
The background of the cover is a dark, textured surface. A robotic arm, primarily blue and black with some red accents, is positioned diagonally across the frame. It holds a large, circular, highly reflective object that shows a distorted reflection of the arm and the background. The object has a central circular feature with some text and markings around its edge, including '1463' and 'by P.D.O.'. The overall lighting is dramatic, with highlights on the metallic surfaces of the arm and the reflective surface of the object.

# PRODUCTION AND OPERATIONS MANAGEMENT

*Focusing  
on Quality  
and Competitiveness*

*Roberta S. Russell / Bernard W. Taylor III*





# **PRODUCTION AND OPERATIONS MANAGEMENT**

*Focusing on Quality and Competitiveness*

**Roberta S. Russell**

*Professor*

*Virginia Polytechnic Institute and State University*

**Bernard W. Taylor III**

*R.B. Pamplin Professor*

*Virginia Polytechnic Institute and State University*



**Prentice-Hall, Inc.**

**Englewood Cliffs, New Jersey 07632**



**Library of Congress Cataloging-in-Publication Data**

Russell, Roberta S.

Production and operations management : focusing on quality and competitiveness / by Roberta S. Russell and Bernard W. Taylor.

p. cm.

Includes bibliographical references and indexes.

ISBN 0-205-14733-X : \$48.75. — ISBN 0-205-16340-8 (AIE)

1. Production management. 2. Quality control. I. Taylor, Bernard, 1931- II. Title.

TS155.R755 1995

658.5—dc20

94-3609

CIP

Editor-in-Chief: Rich Wohl

Acquisitions Editor: Tom Tucker

Production Editor: Barbara Barg

Managing Editor: Joyce Turner

In-House Liaison: Penelope Linskey

Manufacturing Buyer: Marie McNamara

Editorial Assistant: Andrea Cuperman

Production Assistant: Renée Pelletier

Design Director: Patricia Wosczyk

Interior Design: Glenna Collett

Cover Design: Patricia Wosczyk

Cover Art: David M. Jones/© Uniphoto, Inc.

Photo Research: Sarah Evertson/Photosynthesis

Illustration: Precision Graphics, Inc.

Compositor: Omegatype Typography, Inc.

Printer/Binder: R. R. Donnelley



© 1995 by Prentice-Hall, Inc.

A Simon & Schuster Company

Englewood Cliffs, New Jersey 07632

All rights reserved. No part of this book may be reproduced, in any form or by any means, without permission in writing from the publisher.

Printed in the United States of America

10 9 8 7 6 5 4 3 2 1

ISBN 0-205-14733-X

**Photo Credits** are found on page 917, which should be considered an extension of the copyright page.

Prentice-Hall International (UK) Limited, *London*

Prentice-Hall of Australia Pty. Limited, *Sydney*

Prentice-Hall Canada Inc., *Toronto*

Prentice-Hall Hispanoamericana, S.A., *Mexico*

Prentice-Hall of India Private Limited, *New Delhi*

Prentice-Hall of Japan, Inc., *Tokyo*

Simon & Schuster Asia Pte. Ltd., *Singapore*

Editora Prentice-Hall do Brasil, Ltda., *Rio de Janeiro*

*To my children*  
Travis and Amy Russell



*To my parents*  
Jean V. Taylor and Bernard W. Taylor, Jr.  
*with love and appreciation.*

# ABOUT THE AUTHORS



**Bernard W. Taylor, III**, is the R. B. Pamplin Professor of Management Science and Head of the Department of Management Science in the Pamplin College of Business at Virginia Polytechnic Institute and State University. He received the Ph.D. and M.B.A. from the University of Georgia and B.I.E. from the Georgia Institute of Technology. He is the author of the book *Introduction to Management Science* (4th ed.) and co-author of *Management Science* (4th ed.), both published by Prentice-Hall. Dr. Taylor has published over seventy-five articles in such journals as *Operations Research*, *Management Science*, *Decision Sciences*, *IIE Transactions*, *Journal of the Operational Research Society*, *Computers and Operations Research*, *Omega*, and the *International Journal of Production Research* among others. His paper in *Decision Sciences* (with P. Y. Huang and L. P. Rees) on the Japanese kanban production system received the Stanley T. Hardy Award for its contribution to the field of production and operations management. He has served as President of the Decision Sciences Institute (DSI) as well as Associate Program Chair, Council Member, Vice President, Treasurer, and as the Editor of *Decision Line*, the newsletter of DSI. He is a Fellow of DSI and a recipient of their Distinguished Service Award. He is a former President, Vice-President, and Program Chair of the Southeast Decision Sciences Institute and a recipient of their Distinguished Service Award. He teaches management science and production and operations management courses at both the undergraduate and graduate level. He has re-

ceived the University Certificate of Teaching Excellence on four occasions, the R. B. Pamplin College of Business Certificate of Teaching Excellence Award, and the R. B. Pamplin College of Business Ph.D. Teaching Excellence Award at Virginia Tech.

