Supply Chain Management

The McGraw-Hill Education Series in Operations and Decision Sciences

SUPPLY CHAIN MANAGEMENT

Benton
Purchasing and Supply Chain Management
Third Edition

Bowersox, Closs, Cooper, and Bowersox
Supply Chain Logistics Management
Fifth Edition

Burt, Petcavage, and Pinkerton
Supply Management
Eighth Edition

Johnson
Purchasing and Supply Management
Sixteenth Edition

Simchi-Levi, Kaminsky, and Simchi-Levi
Designing and Managing the Supply Chain: Concepts, Strategies, Case Studies
Third Edition

Stock and Manrodt
Supply Chain Management

PROJECT MANAGEMENT

Brown and Hyer
Managing Projects: A Team-Based Approach

Larson and Gray
Project Management: The Managerial Process
Seventh Edition

SERVICE OPERATIONS MANAGEMENT

Bordoloi, Fitzsimmons, and Fitzsimmons
Service Management: Operations, Strategy, Information Technology
Ninth Edition

MANAGEMENT SCIENCE

Hillier and Hillier
Introduction to Management Science: A Modeling and Case Studies Approach with Spreadsheets
Sixth Edition

BUSINESS RESEARCH METHODS

Schindler
Business Research Methods
Thirteenth Edition

BUSINESS FORECASTING

Keating and Wilson
Forecasting and Predictive Analytics
Seventh Edition

LINEAR STATISTICS AND REGRESSION

Kutner, Nachtsheim, and Neter
Applied Linear Regression Models
Fourth Edition

BUSINESS SYSTEMS DYNAMICS

Sterman
Business Dynamics: Systems Thinking and Modeling for a Complex World

OPERATIONS MANAGEMENT

Cachon and Terwiesch
Operations Management
Second Edition

Cachon and Terwiesch
Matching Supply with Demand: An Introduction to Operations Management
Fourth Edition

Jacobs and Chase
Operations and Supply Chain Management
Fifteenth Edition

Jacobs and Chase
Operations and Supply Chain Management: The Core
Fifth Edition

Schroeder and Goldstein
Operations Management in the Supply Chain: Decisions and Cases
Seventh Edition

Stevenson
Operations Management
Thirteenth Edition

Swink, Melnyk, and Hartley
Managing Operations Across the Supply Chain
Fourth Edition

BUSINESS MATH

Slater and Wittry
Practical Business Math Procedures
Thirteenth Edition

Slater and Wittry
Math for Business and Finance: An Algebraic Approach
Second Edition

BUSINESS STATISTICS

Bowerman, O'Connell, Drougas, Duckworth, and Froelich
Business Statistics in Practice
Ninth Edition

Doane and Seward
Applied Statistics in Business and Economics
Sixth Edition

Doane and Seward
Essential Statistics in Business and Economics
Third Edition

Lind, Marchal, and Wathen
Basic Statistics for Business and Economics
Ninth Edition

Lind, Marchal, and Wathen
Statistical Techniques in Business and Economics
Seventeenth Edition

Jaggia and Kelly
Business Statistics: Communicating with Numbers
Third Edition

Jaggia and Kelly
Essentials of Business Statistics: Communicating with Numbers
Second Edition

McGuckian
Connect Master: Business Statistics

Supply Chain Management

James R. Stock
University of South Florida

Karl B. Manrodt
Georgia College & State University

Mc Graw Hill Education

SUPPLY CHAIN MANAGEMENT

Published by McGraw-Hill Education, 2 Penn Plaza, New York, NY 10121.

This book is printed on acid-free paper.

1 2 3 4 5 6 7 8 9 LWI 21 20 19

ISBN 978-1-260-39559-4
MHID 1-260-39559-6

Portfolio Manager: *Noelle Bathurst*
Product Developer: *Tobi Philips*
Marketing Manager: *Harper Christopher*
Content Project Managers: *Fran Simon/Brian Nacik*
Buyer: *Sandy Ludovissy*
Design: *Debra Kubiak*
Content Licensing Specialist: *Jacob Sullivan*
Cover Image: ©*Shutterstock/Dustit*
Compositor: *MPS Limited*
All credits appearing on page or at the end of the book are considered to be an extension of the copyright page.

Library of Congress Cataloging-in-Publication Data

Stock, James R., author. | Manrodt, Karl B., 1957- author.
Supply chain management / James R. Stock, University of South Florida,
Karl B. Manrodt, Georgia College & State University.
1 Edition. | Dubuque : McGraw-Hill Education, [2020]
LCCN 2019004322 | ISBN 9781260395594 (alk. paper)
LCSH: Business logistics.
LCC HD38.5 .S756 2019 | DDC 658.5–dc23
LC record available at https://lccn.loc.gov/2019004322

mheducation.com/highered

Dedicated to our wives,
Katheryn Stock and Susan Manrodt

About the Authors

James R. Stock is the USF Distinguished University Professor and Frank Harvey Endowed Professor of Marketing at the University of South Florida. He was elected as an AAAS Fellow of the American Association for the Advancement of Science in 2017. Professor Stock was also the Fulbright-Hanken Distinguished Chair of Business & Economics at the Hanken School of Economics in Helsinki, Finland, on a flex Fulbright Award in 2016 and 2017. He has been an invited speaker on programs in more than 45 countries. He is the author or co-author of over 150 publications including books, monographs, and articles. Professor Stock has co-authored several textbooks on logistics management and reverse logistics. He received the CSCMP Distinguished Service Award in 2011, Armitage Medal (1988) and the Eccles Medal (2003) from SOLE–The International Society of Logistics, and Lifetime Achievement Awards from the Reverse Logistics Association (2016) and Yasar University/IX International Logistics and Supply Chain Congress in Turkey (2011). His research interests include reverse logistics/product returns, supply chain sustainability, and customer satisfaction. His background includes faculty positions at the University of Notre Dame, University of Oklahoma, Air Force Institute of Technology, and Michigan State University. He received B.A. and M.B.A. degrees from the University of Miami (FL) and his Ph.D. from The Ohio State University.

Karl B. Manrodt is Professor of Logistics in the Department of Management, Marketing, and Logistics at Georgia College & State University. He is a prolific researcher, having authored seven books and over 50 scholarly articles in leading journals. His degrees include a B.A. in Philosophy and Psychology from Wartburg College, M.S. in Logistics from Wright State University, and Ph.D. from the University of Tennessee. Dr. Manrodt was recognized as a “Rainmaker” by *DC Velocity Magazine* and was awarded the Eugene Bishop Award for Sustained Academic Excellence by the College of Business at GSU. He has served on the board of directors for the Council of Supply Chain Management Professionals as well as in other leadership roles with the Warehouse Education Research Council. Dr. Manrodt has over 25 years of experience in logistics, transportation, and supply chain research. His research projects have been funded by a wide range of participants in the supply chain: consulting firms, associations, carriers, software providers, and shippers. Some of his clients include Oracle, the State of Georgia, FedEx, CSCMP, WERC, Ernst & Young, and the U.S. Department of State.

Preface

Since the start of the new millennium, significant changes and developments have impacted organizations of all types. Omnichannel marketing, the "cloud" for data storage and software applications, smartphone technology, robotics and artificial intelligence, autonomous vehicles used in transport, and many other developments have resulted in significant improvements in business productivity, efficiency, and effectiveness. On the negative side, terrorism, economic uncertainty, global trade wars, recessions, increasing instances of spyware and malware, and political unrest have complicated the picture. At the forefront in the new millennium, supply chain management has become a mainstream strategy in organizations of all shapes, sizes, and types.

A large percentage of the GDP of industrialized and developing nations is impacted by supply chain management activities. As a concept and approach to business, supply chain management has developed into a "C-suite" activity in major corporations, and it has done so in less than four decades since its inception as a business process and strategic orientation. It was only in the mid-1980s that supply chain management began to be recognized as an approach that could benefit customers, companies, and society at large. Many firms, including Amazon, Apple, Bristol-Meyers Squibb, C. H. Robinson, Ford, Google, Walmart, and Whirlpool, to name only a few, have become major players in this new era of supply chain management.

The marketplace has become a 24/7/365 environment given global commerce and customers and suppliers located anywhere in the world. Managing supply chains has become one of the most complex processes that organizations have to implement and maintain. That is why we wrote this book. *Supply Chain Management* approaches the topic from a managerial perspective, utilizing logistics, marketing, and operations management concepts, principles, and strategies to explain and illustrate supply chain management in a global context. In each chapter, basic supply chain concepts are operationalized in a readable format that is immediately useful and practical for decision making. Discussions on customer satisfaction, logistics management, global commerce, software and hardware technologies, and marketing and operations management are the focal points of every chapter. Given the significant international experience of the authors, many of these illustrations are from a diverse group of organizations located throughout the world.

The pragmatic, applied nature of the text; its managerial orientation; and its global perspective emphasizing customer satisfaction and corporate financial well-being make *Supply Chain Management* a must-have reference book for present and future supply chain professionals.

Plan of the Book

We have attempted to provide you, the reader, with the latest and most important issues and topics facing supply chain executives, as well as the basic tools, techniques, and concepts from logistics, marketing, operations management, and supply chain management. We illustrate the discussion with many examples from leading-edge organizations. Additionally, several best-practice case examples of supply chain innovations are presented at the end of the book. These examples come from organizations that were finalists in the annual Supply Chain Innovation Award™ competition for most innovative supply chain strategies and tactics jointly sponsored by the Council of Supply Chain Management Professionals (CSCMP) and *SupplyChainBrain* magazine.

This book begins in Chapter 1 with an overview of supply chain management (SCM) and both societal and business issues that impact supply chains. Various modes of SCM are presented, although the SCOR Model will be the focus of this book. We address customer service and satisfaction, the cornerstone of successful supply chain management, next in Chapter 2. Without excellent customer service that satisfies customers, all supply chain activities are in vain. Customer satisfaction and customer service are linked to the marketing concept and logistics. Various measures and metrics of customer service and satisfaction are presented, with a discussion of how customer satisfaction strategies are developed and implemented by SCM professionals.

In Chapter 3, we examine the important role of information in supply chains, including its uses and how various technologies aid in the collection, dissemination, and distribution of information within supply chains. Related to the importance of information, sales forecasting and inventory management are the subject of Chapter 4, where we discuss some of the basics of inventory management, along with the role of sales forecasting in determining optimal levels of inventory that an organization should hold.

Chapters 5, 6, and 7 feature the fundamental elements of logistics management, often ignored or given little discussion in supply chain texts. Chapter 5 provides a general overview of transportation and transport modes, transportation infrastructure, and transportation management strategies. The importance of transportation measures and metrics shows that you cannot manage what you don't measure. Chapter 6 examines warehousing management; warehousing strategies, measures, and metrics; and external dimensions of warehousing, including international and financial dimensions. Chapter 7 examines in specific detail the equipment and systems that manage inventory within warehouses and some of the latest technologies being used to handle, store, and manage inventory. Packaging is integral in materials management, and the discussion in Chapter 7 includes the environmental and sustainability aspects of packaging.

Chapter 8 identifies the importance of good sourcing and procurement in the supply chain and examines issues of human resources, global networks, and environmental/sustainability issues. Today, much of sourcing occurs electronically, that is, by e-sourcing. Supplier relationship management is a core element of sourcing. As in most chapters of this book, measures and metrics related to sourcing and procurement are discussed.

Because supply chain management includes many functions and processes of business, Chapter 9 examines the roles of manufacturing, marketing, and finance in supply chains. Important topics such as omnichannel distribution, data analytics, supply chain financing, product stock-outs, and reverse logistics are explored in this chapter.

Chapter 10 looks at managing different types of relationships in supply chains, especially the crucial relationships with customers and suppliers. Collaboration and coordination between supply chain partners are increasingly important in the global environment of the new millennium. The chapter describes the key elements of successful supply chain relationships.

