this book in class and provided helpful feedback. I would especially like to thank Carolyn Weigel Schriefer, my research assistant for this book. I am also grateful to Professor L. S. Hiraoka's P/OM students at Kean College of New Jersey, who told us what pedagogical elements were most useful to them as they studied and who evaluated the proposed design of the text. Second, I would like to thank the following faculty reviewers who reviewed various drafts very conscientiously and provided superb comments to improve the style and content of the text.

| | |
|-----------------|------------------------------------|
| John Buzacott | York University |
| Barbara Flynn | Iowa State University |
| Frank Forst | Loyola University of Chicago |
| Gregory Frazier | University of Oregon |
| Manton Gibbs | Indiana University of Pennsylvania |
| S. K. Goyal | Concordia University, Montreal |
| Jeff Heyl | DePaul University |

| | |
|------------------|---|
| Tim Ireland | Oklahoma State University |
| Thomas Johnson | University of Southern Florida |
| V. Kannan | Michigan State University |
| Gary Kern | University of Notre Dame |
| Jerzy Kyparisis | Florida International University |
| Hon-Shiang Lau | Oklahoma State University |
| Phillip Lederer | University of Rochester |
| Lewis Litteral | University of Richmond |
| Timothy Lowe | University of Iowa |
| James Luxhoj | Rutgers University |
| Lance Matheson | Virginia Polytechnic Institute |
| George Monahan | University of Illinois-Urbana-Champaign |
| C. Carl Pegels | SUNY-Buffalo |
| Fred Raafat | San Diego State University |
| Farhad Raiszadeh | University of Tennessee-Chattanooga |
| Jeffrey Ringuest | Boston College |
| Dan Rinks | Louisiana State University |
| Rudolph Russell | University of South Carolina |
| Joseph Sarkis | University of Texas-Arlington |
| Todd Schultz | Augusta College |
| Ramesh Soni | Indiana University of Pennsylvania |
| Ashok Srinivasan | Purdue University |
| John Steelquist | Chaminade University |

Third, I would like to thank those people at Wiley who believed in this project and helped to produce a book of which I can be proud: Beth Lang Golub, Nancy Perry, Leslie Hines, Francine Banner, David Kear, Charlotte Hyland, Anna Melhorn, Laura Nicholls, and Hilary Newman. Many thanks also go to Suzanne Ingrao for her work in producing the book. I would like to give special thanks to Elisa Adams, my development editor. Throughout the process she gave me direct and constructive comments and helped me to keep up my spirits and to maintain at least a modicum of sanity. Fourth, I would like to thank those people featured in the "On the Job" profiles, those who helped with the plant tours, and those people and companies who provided photos and reviewed narratives used in the book. Finally, this is a "first edition" book, so I hope instructors will be patient with any deficiencies they find. Many difficult trade-offs and decisions had to be made about what topics to include and how to present them. The collective experiences and wisdom of my P/OM colleagues is far beyond my own knowledge. So I seek your suggestions, advice, and even critical comments that will help me to make future editions better. I want to practice continuous improvement and make the second edition even better than the first. Please feel free to e-mail me at martinic@umslvma.umsl.edu.