**Roberta S. Russell** is Professor of Management Science. She received the Ph.D. from Virginia Polytechnic Institute and State University, an M.B.A. from Old Dominion University and a B.S. degree from Virginia Polytechnic Institute and State University. Dr. Russell's primary research and teaching interests are in the areas of production and operations management, service operations management, simulation, and quality. She has published in *Decision Sciences*, *IIE Transactions*, *The International Journal of Production Research*, *Material Flow*, *Business Horizons*, *Computers, Environment and Urban Systems*, *Computers and Operations Research* and others. She is also co-author of the Prentice-Hall text, *Service Operations Management*. Dr. Russell is a member of DSI, TIMS, ASQC, and IIE, and a certified fellow of APICS. She is Past President of the Southwest Virginia Chapter of APICS and has held numerous offices in Southeast DSI. She has received the R. B. Pamplin College of Business Certificate of Teaching Excellence, the University Certificate of Teaching Excellence, and the MBA Association's Outstanding Professor Award. She is also listed in Outstanding Young Women of America and is a recipient of the Virginia Tech Outstanding Young Alumna Award.

# PREFACE

We embarked on this project to create a new text in production and operations management with several objectives in mind. First, we want the text to be eminently readable for the student—clear, concise, and organized. We want to include lots of features and examples to make the topics interesting. We want the concepts we describe to be logical and easily understood. We want to make efficient use of the English language to avoid drowning straightforward topics in a sea of verbiage. And most important, we want the student to feel excited about production and operations management because we live in an exciting time with many new, unique, and interesting changes occurring in manufacturing and service operations around the world. We hope and believe we have accomplished this objective but the reader must be the ultimate judge on this account.

A second objective is to make the text contemporary and comprehensive. There are many new and important changes taking place in production and operations management today, and we want to make sure that they are conspicuously integrated with the more traditional topics in POM. That is why we focused our attention on quality management and competitiveness as consistent themes throughout the text. We do not believe that quality is simply a recent trend, but rather a pervasive philosophy that impacts on and influences all the other topics and functions in production and operations management. Quality especially impacts on the ability of firms to compete in today's global market. As the student and instructor proceed through this text, they will see how decision making for all operations has quality as a consistent and ultimate objective. Traditional functions such as planning, product and service design, facility layout and location, scheduling, and job design are considered by operations managers based on how effectively they fit in with an overall program of quality management, and thus, how effectively they enhance the firm's competitiveness. In the oft-used term *total quality management*, or TQM, the key word is *total*. The pursuit of quality has become all encompassing in today's management of operations, and that totality of commitment is reflected in our text.

A third objective is to strike a balance between the quantitative and managerial (or behavioral) aspects of production and operations management. Too often in the past, POM texts have seemed to be simply a loose compilation of different quantitative techniques applied to various functional topics. In the contemporary world of operations management, the quantitative and technological aspects are probably more important than ever. However, the ability to manage people and resources effectively, to motivate, organize, control, evaluate, and particularly to adapt to change, have become critical to achieving total quality and to competing in today's international markets. Thus, throughout this text we seek to explain and demonstrate how the successful operations manager manages, and when quantitative techniques are applicable, how they are used to manage and make decisions.

We also have attempted to strike a balance between manufacturing and service operations in our text. Traditionally when one thought of operations man-


agement it was in terms of manufacturing, and POM texts frequently reflected this bias. However, in the United States today there has been a perceptible shift in the economy toward service industries and away from manufacturing. Thus, managing service operations has become equally as important as managing manufacturing operations. In many cases, management techniques and processes are indistinguishable between service and manufacturing operations. However, in numerous other cases, service operations present unique situations and problems that require focused attention and unique solutions.

Another important objective is to have a well-organized text that flows smoothly and follows a logical progression of topics that places the different functions in operations management in their proper perspective. Although we have not formally subdivided our book into groupings or sections, it does have a logical organizational structure. The first two chapters introduce the subject of production and operations management and the environment for making decisions and managing operations. These chapters seek to place POM in a proper perspective and emphasize its importance in today's highly competitive world marketplace, as well as provide an overview of what is to come in the remainder of the text. The next two chapters focus on quality management from both the managerial perspective in Chapter 3 and the quantitative perspective in Chapter 4. These chapters set the tone and form the basis for our emphasis on quality management in the chapters that follow. Chapters 5 through 9 comprise a group that addresses the design of operations, while chapters 10 through 17 focus on operating functions. Thus, a logical flow is created from establishing the operating environment, to setting the quality program, to designing the operation to meet the objectives for quality, and finally to producing the service or product that will achieve the quality objectives and compete in the world market.




In order to help us achieve these objectives we have included a number of features in the text, which we will describe as follows.

## **LEARNING FEATURES**

### ***Focus on Quality Management***

Throughout the text,  icons in the margins identify locations where we specifically discuss how the topic under discussion relates to, and is impacted by, quality management.

