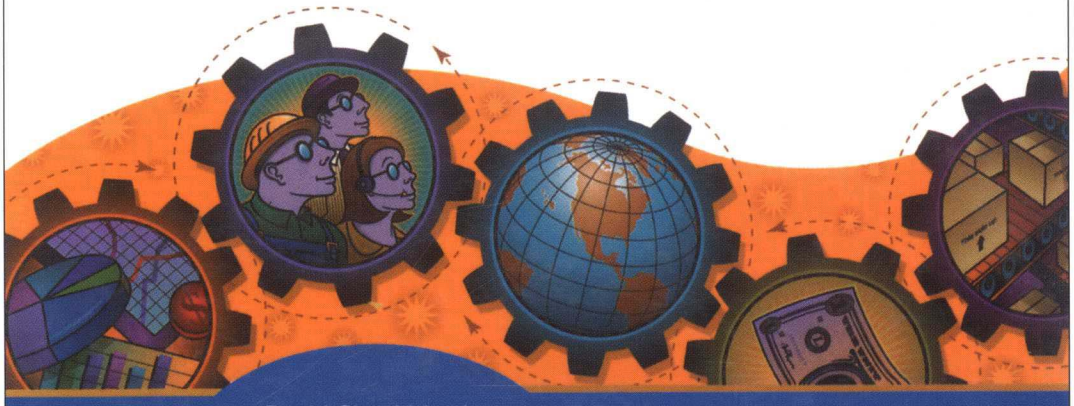
INTERNATIONAL EDITION

Designing & Managing THE Supply Chain

CONCEPTS, STRATEGIES & CASE STUDIES

SECOND EDITION



David Simchi-Levi

Philip Kaminsky

Edith Simchi-Levi

McGRAW-HILL

DESIGNING AND MANAGING THE SUPPLY CHAIN

Concepts, Strategies, and Case Studies

SECOND EDITION

David Simchi-Levi

Massachusetts Institute of Technology (MIT), Cambridge, Massachusetts

Philip Kaminsky

University of California, Berkeley

Edith Simchi-Levi

LogicTools, Inc., Lexington, Massachusetts

Boston Burr Ridge, IL Dubuque, IA Madison, WI New York San Francisco St. Louis
Bangkok Bogotá Caracas Kuala Lumpur Lisbon London Madrid Mexico City
Milan Montreal New Delhi Santiago Seoul Singapore Sydney Taipei Toronto

McGraw-Hill Higher Education
A Division of The McGraw-Hill Companies

DESIGNING AND MANAGING THE SUPPLY CHAIN: CONCEPTS, STRATEGIES, AND CASE STUDIES
International Edition 2003

10 09 08 07 06 05 04 03 02 01
20 09 08 07 06 05 04 03
CTF SLP

Cover image: © *Jeffrey Pelo/Folioplanet*

Library of Congress Cataloging-in-Publication Data

Simchi-Levi, David
Designing and managing the supply chain: concepts, strategies, and case studies / David Simchi-Levi, Philip Kaminsky, Edith Simchi-Levi.—2nd ed.
p. cm.—(The McGraw-Hill/Irwin series in operations and decision sciences)
Includes bibliographical references and index.
ISBN 0-07-249256-2 — ISBN 0-07-119896-2
1. Physical distribution of goods—Management. 2. Marketing channels—Management. 3. Business logistics. 4. Industrial procurement. I. Kaminsky, Philip. II. Simchi-Levi, Edith. III. Title. IV. Irwin/McGraw-Hill series in operations and decision sciences.
HF5415.7.S425 2003
658.5—dc21 2002026413

When ordering this title, use ISBN 0-07-123205-2

Printed in Singapore

www.mhhe.com

DESIGNING AND MANAGING THE SUPPLY CHAIN

Concepts, Strategies, and Case Studies

SECOND EDITION

The McGraw-Hill/Irwin Series in Operations and Decision Sciences

QUANTITATIVE METHODS AND MANAGEMENT SCIENCE

Bodily, Carraway Frey, and Pfeifer
Quantitative Business Analysis: Casebook
First Edition