Chapter 11 is an all-important chapter that presents various approaches to integrating the many processes and components of supply chains. Chapter 11 includes more in-depth discussion of the SCOR Model. Another approach used by many organizations is the APQC Process Classification Framework.

Chapters 12 and 13 explore global aspects of supply chain management, and the inclusion of this global material represents one of the strengths of this book. Many of the basics of international supply chain management are presented in Chapter 12, including some of the controllable and uncontrollable aspects of global supply chains. Chapter 13, based on the material in Chapter 12, discusses the best approaches to managing supply chains in global markets. Topics include the business environment, logistics infrastructure, and supply chain practices.

Chapter 14 examines network design, including an overview of designing a supply chain network, synthesizing a network, and optimizing a network once it's established. Chapter 15 follows up this discussion with an examination of important issues within supply chain networks, specifically, human resource, organizational, and strategy issues, including current topics such as cloud technology, social networks, and others.

Finally, while measures and metrics have been discussed throughout the book, Chapter 16 offers more in-depth supply chain performance measurement and metrics, including the use of key performance indicators.

In sum, we have attempted to provide readers of *Supply Chain Management* with a combination of the basics and the complex aspects of supply chain management. It is our expectation that when you have completed your reading and study of this material, you will understand the important roles that supply chain management performs in organizations and society.

Acknowledgments

Any work of this magnitude is seldom the exclusive work of the authors. Many individuals assisted in the completion of this project. First, I thank God that He gave me the talents and skills to do what I do well and to achieve a modicum of success. He has been my guide and encourager throughout my many years of teaching and research. Second, I want to thank my Ph.D. dissertation chair and long-time mentor, Bernard J. La Londe. Although now deceased, he continues to be an inspiration to me. His model of hard work, caring about others, and being an all-around nice guy has served me well throughout my career. Next, at the University of South Florida, thanks go to Dean Moez Limayem for creating an atmosphere conducive to research and scholarship in the Muma College of Business. For moral support and encouragement, colleagues in the Department of Marketing's supply chain program deserve recognition, including Donna Davis (Marketing Department chair), Robert Hooker, Jeannette Mena Mercado, Richard Plank, and Kerry Walsh. Other colleagues have also been influential in the writing and structure of this book, including Walter Zinn, Kate Vitasek, and the late Tom Speh. Of course, thanks also go to our many supply chain management students in whose classes we tested out many of the concepts incorporated in this book. Gratitude also goes to the many firms who support our teaching and research efforts, especially the Founder Members of our Center for Supply Chain Management & Sustainability in the Muma College of Business at USF—MercuryGate and Bristol-Myers Squibb—and the other firms who have supported our efforts financially and through internships and full-time positions for our graduates. Monica Wooden and John Tuttle have been especially supportive. Special thanks go to Wendy Jennings (office manager) and Megan Barrios (secretary) for making the department a nice place to work. Also, thanks go to various organizations that provided many of the materials used in the book, including the Council of Supply Chain Management Professionals (CSCMP) and Warehousing Education & Research Council (WERC). Of course, many people at McGraw-Hill have been instrumental in bringing this textbook to completion. Special acknowledgment goes to Noelle Bathurst, Tobi Philips, and Fran Simon for their continued assistance and support throughout the publication process.

Finally, I wish to acknowledge the support of my family, especially my wife of 46 years, Kathy, and my two children, Beth and Matt, who have grown up to be great adults. They have always been my main focus throughout my career, and I am thankful for their continuing love, encouragement, and support.

James R. Stock

As Jim has so eloquently noted, to God goes the glory, as we are thankful for the talents He has provided us. We hope that we use them wisely in all that we do, both professionally and personally. To that end, I want to thank the many students who have encouraged me and supported my career. It is a rare privilege to be at the starting point as students consider and begin their professional careers. It is rewarding to hear of your successes and how you persevered in times of trial. It is amazing to see you grow, to meet your spouse, and be introduced to your children. I would like to thank Kate Vitasek, Joe Tillman, and Walter Zinn for their support and encouragement during our many endeavors and especially help with this book. Mary Holcomb, Donnie Williams, Rod Thomas, Stephanie Thomas, Sara Lia-Troth, Pete Moore, and Jerry Ledlow have all been understanding when deadlines have been revised. Mitch MacDonald (*DC Velocity*) and Mike Levans (*Logistics Management*) as well as Michael Mikitka (WERC) have provided me opportunities to serve the profession, for which I'm thankful. Finally, thanks to the wonderful people at Georgia College who continually model professionalism under pressure: Lynn Hanson, Rachel Noles, Renee Mosley, and Paula Jefferson.

I would like to thank Susan, my wife, for over 37 years of support and encouragement. She has made much possible. And special thanks to our children, Ben, Sarah, and Kate, and to Kate's husband Corey. Thank you for your understanding and support; we are proud of you!

Karl B. Manrodt

We would also like to thank the following instructors for their thoughtful reviews of the text throughout the development process:

- **Suryanarayanan Gurumurthi,** *Hong Kong University of Science & Technology*
- **Marcia McLure Hardy,** *Northwestern State University of Louisiana*
- **Nathan A. Heller,** *Tarleton State University*
- **Kazimierz Kleindienst,** *California State University Fullerton*
- **David L. Levy,** *Bellevue University*
- **Kathryn Marley,** *Duquesne University*
- **Seong-Hyun Nam,** *University of North Dakota*
- **Abirami Radhakrishnan,** *Morgan State University*
- **Dr. Jason M. Riley,** *Sam Houston State University*
- **Frank Reeder Scheer,** *University of Maryland University College*
- **Robert G. Stoll,** *Ashland University*
- **Richard C. Yokeley,** *Forsyth Technical Community College*
- **George A. Zsidisin,** *Virginia Commonwealth University*

Supplements

McGraw-Hill Connect® Learn Without Limits!

Connect is a teaching and learning platform that is proven to deliver better results for students and instructors. Connect empowers students by continually adapting to deliver precisely what they need, when they need it, and how they need it, so your class time is more engaging and effective.

Connect includes multiple-choice questions for each chapter to be used as practice or homework for students, SmartBook®, instructor resources, and student resources. For access, visit **connect.mheducation.com** or contact your McGraw-Hill sales representative.

Instructor Library

A wealth of information is available online through McGraw-Hill's Connect. In the Connect Instructor Library, you will have access to supplementary materials specifically created for this text, such as solutions files, sample tests, and data sets for cases.

Students have access to course materials and study tools directly within their Connect course.

SmartBook®

Proven to help students improve grades and study more efficiently, SmartBook contains the same content within the print book, but actively tailors that content to the needs of the individual. SmartBook's adaptive technology provides precise, personalized instruction on what the student should do next, guiding the student to master and remember key concepts, targeting gaps in knowledge and offering customized feedback, and driving the student toward comprehension and retention of the subject matter. Available on desktops and tablets, SmartBook puts learning at the student's fingertips—anywhere, anytime.

Assurance of Learning

Many educational institutions today are focused on the notion of assurance of learning, an important element of some accreditation standards. *Supply Chain Management* is designed specifically to support your assurance of learning initiatives with a simple, yet powerful, solution.

Each test bank and end-of-chapter question for *Supply Chain Management* maps to a specific chapter learning goal listed in the text. You can use the test bank software to easily query for learning goals that directly relate to the learning objectives for your course. You then can use the reporting features of the software to aggregate student results in similar fashion, making the collection and presentation of assurance of learning data simple and easy.

McGraw-Hill Customer Care Contact Information

At McGraw-Hill, we understand that getting the most from new technology can be challenging. That's why our services don't stop after you purchase our products. You can e-mail our Product Specialists 24 hours a day to get product training online. Or you can search our knowledge bank of Frequently Asked Questions on our support website.

For Customer Support, call **800-331-5094** or visit www.mhhe.com/support. One of our Technical Support Analysts will be able to assist you in a timely fashion.

Mc Graw Hill Education **connect**®

Students—study more efficiently, retain more and achieve better outcomes. Instructors—focus on what you love—teaching.

SUCCESSFUL SEMESTERS INCLUDE CONNECT

FOR INSTRUCTORS

You're in the driver's seat.

Want to build your own course? No problem. Prefer to use our turnkey, prebuilt course? Easy. Want to make changes throughout the semester? Sure. And you'll save time with Connect's auto-grading too.

65%

Less Time Grading

They'll thank you for it.

Adaptive study resources like SmartBook® help your students be better prepared in less time. You can transform your class time from dull definitions to dynamic debates. Hear from your peers about the benefits of Connect at **www.mheducation.com/highered/connect**

Make it simple, make it affordable.

Connect makes it easy with seamless integration using any of the major Learning Management Systems—Blackboard®, Canvas, and D2L, among others—to let you organize your course in one convenient location. Give your students access to digital materials at a discount with our inclusive access program. Ask your McGraw-Hill representative for more information.

©Hill Street Studios/Tobin Rogers/Blend Images LLC

Solutions for your challenges.

A product isn't a solution. Real solutions are affordable, reliable, and come with training and ongoing support when you need it and how you want it. Our Customer Experience Group can also help you troubleshoot tech problems—although Connect's 99% uptime means you might not need to call them. See for yourself at **status.mheducation.com**

FOR STUDENTS

©Shutterstock/wavebreakmedia

Effective, efficient studying.

Connect helps you be more productive with your study time and get better grades using tools like SmartBook, which highlights key concepts and creates a personalized study plan. Connect sets you up for success, so you walk into class with confidence and walk out with better grades.

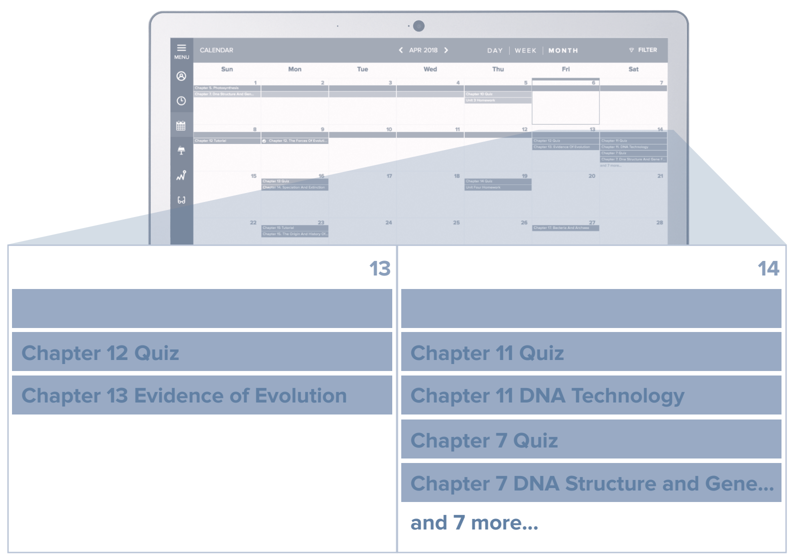
> "I really liked this app—it made it easy to study when you don't have your text-book in front of you."
>
> - Jordan Cunningham,
> Eastern Washington University

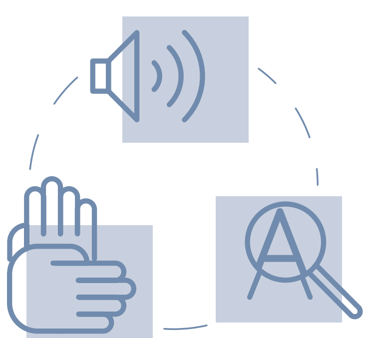
Study anytime, anywhere.

Download the free ReadAnywhere app and access your online eBook when it's convenient, even if you're offline. And since the app automatically syncs with your eBook in Connect, all of your notes are available every time you open it. Find out more at **www.mheducation.com/readanywhere**

No surprises.

The Connect Calendar and Reports tools keep you on track with the work you need to get done and your assignment scores. Life gets busy; Connect tools help you keep learning through it all.





Learning for everyone.