### ***Global and Service Highlights***

In addition to the  icon, we also use several other icons throughout the text to highlight topics related to the global market or competitiveness, and to service operations. The  icon is employed to identify global topics, specifically when we are discussing POM or a company in a country other than the United States; and the  icon is used when we are talking about a specific service operation or company.

### ***"Gaining the Competitive Edge" Application Boxes***

These boxes are located in every chapter and supplement in the text. They describe how a company, organization, or agency uses the particular management technique or function being discussed in the chapter to compete in a global environment. There are more than 60 of these boxes throughout the text and they encompass a broad range of service and manufacturing operations, foreign and domestic.

### ***Introductory Applications***

Each chapter begins with a description relating the subject of the chapter to an actual application in a company. These applications are provided first to give the reader a realistic perspective of the topic prior to embarking on its discussion.

### ***Photos***

The text includes a variety of color photographs that enhance and complement the presentation of the written textual material. These photos accompany the introductory application that starts off each chapter, and they are located at other points of interest in the chapters.

### ***Quantitative Supplements***

The text includes three chapter supplements that address three of the more traditional and mathematically rigorous quantitative techniques used in production and operations management: linear programming, transportation solution methods, and simulation. These topics have been segregated from the normal chapters because in many instances students already will have studied them in a separate quantitative methods course. In addition, their study can be time consuming and often the instructor will prefer not to take time from the coverage of other important POM topics.


### ***Margin Notes***

Notes are included in the margins that serve the same basic function as notes that students themselves might write in the margin. They highlight certain topics to make it easier for the student to locate them, they summarize topics and important points, and they provide brief definitions of key terms and concepts.

### ***Examples***

Examples are liberally inserted throughout the text, primarily to demonstrate quantitative techniques and to make them easier to understand. The examples illustrate how the results of the quantitative technique may be used to help the manager make decisions. The examples are organized into a "problem statement" and "solution" format. We also make frequent use of real world applications, often citing the experiences of companies as they relate to individual topics.

### ***AB:POM Computer Software***

The computer software package that accompanies this text, AB:POM, is very user friendly. It is easy to understand and use, requiring virtually no preliminary instruction, although a tutorial on its use that describes its features is included in Appendix A. It is used whenever possible in the text to show how to solve example problems on the computer. Also a portion of the homework problems require computer solutions and are so designated by a personal computer icon  in the margin. This text can also be packaged with QSOM or STORM software.

### ***Summary of Key Formulas***

Following the summary at the end of each chapter is a "Summary of Key Formulas" that provides a list of the most important formulas derived in the presentation of any quantitative techniques introduced in the chapter. These enable the student to turn to a specific location to refresh their memories about a formula without having to search through the chapter.



### ***Summary of Key Terms***

Following the “Summary of Key Formulas” at the end of each chapter is a “Summary of Key Terms.” It provides a list of the most important terms for the chapter and their definitions. This list enables the student to access a specific location to refresh their memories about an important term without having to search through the chapter or marginal notes.

### ***Solved Example Problems***

At the end of each chapter just prior to the homework questions and problems, there is a section with solved examples that serve as a guide for doing the homework problems. These examples are solved in a detailed, step-by-step fashion.

### ***Supplemental Items***

The text is accompanied by a number of supplemental items that the instructor may wish to use in the course. These supplements include a set of videos that complement the textual presentation of material in a number of locations throughout the text. The locations where these videos might be used, and a description of each video, is provided in the Annotated Instructor’s Edition (AIE) of this text. The AIE also includes teaching notes for the instructor, alternate examples to those examples provided in the text, and summaries of the videos that can be used in these chapters. Also included with this text is the Solutions Manual detailing answers to end-of-chapter questions, homework problems, and case problems; a Text Bank; and Transparency Masters. Other available supplements include a Study Guide and the books *Profiles of Malcolm Baldrige Award Winners*, *Profile of ISO 9000*, *Games and Exercises in Production and Operations Management*, and *Cases and Readings in Production and Operations Management*, all published by Prentice-Hall.

## **ACKNOWLEDGMENTS**

The writing of a textbook, like any large project, requires the help of many people and this is certainly not the exception. We especially appreciate the guidance, support, ideas, suggestions, and help of our editor, Rich Wohl. We willingly acknowledge that this book was his suggestion, and we especially appreciate his confidence in us that we could carry his idea to fruition. We also thank the various support personnel at our publisher, including Mark Palmer, Jennifer Strada, Marjorie Payne, Joyce Turner, and numerous other people who work behind the scenes and whom we never saw or talked to. We would also like to thank Barbara Barg for all of her help and suggestions during the editing and production process. We are indebted to the reviewers of the initial draft of this text, including: Dennis Krumwiede, Kansas State University; Reino V. Warren, Eastern Michigan University; Ramesh G. Soni, Indiana University of Pennsylvania, Michael S. Spencer, University of Northern Iowa; Lance Heiko, Bryant College; Craig Cowles, Bridgewater State University; Ali Behnezhad, California State University, Northridge; Richard A. Reid, University of New Mexico, Albuquerque. They contributed numerous suggestions, comments, and ideas that dramatically changed and improved on our original effort. We offer our sincere thanks to these colleagues and hope that they can take some satisfaction in their contribution to our final product. We wish to thank our students who have class-tested, critiqued, and contributed to the material from a consumer’s point of view. We are especially grateful to Tracy Black and Jay Teets for their contributions to specific homework and example problems. Last, but certainly not least, we would like to thank Tracy McCoy at Virginia Tech for her unstinting help, hard work, and patience.

