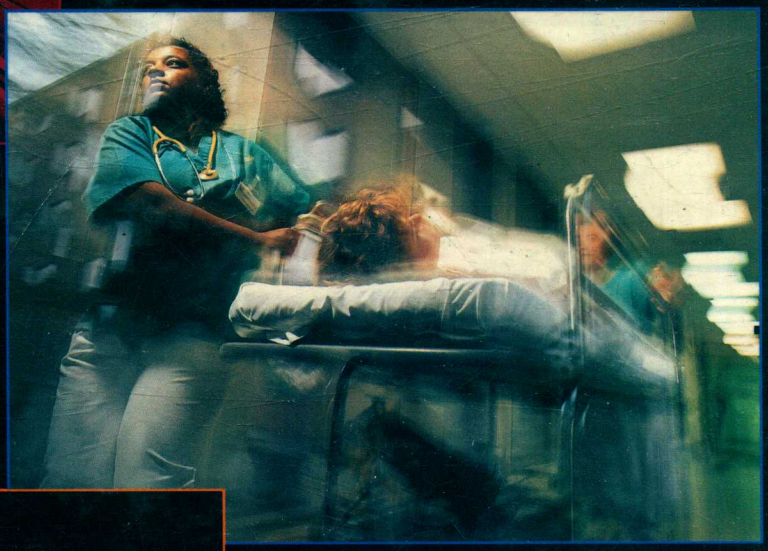
Production and Operations Management

An Applied Modern Approach



Joseph S. Martinich

PRODUCTION AND OPERATIONS MANAGEMENT

AN APPLIED MODERN APPROACH

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University of Missouri-St. Louis

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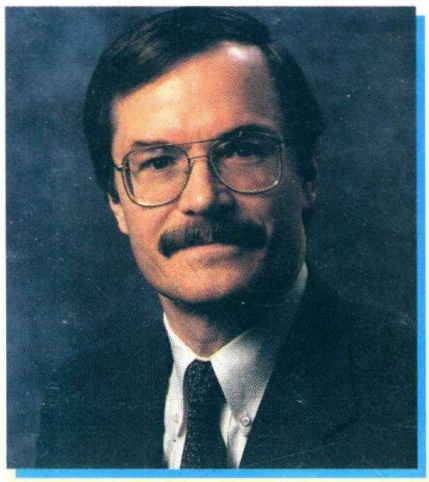
ABOUT THE AUTHOR

To Vicki: My wife and pipeline to computer technology



Joseph S. Martinich is Professor of Operations Management at the University of Missouri-St. Louis. He holds a B.S. degree in Industrial Engineering from Northwestern University; an M.A. in Economics from California State University-Fullerton; and a Ph.D. in Industrial Engineering and Management Sciences from Northwestern University. He has worked and/or consulted for companies in the steel, oil and chemical, paperboard and packaging, retail, business services, and publishing industries, as well as for governmental and not-for-profit organizations. He has held visiting and adjunct faculty positions at the John M. Olin School of Business Administration of Washington University (St. Louis), the Engineering Management Department of the University of Missouri-Rolla, and the Industrial Engineering Department of California State Polytechnic University-Pomona.

Dr. Martinich is the co-author (with Arthur P. Hurter) of the book *Facility Location and the Theory of Production* (Kluwer Academic), and he is the author of nearly 20 scholarly articles and reviews. His work has appeared in leading journals, such as *Decision Sciences*, *European Journal of Operational Research*, *Naval Research Logistics*, *American Economic Review*, *Journal of Regional Science*, and *Technological Forecasting and Social Change*. His early research focused on the interrelationship between production technology, process selection, and facility location decisions, and the effects of uncertainty and government intervention on these decisions. His current research includes the environmental aspects of operations management, and the application of Lean Production methods to service systems, not-for-profit organizations, and small businesses.

PREFACE

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 nonmajors; 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 linerboard 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 quantitative 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 discussion 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.

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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 Carolyne 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.

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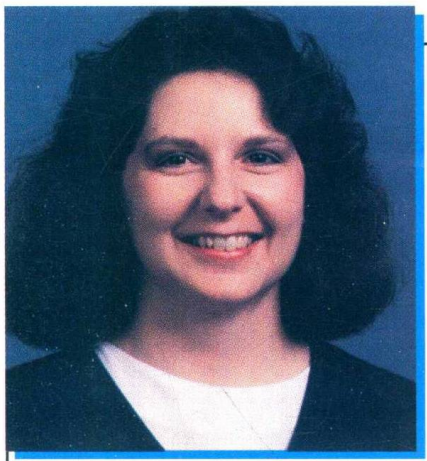
STUDENT TO STUDENT



Hello!

I am a business student with an emphasis in accounting, and I hope to get a job as a staff accountant in a large firm. I took a required production/operations management course. I was pleasantly surprised at how interesting and exciting this course was. I had expected a rather dry description of production systems but soon realized that operations management is about how all types of companies can effectively manage and improve the way they conduct their business. This course has introduced me to the management tools that can help me become more organized and efficient in my duties as a staff accountant.

If you are like me, you've probably never seen the inside of a manufacturing plant. You will find the plant tours in Chapter 3 very helpful in describing the components of a production system as well as introducing the issues and problems that are relevant to operations management. In each chapter, Dr. Martinich gives you many examples of how actual service and manufacturing companies deal with the basic operations topics of process design, queueing, and scheduling. For instance, the "In Good Company" box describes how a company has applied the concepts discussed in the chapter to solve its specific problems and improve its performance.

This course can be difficult because much of the material is quantitative in nature. Dr. Martinich explains the reasons behind the quantitative models and makes the necessary math more intuitive and easier to understand. Further, to illustrate how real problems are solved, Dr. Martinich combines the quantitative solutions with the qualitative factors that are important to operations. The interplay between quantitative and qualitative factors is presented in the fun and interesting cases at the end of each chapter.

Recently, you have probably read many newspaper and business magazine articles on lean and just-in-time production, electronic data interchange, total quality management, and environmentally responsible companies. This text will give you more background in these and many other current topics as it describes how businesses are using this information to remain competitive. The "On the Job" boxes demonstrate how today's POM professionals and those in various other professions are using the principles of operations management on a daily basis to solve problems and improve the quality of their work.

Good luck, and I hope you enjoy this course as much as I did!

Carolyne Weigel Schriefer
University of Missouri–St. Louis

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PART 1 An Introduction to Operations and Strategy