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Regd. Office: 576, Masjid Road, Jangpura, New Delhi-110014, India
E-mail: helpline@vikaspublishing.com
VIKAS® www.vikaspublishing.com

UK Original Price: £ 86.00
Special Indian Price: ₹ 895

CRC Press
Taylor & Francis Group
an informa business
www.taylorandfrancisgroup.com

6000 Broken Sound Parkway, NW
Suite 300, Boca Raton, FL 33487
711 Third Avenue
New York, NY 10017
2 Park Square, Milton Park
Abingdon, Oxon OX14 4RN, UK

K10602
ISBN: 978-1-4398-1198-6
90000
9 781439 811986
www.crcpress.com

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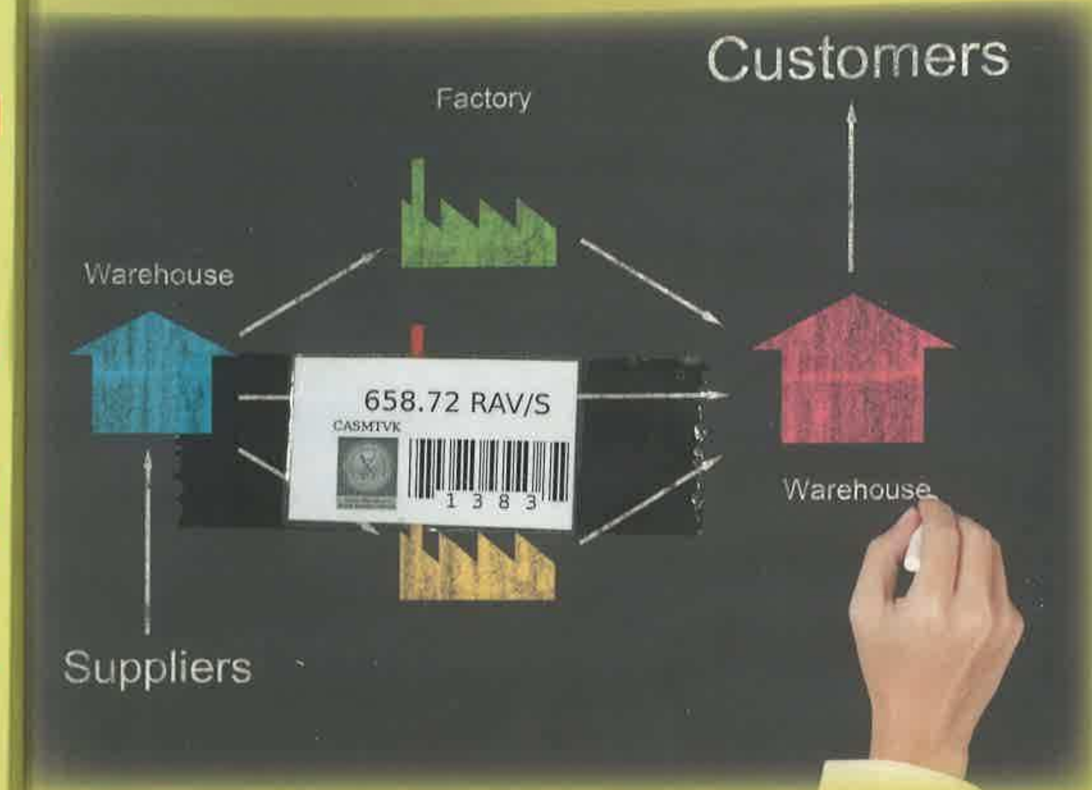

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FIRST INDIAN REPRINT, 2015

CRC Press
Taylor & Francis Group
6000 Broken Sound Parkway NW, Suite 300
Boca Raton, FL 33487-2742

Printed and bound in India by Nutech Print Services

International Standard Book Number: 978-1-4398-1198-6

Library of Congress Cataloging-in-Publication Data

Ravindran, A., 1944-
Supply chain engineering : models and applications / A. Ravi Ravindran, Donald P. Warsing, Jr.
p. cm. -- (The operations research series)
Includes bibliographical references and index.
ISBN 978-1-4398-1198-6 (hardback)
1. Business logistics. I. Warsing, Donald Paul. II. Title.