# BRIEF CONTENTS

<b>1</b>	OPERATIONS, COMPETITIVENESS, AND STRATEGY	1	<b>10</b>	FORECASTING	483
<b>2</b>	OPERATIONAL DECISION MAKING	29	<b>11</b>	AGGREGATE PRODUCTION AND CAPACITY PLANNING	543
<b>2</b>	SUPPLEMENT LINEAR PROGRAMMING	61	<b>12</b>	INVENTORY MANAGEMENT	579
<b>3</b>	QUALITY MANAGEMENT	85	<b>12</b>	SUPPLEMENT SIMULATION	629
<b>4</b>	STATISTICAL QUALITY CONTROL	145	<b>13</b>	MATERIAL REQUIREMENTS PLANNING	647
<b>5</b>	PRODUCT AND SERVICE DESIGN	209	<b>14</b>	SCHEDULING	705
<b>6</b>	PROCESS PLANNING AND TECHNOLOGY DECISIONS	275	<b>15</b>	JUST-IN-TIME AND CONTINUOUS IMPROVEMENT	747
<b>7</b>	FACILITY LAYOUT	323	<b>16</b>	WAITING LINE MODELS AND SERVICE IMPROVEMENT	781
<b>8</b>	LOCATION ANALYSIS AND LOGISTICS MANAGEMENT	373	<b>17</b>	PROJECT MANAGEMENT	823
<b>8</b>	SUPPLEMENT TRANSPORTATION MODEL SOLUTION METHODS	417		EPILOGUE: CHANGE	873
<b>9</b>	JOBS: DESIGN, ANALYSIS, AND MEASUREMENT	431		APPENDICES	
				A. Starting AB:POM	876
				B. Tables	887
				Solutions to Selected Odd-Numbered Problems	897
				Index	905

# CONTENTS

## 1

### OPERATIONS, COMPETITIVENESS, AND STRATEGY 1

They All Believe in Quality	2
The Operations Function	4
The Evolution of Production/Operations Management	5
U.S. Competitiveness	7
Short-term Financial Orientation	9
Lack of Cooperation	9
Human Resource Management	10
Technological Practice	11
Strategic Weaknesses	11
<i>U.S. Manufacturers Fight Back</i>	12
Strategy	13
<i>Technology as a Distinctive Competence</i>	15
Operations Strategy	15
Competing on Cost	16
Competing on Quality	17
<i>Wal-Mart Brings It All Together</i>	17
Competing on Flexibility	18
Competing on Speed	19
<i>Mitsubishi's "Slow-and-Steady" Strategy Leapfrogs the Competition</i>	20
Policy Deployment	21
Issues and Trends in Operations	22
Purpose and Organization of This Book	23
Summary	24
Summary of Key Terms	25
Questions	25
Case Problem: Whither an MBA at Strutledge?	26
References	27

## 2

### OPERATIONAL DECISION MAKING 29

Operational Decision Making at Reynolds Metals Company	30
The Focus of Operational Decision Making	31

Areas of Operational Decision Making	32
Quality	32
Designing Products and Services	33
Planning the Production Process	33
Laying Out the Facility	34
Locating the Facility and Transporting Materials and Products	34
Designing Jobs and Work	34
Forecasting Demand for Products and Services	34
Production Planning and Scheduling	34
Quantitative Techniques for Decision Making	35
The Decision-Making Process	36
Observation	36
Identification and Definition of the Problem	36
Model Formulation	36
Model Solution	37
Decision Making	37
Implementation of Results	37
Decision Analysis	38
Decision Making Without Probabilities	38
Decision Making with Probabilities	42
Expected Value of Perfect Information	42
Sequential Decision Trees	43
Computer Solution of Decision Analysis Problems	46
Support Systems for Decision Making	47
Management Information Systems	47
<i>Selecting Health-Care Providers for a Bank's Employees</i>	48
Decision Support Systems	49
Interactive Decision Making	49
Expert Systems and Artificial Intelligence	50
<i>A DSS for Evaluating Freight Transportation Alternatives at Heinz</i>	51
Summary	51
Summary of Key Formulas	52
Summary of Key Terms	52
Solved Problem	53
Questions	54
Problems	55
Case Problem: Steeley Associates Versus Concord Falls	59
References	60