McGraw-Hill works directly with Accessibility Services Departments and faculty to meet the learning needs of all students. Please contact your Accessibility Services office and ask them to email accessibility@mheducation.com, or visit **www.mheducation.com/about/accessibility.html** for more information.

Brief Contents

Preface **vii**

1 Supply Chain Management: Operations and Integration 1
2 Customer Service and Satisfaction 34
3 The Role of Information in Supply Chains 66
4 Sales Forecasting and Inventory Management 92
5 Transportation: Overview, Infrastructure, Measures, and Management 121
6 Warehouse Management 160
7 Materials Management and Handling in the Supply Chain 198
8 Sourcing and Procurement 232
9 The Role of Manufacturing, Marketing, and Finance in Supply Chains 255
10 Managing Relationships with Customers and Suppliers 285
11 Supply Chain Process Integration 314
12 Global Supply Chain Management 343
13 Managing Supply Chains in Global Markets 378
14 Strategic Supply Chain Network Design 398
15 Collaboration, Cooperation, and Integration in the Supply Chain: Talent, Organizational, Technology, and Strategy Issues 421
16 Supply Chain Performance Measurement and Metrics 446

Cases **465**

Index **513**

Table of Contents

About the Authors vi

Preface vii

Chapter 1
Supply Chain Management: Operations and Integration 1

Introduction 1
- **Exhibit:** *Listen for the Clatter of 105,000 Semi-tractor Trailers on Your Rooftop This Christmas Eve* 3

Supply Chain Management—An Overview 4
- *Definition of Supply Chain Management (SCM)* 4
- *Perspectives on SCM* 5
- *Historical Development of SCM* 5
- **Exhibit:** *The First Global Supply Chain* 10

A Model of Supply Chain Management 10
- *Elements of SCM* 10
- *Role of Logistics in SCM* 11
- *Approaches to Modeling Supply Chain Management* 12

Societal Issues Impacting Supply Chains 13
- *Supply Chain Management and Gross Domestic Product (GDP)* 13
- *Globalization* 14
- *Sustainability in the Supply Chain* 16
- **Exhibit:** *The Cornerstones of IKEA's Sustainability Strategy* 17
- *Infrastructure* 18
- *Regulatory Issues* 19
- *Security and Risk* 19
- *Supply Chain Disruptions* 21
- *Disaster Preparedness and Relief* 23

Business-Related Issues Impacting Supply Chains 24
- *Customer Service and Satisfaction* 24
- **Exhibit:** *Even Formula One Race Cars Utilize Supply Chain Management* 25
- *Human Resources* 26
- **Exhibit:** *A New Human Resources Issue: The "Millennial" Generation* 27
- *Organizational Issues* 27
- *Technology* 28
- *Financial Aspects and Metrics* 30

Summary 31

Chapter 2
Customer Service and Satisfaction 34

Introduction 34
- **Exhibit:** *What Does Customer Satisfaction Look Like?* 35

Fundamentals of Customer Service and Satisfaction 36
- *Definitions of Customer Service and Customer Satisfaction* 36
- *Customer Satisfaction and the Marketing Concept* 37
- **Exhibit:** *Poor Service Can Result in Lost Customers* 38
- **Exhibit:** *The Dilemma of Harry Potter: How Do You Get 12 Million Books to Appear on Bookstore Shelves Worldwide at the Same Time?* 39
- *Elements of Customer Service Based on the Concept of Marketing Exchanges: Before, During, and After the Sale* 40
- *The Importance of Consistency* 42
- *Customer Service and Satisfaction and the SCOR Model of Supply Chain Management* 43

Measures and Metrics 45
- *Key Performance Indicators (KPIs)* 45
- *Strategic Profit Model* 47
- *Balanced Scorecard* 49

Developing Customer Satisfaction Strategies 50
- *Utilizing Marketing Research in Developing Customer Satisfaction Strategies and Programs* 52
- **Exhibit:** *Executives Talk about Customer Expectations* 52
- *Product Stock-outs and Customer Service Implications* 53
- *Cost-Service Trade-offs* 56
- *Using a Customer-Product Action Matrix in Developing Service Strategies* 57
- *Gap Analysis in Customer Satisfaction* 58
- *Supply Chain Customer Satisfaction Strategies—Some Examples* 59
- *Customer Relationship Management (CRM)* 62

Summary 64

Chapter 3
The Role of Information in Supply Chains 66

Introduction 66

The Uses of Information in Supply Chains 67
- *Maintain Asset Visibility* 67
- *Manage Daily Operations* 67
- *Planning and Strategy* 68

Applying Information Technology to Supply Chain Management 70

Data Capture 71

Data Transmission 74

Transaction Support 77

Planning Support 80

Supply Chain Collaboration Support 84

Order Management 85

Steps in the Order Management Process 85

The Order Management Process 87

The Future Role of Information 88

Blockchain 88

Summary 90

Chapter 4
Sales Forecasting and Inventory Management 92

Introduction 92

Sales Forecasting 93

Forecasting Methods 93

Qualitative Forecasting Methods 93

Quantitative Forecasting Methods 94

Integrating Qualitative and Quantitative Forecasts: S&OP and CPFR 100

Exhibit: *How Sony Used Consensus Forecasting to Improve Forecast Accuracy and Collaboration with Retail Partners* 102

Measuring Forecast Error 103

Mean Absolute Deviation (MAD) 103

Mean Absolute Percent Error (MAPE) 103

Mean Squared Error (MSE) 104

Inventory Management 105

Reasons to Hold Inventory 105

How Much and When to Order 106

Sizing Inventory and the Impact of Uncertainty 109

Exhibit: *How John Deere Reduced Supply Chain Inventory* 113

Safety Stock Management Extensions 113

Methods of Inventory Control 116

Symptoms of Poor Inventory Management 117

Summary 118

Appendix

Normal Distribution Table 119

Chapter 5
Transportation: Overview, Infrastructure, Measures, and Management 121

Introduction 121

Role of Transportation in the Supply Chain 122

Historical Development of U.S. Transportation Regulation and Deregulation 123

Transportation Regulation 123

Impacts of Deregulation 126

Transportation Modes 126

Motor 127

Rail 129

Air 130

Water 131

Pipeline 132

Intermodal Transportation 133

Ancillary Modes, Including Drones 135

Exhibit: *It's Not Always Smooth Sailing for Cargo Ships* 137

Transportation Infrastructure 138

Domestic and International Dimensions 139

Constraints and Limitations 139

Measures and Metrics 140

Carrier and Shipper Metrics 141

Key Performance Indicators (KPIs) 142

Transportation Management Strategies 142

Mode and Carrier Selection 143

Core Carrier Concept 146

Outsourcing: Third Parties (3PLs), Partnerships, and Strategic Alliances 147

Environment, Energy, and Sustainability 148

Last-Mile Delivery 149

Exhibit: *Ways to Reduce Fuel Consumption in Motor Transportation* 150

Exhibit: *Companies Are Recognized by U.S. Environmental Protection Agency's (EPA) SmartWay® Transport Partnership for 2017 Excellence Awards* 151

International Transportation 151

Summary 152

Appendixes

Appendix A: Legally Defined Forms of Transportation 154

Appendix B: Basic Transportation Management Concepts 155

Chapter 6
Warehouse Management 160

Introduction 160

Exhibit: *Where Was America's Alcohol Warehoused during Prohibition?* 161

Nature and Importance of Warehousing in the Supply Chain 161

Types of Warehouses (Public, Private, Contract, Cross-Docking) 164

Warehousing Management Strategies 171

Warehouse Management Systems (WMSs) 171
Using Warehousing to Support JIT Operations 171
Technology: *Five Benefits of a Warehouse Management System* 172
Outsourcing: Third Parties, Partnerships, and Strategic Alliances 173
Environment, Energy, and Sustainability 173
Exhibit: *Nike's Sustainable Distribution Center* 174
Warehouse Productivity 175
Exhibit: *Radwell International's Automated Storage System Handles 22 Million SKUs* 176
Facility Development 177
Size and Number of Warehouses 177
Exhibit: *Amazon Rival JD.com Built the Equivalent of Monaco in Warehouse Space in Three Months* 177
Location Analysis 180
Warehouse Layout and Design 185
Measures and Metrics 186
Warehouse Efficiency and Effectiveness Metrics 186
Exhibit: *A Food Manufacturer Uses SCOR to Improve Its Supply Chain Performance* 187
Key Performance Indicators (KPIs) 188
International Dimensions of Warehousing 189
Financial Dimensions of Warehousing 191
Summary 192

Appendix
Case Study—Public versus Private Warehousing 194

Chapter 7
Materials Management and Handling in the Supply Chain 198

Introduction 198
Materials Handling Equipment 203
Manual or Nonautomated Systems 203
Automated Systems 208
Global: *Greek Yogurt Producer Utilizes AS/RS and WMS to Achieve Efficiency and Growth* 212
Warehouse Information Systems and Computer Technology 215
Warehouse Management Systems (WMSs) 216
Exhibit: *Warehouse Management System (WMS) at GUESS?* 217
Real-Time Location Systems 218
Technology: *Dairy Queen Offers RFID in Addition to Ice Cream, Hamburgers, and Hot Dogs* 219
Order Picking and Selection 220
Packaging 223
Functions of Packaging 223
Pallets 224
Technology: *Who Invented the Shipping Pallet?* 225
Trade-offs in Packaging 226
Sustainable Packaging 227
Exhibit: *16 Myths Regarding Packaging and the Environment* 228
Summary 230

Chapter 8
Sourcing and Procurement 232

Introduction 232
Spend Management 233
Exhibit: *Implementing a Lean Outsourcing Program* 235
Human Resource Issues in Sourcing and Procurement 236
Global Sourcing Issues (Risk, Regulations, Customer Service) 238
Exhibit: *The Logistics of the 2018 Pyeongchang Winter Olympics* 239
Regulations 240
Customer Service 240
Environmental and Sustainability Issues 240
Exhibit: *Green Procurement in Hong Kong* 242
Supplier Relationship Management 242
Exhibit: *Supplier Relations in the Automobile Industry—Locating Suppliers Close to Home* 243
Purchasing and Procurement 243
Exhibit: *Digital Technologies in Purchasing and Procurement* 244
Exhibit: *Six Common Purchasing Mistakes* 245
Supplier/Vendor Selection 245
Contract Negotiation and Management 246
Strategic Partnerships and Alliances 248
E-Sourcing 249
Evaluating Suppliers with Metrics and Key Performance Indicators (KPIs) 250
Summary 252

Chapter 9
The Role of Manufacturing, Marketing, and Finance in Supply Chains 255

Introduction 255
The Role of Manufacturing in Supply Chains 256
Key Manufacturing Issues 256
Exhibit: *ERP in the Craft Beer Industry* 266
Exhibit: *Selecting and Implementing an ERP Solution* 267
The Impact of Manufacturing in Supply Chains 267
Exhibit: *How Rapid Manufacturing Using 3-D Technology Could Transform Supply Chains* 268

The Role of Manufacturing within Supply Chain Process Management 269
The Role of Marketing in Supply Chains 270
Marketing and Supply Chain Interfaces 270
Omnichannel Distribution 271
Data Analytics 273
Consumer Response to Product Stock-outs 274
Product Returns 276
The Role of Finance in Supply Chains 279
Supply Chain Financing Options 279
Financial Aspects of Supply Chain Activities 281
Summary 282

Chapter 10
Managing Relationships with Customers and Suppliers 285

Introduction 285
The 3 Cs of Business Relationships 287
Types of Business Relationships 288
Sourcing Implementation Strategies 288
Conventional Approaches 288
Case Study – *Simple Transaction Based* 290
Case Study – *Approved Provider* 291
Outcome-Based 291
Case Study – *Preferred Provider* 292
Case Study – *Performance Based, U.S. Navy* 294
Case Study – *Vested Outsourcing* 295
Investment-Based Business Model 295
Case Study – *Shared Services–Bell Canada/PSI* 297
Case Study – *Equity Partner/Joint Venture–Samsung and Sony* 298
Reasons to Use More Strategic Approaches 299
Definition of Partnership 299
Partnership Success Factors 299
Managing Innovation 303
Exit Management 304
Contracting Success Factors 304
Exhibit: *Top 10 Terms Used in Negotiations* 305
Elements of a Successful Business Agreement 305
Perverse Incentives of Business Agreement 308
Conflicts in Partnerships 311
Resolving Conflicts 311
Exhibit: *Relationship Issues–Impact and Resolution* 312
Summary 312