Bodily, Carraway Frey, and Pfeifer
Quantitative Business Analysis: Text and Cases
First Edition

Bonini, Hausman, and Bierman
Quantitative Analysis for Business Decisions
Ninth Edition

Hesse
Managerial Spreadsheet Modeling and Analysis
First Edition

Hillier, Hillier, and Lieberman
Introduction to Management Science: A Modeling and Case Studies Approach with Spreadsheets
First Edition

OPERATIONS MANAGEMENT

Bowersox, Closs, and Cooper
Supply Chain Logistics
First Edition

Chase, Aquilano, and Jacobs
Operations Management for Competitive Advantage
Ninth Edition

Davis, Aquilano, and Chase
Fundamentals of Operations Management
Third Edition

Fitzsimmons and Fitzsimmons
Service Management
Third Edition

Gray and Larson
Project Management
First Edition

Harrison and Samson
Technology Management: Text and International Cases
First Edition

Hill
Manufacturing Strategy: Text and Cases
Third Edition

Hopp and Spearman
Factory Physics
Second Edition

Knod and Schonberger
Operations Management: Meeting Customers' Demands
Seventh Edition

Melnyk and Swink
Operations Management: A Value Driven Approach
First Edition

Nahmias
Production and Operations Analysis
Fourth Edition

Olson
Introduction to Information Systems Project Management
First Edition

Schroeder
Operations Management
First Edition

Simchi-Levi, Kaminsky, and Simchi-Levi
Designing and Managing the Supply Chain
Second Edition

Sterman
Business Dynamics
First Edition

Stevenson
Operations Management
Seventh Edition

Vollmann, Berry, and Whybark
Manufacturing Planning and Control Systems
Fourth Edition

Zipkin
Foundations of Inventory Management
First Edition

To our children, Sara and Yuval, who have the patience and humor to survive our work together

D.S.L., E.S.L.

To my family, for their support and encouragement

P.K.

ABOUT THE AUTHORS

DAVID SIMCHI-LEVI is a Professor of Engineering Systems at the Massachusetts Institute of Technogy (MIT). Prior to joining the faculty at MIT, he taught at Northwestern University and Columbia University. Professor Simchi-Levi received his Ph.D. in Operations Research from Tel-Aviv University and has won awards for his work in supply chain management, logistics, and transportation. At MIT he teaches logistics and supply chain management at the Leaders for Manufacturing program as well as Executive Programs at the MIT Sloan School of Management. In 2000, he was named the "Master of Design" by *Supply Chain Management Review*. He is co-author, together with Julien Bramel, of *The Logic of Logistic*, published by Springer, and a co-founder and president of LogicTools Inc., a company that provides decision support planning software for logistics and supply chain management.

PHIL KAMINSKY is Assistant Professor of Industrial Engineering at the University of California at Berkeley. He received his Ph.D. in Industrial Engineering from Northwestern University. Prior to his graduate studies, he worked for the production division of Merck & Co., Inc. He has consulted in the areas of supply chain and production management.

EDITH SIMCHI-LEVI is a co-founder and Vice President of Operations of LogicTools Inc., a leading supply chain planning software company. She has extensive experience in software development and has engaged in numerous consulting projects in logistics and supply chain management. She received her B.S. in Mathematics and Computer Science from Tel-Aviv University.

FOREWORD

In the last few years we have seen an explosion of publications on supply chain management; numerous books have been published and many articles have appeared in academic, trade, and popular magazines. These publications either are too technical—and therefore inaccessible to practitioners and students—or lack the breadth and depth that the topic deserves. Certainly, it is difficult to find a book appropriate for teaching supply chain management to business or engineering students. *Designing and Managing the Supply Chain* solves this problem!

The book is an important contribution and major milestone for the supply chain community. It is the first book that covers a comprehensive breadth of supply chain topics in depth, and addresses the major challenges in this area. It was written by experts from academia and industry who have been researching, consulting, and developing software for supply chain management for many years.