## SUPPLEMENT

## 2

## LINEAR PROGRAMMING 61

Linear Programming	62
Model Formulation	62
<i>A Refinery Linear Programming System at Citgo Petroleum</i>	63
Graphical Solution Method	65
Format for Model Solution	68
The Simplex Method	68
Converting Model Constraints	69
Computer Solution of Linear Programming Models	72
Summary	73
Summary of Key Terms	73
Solved Problem	73
Questions	75
Problems	75
Case Problem: Metropolitan Police Patrol	82
Case Problem: The Big Country Amusement Park	83
References	84

## 3

## QUALITY MANAGEMENT 85

Market-Driven Quality at IBM	86
The Meaning of Quality	88
Quality from the Consumer's Perspective	89
Quality from the Producer's Perspective	90
<i>Reflecting Customer Preferences at Germany's Rational Company</i>	90
Total Quality Management	92
The Evolution of Total Quality Management	92
Principles of Total Quality Management	93
Marketing, Sales, and Consumer Research	93
Engineering and Product Design	94
Purchasing	94
<i>Achieving Supplier Quality</i>	96
Industrial Engineering and Job Design	96
Personnel	97
Employees	97
Production Management	97
Product Inspection	98
Packaging, Storage, and Shipping	98
<i>TQM at Kurt Manufacturing</i>	98
Consumer Service	99
The Cost of Quality	100
The Cost of Achieving Good Quality	100
<i>Defect Prevention in the U.S. Air Force</i>	101
The Cost of Poor Quality	101
Measuring and Reporting Quality Costs	102
The Traditional Quality-Cost Trade-off	104
The Effect of Quality Management on Productivity	107
Productivity	107
Measuring Product Yield and Productivity	107
The Quality-Productivity Ratio	110
Just-in-Time and Productivity	111
<i>Increasing Productivity Through Total Quality Management at ITT</i>	112
Quality and the Role of Management	112
Top Management	113
Middle Management	113
<i>Strategic Planning at Union Carbide</i>	114
Supervisory Management	114
Quality Improvement and the Role of Employees	115
Quality Circles	116
<i>Employee Quality Awareness at Disneyland</i>	117
Employee Suggestions	119
<i>Employee Involvement at Molded Fiber Glass Company</i>	119
<i>An Employee Suggestion Program at Atlantic Research Corporation</i>	120
Identifying Quality Problems and Causes	120
Pareto Analysis	120
Flowcharts	122
Check Sheets and Histograms	122
Scatter Diagrams	122
Process Control Charts and Statistical Quality Control	122
Cause-and-Effect Diagrams	122
Current Trends and Philosophies in Quality Management	123
Walter Shewhart and Harold Dodge: Quality Pioneers	124
W. Edwards Deming: The Fourteen Points	124
Joseph M. Juran: Quality Control, Improvement, and Planning	126
Phillip B. Crosby: Quality Is Free	126
Armand V. Feigenbaum: Total Quality Control	126
Kaoru Ishikawa: The Japanese Quality Movement	127
Genichi Taguchi: The Taguchi Method	127
Quality Awards and the Competitive Spirit	127
The Malcolm rige Award	128
The Deming Application Prize	128
<i>The 1992 Malcolm Baldrige Award Winners</i>	129
The President's Award for Quality	129
The IIE Award for Excellence in Productivity Improvement	130
NASA's Quality and Excellence Award	130
<i>Rockwell International and NASA's Quality and Excellence Award</i>	130
ISO 9000	131
The ISO 9000 Series Standards	131
Implications of ISO 9000 for U.S. Companies	132
Achieving ISO 9000 Accreditation	133
<i>The AT&amp;T Quality Registrar</i>	134
<i>Combining the Malcolm Baldrige Award and ISO 9000</i>	135
Summary	136
Summary of Key Formulas	136
Summary of Key Terms	137

Solved Problems	137
Questions	138
Problems	139
Case Problem: TQM at State University	142
Case Problem: Product Yield at Continental Luggage Company	143
References	144

## 4 STATISTICAL QUALITY CONTROL 145

Statistical Process Control at Kurt Manufacturing	146
Inspection	148
The Changing Role of Inspection	148
How Much to Inspect	149
Inspection Location	149
Statistical Process Control	150
SPC in a TQM Environment	151
Quality Measures: Attributes and Variables	151
Statistical Process Control at ITT	152
Control Charts	153
Control Charts for Attributes	154
p-Chart	154
Process Control Charts at P*I*E Nationwide	158
c-Chart	158
Control Charts for Variables	160
Mean ( $\bar{x}$ -) Chart	160
Using $\bar{x}$ -charts at Frito-Lay	161
Range (R-) Chart	161
Using $\bar{x}$ - and R-Charts Together	164
Control Chart Patterns	166
Sample Size Determination	169
Design Tolerances and Process Capability	169
Achieving Design Tolerances at Harley-Davidson Company	171
Computerized Statistical Process Control	172
Acceptance Sampling	174
Single-Sample Attribute Plan	175
Producer's and Consumer's Risks	175
The Operating Characteristic Curve	176
Standardized Sampling Plans	181
Average Outgoing Quality	182
Double-Sampling Plans	185
Multiple-Sampling Plans	185
Selecting an Attribute Plan	186
Variable-Sampling Plans	186
Standardized Variable Plans	188
Computerized Acceptance Sampling	188
A Quality Control Decision-Support System for a Farm Implements Business	190
Summary	191
Summary of Key Formulas	191
Summary of Key Terms	192
Solved Problems	193
Questions	197