Chapter 11
Supply Chain Process Integration 314

Introduction 314
Methods to Define and Integrate Processes 316
Process Mapping 317
Exhibit: *Process Mapping in Action* 318
Business Process Frameworks 319
Exhibit: *UPS Develops Its Business Process Framework* 319
What Makes an Effective Framework? 320
Supply Chain Operations Reference (SCOR) Model 321
Components of the SCOR Model 323
Exhibit: *SCOR Model in Action* 331
APQC's Process Classification Framework 332
Components of the PCF 333
Operating Processes 334
Management and Support Services Processes 335
*The Open Standards Benchmarking Collaborative*SM 336
Exhibit: *APQC's Process Classification Framework in Action* 337
The Future of Supply Chain Frameworks 337
What's Missing from the Frameworks 338
Common Uses of Frameworks 338
Importance of Collaboration 340
Summary 342

Chapter 12
Global Supply Chain Management 343

Introduction 343
Development of Global Supply Chains 343
International Market Entry Strategies 347
Exporting 347
Exhibit: *Pizzas for Patriots* 349
Licensing 349
Joint Ventures 350
Ownership 350
Exhibit: *Maersk and IBM Enter Joint Venture on Blockchain* 351
Global: *Walmart: A Global Company* 351
Importing and Global Sourcing 352
Documentation 354
Terms of Trade 355
Free Trade Zones 356
Planning for Global Supply Chain Involvement 357
Global Market Opportunities 358
The Global Marketplace–Uncontrollable Elements 364
Economic 366
Competition 368
Technology 369
Geography 370
Social and Cultural 372
Political and Legal 373
Summary 376

Chapter 13
Managing Supply Chains in Global Markets 378

Introduction 378
Global Supply Chain Assessment Model 379
General Background 380
Business Environment 382
Inflation and Interest Rates 382
Interest Rate and Labor Cost 383
Government Regulation 384
Market Competition 385
The Legal Environment 386
Taxation 386
The Labor Force 388
The Logistics Infrastructure 390
Transportation 390
Exhibit: *Low Tech and High Efficiency: How the Dabbawalas Deliver Meals in India* 391
Exhibit: *Spoiled Food: Why Proper Warehousing Matters* 393
Communication and Information Technology 393
Third-Party Services 394
Supply Chain Practices and Issues 395
Summary 396

Chapter 14
Strategic Supply Chain Network Design 398

Introduction 398
What Is Supply Chain Network Design? 399
Exhibit: *Zara Designs Its Supply Chain to Deliver New Fashions in Two Weeks* 400
Designing a Supply Chain Network 401
Exhibit: *Participants in the Supply Chain Mapping Process* 403
Supply Chain Strategy 404
Exhibit: *Supply Chain Network Tools Classification* 404
Use of Technology in Network Design 405
Exhibit: *Network Management Megatrends* 405
Technology: *Electrolux Manages Outsourced Supply Chain through Planning Capabilities* 406
Lean Management Principles 406
Exhibit: *Creating a Business Case for the Implementation of ERP Systems* 408
Exhibit: *5 Mistakes Firms Make When Implementing ERP* 409
Six Sigma 409
Organizational Structures 411
Use of 3PLs 412
Reverse Logistics 412
Omnichannel Networks 413
Network Synthesis 415
Optimizing the Supply Chain Network 416
Exhibit: *Symptoms of Possible Supply Chain Network Design Problems* 417
Summary 418

Chapter 15
Collaboration, Cooperation, and Integration in the Supply Chain: Talent, Organizational, Technology, and Strategy Issues 421

Introduction 422
Importance of an Efficient and Effective Supply Chain Organization 422
Talent Issues in Supply Chain Management 423
Exhibit: *Work and the Social Enterprise* 424
Hiring and Rewarding Personnel 424
Exhibit: *Salary Survey of Logistics Executives* 426
Exhibit: *Employee Skills Demanded by Employers for Supply Chain Management Jobs* 427
Onboarding 428
Exhibit: *Reasons That Performance Objectives Are Not Met by Employees* 428
Supply Chain Structures 429
Historical Development of Business Structures 430
Exhibit: *Reasons Why You Might Need a 4PL* 431
Keiretsu Structures 433
Decision-Making Strategies in Organizing for SCM 434
Mission Statements 434
Factors Impacting the Effectiveness of a Supply Chain Organization 435
Collaboration and Integration through Technology 436
Information Systems 436
Cloud Technology 437
Technology: *Cloud Computing* 439
Social Networks 439
Measures and Metrics 440
Summary 443

Chapter 16
Supply Chain Performance Measurement and Metrics 446

Introduction 446
What to Measure? 447
Function and Process Metrics 450
Exhibit: *Supply Chain Management Cost and Performance Metrics* 451

The Perfect Order 452
Cost Metrics 452
Exhibit: *Santa Claus and the Perfect Order* 453
Service Metrics 454
Combination of Cost and Service Metrics 455
Benchmarking 456
Exhibit: *Selected Examples of Benchmark Metrics* 457
Key Performance Indicators 458
Scorecards 461
Exhibit: *Benefits of Implementing a Balanced Scorecard Approach* 462
Summary 463

Cases 465

Index 513

Chapter 3

The Role of Information in Supply Chains

Objectives of This Chapter

LO 3-1 To describe the uses of information in supply chains.

LO 3-2 To describe tools used to capture and transmit data in supply chains.

LO 3-3 To describe tools used to support transactions, planning, and collaboration in supply chains.

LO 3-4 To describe the order management process.

Introduction

The digital world has made time and space obsolete. Consumers can shop online, at anytime, virtually anywhere in the world, and, in some cases, get what they ordered delivered to them within a few short hours. For this reason, information is the lifeline of a supply chain.

Every time a product is moved, stored, or acquired, the action must be recorded. The same is true of all assets used in supply chain operations, such as trucks, trains, pallets, and other equipment. This is needed not only for daily operations, but also for planning purposes. In daily operations, managers use information to decide how to fulfill orders, allocate assets, forecast sales, and plan warehouse operations. For example, a warehouse manager planning operations for the following day needs information about the orders to be delivered, inventory levels, readiness of warehouse equipment, labor availability, as well as current and forecasted customer orders. When planning, managers need information to decide how much inventory to keep in different locations, the level of service to offer various customers, and whether to use private or third-party logistics and transportation providers. Information is needed in every aspect of supply chain operations and planning. Accordingly, in this chapter we will first describe the different uses of information in supply chains and then look at different issues related to capturing, transmitting, and utilizing that information. We will describe the order management process, which is a key process in the operation of supply chains. Lastly, we'll look to see what role information will play in supply chains in the future.

The Uses of Information in Supply Chains

Supply chain managers need information for three basic purposes. The first is to know where the assets under the manager's control are. The second is to use information to manage daily operations. And the third is to make planning and strategic decisions regarding the management of the supply chain.

Maintain Asset Visibility

A supply chain manager controls assets belonging to firms in the supply chain, such as trucks, inventory, pallets, containers, and lift trucks. The manager needs to know where those assets are in order to maintain control and to make the best possible use of them. For example, vehicle routing software is used to optimize the utilization of trucks while maintaining a predetermined level of service to customers. In many cases, trucks may be rerouted to accommodate changes in the delivery schedule, weather conditions, accidents, or highway maintenance. Rerouting is only possible if the firm knows in real time the location of each truck. To this end, there are scores of firms that offer GPS tracking systems of trucks.

Asset visibility is also important to support safety and security. The same wireless technology available to track trucks is used to enhance the protection of drivers against possible crime. Another safety and security issue is visibility of inventory against theft or to counter product tampering. One of the most infamous cases involved Tylenol, a pain reliever, where bottles were criminally tampered with in 1982. The manufacturer was able to quickly trace the origin of the problem because all of the tampered bottles were traced to a single store in Chicago. This was only possible because the company had visibility of inventory assets in the supply chain.[1] Product tampering and contamination remains a recurring problem. For example, when an insecticide harmful to humans contaminated eggs sold in 15 EU countries, German buyers used an app to translate the eggs' serial number and determine where the eggs came from.[2]

Manage Daily Operations

Information is central to the daily operation of a supply chain. Walter Wriston, the former CEO of Citicorp, once wrote, "Information about money has become almost as important as money itself."[3] It could be said that in today's digital economy, information about products has become almost as important as the products themselves. Information sharing is critical both within individual firms and among firms in the supply chain. Within individual firms, information is needed to coordinate activities within and among functions. Firm functions refer to traditional organizational specializations such as marketing, logistics, manufacturing, or finance. For example, to decide the level of inventory to keep, managers must know the level of service promised to customers. Thus, information must be exchanged between the customer service and inventory management. Another example of information sharing among functions is when a customer's order is returned. Warehouse and inventory management need the information to put the product back in inventory, accounting needs to credit the customer's account, and customer service is tasked with

[1] Paul Shrivastava, Ian Mitroff, Danny Miller, and Anil Migliani, "Understanding Industrial Crises," *Journal of Management Studies*, Vol. 25, No. 4 (1988), pp. 285–303.
[2] Daniel Boffey and Kate Connolly, "Egg Contamination Scandal Widens as 15 EU States, Switzerland and Hong Kong Affected," *The Guardian*, August 11, 2017, https://www.theguardian.com/world/2017/aug/11/tainted-eggs-found-in-hong-kong-switzerland-and-15-eu-countries.
[3] Walter Wriston, *Bits, Bytes and Balance Sheets: The New Economic Rules of Engagement in a Wireless World* (Stanford, CA: Hoover Institution Press, 2007).

TABLE 3.1
Sample Information Typically Exchanged Among Functions of the Firm

Information Flow	Accounting/ Finance	Logistics	Manufacturing	Marketing/Sales	Procurement
Accounting/ Finance		Shipment/ Delivery Notifications	Production Forecasts	Sales Forecasts	Spend
Logistics	Customer Credit Releases		Production Schedules	Customer Service Requirements	Inbound Transportation Needs
Manufacturing	Capital Investment Approvals	Inventory Status		New Product Developments	Raw Materials Delivery Schedules
Marketing/Sales	Customer Credit Status	On-Time Delivery Reports	Available to Promise Information		Raw Materials Shortage Estimates
Procurement	Purchasing Budget	Emergency Resupply Requests	Raw Materials Need Estimates	Sales Forecast	

finding out the reasons for the return. Table 3.1 presents a sample of information typically exchanged among functions of the firm.

Exchanging information among firms in the supply chain is equally important, although it has been shown visibility decreases as one moves farther upstream to suppliers and suppliers' suppliers.[4] These information inefficiencies increase risk—and costs—and can be a catalyst for investigation and change. To be effective, managers need input from other supply chain firms to make operational decisions affecting the supply chain and their individual firm. For example, a customer's sales forecast can be very helpful in determining a firm's production schedule because the size and timing of the customer's demand becomes less uncertain. As a result, the production schedule more closely matches the demand.

The exchange of information in the supply chain must include everyone in the supply chain—from third-party service providers to brokers to transportation providers. For instance, a public warehouse needs sales information from its customers in order to plan warehouse operations. The public warehouse also provides inventory availability information to its customers and, upon request, to its customers' customers. Figure 3.1 provides a sample of information typically exchanged among firms in the supply chain.