This book includes many classic and new case studies, numerous examples as well as in-depth analyses of some of the technical issues involved in inventory management, network design, and strategic partnering, to name a few. It is therefore an ideal textbook for classes on supply chain management at the undergraduate, Master's, and M.B.A. levels. Since each chapter is self-contained, instructors can pick the chapters they want to use, depending on the length of the class and its requirements. The book comes with two computerized games. The Computerized Beer Game provides an excellent instructional tool that engages students in managing a supply chain and provides a starting point for discussing the value of information in the supply chain, strategic partnering, centralized decision making, and so forth. The Risk Pool Game allows students to gain insight on an important concept in supply chain management, called risk pooling. The authors have been most creative in using games to motivate and expose students to challenging subjects.

Finally, since many companies view supply chain management as the core of their business strategy, this book will also be of interest to managers involved in any of the processes that make up the supply chain.

I want to compliment the authors for having written such an outstanding textbook for the supply chain community.

Hau L. Lee
Kleiner Perkins, Mayfield, Sequoia Capital Professor
Director, Stanford Global Supply Chain Forum
Stanford University

PREFACE

Two years ago, when we wrote the first edition of this text, our objective was to present, in an easily accessible manner, supply chain concepts, strategies, and models. We are pleased to note that the text was very successful; we received a tremendous response from adopters, students, executives, and consultants. The success of that edition, as well as new concepts and recent technological changes, have motivated us to revise the book. In this edition, we have attempted to build on the positive elements of the first edition and to include what we have learned in the last two years.

The first edition of this book grew out of a number of supply chain management courses and Executive Education programs we taught at Northwestern University over the past several years, as well as numerous consulting projects and supply chain decision-support systems we developed at LogicTools. Since then, we have continued teaching executive courses, both at Massachusettes Institute of Technology and at the University of California, Berkeley, and have continued to develop a variety of supply chain decision-support tools. These courses have spawned many innovative and effective supply chain education concepts. The focus in these programs has always been on presenting, in an easily accessible manner, recently developed state-of-the-art models and solution methods important in the design, control, and operation of supply chains. Similarly, the consulting projects and decision-support systems developed by LogicTools have focused on applying these advanced techniques to solve specific problems faced by our clients. In the last two years, we have added new models and techniques to these courses as they have been developed, and we have begun to put all of these techniques into perspective, and to develop frameworks to integrate all of these models and solution methods.

Interest in supply chain management, both in industry and in academia, has grown rapidly over the past several years, and continues to grow. A number of forces have contributed to this trend. First, in recent years it has become clear that many companies have reduced manufacturing costs as much as practically possible. Many of these companies are discovering the magnitude of savings that can be achieved by planning and managing their supply chain more effectively. Indeed, a striking example is Wal-Mart's success, which is partly attributed to implementing a new logistics strategy called cross-docking. At the same time, information and communication systems have been widely implemented, and provide access to comprehensive data from all components of the supply chain.

In particular, the influence of the Internet and e-commerce on the economy in general, and business practice in particular, has been tremendous. Changes are happening extremely fast, and the scope of these changes is breathtaking! For instance, the direct-business model employed by industry giants such as Dell Computers and Amazon.com enables customers to order products over the Internet and thus allows companies to sell their products without relying on third-party distributors or conventional stores. Similarly, business-to-business e-commerce, which is predicted by Forrester Research to skyrocket from $43 billion in 1998 to $1.3 trillion in 2003, has tremendous potential to increase the efficiency of a variety of businesses.

Finally, deregulation of the transportation industry has led to the development of a variety of transportation modes and reduced transportation costs, while significantly increasing the complexity of logistics systems.

