SECOND EDITION

OPERATIONS MANAGEMENT

Focusing on Quality and Competitiveness

Roberta S. Russell / Bernard W. Taylor III

SECOND EDITION

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.
Upper Saddle River, New Jersey 07458

Library of Congress Cataloging in Publication Data
Russell, Roberta S.
Operations management : focusing on quality and competitiveness / Roberta S. Russell, Bernard W. Taylor III. —2nd ed.
p. cm.
Rev. ed. of: Production and operations management. c1995.
Includes bibliographical references and index.
ISBN 0-13-849936-5
1. Production management. 2. Quality control. I. Taylor, Bernard W. II. Russell, Roberta S. Production and operations management.
TS155.R755 1998
658.5—DC21 97-650
CIP
Rev.

Acquisitions Editor: Tom Tucker
Development Editor: Michael Elia
Assistant Editor: Audrey Regan
Marketing Manager: Patrick Lynch
Editor-in-Chief: Natalie Anderson
Director of Development: Steve Deitmer
Production Editor: Susan Rifkin
Production Coordinator: Cindy Spreder
Managing Editor: Katherine Evancie
Senior Manufacturing Supervisor: Paul Smolenski
Manufacturing Manager: Vincent Scelta
Senior Designer: Suzanne Behnke
Interior Design: Gerri Davis
Cover Design: Suzanne Behnke
Cover Art: Boris Lyubner/SIS
Composition/Interior Art: University Graphics

Printed in the United States of America
10 9 8 7 6 5 4 3 2 1

ISBN 0-13-849936-5

Prentice Hall International (UK) Limited, London
Prentice Hall of Australia Pty. Limited, Sydney
Prentice Hall of 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 family
Tom, Travis, and Amy

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

About the Authors

Bernard Taylor and Roberta Russell

Bernard W. Taylor, III, is the R. B. Pamplin Professor of Management Science and Head of the Department of Management Science and Information Technology 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* (5th ed.) and co-author of *Management Science* (4th ed.), both published by Prentice-Hall. Dr. Taylor has published over eighty 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 received 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 and Information Technology. 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 originally embarked on this project to create a textbook in operations management with several objectives in mind. First, we wanted the text to be eminently readable for the student—clear, concise, and organized. We also wanted to include lots of features and examples to make the topics interesting. Next, we wanted the concepts we describe to be logical and easy to understand. We wanted to make efficient use of the English language to avoid drowning straightforward topics in a sea of verbiage or a blizzard of mathematical notation. And most important, we wanted the student to feel excited about 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 like to think that we accomplished these objectives to a large degree in our first edition, but there is always room for improvement in a project like this, so much of this second edition focuses on how to better achieve these objectives and achieve new ones.

MAJOR TEXT THEMES

We have sought to make our textbook contemporary and comprehensive. There are many new and important changes taking place in operations management today, and we want to make sure that they are conspicuously integrated with the more traditional topics in OM. That's why we focus a lot of our attention on *quality* and *competitiveness*, and their implications for *strategy*, 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 operations management. Quality has become an especially important part of a company's overall strategy to compete in today's global market. For many companies, their total quality management program (TQM) is the engine that drives their strategic plan.

Operations managers make decisions in functional areas such as product and service design, facility layout and location, planning and scheduling, and supply chain management based on how effectively these decisions fit together in a strategic design to achieve the firm's goals. The chapters in this text are organized around functional topics, some new and some traditional. However, in each case we attempt to show how these topics are connected to the common themes of quality and competitiveness, and then are connected to each other in terms of strategy.

Quality

We cover our two primary topics related to quality, Quality Management and Statistical Quality Control, in Chapters 3 and 4, respectively. We put these topics together because in most companies they are so closely interrelated in an overall total quality management program that it is hard to consider one separate from the other. We introduce them early in the text so that the student can see how the functional topics in subsequent chapters are affected by, and affect, quality management. For example, in Chapter 5 on Product and Service Design our discussion focuses on Improving the Design Process through well-recognized TQM processes, and, in Chapter 10 on Forecasting we discuss how forecasting is related to TQM in a company's strategic design process.

Competitiveness

Although most firms express their goals in terms of customer satisfaction or level of quality, their underlying objective is to beat out their competitors. One way in which companies can gain a competitive edge is by deploying the basic functions of operations management in a more effective manner than their rivals. In each chapter we give numerous examples of how companies deploy specific operations functions in a way that has provided them with a competitive edge and made them successful. We begin our discussion of competitiveness in Chapter 1 and continue throughout the text with "Competitive Edge" boxes describing how successful companies have gained a competitive edge through operations.