HD38.5.R38 2012
658.5--dc23 2012031946

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To our wives

Bhuvana and Mary

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Preface

This book emphasizes a quantitative approach to solving problems related to designing and operating supply chains. Importantly, though, it is not so "micro" in its focus that the perspective on the larger business problems is lost, nor is it so "macro" in its treatment of that business context that it fails to develop students' appreciation for, and skills to solve, the tactical problems that must be addressed in effectively managing flows of goods in supply chains. Economists often speak of the need to understand "first principles" before one can understand and solve larger problems. We share that view, and we have therefore structured the book to provide a grounding in the "first principles" relevant to the broad and challenging problem of managing a supply chain that spans the globe. We feel strongly that students of supply chain engineering are best served by *first* developing a solid understanding of, and a quantitative toolkit for, tactical decision making in areas such as demand forecasting, inventory management, and transportation management—in both an intrafirm and firm-to-firm (dyadic) context—*before* making any attempt to "optimize the supply chain," a task that is clearly much easier said than done, or to optimize large swaths of any given supply chain.

Still, the idea of optimization is indeed prevalent throughout the book. This book is careful and deliberate in its approach to supply chain optimization. Indeed, the perspective taken is one that is well known to engineers of all types, namely, the perspective of *design*. Engineers design things. Some engineers design discrete physical items, and some design collections of items that operate together as systems. Engineers that design supply chains take on the latter challenge. But, in the same way that it is difficult to say that an engineer that designs automotive suspension systems that achieve a particular set of objectives is in some way "optimizing the automobile," it is difficult to say that an engineer who formulates a decision to locate a distribution center in order to achieve a particular set of objectives for the firm that owns and/or manages that distribution center is somehow "optimizing the supply chain." What that engineer is doing, however, is critically important to the function of the portion of the supply chain that is connected to that distribution center.

Thus, a devotion to mathematical precision and optimization is evident throughout the book. Each chapter is presented from this mathematical perspective, and in each chapter, specific mathematical problems are formulated and solved. In addition, in the latter half of the text, specifically in Chapters 6 through 8, we address another important issue in designing supply chains and their supporting systems, namely, the issue of *conflicting criteria*. Indeed, a key issue in designing anything—be it an automotive suspension or a network that connects sources of supply to points of final consumption—is the

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Formally incorporating MCDM in supply chain design and decision making is one of the unique aspects of this book. Therefore, we include an appendix on MCDM that discusses important principles from this area of applied mathematics. This appendix serves as an important resource to Chapters 6 through 8, where we integrate MCDM into the process of designing and managing portions of the supply chain. This fresh perspective, utilizing MCDM in supply chain management and design, is particularly important to our treatment of supplier selection in Chapter 6 and supply chain risk management in Chapter 7.

Other unique aspects of the book are as follows:

- An emphasis on contemporary techniques and a focus on realism in modeling. These are evident, for example, in Chapter 4, where we extensively utilize publicly available data on truck transportation rates in building various examples to illustrate the effects of incorporating transportation cost in inventory decision models.
- Our emphasis on contemporary techniques is also evident in Chapter 5, where we make significant use of the concept of risk pooling in identifying whether more centralized or more decentralized networks are preferred, based on the relevant supply chain costs.
- We devote an entire chapter to managing risks in the supply chain, emphasizing risk quantification models and risk mitigation strategies, and presenting important problems that extend beyond the traditional treatment of supply chain management.
- We include an entire chapter on the effects of globalization on managing supply chains.

The flow of the book proceeds from a basic overview that defines supply chain engineering and establishes the book's emphasis on design, and then presents several topics addressed by nearly all books on supply chain management (forecasting, inventory, transportation, and network design), although in some unique ways, as we discussed earlier. Then, we establish the link to MDCM through a series of chapters that address topics that are not often covered in the level of depth that we devote in this book, namely, supplier selection, supply chain risk management and mitigation, and global supply chain management. Each chapter concludes with a section that presents a collection of further readings, extending from, and beyond, the concepts discussed in the chapter. This is followed by a series of end-of-chapter exercises. Each set

of exercises includes 5–6 conceptual questions, 5–6 quantitative problems, and 1–2 "mini case studies." An instructor's manual, with solutions to the quantitative problems and mini case studies, is available for those adopting the book for classroom use.