It is therefore not surprising that many companies are involved in the analysis of their supply chains. In most cases, however, this analysis is performed based on experience and intuition; very few analytical models or planning tools have been used in this process. In contrast, in the last two decades the academic community has developed various models and tools for supply chain management. Unfortunately, the first generation of this technology was not robust or flexible enough to allow industry to use it effectively. This, however, has changed over the last few years, during which improved analysis and insight, and effective models and decision-support systems, have been developed; however, these are not necessarily familiar to industry. Indeed, to our knowledge there is no published work that discusses these problems, models, concepts, and tools at an appropriate level.

In this book, we intend to fill this gap by providing state-of-the-art models, concepts, and solution methods that are important for the design, control, operation, and management of supply chain systems. In particular, we have attempted both to convey the intuition behind many key supply chain concepts and to provide simple techniques that can be used to analyze various aspects of the supply chain.

The emphasis is on a format that will be accessible to executives and practitioners, as well as students interested in careers in related industries. In addition, it will introduce readers to information systems and decision-support tools that can aid in the design, analysis, and control of supply chains.

The book is written to serve as

- A textbook for M.B.A.-level logistics and supply chain management courses.
- A textbook for B.S. and M.S. industrial engineering courses on logistics and supply chain management.
- A reference for teachers, consultants, and practitioners involved in any one of the processes that make up the supply chain.

Of course, supply chain management is a very broad area, and it would be impossible for a single book to cover all of the relevant areas in depth. Indeed, there is considerable disagreement in academia and industry about exactly what these relevant areas are. Nevertheless, we have attempted to provide a broad introduction to many critical facets of supply chain management. Although many essential supply chain management issues are interrelated, we have strived wherever possible to make each chapter as self-contained as possible, so that the reader can refer directly to chapters covering topics of interest. The discussion ranges from basic topics of inventory management, logistics network design, distribution systems, and customer value to more advanced topics of strategic alliances, the value of information in the supply chain, information

technology, decision-support systems, and international issues in supply chain management. Each chapter utilizes numerous case studies and examples, and mathematical and technical sections can be skipped without loss of continuity.

We have made substantial changes to the second edition of this text. As we continued to teach, consult, and research supply chain management issues, we have placed an increasing importance on finding or developing effective frameworks that illustrate many important supply chain issues. This is reflected in the second edition; many of the chapters have been reorganized around frameworks that will help the reader to understand the relationships between many critical supply chain issues. In addition, motivated by new developments in industry, for example, the impact of Internet technology on business practices, we have added a variety of new topics to the text and increased coverage of others. For example:

- We cover topics such as e-business and its impact on supply chain strategies (Chapter 5).
- We have added a chapter on procurement and outsourcing (Chapter 7).
- We discuss supply contracts and their impact on supply chain optimization (Chapter 3).
- We consider pricing and revenue management strategies and the implication of these strategies for supply chain management (Chapter 10).
- We cover additional inventory models (Chapter 3).
- We have increased coverage of forecasting (Chapter 3).
- We have increased our coverage of product and process modularity (Chapter 7 and Chapter 9).
- We have additional material concerning supply chain distribution strategies (Chapter 5).
- We introduce a new framework that illustrates the impact of various technologies on supply chain excellence (Chapter 11 and Chapter 12).
- We provide a detailed analysis of the latest information technology trends (Chapter 11).

We have also added supporting material:

- Several cases, including *Meditech Surgical*, *Sport Obermeyer, FreeMarkets OnLine*, and *Hewlett-Packard Company: Network Printer Design for Universality*.
- Numerous examples.
- Discussion questions and case exercises at the end of most of the chapters,

The book also includes two software packages, the **Computerized Beer Game** and the **Risk Pool Game**, that help to illustrate many of the concepts we discuss in the book. Indeed, in teaching executives and M.B.A. students, we have found that these games help students better understand issues and concepts such as the bullwhip effect, the value of information in the supply chain, and the impact of lead times, centralized decision making, and risk pooling on supply chain operations. For this edition, we have added a Microsoft Excel spreadsheet, which helps students understand many of the concepts introduced in Chapter 3, especially with regard to supply contracts.