C O N T E N T S

PART 1

AN INTRODUCTION TO OPERATIONS AND STRATEGY

| | |
|---|---|
| <p>CHAPTER 1 PRODUCTION SYSTEMS AND OPERATIONS MANAGEMENT 5</p> <hr style="border: 0.5px solid black; margin-top: 5px;"/> <p><i>1.1 P/OM'S VALUE TO YOU</i> 6 <i>On the Job:</i> Carol R. Caruthers, Price Waterhouse LLP 6</p> <p><i>1.2 PRODUCTION SYSTEMS AND THE FUNCTIONAL UNITS OF ORGANIZATIONS</i> 7 Production of Goods and Services 7 Functional Units of the Organization 9</p> <p><i>1.3 WHAT IS OPERATIONS MANAGEMENT?</i> 10 Operations as a Strategic Weapon: Reaching the Goals 11 <i>In Good Company:</i> Quality Drives the Gap 12 Responsibilities and Challenges Facing Operations Managers 13 Skills and Knowledge Needed to Be a Successful Operations Manager 16</p> <p><i>1.4 THE HISTORY OF OPERATIONS MANAGEMENT</i> 18 The Industrial Revolution 18 Scientific Management 20 The Human Relations Movement 23 Operations Research/Management Science (OR/MS) 24 Computers in Operations Management 24 The Japanese Production System 25 Operations Management Today 27</p> <p><i>1.5 OPERATIONS MANAGEMENT, PRODUCTIVITY, AND COMPETITIVENESS</i> 28</p> | <p><i>1.6 OPERATIONS MANAGEMENT IS FOR EVERYONE</i> 29</p> <p>CHAPTER 2 OPERATIONS STRATEGY 34</p> <hr style="border: 0.5px solid black; margin-top: 5px;"/> <p><i>2.1 STEERING THE SHIP</i> 35 <i>On the Job:</i> Bob Anastasi, CTI-Cryogenics 35</p> <p><i>2.2 THE ORGANIZATION'S STRATEGY</i> 36 Goals 36 Market and Competitive Analysis 37 Selecting Products, Markets, and Order-Winning Dimensions 37 Philosophy and Policies 38 The Business Unit Strategy 38</p> <p><i>2.3 OPERATIONS AS A COMPETITIVE WEAPON</i> 38</p> <p><i>2.4 DEVELOPING AN OPERATIONS STRATEGY</i> 40</p> <p><i>2.5 OPERATIONALIZING GOALS AND MEASURING PERFORMANCE</i> 41 Measuring Productivity 42 Cost Measures and Accounting Practices 44 Goal-Based Measures of Performance 45</p> <p><i>2.6 GUIDING OPERATIONS DECISIONS: OPERATIONS SUBSTRATEGIES</i> 47 Technology Strategy: Capabilities and Expertise 47 Capacity Strategy 49 Facility Location Strategy 51 Process Strategy 53 Quality Strategy 56 Human Resources Strategy 56 Information in Operations Strategy 57</p> |
|---|---|

| | | | | | |
|-------------------------------|---|----|-----|--|----|
| 2.7 | PRODUCTION COST STRUCTURE AND THE OPERATIONS AND MARKETING STRATEGIES | 58 | 3.3 | STANDARD REGISTER COMPANY: PRODUCTION OF BUSINESS FORMS | 79 |
| | Leverage and Capacity Utilization | 58 | | Order Receipt and Production Scheduling | 81 |
| | Using Experience Effects and Economies of Scale Strategically | 60 | | Printing | 82 |
| | <i>In Good Company: Hewlett-Packard's Strategy Takes Aim at Its Competitors</i> | 63 | | Collating and Finishing | 83 |
| 2.8 | REVISING AND UPDATING THE OPERATIONS STRATEGY | 63 | | Packing and Shipping | 84 |
| | <i>Walt Disney World, Orlando, Florida: An Operations Strategy Case</i> | 68 | | Major Operational Issues | 84 |
| <hr/> | | | | | |
| CHAPTER 3 TOURS OF OPERATIONS | | 71 | 3.4 | UNITED PARCEL SERVICE (UPS): LOCAL, NATIONAL, AND WORLDWIDE DELIVERY | 87 |
| 3.1 | ONE SIZE DOES NOT FIT ALL | 72 | | The Delivery Network and a Typical Delivery Cycle | 87 |
| 3.2 | JEFFERSON SMURFIT CORPORATION: PAPERBOARD MANUFACTURING | 72 | | The Facility | 89 |
| | Products | 73 | | Sorting | 89 |
| | Pulp Preparation | 74 | | Loading | 90 |
| | The Fourdrinier Machine | 75 | | Major Operational Issues | 90 |
| | Winding, Cutting, and Shipping | 76 | 3.5 | APPROVED STATEWIDE TITLE AGENCY: PROCESSING TITLE INSURANCE | 91 |
| | Major Operational Issues | 76 | | Customers and Products | 92 |
| | | | | The Production Process | 93 |
| | | | | Major Operational Issues | 94 |