The book is targeted to serve in the following contexts:

- A textbook for graduate-level and advanced undergraduate-level courses in industrial engineering
- A textbook for, or reference book to support, advanced MBA elective courses in operations management, logistics, management science, or supply chain management that emphasize quantitative analysis
- A reference for technical professionals and researchers in industrial engineering, operations management, logistics, and supply chain management

This book grew out of two sources. One is a graduate course in supply chain engineering taught in the industrial and manufacturing engineering department at Pennsylvania State University since the fall 2002 semester. The other is a comprehensive chapter on supply chain management written for the *Operations Research and Management Science Handbook* (2008, CRC Press), which itself was based on materials developed for graduate courses, one in supply chain management, taught at the Smeal College of Business at Penn State, and one in logistics management, taught at the Poole College of Management at North Carolina State University. The book was the result of a realization by the authors—one of whom wrote the comprehensive chapter while the other edited the volume in which it appears—that there was clear value in combining these two pools of content and organizing them into a targeted textbook that uses the precise tools of engineering analysis to address broad and challenging problems in supply chain management. The result, we believe, fills a gap that has resulted from various textbooks on these topics focusing only on one or the other of these perspectives.

Thus, the book is organized to present each of the elemental problems undergirding supply chain management, building up the reader's content knowledge before finally tackling broad issues related to managing across company boundaries and country boundaries. This approach has been influenced by other textbooks utilized in our teaching. Ultimately, though, we found that the books that are best at framing the important strategic issues in supply chain management fail to sufficiently build the kinds of skills in modeling and analysis that we believe are critical for effective tactical decision making, while the books that are best at presenting quantitative models for tactical decision making generally fail to place those modeling efforts in a larger context that aids in students' understanding of the important strategic issues in supply chain management. This book blends the best of those two perspectives, "bookending" the text, as it were, with an introductory discussion that lays out the strategic framework for effective design of the supply chain and its supporting policies, then studying the elemental problems one by one, and finally pulling this content knowledge together in the context of managing the global supply chain. The result is what we believe to be a comprehensive treatment of the subject that we hope will serve many students and practitioners of the science of designing effective supply chains for many years to come.

A. Ravi Ravindran
University Park, Pennsylvania

Donald P. Warsing, Jr.
Raleigh, North Carolina

Acknowledgments

First and foremost, we express our sincere appreciation to Madhana Raghavan, an industrial engineering doctoral student at Penn State University, for his outstanding help with the preparation of this book, typing several chapters and reviewing the examples used. We also acknowledge the valuable contributions of Subramanian Pazhani, another doctoral student, who joined the book project recently.

We thank our former PhD students—Ufuk Bilsel, Rodolfo Portillo, Vijay Wadhwa, and Tao Yang—for their valuable contributions to the material presented in Chapters 6 through 8. Their reviews of the chapter drafts are also much appreciated. In addition, several former and current industrial engineering graduate students at Penn State helped us by reviewing several chapters and providing valuable comments that improved the presentation. In particular, we wish to acknowledge the reviews provided by Pastor Casanova, Aixa Cintron, Nok Kungwalsong, Abraham Mendoza, Ajay Natarajan, Richard Titus, Aineth Torres, and Victor Valdebenito. Special thanks go to P. Balasubramanian of Theme Work Analytics for his careful review and helpful comments on several chapters. We also acknowledge the early typing assistance provided by Sharon Frazier.

Colleagues at North Carolina State provided significant and valuable support and insights on the material in Chapters 3 and 4. In particular, we thank Reha Uzsoy for his insights on multi-echelon base-stock models and Michael Kay for providing a fresh perspective on data sources and modeling for freight transportation. Also, we would be remiss if we did not recognize the work of Farhad Azadivar and Atul Rangarajan, whose chapter on inventory control in the *Operations Research and Management Science Handbook* (CRC Press, 2008) provided a solid basis upon which to build our discussion of the multi-echelon economic order quantity models. Of course, any errors of commission or omission in assimilating these insights into our work are ours alone.

We thank Cindy Renee Carelli, senior acquisitions editor at CRC Press, for her constant support and encouragement from inception to completion of this book. Finally, we thank our families for their support, love, understanding, and encouragement, when we were focused completely on writing this book.