Problems	198
Case Problem: Quality Control at Rainwater Brewery	205
Case Problem: Quality Control at Grass, Unlimited	206
References	207

## 5 PRODUCT AND SERVICE DESIGN 209

Designing a Better Golf Ball	210
The Design Process	212
Idea Generation	213
Feasibility Study	216
Preliminary and Final Design	217
Functional Design	217
Form Design	222
Production Design	222
Process Planning	223
Making Xerox Copiers Easier to Use	224
Improving the Design Process	225
Design Teams	226
Team Viper and Team Neon	227
Concurrent Design	228
The Role of Design Engineer	229
Design for Manufacture	230
Design for Environment	233
Westinghouse's Design Calculator	234
Giving It Back	235
Measures of Design Quality	236
Quality of Design	237
Quality Classifications	237
Quality Function Deployment	239
Taguchi Methods for Robust Design	243
DEC Designs Better Products in Half the Time at Half the Cost	248
Technology in Design	249
Computer-Aided Design	249
Benefits of CAD	252
Three Miles of Tubing	253
Future Developments in Technology	253
Ford Engages in Long-Distance Design	255
Service Design	255
Characteristics of Services	255
The Service Concept	257
Performance and Design Specifications	258
USC Creates Customer Delight	258
Summary	259
Summary of Key Formulas	260
Summary of Key Terms	260
Solved Problems	261
Questions	263
Problems	265
Case Problem: In Search of Perfectly Popped Popcorn	272



Case Problem: Sure, the Highway May Be Intelligent, But What Can It Do for ME?	272
References	274

**6****PROCESS PLANNING AND  
TECHNOLOGY DECISIONS 275**

Assembling Laser Printers Is a Snap	276
Process Planning	277
Product Analysis	277
Make-or-Buy Decisions	283
Types of Processes	284
Process Selection	287
<i>Making Salsas Simple</i>	288
<i>Volvo's Torslanda Plant Stands Out</i>	290
Break-Even Analysis	290
Specific Equipment Selection	294
Process Plans	295
<i>Hewlett-Packard Rereads the Numbers</i>	296
Technology Decisions	297
Manufacturing Processes	299
Levels of Automation	300
Automated Material Handling	301
<i>Automated Machining Center at Ingersol-Rand</i>	302
Flexible Manufacturing Systems	302
Robotics	303
Computer-Integrated Manufacturing	307
Adoption of Technology	310
<i>Motorola's Latest CIM Project Is Pure "Fusion"</i>	310
Summary	311
Summary of Key Terms	312
Solved Problem	313
Questions	314
Problems	315
Case Problem: Streamlining the Refinancing Process	320
References	321

**7****FACILITY LAYOUT 323**

Pittsburgh International: An Efficient Layout	324
Basic Types of Layouts	325
Designing Process Layouts	331
Block Diagramming	331
Relationship Diagramming	334
Computerized Layout Solutions	336
<i>Relationship Diagramming at Fairtron</i>	336
Service Layouts	337
<i>A Flexible Layout at the Ritz-Carlton Pavilion</i>	338
Designing Product Layouts	338
Line Balancing	339
Heuristic and Computerized Line Balancing	343
Hybrid Layouts	345

Cellular Layouts	345
<i>A New Focused Factor for USRAC</i>	346
<i>Cellular Layout Improves Washing Tub Assembly</i>	350
<i>Chickahominy Middle School Uses the Cellular     Concept</i>	352
Flexible Manufacturing Systems	353
<i>Saturn Uses Flexible Machining Cells</i>	353
<i>An FMS at LTV</i>	356
Mixed-Model Assembly Lines	357
Summary	359
Summary of Key Formulas	360
Summary of Key Terms	360
Solved Problems	361
Questions	363
Problems	364
Case Problem: Arranging Darian's Gymnastics Center	370
References	372