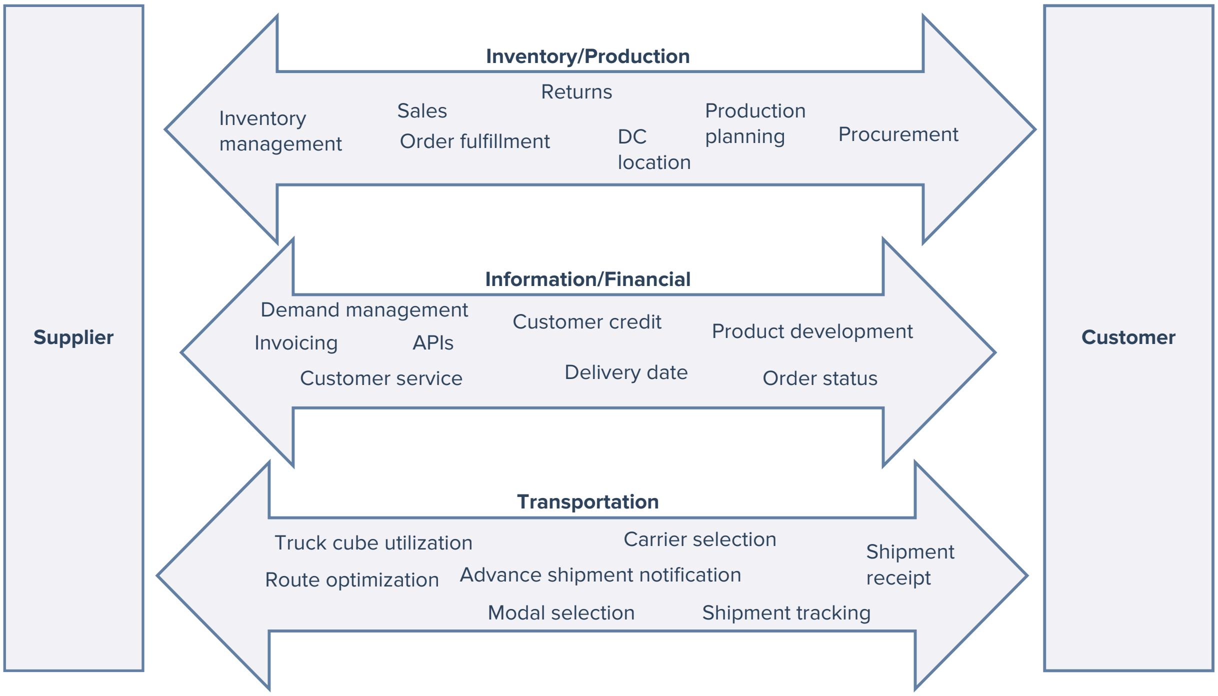
Planning and Strategy

The management of supply chains goes beyond daily operations. Managers must also use information to plan future operations and make strategic decisions.

Supply chain planning refers to decision making related to future operations in the supply chain. The objective is to meet service and quality requirements with the lowest possible use of resources. For example, in order to ship products to customers, supply chain managers must anticipate the number of trailers required before actually needing them. This is

[4] Mary Collins Holcomb, Karl B. Manrodt, and Tommy Barnes, "26th Annual Trends in Logistics Study," Council of Supply Chain Management Professionals Annual Conference, Atlanta, GA, September 25, 2017. Also see David J. Closs, Thomas J. Goldsby, and Steven J. Clinton, "Information Technology Influences on World Class Logistics Capability," *International Journal of Physical Distribution*, Vol. 27, No. 1 (1997).

FIGURE 3.1
Sample Information Exchanged by Firms in Supply Chains



because time is needed to procure a sufficient number of trailers. The earlier the information is available, the more time can be allocated to finding the right trailers at a low cost.

Some of the key supply chain planning areas are listed below. In subsequent sections in this chapter, we will describe many of the tools available in supply chain planning.

- Demand planning
- Transportation
- Production
- Warehousing
- Inventory
- Collaborative planning

Supply chain strategy must fit within the overall corporate strategy. Corporate strategy refers to the use of resources to gain a competitive advantage. As proposed by Porter, there are three basic strategic choices: cost leadership, differentiation, and focus.[5] The first refers to using corporate resources to become a low-cost leader. In a differentiation strategy, firms seek to offer unique products and services to customers. Lastly, in a focus strategy, resources are concentrated on a narrow segment of the market.

Corporate strategy determines whether the supply chain organization will have a strategic or a supporting role. In the former case, the aim is to either provide differentiated services to customers or attain cost leadership.[6] The supply chain organization can play a key role in providing differentiated services to customers. These services may include just-in-time delivery and other forms of customer service.

[5] Michael E. Porter, *Competitive Advantage* (New York: The Free Press, 1985), pp. 11–15.
[6] Donald J. Bowersox and Patricia J. Daugherty, "Logistics Paradigms: The Impact of Information Technology," *Journal of Business Logistics*, Vol. 16, No. 1 (1995), pp. 65–80.

The supply chain organization may also support a low-cost leadership strategy. Walmart provides a good example. Through cost management, its supply chain organization has a strategic role in enabling the firm's low-price strategy.

Alternatively, the supply chain organization may have a supporting role when the focus of corporate strategy is to differentiate product on the basis of product design or branding, for instance. In this case, the supply chain organization provides cost and service management support.

Supply chain strategy is developed once the role of the supply chain organization in corporate strategy is decided. This involves three main issues. One is network design, where a decision is made regarding the number and size of nodes in the supply chain, particularly plant and warehouse sizes and locations. Network design decisions require a substantial amount of cost and customer service information. Some organizations, such as Limited Brands, an apparel, cosmetics, and housewares retailer, have designed their network to have two warehousing locations to support a national distribution effort. On the other hand, Cardinal Health, a distributor of pharmaceuticals, has more than 60 warehouses supporting its national distribution.

The second issue refers to the level of outsourcing in the supply chain. Should the firm own its supply chain assets, or should it outsource them to third-party service providers? What is the type of relationship, or strategic sourcing business model, that firms in the supply chain should maintain with each other?

A third issue in supply chain strategy is to decide which channels to use to bring products to market. A manufacturer or importer may select a direct-to-consumer channel, a wholesale-based channel, or a direct-to-retail channel. Often, combinations of channels are chosen. Today, many customers can be in a physical store while getting additional information from their mobile devices. Uniting all of these inputs and experiences into a coherent whole is the focus of the omnichannel, which will be discussed later.

The digital economy has made answering these three questions much more challenging. Recent research has shown that many firms are utilizing a "be all things to all people" approach to strategy.[7] Porter would refer to this strategy as being "stuck in the middle." This strategy places greater pressure on the supply chain, as it must be flexible, adaptive, effective, and efficient. For instance, think of all the ways Amazon can service its customers. In larger metropolitan markets, Amazon Prime Now can deliver products within two hours. Amazon Prime will deliver in two days, and normal shipments take longer. Each method serves different customer needs, and all at different price points. Each method is enabled by technology, making this approach more viable today than in years past.

These three issues will be examined in greater detail elsewhere in this book. For now, it is important to keep in mind that supply chain planning and strategy decisions require a great deal of information as input. In the next section we examine the tools available to obtain and manage such information.

Applying Information Technology to Supply Chain Management

We conclude from the previous section that the level of detail and volume of information needed to manage supply chains are quite significant. The information must be first captured and transmitted as data and then processed in support of supply chain transactions, planning, and collaboration. In this section of the chapter we will review the main tools available to manage the flow of information in supply chains.

[7] Joe Tillman, Karl B. Manrodt, and Donnie Williams, "DC Measures 2017," *WERCWatch*, Spring 2017, Warehouse Education Research Council, Chicago, IL.

Data Capture

Data capture is the process by which data enters an information system. This may be accomplished by manual or automated processes. In the former, a person types the data into a computer. Alternatively, in automated processes, data is captured electronically. In this case, data is captured with greater speed and accuracy. Automation is the only way to quickly capture large volumes of data. We describe below the two main forms of automated data capture: bar codes and radio frequency identification (RFID).

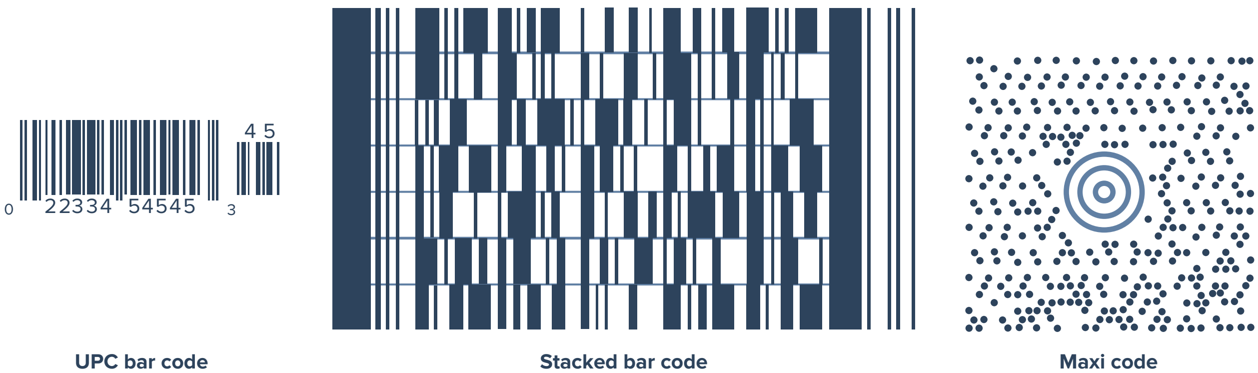
A *bar code* is simply a machine-readable alphanumeric code. It is made up of dark bars and spaces that represent ones and zeros. The ones and zeros are combined to represent numbers and letters. A code is needed to specify that each combination of ones and zeros corresponds to a single number or letter. One of these codes is the Universal Product Code (UPC) that is widely used in the packaged goods industry to identify products. Figure 3.2 shows a bar code and the number it represents using a UPC code.

Bar code technology is also available in two dimensions. While data in basic bar codes is only available in one dimension (horizontal), two-dimensional (2D) codes present data in a vertical dimension as well. Thus, 2D codes are able to either store more data than basic bar codes or enable faster scans. Two common types of 2D codes are Data Matrix and MaxiCode. Stacked bar codes hold more data than simple bar codes. MaxiCodes are designed to be read very quickly. They are used in the package delivery business where codes must be read quickly as each package passes by in a conveyor system. These two types are also displayed in Figure 3.2.

Applications of bar code technology are visible in everyday life. For instance, they are used by railroads to identify and track rail cars, by booksellers to identify titles, or by airlines, who use bar codes to track both boarding passes and passengers' luggage. However, bar codes are most widely used in consumer products.

Manufacturers and retailers of consumer products benefit from bar code adoption for several reasons. First, bar codes are a labor-saving technology. Consider, for example, a cashier at a supermarket who is able to quickly scan each item purchased by a customer. This is only possible because each item is identified with a bar code. In the past, cashiers would have had to read and then manually enter the price of each item purchased. Second, bar codes facilitate sales tracking, enabling both manufacturers and retailers to efficiently identify fast and slow movers. This data can then be used to improve store replenishment because items are shipped to locations where they are selling. The data can also be used to improve inventory control and serve as sales forecasting input.

FIGURE 3.2
Bar Codes and Two-Dimensional Codes



Source: http://www.data-net.com/education/barcodes.html.

Another well-known bar code application is package tracking. Major package carriers, such as the U.S. Postal Service, FedEx, DHL, and UPS use bar codes to track their packages. This is done to plan operations and to provide customer service. When a carrier is able to track a package from origin to destination, it is able to better allocate resources. For example, if a carrier knows exactly how many packages must be picked up and delivered in a particular city, it also knows how much labor and transportation assets will be needed at that location. This improves planning efficiency and the utilization of resources. Moreover, whenever there is an unforeseen problem, such as a major snow storm, it is easier to amend plans because the location of each package is known. Package tracking is also a service to customers, who are able to use package location information in their own planning.