PART 2

DESIGNING PRODUCTION SYSTEMS 98

| | | | | | |
|-----------------------|---|-----|-----|---|-----|
| CHAPTER 4 FORECASTING | | 101 | | When to Use Qualitative Methods | 107 |
| 4.1 | GOOD DECISIONS BEGIN WITH GOOD FORECASTS | 102 | | How to Improve Qualitative Forecasting | 107 |
| | <i>On the Job: Jayne Rosselli, Garden Valley Ranch</i> | 102 | 4.4 | QUANTITATIVE FORECASTING METHODS | 110 |
| | What Is Forecasting? | 102 | | Background and Strategy of Quantitative Forecasting | 110 |
| | Importance of Demand Forecasting | 103 | | Steps in Modeling | 111 |
| | <i>In Good Company: Compaq Bets on Forecasts—and Wins Big</i> | 104 | | Time Series and Causal Models | 113 |
| 4.2 | FORECASTING METHODS | 105 | 4.5 | CONSTANT PROCESSES AND THE CUMULATIVE AVERAGE | 115 |
| | The Role of Time | 105 | | | |
| | Quantitative versus Qualitative Methods | 106 | 4.6 | QUASI-CONSTANT PROCESSES | 117 |
| 4.3 | QUALITATIVE FORECASTING METHODS | 106 | | Simple Moving Average | 118 |
| | | | | Weighted Moving Average | 119 |
| | | | | Simple Exponential Smoothing | 120 |

CHAPTER 5 PRODUCT DESIGN AND OPERATIONS 211

| | | |
|-----|--|-----|
| 5.1 | THE PRODUCT DESIGN REVOLUTION | 212 |
| | <i>On the Job:</i> Dee Ambrosia, Standard Register Company | 212 |
| 5.2 | PRODUCT DEVELOPMENT | 213 |
| 5.3 | THE PRODUCT DESIGN PROCESS | 214 |
| | Designing for Production | 215 |
| | Concurrent Design and Engineering | 215 |
| | Team Design | 217 |
| | Working with Customers and Suppliers | 217 |
| 5.4 | BASIC PRINCIPLES OF DESIGNING PRODUCTS FOR PRODUCTION | 219 |
| | Minimize the Number of Parts Used | 220 |
| | Use Common Components | 221 |
| | Use Standard Components | 221 |
| | Simplify the Assembly Process | 222 |
| | Use Modularity to Obtain Product Variety | 225 |
| | Make Product Specifications and Tolerances Reasonable | 226 |
| | Design for Robustness | 227 |
| 5.5 | PRODUCT DESIGN TOOLS | 228 |
| | Quality Function Deployment | 228 |
| | Value Analysis | 231 |
| | The Taguchi Method | 232 |
| | Computer-Aided Design | 234 |
| | Design for Manufacturability and Design for Assembly | 235 |
| | <i>In Good Company:</i> Boeing's Design Takes Off | 236 |
| | Prototyping | 237 |
| 5.6 | PRODUCT DESIGN FOR SERVICES | 237 |
| 5.7 | PRODUCTION DOCUMENTS | 238 |
| 5.8 | ENVIRONMENTALLY SENSITIVE DESIGN | 240 |
| | <i>Fibre-Pack:</i> A Product Design Case | 244 |

CHAPTER 5 SUPPLEMENT
PRODUCT RELIABILITY 247

| | | |
|------|-------------------------------|-----|
| 5s.1 | COMPUTING PRODUCT RELIABILITY | 247 |
|------|-------------------------------|-----|