Authors

A. Ravi Ravindran is a professor and former department head of industrial and manufacturing engineering at the Pennsylvania State University since 1997. Formerly, he was a faculty member in the School of Industrial Engineering at Purdue University for 13 years (1969–1982) and at the University of Oklahoma for 15 years (1982–1997). At the University of Oklahoma, he served as the director of the School of Industrial Engineering for 8 years and as the associate provost of the university for 7 years with responsibility for budget, personnel, and space for the academic area. He received his BS in electrical engineering with honors from BITS Pilani, India, and his MS and PhD in industrial engineering and operations research from the University of California, Berkeley.

Dr. Ravindran's area of specialization is operations research, with research interests in multiple criteria decision-making, financial engineering, health-care delivery systems, and supply chain optimization. He has published five books (*Operations Research: Principles and Practice, Engineering Optimization: Methods and Applications, Handbook of Operations Research and Management Science, Operations Research Methodologies,* and *Operations Research Applications*) and over 100 journal articles in operations research. He is a Fulbright Fellow and a fellow of the Institute of Industrial Engineers (IIE). In 2001, he was recognized by IIE with the Albert G. Holzman Distinguished Educator Award for significant contributions to the industrial engineering profession by an educator. He has been a consultant to AT&T, General Motors, IBM, Kimberly Clark, General Electric, U.S. Department of Transportation, the Cellular Telecommunications Industry Association, and the U.S. Air Force. He currently serves as the operations research series editor for Taylor & Francis Group/CRC Press.

Donald P. Warsing, Jr. is an associate professor of operations and supply chain management at the Poole College of Management at North Carolina State University (NC State). Prior to joining the faculty at NC State, Dr. Warsing served on the faculty of the Smeal College of Business at Pennsylvania State University and also worked for several years at IBM Corporation in roles spanning from industrial engineering to manufacturing management. He received his PhD in operations management from the Kenan-Flagler Business School at the University of North Carolina-Chapel Hill, a master of science in management with a concentration in industrial engineering from North Carolina State University, and a bachelor of science in industrial and systems engineering from Ohio State University.

Dr. Warsing's research concerns the development of tools and policies for effectively managing inventory, logistics, and business operations and studying the ways in which various management practices contribute to improved performance outcomes. His work has been published in *Production and Operations Management*, the *Journal of Operations Management*, *Decision Sciences*, the *European Journal of Operational Research*, and the *International Journal of Logistics*. He is also the author of several book chapters on logistics and supply chain management, including one that appears in both the *Operations Research and Management Science Handbook* (CRC Press, 2008) and *Operations Research Applications* (CRC Press, 2009).

1

Introduction to Supply Chain Engineering

At its heart, this is a book about design. This stands to reason since a prominent word in its title is "engineering." Design is the province of much of engineering. While some engineers design physical products (e.g., computers, automobiles, bridges), others design systems. Having said that, we must briefly clarify the concept of a system. While the prevailing notion of a system is that it is "more than the sum of its parts," we can perhaps be a little clearer than that. One of the most concise and useful definitions of a system, in our minds, was offered some years ago by the Nobel-prize-winning economist Herb Simon, who stated that a system is comprised of a "number of parts that interact in a non-simple way." The "nonsimple-ness" (i.e., complexity) of the interaction of the parts is the hallmark of a system, and what leads to the "more than the sum of its parts" notion of how a system operates (Simon, 1962).

Indeed, the design focus of some engineers goes beyond individual, discrete products to deal with systems, which are, collections of discrete entities that interact—often in "non-simple" ways—to produce a desired outcome. In some cases, those systems are comprised of entities that are physical and tangible, like the heating and air conditioning system designed by a mechanical engineer. In some cases, some aspects of the systems being designed are more conceptual in nature. Industrial engineers (IEs) design such systems. IE-related systems are typically comprised of a mix of tangible and intangible components. For example, production systems take physical inputs (e.g., materials and labor) and conceptual inputs (e.g., projected consumer demand, short-term and long-term business plans) to achieve an output of physical products that ultimately are sold to satisfy customers. Moreover, distribution systems take as their input the products generated by the production system and, along with labor and other plans related to business goals and customer demand, coordinate the movement, storage, and transport of those products to ultimately satisfy that demand, hopefully on-time and in the right quantity. Our focus in this book is on the design of the *supply chain system*, which involves connecting many such production and distribution systems, often across wide geographic distances, in such a way that the businesses involved can ultimately satisfy consumer demand as efficiently as possible, resulting in maximum financial returns to those businesses connected to that supply chain system.

Having established that this book is about design, let us be clear about another important issue, specifically that design always involves *tradeoffs*.

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