UPS serves as an illustration of how bar codes are used to track packages.[8] Each package receives a unique tracking identification number, which is represented as a bar code on the package. Whenever a package is picked up, is delivered, or moves through a UPS facility, it is scanned. The information is then relayed via cellular technology to UPS's mainframe repository in Mahwah, New Jersey. Once in the system, the package tracking information can be accessed either internally or by customers via e-mail, the Internet, and even cellular phone.

Radio Frequency Identification (RFID) technology is an advancement with respect to bar codes. Data is stored in a chip. Like bar codes, RFID chips also store alphanumeric data. However, contrary to bar codes, RFID chips can transmit the stored data via a radio frequency. Therefore, RFID chips do not require "line-of-sight" to be read, as do bar codes. This means that RFID chips are more efficient because data from RFID chips can be collected from a wider area.

RFID chips are also able to uniquely identify each unit of product, unlike a bar code that identifies all products with the same characteristics (i.e., a stockkeeping unit or sku). For example, in a supermarket, all boxes of a particular size, package, and brand of cereal made on the same day or same batch carry the same bar code. On the other hand, RFID chips are able to uniquely identify each individual box of cereal.

There are active and passive RFID chips. They differ because active chips are equipped with an antenna that enables them to be read from a longer distance. Active chips are also considerably more expensive. Most RFID chips in use are passive. The relatively lower cost of passive RFID chips makes them ideal to identify low-cost items in an environment where the chip can be read from a distance. For example, in order to improve product tracking in its distribution centers, Walmart was one of the first to mandate its most important suppliers identify pallets and cases with passive RFID chips. This was followed by the U.S. Department of Defense, Macy's, Target, and Bloomingdale's, just to mention a few.[9] Active chips are used to identify items either of higher value or that need to be read from a longer distance. For example, the location of lift trucks in a warehouse or yard can be tracked with active RFID chips.

There are many potential applications of RFID technology in supply chains. By tracking inventory more efficiently, firms are able to improve inventory replenishment in supply chain facilities and reduce shrinkage, that is, inventory reduction due to loss, theft, breakage, or deterioration. For example, the specialty retailer American Apparel implemented an RFID solution that led to increased sales and sales floor space, less shrinkage, and a 9 percent reduction in inventory levels over a two-year period.[10] Libraries across the globe

[8] "UPS Parcel Delivery Tracking Application," *Mobileinfo.com*, June 2001, http://www.mobileinfo.com.
[9] Anna Turri, Ronn Smith, and Steven Kopp, "Privacy and RFID Technology: A Review of Regulatory Efforts," *Journal of Consumer Affairs*, Vol. 51, No. 2 (Summer 2017), pp. 329–354.
[10] Xterprise, "American Apparel," 2014, https://www.ramprfid.com/wp-content/uploads/2014/07/American-Apparel-Case-Study.pdf.

are implementing RFID solutions for item identification, tracking, and automating many of their processes.[11] Advanced E-Textiles is developing a washable microelectronic RFID that is woven into the fabric. These tags can track the life cycle of a garment, and more easily identify counterfeit luxury items.[12]

In a supply chain environment, firms may implement RFID at different levels. These may range from major assets such as containers or trailers, to smaller units such as pallets, cases, and even individual items. The decision depends on a number of factors, including the goals of the application, cost, and privacy. For instance, if a firm's RFID application goal is to improve warehouse operations and store replenishment, such as in the American Apparel example above, then item-level implementation would be unnecessary. Tracking cases or pallets is sufficient to achieve the goals of the application because stores are replenished in pallet and case quantities. On the other hand, there are instances where the goal of the application is to track individual items, such as ensuring the authenticity of prescription medication.

The level of RFID implementation is also a function of cost. In general, the smaller the unit receiving RFID tags, the greater the cost of the implementation. There are two reasons for that. First, the smaller the unit, the more tags are needed. Tagging every individual unit requires more tags than tagging pallets, for instance. Over time, as the cost of tags continues to decrease, this reason may become less of a factor in RFID decisions. Second, there is also a substantial cost to keep the related information in databases. If every individual item receives a separate identification number, then each individual item is maintained as a separate line in a database, which boosts the size of the required database. Fewer lines are certainly needed if all items in a pallet are identified with the same tag.

In addition, in the case of RFID implementation at the individual item level, there are social concerns with the issue of privacy. Like any wireless technology, these devices can be read remotely, making them inherently insecure. Consumer privacy groups fear that RFID technology enables firms and the government to track the shopping habits of citizens without their consent.[13] These concerns may limit the use of RFID technology in stores but have a negligible impact on the tagging of cases and pallets elsewhere in the supply chain.

At the same time, significant obstacles to RFID implementation remain. First, the investment in RFID readers, supporting IT systems, and the chips themselves can be substantial. Second, the implementation is more complex when firms have to cope with legacy systems. Legacy systems are preexisting hardware or software that, while still functional, does not work well together with newer hardware or software being implemented. Third, significant issues remain with the technology itself. For instance, tag interference occurs when the chip's radio signal is not read because it cannot pass through metal or densely packed items. Uncertainty around the standards used by RFID components still needs to be addressed. Finally, as noted above, privacy may pose an additional obstacle to RFID implementation at the individual item level.[14]

[11] Yogesh K. Dwivedi, Kawaljeet K. Kapoor, Michael D. Williams, and Janet Williams, "RFID Systems in Libraries: An Empirical Examination of Factors Affecting System Use and User Satisfaction," *International Journal of Information Management*, Vol. 33, No. 2 (April 2013), pp. 367–377.
[12] Haniya Rae, "Stop Thief: These New RFID Tags Could Help Luxury Clothing Brands Guard Against Theft," *Forbes*, August 11, 2016, https://www.forbes.com/sites/haniyarae/2016/08/11/rfid-brands-theft/#cb61c3318de9.
[13] Zebra Technologies, "RFID and Your Privacy: Myths and Facts," *White Paper*, June 2013, https://www.zebra.com/content/dam/zebra/white-papers/en-us/rfid-your-privacy-en-us.pdf.
[14] Lynn Fish, "A Historic Perspective on RFID Implementation over the Past Decade with a Focus on Apparel Retailers: Are We at the 'Tipping Point'?," Proceedings for the Northeast Region Decision Sciences Institute (NEDSI), March 22, 2017, pp. 821–839.

Data Transmission

Once captured, data must be disseminated within the organization and the supply chain. In this process, both the transmitting and receiving parties must agree on how the data will be exchanged. We first describe two different forms of data transmission: Electronic Data Interchange (EDI) and EXtensible Markup Language (XML). We thereafter also look at an intermediated approach to data transmission, the Value Added Network (VAN).

Electronic Data Interchange (EDI), created in 1948, is a one-way communication standard designed to exchange structured computer-to-computer messages.[15] These messages are typically transaction-related documents such as purchase orders, invoices, order status inquiries, shipment information, and others. Each EDI document serves the same function as its paper-based equivalent but is transmitted electronically, usually via either a phone line or the Internet. EDI messages are structured because both parties must adhere to a standardized, predetermined format for each document. There are multiple standards available to be adopted by individual firms, industries, and regions of the world. Table 3.2 lists several documents typically used in supply chain information exchanges. These documents conform to the ANSI ASC X.12 standard, which is commonly used in the United States.

TABLE 3.2
Partial EDI Document List (ANSI ASC X.12 Standard)

	Order Series
810	Invoice
832	Price/SalesCatalog
850	Purchase Order
855	Purchase Order Acknowledgment
857	Shipment and Billing Notice
	Materials Handling Series
840	Request for Quotation
843	Response to Request for Quotation
845	Price Authorization Acknowledgment/Status
879	Price Information
	Warehousing Services Series
940	Warehouse Shipping Order
945	Warehouse Shipping Advice
947	Warehouse Inventory Adjustment Advice
990	Response to a Load Tender
	Financial Services Series
812	Credit/Debit Adjustment
820	Payment Order/Remittance Advice
829	Payment Cancellation Request
859	Freight Invoice

[15] Ben Ames, "IT Firm Rolls Out Platform to Expedite Data Exchange among Carriers, 3PLs, Shippers," *DC Velocity*, December 9, 2015, http://www.dcvelocity.com/articles/12051209-it-firm-rolls-out-platform-to-expedite-data-exchange-among-carriers-3pls-shippers/.

	Manufacturing Series
846	Inventory Inquiry/Advice
867	Product Transfer and Resale Report
869	Order Status Inquiry
870	Order Status Report
	Delivery Series
853	Routing and Carrier Instruction
856	Ship Notice/Manifest (ASN)
857	Shipment and Billing Notice
862	Shipping Schedule
	Transportation Series
110	Air Freight Details and Invoice
204	Motor Carrier Load Tender
211	Motor Carrier Bill of Lading
300	Reservation (Booking Request) (Ocean)
310	Freight Receipt and Invoice (Ocean)
312	Arrival Notice (Ocean)
317	Delivery/Pickup Order
456	Railroad Equipment Inquiry or Advice
463	Rail Rate Reply
466	Rail Rate Request

ANSI is the American National Standards Institute. Founded in 1918, it is a nonprofit organization "overseeing the creation, promulgation and use of norms and guidelines that directly impact businesses."[16] It established the Accredited Standards Committee (now named X12) to develop EDI standards.[17]

In a typical but simplified transaction, a buyer sends a purchase order (EDI 850) to a seller and receives back an EDI 855, a purchase order acknowledgment. When the order is ready for shipment, the seller sends a motor carrier an EDI 204, motor carrier load tender, specifying shipment details such as scheduling, required equipment, and the commodity. The carrier responds with an EDI 990, a response to load tender, either accepting or rejecting the tender. When the order is picked up, the buyer sends an EDI 211, bill of lading, to the carrier. Prior to delivery, the seller sends the buyer an advanced shipping notice (EDI 856) informing the buyer of the delivery date and other details. After the order is delivered, the carrier sends the responsible party (e.g., the seller) a freight invoice (EDI 859), and the seller sends the buyer an EDI 810, an invoice. Both invoices may be paid electronically with an EDI 820, payment order/remittance advice.

EDI technology offers several advantages over paper-based document exchanges. EDI is less costly because minimal human interaction is required. This is mostly because the labor cost involved in preparing paper-based documents is avoided. The lack of human

[16] American National Standards Institute, "About ANSI," accessed January 9, 2018, https://www.ansi.org/about_ansi/introduction/history?menuid=1.
[17] American Standards Committee X12, "About X12," http://x12.org/x12org/about/asc-x12-about.cfm.

input also reduces the number of errors in documents because the data input into EDI documents is drawn directly from the firm's databases. Finally, because data moves faster than paper, EDI speeds up supply chain processes. Recent research has shown that firms should consider using EDI to improve relational and information flows between supply chain partners.[18]

On the other hand, the implementation of EDI can be challenging.[19] In addition to the initial setup cost of acquiring hardware, software, and the corresponding training expenses, EDI requires changes in business processes. This is because processes developed for paper-based transactions are often inadequate for EDI transactions. For example, payment of invoices can be processed much faster in an EDI environment because the order cycle time is shorter. In many cases, electronically transmitted invoices may arrive before the corresponding merchandise is received.

Moreover, data security is an issue in EDI implementation because sensitive data might be accessed by unauthorized parties. To minimize this possibility, EDI transactions are often encrypted. Finally, EDI implementation may alter the relationship between buyer and seller. In some cases, for instance, buyers may resist EDI implementation out of concern that automated transactions will reduce their control of the process. Despite these challenges, EDI technology is gaining worldwide acceptance.[20]

In many cases, EDI implementation is mandated by customers. For example, the Kroger Co., a retail grocery chain, considers EDI a key priority and mandates that its suppliers be able to send and receive certain EDI messages, including purchase orders and invoices. Kroger assists vendors in the implementation of EDI by providing information on its website. On the other hand, Kroger imposes a fine on vendors for each transaction executed manually.[21]

EXtensible Markup Language (XML) is an alternative technology to exchange data among firms in the supply chain. It is a simple and flexible syntax for exchanging data through the Internet. XML messages contain not only the data being transmitted but also "tags" located before and after the information. The role of the tags is to label each data point in the message. For example, part of an XML message (e.g., a purchase order) may read: <quantity>53</quantity>. In this case, the data point is 53 and the opening and closing tags indicate that 53 represents the quantity ordered. This is in contrast with an EDI message where there are no tags. In an EDI message the order quantity in known by the position of the number 53 in a standardized document.