**8****LOCATION ANALYSIS AND LOGISTICS  
MANAGEMENT 373**

Supplier Location for the Moscow McDonald's	374
Types of Facilities	376
Heavy Manufacturing	376
Light Industry	376
Warehouses and Distribution Centers	377
Retail and Service	377
Site Selection: Where to Locate	377
Country	378
Region	378
Community	379
Site	379
The Site Evaluation Process	379
Critical Factors in Location Analysis	380
Labor	380
Transportation and Logistics	380
Customers and Markets	381
Community Environment	382
Site Characteristics	382
<i>Selecting Hotel Sites</i>	383
Facility Location and Quality Management	383
<i>McDonald's Distribution System in Australia</i>	386
Location Analysis Techniques	387
Location Factor Rating	387
Center-of-Gravity Technique	388
Load-Distance Technique	389
Computerized Location Analysis	391
Logistics Management	392
Transport and Distribution Systems	393
Railroads	393
<i>Meeting JIT Delivery Schedules at Roadway       Express, Inc.</i>	394
Trucking	395
Airfreight	395
<i>The Federal Express Superhub</i>	395



Water	396
Pipelines	397
The Transportation Method	397
Computer Solution of a Transportation Model	399
Summary	402
Summary of Key Formulas	402
Summary of Key Terms	403
Solved Problem	403
Questions	404
Problems	404
Case Problem: Scheduling at Hawk Systems, Inc.	413
References	415

## SUPPLEMENT

## 8

## TRANSPORTATION MODEL SOLUTION METHODS 417

Initial Solution Methods	418
The Northwest Corner Method	418
The Minimum Cell Cost Method	419
Vogel's Approximation Method	420
The Stepping-Stone Solution Method	421
The Unbalanced Transportation Model	424
Degeneracy	425
Prohibited Routes	426
Summary	426
Summary of Key Terms	427
Solved Problem	427
Questions	429
Problems	429
References	430

## 9

## JOBS: DESIGN, ANALYSIS, AND MEASUREMENT 431

Employee Satisfaction at Federal Express	432
The Changing Nature of Jobs and Job Design	434
Scientific Management	434
The Assembly Line	436
Limitations and Failures of Traditional Job Design Approaches	437
Behavioral Influences on Job Design	438
Worker Training in the German Trumpf Company	439
Contemporary Trends in Job Design	439
Job and Task Flexibility	440
Quality Improvement Responsibility	441
Increased Skill and Ability Levels	441
Worker Empowerment at Harley-Davidson	441
Employee Involvement	442
Employee Training at Quad Graphics, Inc.	442
Employee Involvement at Xerox	443
Evaluation and Reward	443
Worker Compensation	444

## An Incentive Compensation Program at Viking Freight 444

Technology and Automation	445
Job Satisfaction	446
U.S. Adaptation of Trends in Job Design	446
The Elements of Job Design	447
Task Analysis	447
Worker Analysis	448
Environmental Analysis	449
Job Analysis	449
Process Flowchart	449
Worker-Machine Chart	450
Motion Study	452
Work Measurement	454
Stopwatch Time Study	455
Number of Cycles	459
Elemental Time Files	459
Predetermined Motion Times	460
Work Sampling	461
Learning Curves	464
Determining Learning Curves with the Computer	467
Summary	469
Summary of Key Formulas	469
Summary of Key Terms	469
Solved Problems	470
Questions	472
Problems	473
Case Problem: Measuring Faculty Work Activity at State University	479
References	481

## 10

## FORECASTING 483

Forecasting Aircraft Parts Demand at American Airlines	484
Forecasting and Quality Management	485
Components of Forecasting Demand	486
Time Frame	487
Demand Behavior	487
Forecasting Methods	488
The Forecasting Process	489
Time Series Methods	490
Moving Average	490
Weighted Moving Average	493
Exponential Smoothing	494
Adjusted Exponential Smoothing	497
Linear Trend Line	499
Seasonal Adjustments	502
Forecast Accuracy	504
Mean Absolute Deviation	504
Cumulative Error	506
Forecast Control	507
Time Series Forecasting Using a Computer	510
Forecasting Wholesale Prices and Product Volume at Citgo Petroleum	512
Regression Methods	513

Linear Regression	513
Correlation	516
Multiple Regression	517
Regression Analysis with a Computer	517
Qualitative Methods	518
In-House Forecasting	518
Consumer Research	519
The Delphi Method	519
The Forecasting Industry	520
<i>Assessing the Forecasting Accuracy of a Business Week Industry Outlook</i>	521
Summary	521
Summary of Key Formulas	522
Summary of Key Terms	523
Solved Problems	524
Questions	528
Problems	529
Case Problem: Forecasting at State University	539
Case Problem: Tech Bookstore Warehouse Expansion	539
References	541

## 11 AGGREGATE PRODUCTION AND CAPACITY PLANNING 543

Planning Hospital Needs	544
Strategies for Meeting Demand	547
<i>Meeting Peak Holiday Demand at Neiman Marcus</i>	549
Aggregate Production and Capacity Planning Techniques	550
Trial-and-Error Techniques	550
General Linear Programming Model	553
Transportation Method of Linear Programming	558
Linear Decision Rule	562
Search Decision Rule	563
Management Coefficients Model	563
Strategies for Managing Demand	564
Disaggregation	564
<i>Fine Furniture on Demand</i>	565
Aggregate Planning for Services	566
<i>Yield Management at American Airlines</i>	567
Summary	567
Summary of Key Terms	568
Solved Problems	568
Questions	571
Problems	572
Case Problem: An Aggregate Plan for Darian's Gymnastics Center	576
References	577