| | | |
|------|--|-----|
| 5s.2 | INCREASING RELIABILITY USING REDUNDANT (BACKUP) COMPONENTS | 247 |
|------|--|-----|

CHAPTER 6 CAPACITY PLANNING AND FACILITY LOCATION 250

| | | |
|-----|--|-----|
| 6.1 | THE IMPORTANCE OF CAPACITY AND LOCATION DECISIONS | 251 |
| | <i>On the Job:</i> Sandy Boyd, Espresso Roma | 251 |
| 6.2 | MEASURING CAPACITY | 252 |
| | Factors That Determine Capacity | 253 |
| 6.3 | CAPACITY STRATEGY | 255 |
| | The Organization of Production and Facility Focus | 255 |
| | Capacity Expansion Strategies | 257 |
| | Demand Strategies | 260 |
| 6.4 | CAPACITY PLANNING AND EVALUATION METHODS | 262 |
| | Forecasting Demand and Capacity Requirements | 262 |
| | Break-Even Analysis | 263 |
| | Decision Analysis | 265 |
| 6.5 | FACILITY LOCATION | 266 |
| 6.6 | LOCATION DECISION STAGES AND FACTORS AFFECTING FACILITY LOCATION | 266 |
| | The Regional Decision | 267 |
| | The Local Decision | 268 |
| | The Site Decision | 270 |
| | Public Service Facilities | 270 |
| | Retail/Competitive Service Facilities | 271 |
| 6.7 | A SCORING RULE FOR LOCATION DECISION MAKING | 272 |
| | <i>In Good Company:</i> Mercedes Benz Finds a Home in Alabama | 274 |
| 6.8 | MATHEMATICAL MODELS FOR FACILITY LOCATION PLANNING | 275 |
| | Adding Capacity at an Existing or New Facility | 278 |
| | Locating Several Facilities Simultaneously: Fixed-Charge Problem | 278 |
| | Public Service Facility Location Models | 280 |
| | Planar Location: Median and Center of Gravity Models | 282 |

| | | | | |
|---|---|-----|--|--|
| 6.9 | LOCATING FACILITIES GLOBALLY | 285 | | |
| | Why Have Foreign Operations? | 285 | | |
| | A Checklist for Evaluating Foreign Sites | 286 | | |
| | <i>Shenandoah Valley Trauma Centers: A Facility Location Case</i> | 295 | | |
| CHAPTER 6 SUPPLEMENT | | | | |
| | SOLVING TRANSPORTATION PROBLEMS | 298 | | |
| 6s.1 | INTRODUCTION | 298 | | |
| 6s.2 | PREPARING THE PROBLEM AND THE TRANSPORTATION TABLEAU | 298 | | |
| 6s.3 | OBTAINING AN INITIAL FEASIBLE SOLUTION | 299 | | |
| | Northwest Corner Method | 300 | | |
| | Vogel's Approximation Method | 300 | | |
| 6s.4 | THE STEPPING STONE METHOD | 301 | | |
| | Checking for Optimality | 301 | | |
| | Obtaining an Improved Solution | 302 | | |
| 6s.5 | THE MODIFIED DISTRIBUTION METHOD | 303 | | |
| 6s.6 | SPECIAL SITUATIONS | 304 | | |
| | Maximization Problems | 304 | | |
| | Total Supply Not Equal to Total Demand | 304 | | |
| | Degeneracy | 305 | | |
| | TUTORIAL 2 DECISION ANALYSIS | 312 | | |
| T2.1 | UNCERTAINTY AND RISK IN DECISION MAKING | 313 | | |
| T2.2 | STATIC DECISIONS | 313 | | |
| | Decision Criteria | 313 | | |
| T2.3 | SEQUENTIAL DECISIONS AND DECISION TREES | 315 | | |
| | Constructing a Decision Tree | 315 | | |
| | Folding Back the Tree and Computing the Expected Payoff | 315 | | |
| | Expected Value of Perfect Information | 318 | | |
| CHAPTER 7 SELECTING THE PROCESS STRUCTURE AND TECHNOLOGY | | | | |
| | TECHNOLOGY | 325 | | |
| 7.1 | THERE'S MORE THAN ONE WAY TO MAKE THAT PRODUCT | 326 | | |
| | <i>On the Job: Marvin D. Dixon, Nabisco Foods, Inc.</i> | 326 | | |
| 7.2 | A COMMON CLASSIFICATION OF PRODUCTION PROCESS STRUCTURES | 327 | | |
| 7.3 | FLOW PROCESSES | 328 | | |
| | Continuous Flow Processes | 329 | | |
| | Repetitive or Discrete Flow Processes | 330 | | |
| | Disconnected or Batch Flow Processes | 331 | | |
| | Advantages and Disadvantages of Flow Processes | 331 | | |
| 7.4 | JOB-SHOP PROCESSES | 332 | | |
| 7.5 | CELLULAR PROCESSES | 335 | | |
| 7.6 | PROJECT PROCESSES | 340 | | |
| 7.7 | MODERN PRODUCTION TECHNOLOGIES | 340 | | |
| | Group Technology | 341 | | |
| | Process Automation | 342 | | |
| | Computer-Aided Design/Computer-Assisted Manufacturing | 344 | | |
| | Flexible Manufacturing Systems | 344 | | |
| | Computer-Integrated Manufacturing | 346 | | |
| | Bar Coding and Optical Scanning | 346 | | |
| | Electronic Data Interchange | 347 | | |
| | Process Technology and the Environment | 348 | | |
| | <i>In Good Company: Waste Turns to Energy for Anheuser-Busch</i> | 349 | | |
| 7.8 | METHODS FOR EVALUATING PROCESS AND TECHNOLOGY ALTERNATIVES | 349 | | |
| | Product Variety and Volume | 350 | | |
| | The Product-Process Matrix | 350 | | |
| | Analyzing Costs and Risk: Crossover Analysis | 352 | | |
| | Capital Investment Analysis: Net Present Value | 355 | | |
| 7.9 | SERVICE SYSTEMS STRUCTURE | 356 | | |
| | The Service Package and Intended Customers | 357 | | |
| | Customer Contact Intensity | 358 | | |
| | Service System Design and Strategy | 360 | | |