XML is more flexible and less costly to implement than EDI. It is more flexible because partners do not have to conform to a rigid EDI standard. Documents can be customized for specific applications. XML is less costly to implement and use because it does not require customized mapping to each new customer or supplier.[22] Another advantage is that XML is human readable and thus enables people to look at the data without using software.

[18] T. Keah Choon, Vijay Kannan, Chin-Chun Hsu, and Keong Leong, "Supply Chain Information and Relational Alignments: Mediators of EDI on Firm Performance," *International Journal of Physical Distribution & Logistics Management*, Vol. 40, No. 5 (2010), pp. 377–394. Also see Cornelia Dröge and Richard Germain, "The Relationship of Electronic Data Interchange with Inventory and Financial Performance," *Journal of Business Logistics*, Vol. 21, No. 2 (2000), pp. 209–230.
[19] Margaret A. Emmelhainz, *Electronic Data Interchange: A Total Management Guide* (New York: Van Nostrand Reinhold, 1990), pp. 156–168.
[20] David J. Closs and Kefeng Xu, "Logistics Information Technology Practice in Manufacturing and Merchandising Firms," *International Journal of Physical Distribution and Logistics Management,* Vol. 30, No. 10 (2000), pp. 869–886.
[21] See "EDI Compliance Requirements," http://edi.kroger.com/edi/comp_001.htm.
[22] Remarkable, "EDI–Electronic Data Interchange–and XML Comparisons," http://www.remarkable.co.nz/ebusiness/edi.htm.

There are also disadvantages when selecting XML to exchange data in supply chains. Because tags are included in every message, XML files are larger than comparable files transmitted in EDI messages. This problem may be overcome by compressing files using a wide range of XML compressors.[23] Another disadvantage is the lack of one or two main XML standards; at this time there are dozens to choose from. And, as of now, EDI dominates the market, making newer market entries difficult.[24]

An intermediated approach to data transmission is the Value Added Network (VAN). Firms with the capability of transmitting EDI or XML messages benefit most by exchanging messages with multiple partners. As the number of partners grows, complexity also grows because different trading partners often use different standards. This is particularly true when partners belong to different industries and operate in different regions of the world. For example, a firm using the ANSI ASC X.12 standard may need to exchange messages with a European partner who uses the EDIFACT standard. This is the United Nations EDI standard used in Europe and other regions of the world.

This complexity means that firms must have the capability of exchanging messages in multiple standards, which is costly. VANs help to solve this problem by offering a translation service. This enables firms to transmit data in whatever standard they use and have the VAN translate that into the standard used by the recipient. Instead of sending the message directly to the receiver, the sender transmits a message to the VAN, which, after translating, resends the message to the receiver. VANs are also capable of translating EDI documents into XML documents and vice versa.

Most VANs provide additional services as well. One is a mailbox service whereby messages received by the VAN are stored for a customer in an electronic mailbox until the customer is ready to download them. This enables the customer to process incoming messages in batches, which is more efficient. Security services such as message encryption and firewalls ensure that messages are read only by the intended recipients. In broadcasting, the same message is distributed to a large number of recipients. Messages may also be audited through an automatic error detection service.

Transaction Support

Recall that we began this chapter with a description of the different uses of information in supply chains, namely to maintain asset visibility, manage daily operations, and make planning and strategy decisions. We subsequently explored different issues related to capturing and transmitting data in supply chains. In the former, we looked into two forms of data capture, bar codes and RFID. In the latter, we discussed EDI, XML, and VANs. We now turn to transaction support. Once data is captured and received, it must be organized to facilitate record keeping and to serve as input into the planning systems we discuss in future sections of this chapter.

Application Programming Interfaces (APIs) are a clearly defined means of communicating between various software programs. APIs happen in real time, without human intervention. When you check the weather on your phone, or order your favorite Starbucks from your phone, you are using APIs.

With APIs, transportation transactions such as requesting rates, dispatching a shipment, or tracking a shipment are automatically triggered and answered through the systems. This allows shippers, for instance, to spend more time on activities that can improve their business. Connectivity gaps inherent in EDI transmissions, as well as delays caused by batching EDI transmission, cause shippers to act on stale or inaccurate information. With

[23] Sherif Sakr, “Investigate State-of-the-Art XML Compression Techniques,” IBM developerWorks, July 19, 2011, https://www.ibm.com/developerworks/library/x-datacompression/index.html.
[24] Steve Brewer, “Why Hasn’t XML Replaced EDI?,” *CovalentWorks*, May 21, 2013, https://blog.covalentworks.com/why-hasnt-xml-replaced-edi/.

cloud-based APIs, the data and information surrounding a shipment are reliable, up-to-date, and dynamic, providing supply chains the opportunity to maximize performance and implement proactive strategies.

One might compare EDIs and APIs by an analogy: EDIs are similar to buses, and APIs are like Uber. Information boards the bus, and it starts on its route. It makes a stop, and some passengers get off while others may board. In the same manner, information in an EDI message is routed through many stops and transformations, as information is pulled out.

In contrast, APIs are like Uber. Information from the API goes straight to where it needs to go, without transformation and with little need of processing. And with that speed comes greater flexibility and, most importantly, visibility. While sharing is possible, the network ensures that users specifically select this option with both cost and time dimensions immediately available as part of the decision-making process.[25]

Jett McCandless, cofounder of project44, an API transportation provider, notes another key advantage of APIs. Specifically, carriers can dynamically change rates—much like airlines, Uber, and hotels—instead of relying on static rate tables. For instance, if demand for freight movements to Miami increases, prices can be raised to reflect this increased demand.[26]

APIs are aggressively competing with EDIs in the marketplace. Given the dynamic nature of consumer demands and expectations, companies have to be able to respond to customer requests faster, an area where APIs excel. Regardless, both EDIs and APIs will coexist for some time, given the size and complexity of the market.[27]

Enterprise Resource Planning (ERP), as defined by Oracle, an ERP provider, refers to the systems and software packages used by organizations to manage day-to-day business activities, such as accounting, procurement, project management, and manufacturing.[28] ERPs emerged in the 1990s as an outgrowth of Materials Requirement Planning (MRP) and Manufacturing Resource Planning (MRP II) software that were initially used to schedule and manage manufacturing operations. ERP software evolved as improvements in computer capabilities enabled companies to add more functionality and promote their integration.[29]

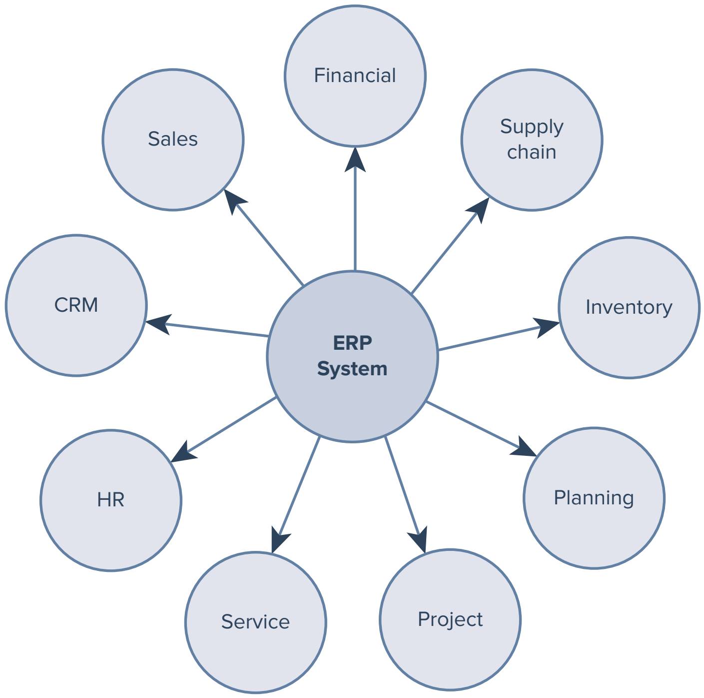
Benefits from an ERP solution can be significant. Real-time information can improve business insight and assist in lower costs. Utilizing the same data enhances integration with other internal functional areas, as they are viewing the same standardized data. And this enhances collaboration with external customers and suppliers as data can be shared in a seamless manner. There is reduced risk, as data integrity and financial controls are in place.[30]

Figure 3.3 displays a typical ERP system. It shows how a central database is integrated with individual modules. These modules focus on business applications such as manufacturing, sales and delivery, finance, inventory and supply, service, human resource management, and reporting. The business application modules are connected to users inside the enterprise (management, sales force, administrators, etc.). Users will either input data in the system or use system output in the management of the enterprise. Finally, ERP systems can also be extended to include outside parties such as customers and suppliers.

[25] Karl B. Manrodt and Mary C. Holcomb, "Learn. Lift. Lead. The Road to Profitability Is a Web Service Connection," project44, Chicago, IL, http://manrodt.com/wp-content/uploads/2016/03/The-Road-to-Profitability-is-a-Web-Service-Connection-Freight-APIs.pdf.
[26] Ben Ames, "IT Firm Rolls Out Platform to Expedite Data Exchange among Carriers, 3PLs, Shippers," *DC Velocity*, December 9, 2015, http://www.dcvelocity.com/articles/12051209-it-firm-rolls-out-platform-to-expedite-data-exchange-among-carriers-3pls-shippers/.
[27] Ibid.
[28] "What Is ERP?," Oracle Corporation, https://www.oracle.com/applications/erp/what-is-erp.html.
[29] Robert F. Jacobs and F. C. (Ted) Weston Jr., "Enterprise Resource Planning–A Brief History," *Journal of Operations Management*, Vol. 24, No. 2 (2007), pp. 357–363.
[30] "What Is ERP?"

FIGURE 3.3
Typical ERP Solution

Source: Retrieved January 10, 2018, http://www.omnicomponents.com/wp-content/uploads/2015/09/erpsoftware.jpg.



In addition to integrating information flows across business functions, ERP systems also serve as platforms for more advanced applications in supply chain management. These applications use data downloaded from ERP systems as input. Thus, firms may add customer relationship management (CRM) and supplier relationship management (SRM) software, which are designed to help manage relationships with customers and suppliers. Other "add-ons" include transportation management systems (TMSs), warehouse management systems (WMSs), and yard management systems (YMSs). These applications fill a significant role in the management of supply chains. TMS, WMS, and YMS will be described in greater detail in upcoming sections in this chapter.

Historically, the implementation of an ERP system was costly and complex.[31] The software itself was expensive and technically challenging to implement. Firms usually had to hire specialized consultants to assist with the implementation. The process required thousands of man-hours and could take more than a year to complete. Dedicated servers had to be purchased and maintained by the customer. Updating the system was difficult, especially if the system had been customized to meet the needs of the customer.

To keep costs down, and to expand the overall ERP market, providers began to offer their solution in the cloud. Cloud ERP solutions have several benefits. The solution is not on the customer's proprietary servers, making updates easier, as well as increasing connectivity both internally and externally. Research has found that cloud solutions offer scalability, reliability, and lower costs (both initial and ongoing costs).[32]

[31] Robert Plant and Leslie Willcocks, "Critical Success Factors in International ERP Implementations: A Case Research Approach," *Journal of Computer Information Systems,* Spring 2007, pp. 60–70.
[32] Mohamed Elmonem, Eman Nasr, and Mervat Geith, "Benefits and Challenges of Cloud ERP Systems: A Systematic Literature Review," *Future Computing and Informatics Journal*, Vol. 1, Issues 1–2 (2016), pp. 1–9.