Parts of this book are based on work we have done either together or with others. Chapters 1 and 2 borrow extensively from *The Logic of Logistics*, written by Julien Bramel and David Simchi-Levi and published by Springer in 1997. This, of course, is done by permission of the copyright owner. The Computerized Beer Game is discussed in an article by Philip Kaminsky and David Simchi-Levi that appeared in *Supply Chain and Technology Management*, edited by Hau Lee and Shu Ming Ng and published

by The Production and Operations Management Society. Some of the material on the bullwhip effect appears in an article by Chen, Drezner, Ryan, and Simchi-Levi in *Quantitative Models for Supply Chain Management*, edited by Sridhar Tayur, Ram Ganeshan, and Michael Magazine, and published by Kluwer Academic Publishers. The material in Chapter 5 is taken from two papers, one written by the first and the third authors of this book and the second written by these two authors and M. Watson. This paper is going to appear in *The Practice of Supply Chain Management*, edited by C. Billington, T. Harrison, H. Lee, and J. Neale, to be published by Kluwer Academic Publishers.

ACKNOWLEDGMENTS

It is our pleasure to acknowledge all those who helped us with the first and the second editions of this manuscript. First, we would like to thank Dr. Myron Feinstein, former director of supply chain strategy development at Unilever, New York City, who read through and commented on various chapters. Similarly, we are indebted to the reviewers of the first edition, Professors Michael Ball (University of Maryland), Wendell Gilland (University of North Carolina, Chapel Hill), Eric Johnson (Dartmouth College), Douglas Morrice (The University of Texas, Austin), Michael Pangburn (Pennsylvania State University), Powell Robinson (Texas A&M University), William Tallon (Northern Illinois University), and Rachel Yang (University of Illinois, Urbana-Champaign). We are also grateful to Dr. Deniz Caglar of Booz Allen Hamilton for his comments on earlier drafts of the book.

The second edition benefited from comments and suggestions we received from many people. These include Professors Arjang Assad, Michael Ball, and their colleagues from the University of Maryland–College Park; Chia-Shin Chung (Cleveland State University); Brian Gibson (Auburn University); Boaz Golany (Technion, Israel); Isaac Gottlieb (Rutgers University); Shelly Jha (Wilfrid Laurier University, Ontario, Canada); Dana Johnson (Michigan Technical University); Mary Meixell (George Mason University); Dan Rinks (Louisiana State University); Tony Arreola-Risa (Texas A&M University); and Joel Wisner (University of Nevada–Las Vegas). These comments were invaluable in improving the organization and presentation of the book.

Professor Ravi Anupindi (University of Michigan, Ann Arbor), Professor Yehuda Bassok (University of Southern California), Dr. Jeff Tew (General Motors), and Professor Jayashankar Swaminathan (University of North Carolina, Chapel Hill) provided valuable insights that we have incorporated into the second edition of the text.

We are grateful to our colleagues at Massachusetts Institute of Technology; the University of California, Berkeley; and LogicTools who have provided us with opportunities to interact with some of the brightest minds in our field and to learn from their research and development. Three people stand out in this regard: Professors Charles H. Fine and Stephen C. Graves (MIT), with whom Professor Simchi-Levi has closely collaborated in the last two years, and Dr. Michael S. Watson from LogicTools.

We thank Dr. Kathleen A. Stair and Ms. Ann Stuart for carefully editing and proofreading many chapters. Ms. Ann Stuart has also provided invaluable assistance in preparing the second edition.

Finally, we wish to thank Ms. Colleen Tuscher, who assisted us in the initial stage of the project; our editor, Mr. Scott Isenberg; and his assistants, Ms. Nicolle Schieffer and Ms. Lee Stone of Irwin/McGraw-Hill, who encouraged us throughout and helped us complete the book. Also, thanks to Ms. Anna Chan, Mr. James Labeots, and the production staff at McGraw-Hill for their help.

David Simchi-Levi
Cambridge, Massachusetts

Philip Kaminsky
Berkeley, California

Edith Simchi-Levi
Lexington, Massachusetts

LIST OF CASES

BRIEF CONTENTS

CONTENTS