Strategy

A company's battle plan for achieving a competitive edge is its strategy. The success of a strategic plan is determined by how well a company coordinates all of its internal functions, including operations, and brings them to bear on its goals. Throughout the text we try to show how the functions and processes described in each chapter fit into a company's strategic plan. The importance of strategy in operations management is emphasized by our creation of a new Chapter 2—Operations Strategy—and its placement up front in the text. In each subsequent chapter we emphasize the need for considering the overall strategic implications of particular operating decisions. For example, in Chapter 3 on Quality Management we discuss the "strategic implications of TQM," in Chapter 9 on Supply Chain Management we emphasize that "supply chain design is a strategic issue," and in Chapter 11 we discuss "capacity planning as a long-term strategic decision."

Services and Manufacturing

We have attempted to strike a balance between manufacturing and service operations in our text. Traditionally operations management was thought of almost exclusively in a manufacturing context, and OM texts frequently reflect this bias. However, in the United States and other highly industrialized nations, 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, operations management techniques and processes are indistinguishable between service and manufacturing. However, in many other instances, service operations present unique situations and problems that require focused attention and unique solutions. We have tried to reflect the uniqueness of service operations in our text by providing numerous examples that address service situations, and by providing focused discussions on service operations when there is a clear distinction between operations in a service environment and in a manufacturing environment. For example, in Chapter 3 on Quality Management we specifically address the unique conditions of "TQM in service companies"; in Chapter 5 on Product and Service Design; we emphasize the differences in design considerations between manufacturing and services; and in Chapter 11, we discuss "aggregate planning in services."

Quantitative versus Qualitative Processes

We have also attempted to strike a balance between the quantitative aspects of operations management and the qualitative (or behavioral) aspects. Too often in the past, OM texts have presented themselves as 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 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 and technology are applicable, how they are used to help manage and make decisions.

LEARNING FEATURES

We have introduced many features in our text which we hope will help sustain and accelerate the student's learning of the material. Some of these features remain from the first edition while others are new to this edition. In the following sections we summarize the various learning features that appear in the text.

Text Organization

One of our most important objectives is to have a well-organized text that flows smoothly, follows a logical progression of topics, and places the different functions of operations management in their proper perspectives. We have organized this new edition of our text into three groupings. The first four chapters focus on *The Strategy of Productive Systems.* These chapters seek to place operations management in a proper perspective and emphasize the importance of strategy and quality for competing in today's highly competitive global marketplace. Chapters 5 through 10 comprise a group we refer to as *Designing Productive Systems,* while Chapters 11 through 17 focus on *Operating Productive Systems.* Thus a logical flow is created from strategically establishing the operating environment and defining a quality program, to designing the operations function to meet the company's strategic goals, and finally to producing the product or service that will achieve the strategic goals and enable a company to compete in a global market.

New Chapters in This Edition

In an effort to keep our book current and abreast of contemporary trends in operations management we have altered several chapters, some to the extent that they appear for the first time in this edition. Chapter 1 contains more information on globalization and competitiveness. Chapter 2 on Operations Strategy is new and emphasizes the importance of making strategic choices consistent with operational capabilities, as well as looking at the strategic issues associated with individual topics in OM. The coverage of policy deployment has been increased and topics such as core competencies, core rigidities, and competency-based strategies have been added. Chapter 5 on Product and Service Design has been streamlined with tightened discussions of Quality Function Deployment and Taguchi methods of design. Chapter 6 on Process Planning and Technology Decisions has been enhanced with new sections on process re-engineering and information technology. Chapter 8 provides a broader, more comprehensive view of human resource management within the operations function than the chapter on job design from the previous edition. Chapter 9 on Supply Chain Management attempts to pull together the related components of this increasingly important topic by looking at its strategic design, while retaining some of the topics from the previous edition on location and transportation. In Chapter 11 we expanded coverage of capacity

planning to include strategies for capacity expansion and for determining the best overall level of productive resources for a firm.

"The Competitive Edge" Application Boxes

These boxes are located in every chapter 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.

Chapter 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 before 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, as well as various other points of interest within the body of the chapters. Each photo is accompanied by an extensive descriptive caption that complements the text material.

Operational Decision-Making Tools Supplements

The text includes four quantitative chapter supplements that address some of the more traditional and mathematically rigorous quantitative techniques used in operations management: *decision analysis, 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 OM topics.

Marginal Notes

Notes that are included in the margins 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.