## 12 INVENTORY MANAGEMENT 579

Parts Inventory Management at IBM	580
-----------------------------------	-----

The Elements of Inventory Management	582
The Role of Inventory	583
Demand	584
Inventory and Quality Management	585
Inventory Costs	586
Inventory Control Systems	587
Continuous Inventory Systems	587
Periodic Inventory Systems	588
The ABC Classification System	589
Economic Order Quantity Models	590
The Basic EOQ Model	591
The EOQ Model with Noninstantaneous Receipt	594
The EOQ Model with Shortages	597
Computer Analysis of EOQ Models	601
Quantity Discounts	601
Quantity Discounts with Constant Carrying Cost	602
Quantity Discounts with Carrying Cost as a Percentage of Price	605
Computer Analysis of the EOQ Model with Quantity Discounts	606
Reorder Point	607
Safety Stocks	608
Service Level	608
Reorder Point with Variable Demand	609
Reorder Point with Variable Lead Time	611
Reorder Point with Variable Demand and Lead Time	611
Order Quantity for a Periodic Inventory System	612
Order Quantity with Variable Demand	613
Summary	614
Summary of Key Formulas	614
Summary of Key Terms	615
Solved Problems	616
Questions	619
Problems	619
Case Problem: The Northwoods General Store	626
References	627

### SUPPLEMENT

## 12 SIMULATION 629

The Monte Carlo Process	630
Simulation Languages and Software	636
<i>Simulating the Dispatching of Freight Carriers At Reynolds Metals Company</i>	636
Areas of Simulation Application	637
Waiting Lines/Service	637
Inventory Management	637
Production and Manufacturing Systems	637
Capital Investment and Budgeting	638
Logistics	638
Service Operations	638
Environmental and Resource Analysis	638
Summary	638
<i>Simulating a Queuing Problem at a Security Gate</i>	639
Summary of Key Terms	640
Solved Problem	640



Questions	642
Problems	642
References	645

## **13** MATERIAL REQUIREMENTS PLANNING 647

Five Million Possibilities at Hubbell	
Lighting	648
Objectives and Applicability of MRP	649
When To Use MRP	649
MRP Inputs	651
Master Production Schedule	652
Product Structure File	653
Inventory Master File	657
MRP Improves Customer Service	658
The MRP Process	659
MRP Outputs	663
Capacity Requirements Planning	665
Advanced Topics in MRP	672
Safety Stock and Safety Lead Time	672
Lot Sizing	672
Processing Frequency	678
Manufacturing Resource Planning (MRP II)	679
Problems and Prospects of MRP/MRP II	680
MRP Works for Small Companies, Too	681
What-If? Planning at John Deere & Co.	683
Summary	684
Summary of Key Formulas	684
Summary of Key Terms	685
Solved Problems	686
Questions	690
Problems	690
Case Problem: Renovating the Grand Palms Hotel	701
Case Problem: Three Long Years	702
References	703

## **14** SCHEDULING 705

Hot, Warm, and Cold at TCONA	706
Objectives in Scheduling	708
Loading	708
Index Method	709
Assignment Method	710
Sequencing	712
Sequencing Jobs Through One Machine	713
Sequencing Jobs Through Two Serial Machines	716
Sequencing Jobs Through Any Number of Machines in Any Order	717
Monitoring	719

Gantt Charts	719
Input/Output Control	720
Finite Scheduling	722
OPT and Synchronous Production	723
Quaker Furniture Gets in Sync	726
Maintenance Scheduling	727
DockPlan Saves American Airlines Big Bucks	731
Employee Scheduling	731
You Can Choose Your Own Hours at McDonald's	734
Summary	735
Summary of Key Formulas	735
Summary of Key Terms	736
Solved Problems	737
Questions	739
Problems	740
Case Problem: From a Different Perspective	745
References	746

## **15** JUST-IN-TIME AND CONTINUOUS IMPROVEMENT 747

JIT in Detroit	748
Basic Elements of JIT	749
Flexible Resources	751
Changes at Corning	752
Cellular Layout	753
The Pull System	754
Kanban Production Control System	755
Small-Lot Production	760
Quick Setups	761
Uniform Production	762
Quality at the Source	764
Supplier Networks	765
Material Handling Innovations Support JIT	766
Continuous Improvement	767
Visual Control	767
Poka-Yoke	768
Total Employee Involvement	769
Principles of Continuous Improvement	769
Large and Small Improvements at Xaloy	770
Benefits of JIT	771
JIT Implementation	771
How Hewlett-Packard Implemented JIT	773
JIT in Services	773
Summary	774
Summary of Key Formulas	775
Summary of Key Terms	775
Questions	776
Problems	777
Case Problem: JIT Woes	778
References	778