| | | | | | |
|-----------|--|-----|-----------|--|-----|
| 7.10 | CUSTOMIZING THE PRODUCTION PROCESS | 360 | 8.6 | LAYOUT OF SOME SERVICE FACILITIES | 408 |
| | <i>Southwest Airlines: A Process Structure and Technology Case</i> | 366 | | Warehouse and Storage Layout | 408 |
| | | | | Retail Facilities Layout | 410 |
| | | | | <i>Pesti-Chemical: A Process Design and Capacity Expansion Case</i> | 422 |
| CHAPTER 8 | PROCESS DESIGN AND FACILITY LAYOUT | 369 | CHAPTER 9 | WAITING LINES | 426 |
| 8.1 | GOING WITH THE FLOW IN PROCESS DESIGN AND LAYOUT | 370 | 9.1 | QUEUEING THEORY | 427 |
| | <i>On the Job: Chuck Wise, U.S. Precision Lens</i> | 370 | | <i>On the Job: Deb Holler, Great Western Bank</i> | 427 |
| 8.2 | DESIGN OF REPETITIVE PROCESSES: LINE BALANCING AND PRODUCT LAYOUT | 371 | 9.2 | CHARACTERISTICS OF QUEUEING SYSTEMS | 429 |
| | Decomposing the Process Into Tasks | 372 | | Customer Characteristics | 430 |
| | Criteria for Evaluating Work Station Design | 372 | | Service Characteristics | 432 |
| | Cycle Time, Production Rate, and Efficiency | 373 | | System Configuration | 433 |
| | A Work Station—Minimizing Heuristic | 374 | 9.3 | NOTATION, TERMINOLOGY, AND THE EXPLODING QUEUE PROPERTY | 434 |
| | Improving Line Design to Increase Balance and Output | 377 | | Measures of System Performance | 435 |
| | Parallel Work Stations | 380 | | Capacity Utilization and the Exploding Queue Property | 436 |
| | Parallel Production Lines | 381 | | The Kendall-Lee Notation for Queueing Systems | 437 |
| | Mixed Model Production | 382 | 9.4 | SINGLE-SERVER SYSTEMS WITH EXPONENTIAL SERVICE TIMES (M/M/1 SYSTEMS) | 437 |
| | Continuous and Batch Flow Processes | 383 | 9.5 | MULTISERVER SYSTEMS WITH EXPONENTIAL SERVICE TIMES (M/M/S SYSTEMS) | 441 |
| | Spatial Configuration | 384 | | Benefits of Pooling Servers Into One System | 445 |
| | The Effects of Randomness on Line Design | 385 | | The Number of Queues for Multiserver Systems | 446 |
| 8.3 | DESIGN OF FUNCTIONAL LAYOUTS | 387 | 9.6 | SINGLE-SERVER SYSTEMS WITH GENERAL OR CONSTANT SERVICE TIMES (M/G/1 AND M/D/1 SYSTEMS) | 448 |
| | Procedure for Designing Functional Layouts | 388 | 9.7 | THE ROLE OF VARIANCE IN QUEUEING SYSTEMS | 450 |
| | Structured Analytical Layout Tools | 391 | | Slower Servers Are Sometimes More Efficient | 451 |
| | Craft | 394 | | Pacing of Customer Arrivals Reduces Waiting | 451 |
| 8.4 | DESIGN OF CELLULAR PROCESSES | 397 | | Exploiting Customer Heterogeneity to Improve Service | 452 |
| | Cell Composition and Type | 397 | | Other Issues Regarding Designated Servers | 454 |
| | Production Flow Analysis | 398 | | | |
| | Trade-offs and Considerations in the Detailed Design | 400 | | | |
| | Spatial Configuration | 402 | | | |
| | <i>In Good Company: Hybrids Bloom at Sony Corporation</i> | 403 | | | |
| 8.5 | DESIGN OF SERVICE SYSTEMS | 404 | | | |
| | The Process Flow Diagram and the Process Chart | 404 | | | |
| | The Service Blueprint | 406 | | | |