POM for Windows Computer Software

This text features illustrations from a computer software package, *POM for Windows*. A disk is packaged with each *instructor's* complimentary copy of this text. *POM for Windows* is very user-friendly software that solves problems in all the decision-making areas of operations management. It is easy to understand and use, requiring virtually no preliminary instruction except for the "help" screens that can be accessed directly from the program. *POM for Windows* is used frequently in the text to show how to solve example problems on the computer. This software can be packaged—at a reasonable additional cost to students—with each copy of the text. If you wish to order this software with the text, please be sure to order ISBN **0-13-667965-X**, as this will ensure that you get the software at a discounted price. For further details, contact your Prentice Hall sales representative or phone Prentice Hall at 1-800-526-0485.

Excel Spreadsheets

Although *POM for Windows* can be used to solve almost any quantitative problem in the text, we also solve many of the quantitative examples in the text with the Microsoft Excel spreadsheet program. Spreadsheets have become an increasingly popular and convenient means for solving operational problems. However, while we generally outline the basic steps for setting up a spreadsheet and solving a problem with Excel, some basic, fundamental knowledge of the Excel program is usually required.

Web Sites and Home Page

Throughout the text **WWW** icons in the margins (as shown at right) identify companies and topics that can be accessed on the internet through our text home page located at *http://www.prenhall.com/russell.* If you are interested in accessing one of the highlighted web sites simply go to the appropriate text chapter on our home page and scroll down to the web site identified by the icon in the margin of the text and click on it. In addition to the web site links provided for each chapter, students will be able to access Internet exercises, virtual factory tours, chapter lectures, interactive chapter quizzes, and sample student projects. Faculty members will be able to access sample course outlines, annotated lecture slides, alternate examples, projects and special assignments, and in-depth background material not included in the text.

www.prenhall.com/russell

Lands' End Boxes and Videos

In ten of the chapters we illustrate various subjects and topics with brief descriptions of operations at Lands' End, the national catalogue retailer. These boxes are similar to "The Competitive Edge" boxes used throughout the text. Taken together, they have the advantage of describing operations across the breadth of an entire company and since it is a service company, they are particularly insightful. Seven of the Land's End boxes are accompanied by video programs that accompany the text.

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 students to turn to a specific location to refresh their memories about a formula without having to

search through the chapter. The formulas are also provided electronically in the faculty section of the web page for easy reproduction for exams.

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 students 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 videos include: *Competitiveness and Continuous Improvement at Xerox, Teams and Employee Involvement at Hewlett-Packard, Statistical Process Control at Kurt Manufacturing, Process Strategy and Selection, Flexible Manufacturing Systems, Operations Strategy at Whirlpool, Product Design and Supplier Partnerships at Motorola, Service Quality and Service Design at Marriott, A Plant Tour of Winnebago Industries,* and seven installments of *On Location at Lands' End.*

The locations where these videos might be used, and a description of each video, is provided on the web site and in the *Instructor's Manual.*

The *Instructor's Manual* contains a wealth of information to help the instructor prepare and deliver a dynamic introductory course in operations management, including sample course syllabi, chapter outlines, teaching notes for the instructor, PowerPoint lecture slides, alternate examples to those examples provided in the text, in-class exercises, projects and special assignments.

Also included with this text is a *Solutions Manual* detailing answers to end-of-chapter questions, homework problems, and case problems; and an extensive *Text Bank.*

Acknowledgments

The writing and revision of a textbook, like any large project, requires the help and creative energy of many people and this is certainly not the exception. We especially appreciate the confidence, support, help, and friendship of our editor, Tom Tucker. We also thank the various support personnel at Prentice Hall including Diane Peirano, Susan Rifkin, Mike Elia, and numerous other people who work behind the scenes and whom we never saw or talked to. We are indebted to the reviewers of the second edition including: Scott A. Dellana, East Carolina University; Thomas Foster, Jr., Boise State University; Lawrence D. Fredenhall, Clemson University; Richard W. Garrett, University of Indiana; Linguo Gong, Louisiana State University; Robert Handfield, Michigan State University; Ray M. Hayes, California Polytechnic State University at San Luis Obispo; John Haywood-Farmer, University of Western Ontario; James K. Higginson, Wilfred Laurier University; Steve Lawrence, University of Colorado; Terry Nels Lee, Brigham Young University; J. R. Minifie, Southwest Texas State University; Michael J. Pesch, St. Cloud State University; Paul H. Randolph, Texas Tech University, and Edward W. Watson, Louisiana State University. They contributed numerous suggestions, comments, and ideas that dramatically improved and changed our first edition. 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 first edition and this revision from a consumer's point of view. We are especially grateful to Tracy McCoy at Virginia Tech for her unstinting help, hard work, and patience.

R.S.R.
B.T.T.

Brief Contents

Contents