Ferro-Stamping Inc.: A Job Redesign Case 548

CHAPTER 10 SUPPLEMENT

LEARNING AND EXPERIENCE CURVES 552

| | | |
|-------|--|-----|
| 10s.1 | LEARNING EFFECTS | 552 |
| 10s.2 | THE RATE OF LEARNING AND LEARNING CURVES | 552 |
| 10s.3 | DERIVING A LEARNING CURVE | 553 |
| | Choice of Production Units | 556 |
| | Forgetting | 556 |
| 10s.4 | EXPERIENCE CURVES | 556 |

CHAPTER 11 THE QUALITY MANAGEMENT SYSTEM 560

| | | |
|------|---|-----|
| 11.1 | THE NEW PHILOSOPHY OF QUALITY | 561 |
| | <i>On the Job:</i> Valerie Mayer, ADT | 561 |
| 11.2 | WHAT IS PRODUCT QUALITY? | 563 |
| | The Dimensions of Quality | 563 |
| | <i>In Good Company:</i> UPS Delivers Relationships | 565 |
| 11.3 | THE QUALITY COST AUDIT | 565 |
| | Quality Cost Categories | 566 |
| | Typical and Desirable Cost Distributions | 567 |
| | Obtaining Quality Cost Data | 569 |
| | Two Examples of Quality Cost Audits and Scorecards | 570 |
| 11.4 | ACHIEVING AND ENHANCING PRODUCT QUALITY | 574 |
| 11.5 | DESIGN QUALITY | 574 |
| | Identifying Customer Preferences | 575 |
| | Incorporating Customer Preferences Into the Product | 575 |
| 11.6 | QUALITY CONFORMANCE | 576 |

| | |
|-----------------------------------|-----|
| Product Design and Quality | |
| Conformance | 576 |
| Process Design and Quality | |
| Conformance | 577 |
| Production Operations and Quality | |
| Conformance | 580 |

| | | |
|-------|---|-----|
| 11.7 | STATISTICAL QUALITY CONTROL | 581 |
| | Statistical Process Control | 582 |
| | SPC by Variables | 583 |
| | SPC by Attributes | 593 |
| | Defect Tracking and Cause-Effect Analysis | 594 |
| 11.8 | SERVICE QUALITY | 597 |
| 11.9 | TOTAL QUALITY MANAGEMENT | 598 |
| | History of TQM | 598 |
| | The Principles of TQM | 599 |
| | Why TQM Programs Fail and Succeed | 601 |
| 11.10 | PROSPECTS FOR PRODUCT QUALITY | 604 |
| | The Baldrige Awards | 604 |
| | ISO 90000 Standards and Certification | 605 |
| | <i>Digicomp Computer:</i> A Quality Management Case | 611 |

CHAPTER 11 SUPPLEMENT

ACCEPTANCE SAMPLING 615

| | | |
|-------|--|-----|
| 11s.1 | THE PURPOSE OF ACCEPTANCE SAMPLING | 615 |
| 11s.2 | TYPES OF ACCEPTANCE SAMPLING PLANS | 615 |
| | Selecting a Plan | 615 |
| 11s.3 | OPERATING CURVES | 616 |
| | Computing α and β for a Typical Sampling Plan | 616 |
| 11s.4 | DERIVING A SAMPLING PLAN | 617 |
| 11s.5 | THE ROLE OF ACCEPTANCE SAMPLING | 618 |