There are several critical success factors that influence successful ERP implementations. Top management support is needed to break down barriers and resistance to change. This means a vision and objectives of the change have to be clearly communicated to the employees. Training of employees on the new system is also critical to long-term success.[33]

Planning Support

As discussed above, the main emphasis of ERP systems is to integrate data from different business functions and potentially with other participants in the supply chain. In this section we focus mostly on internal integration, while the focus of the subsequent section is on external integration.

While ERP systems have some planning capability, the main focus is on transactions among functions and not on planning. However, the data made available by ERP systems creates opportunities to improve the efficiency of supply chain operations. For example, warehouse operations are more efficient if managers receive timely demand and inventory replenishment information. When this happens, managers are able to anticipate the daily manpower required to operate the warehouse and have time to figure out the best way to use available equipment.

Thus, there are software tools available to assist managers plan efficient supply chain operations. These tools apply decision-making algorithms using data from ERP or other software systems as input. There are also software tools available at the strategic level. For instance, a network design tool enables firms to determine the optimal number, location, and size of facilities in the supply chain. In this section, we describe four of the supply chain planning tools available: inventory management, warehouse management systems (WMSs), transportation management systems (TMSs), and yard management systems (YMSs). The four supply chain planning tools and their main functionalities are summarized in Table 3.3.

Inventory management planning tools help companies decide on the optimal level of inventory to maintain. This decision is a significant challenge to supply chain managers. First, managers must balance the need to offer customers a competitive level of inventory availability with the cost of maintaining inventory. Second, this decision must be made at

TABLE 3.3
Supply Chain Planning Software Tools and Main Functionalities

Software Tool	Main Functionalities
Inventory Management	Single Location Inventory Optimization Multi-Echelon Inventory Decisions
Warehouse Management Systems (WMS)	Control Warehouse Operations Optimize Warehouse Utilization Improve Order Processing Visibility Optimize Labor Resources
Transportation Management Systems (TMS)	Carrier Bidding Transportation Planning and Execution Freight Audit and Payment
Yard Management Systems (YMS)	Improve Visibility of Containers and Trailers Optimize Asset and Driver Movements

[33] Ali Tarhini, Hussain Ammar, Takwa Tarhini, and Ra'ed Masa'deh, "Analysis of the Critical Success Factors for Enterprise Resource Planning Implementation from a Stakeholders' Perspective: A Systematic Review," *International Business Research*, Vol. 4, No. 4 (2015), pp. 25–40. Also see Dawn M. Russell and Anne M. Hoag, "People and Information in the Supply Chain: Social and Organizational Influences on Adoption," *International Journal of Physical Distribution & Logistics Management*, Vol. 34, No. 2 (2004), pp. 102–122.

every location where the company holds inventory, be it at plants, distribution centers, or stores. Third, managers must make a decision for every item in the firm's product line, which is especially complex because in recent years product lines have become more extensive. Product lines also change more often as products are added and deleted to meet the competitive challenges of the marketplace.

Inventory management decisions are made at two levels. One is the quantity of inventory needed at each location and the second is a multi-echelon decision where managers look at how inventory should be distributed throughout the supply chain. Multi-echelon inventory optimization (MEIO) decisions are only possible when there is inventory visibility. An inventory management planning tool takes advantage of the visibility of inventory in the supply chain to make MEIO decisions. This visibility is often made possible by the ERP and APS software suites we discussed previously.

The basic rule of MEIO is that inventory should be kept at the lowest-cost location given a customer service constraint. Depending on the situation, the inventory may be at a lower cost if held close to supply; in other cases, costs are minimized by being closer to the customer. Consider when new iPhones are released on the market. Inventory costs are minimized—and service levels maximized—by keeping them in a central location, shipping them out to the retail stores based on orders.

Stanley Black & Decker, a durable consumer products company, wanted to improve service levels for customers. In addition, it wanted to assure high inventory turns and achieve peak manufacturing performance. Its approach was to use MEIO, which was piloted at one facility and then rolled out across the rest of the supply chain. This process allowed it to learn at the one facility, test assumptions, and fine-tune its work. When the project was completed, it reduced inventory by 23 percent and increased service levels from 76 percent to be consistently above 90 percent.[34]

Warehouse management systems (WMSs) are software tools used mainly to control and optimize warehouse operations. Their functionality is comparable to an ERP system that focuses on the warehouse. At their core, WMSs have both transaction and planning capabilities. However, many WMS software suites also incorporate extended capabilities that overlap with other types of software tools such as ERP, inventory management, or transportation management systems.

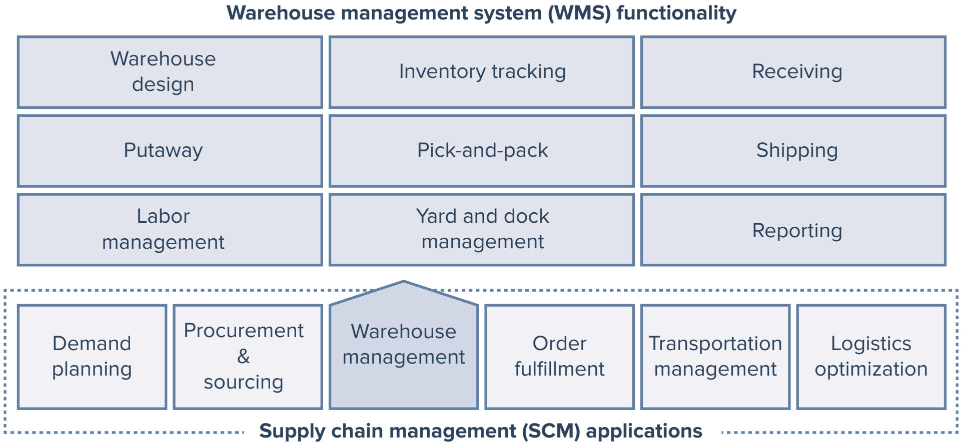
The core capability of a WMS is designed to parallel key warehousing functions such as product receiving, putaway, packing, and shipment. For each function, the WMS controls and optimizes operations. For example, when picking, the WMS keeps track of the items to be picked, the orders they belong to, the location of each item, and the packing station where the orders will be prepared for shipping. In addition to these basic functions, the WMS controls several related activities. One is replenishment, whereby the pick area is restocked with product from other storage areas in the warehouse. Some of the others are inventory counting and value-added services such as light assembly or kitting. Kitting is the assembly of items from different origins into one package to be used for a single purpose. For example, a nurse may use a vaccine kit to immunize a patient. The kit contains all that is needed: syringe, needle, vaccine, cotton, and a bandage. In this case, the value-added service is to assemble all items in a ready-to-use package.

WMSs are designed not only to maintain control of operations, but also to optimize them. Optimization software embedded in WMSs determine, for instance, the sequence in which items should be picked, how items should be slotted (i.e., located in the warehouse), or how labor should be optimally allocated. Managers may select different goals for the optimization. The possibilities include improving warehouse throughput, maximizing usage

[34] Ann Grackin, "Thinking Anew: Transform Your Supply Chain Using Multi-Echelon Inventory Optimization," ChainLink Research, *White Paper*, 2018, http://www.clresearch.com/media/docs/original/ME-Inventory-Optimization.pdf.

FIGURE 3.4
A Typical WMS System

Source: Technology Scribes, https://www.technologyscribes.com/inside-jda-warehouse-management-system.



of warehouse capacity, minimizing cost, or meeting a customer service objective. Figure 3.4 shows a typical WMS system.

The main benefits of a WMS are better utilization of warehouse capacity, improved operational efficiency, better visibility of the order process, and better utilization of labor resources. On the other hand, WMS software is expensive to acquire and implement. In many cases, warehouse processes have to be redesigned to match the requirements of the WMS. As a result, WMS software systems are generally best suited to large warehousing operations.

All types of firms can benefit from the use of a WMS, be they manufacturers, retailers, wholesalers, or 3PLs. One 3PL, Atlanta Bonded Warehouse, started in the confectionery industry in 1948 and now operates contract food-grade, temperature-controlled services for a wide range of clientele. After an 18-month search, it implemented JDA's WMS to standardize its distribution operations across its 12 facilities, and improve customer service for its customers. Having the ability to track and trace food lot codes to support food safety requirements was critical, as the previous manual system was not very efficient. The WMS has allowed Atlanta Bonded Warehouse to onboard new clients faster, increase warehouse efficiency, and capture data to measure individual workers' performance. As Troy Snelson, General Manager of Public Warehouse Operations, noted, "JDA is critical to our business."[35]

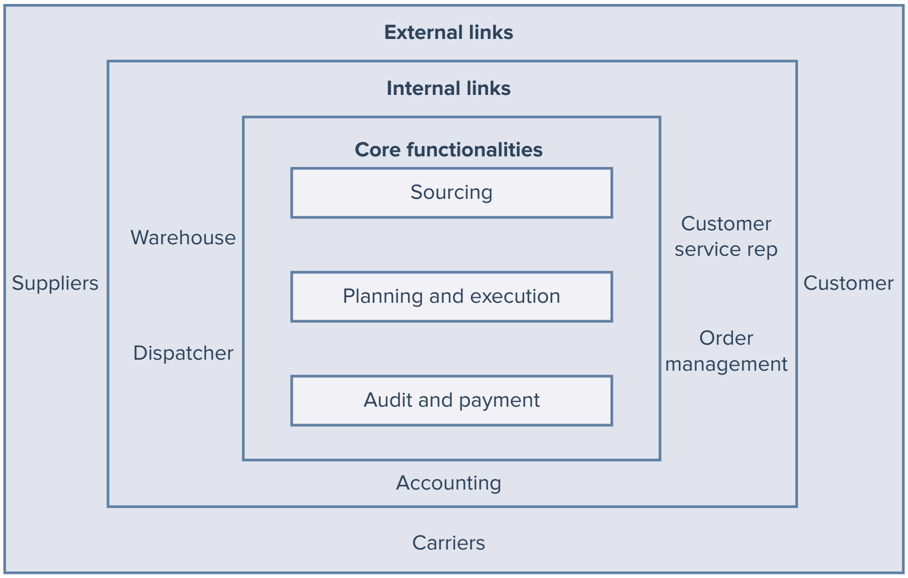
Transportation management systems (TMSs) are software tools designed to manage transportation in the same way that WMS systems are designed to manage warehouses. Adoption of TMSs can be especially impactful because transportation is the largest cost in the supply chain. A unique feature of TMSs is that they have the task of integrating and sharing information among three different parties: shippers, customers, and third parties such as transportation and warehousing companies.[36]

Figure 3.5 shows a typical TMS. It depicts the three core functionalities and the internal and external links provided by TMSs. One key benefit of TMSs is that data flows seamlessly among functionalities, thus interlinking internal and external stakeholders of the system.

[35] "Atlanta Bonded Warehouse–Standardizing Warehouse Operations," *JDA White Paper*, 2017, https://jda.com/knowledge-center/collateral/atlanta-bonded-warehouse-case-study?ts=636516919946233667&l=t.

[36] An infographic regarding the benefits of a TMS solution can be found at https://jda.com/-/media/jda/knowledge-center/infographics/infographic_a-holistic-approach-to-transportation-management-final.ashx.

FIGURE 3.5
A Typical TMS System



The first core functionality is carrier bidding. This enables the firm to automate the bidding of freight over specific lanes to pre-approved carriers. The bidding is often done over the Internet. This functionality also enables the firm to maintain records on carriers, carrier performance, and a freight rates database.

A second core functionality of TMSs is planning and execution. TMS plans and processes each shipment until it is received from a supplier or delivered to the customer. This includes processing order data to select transportation modes, optimizing load building, and determining shipment routing. Load building is the process of allocating cargo to a container or vehicle such that the resulting load is safe and compliant with regulations. It further balances efficiency of loading, weight distribution, and delivery sequence. The TMS also generates the appropriate documentation for each shipment and ensures that orders comply with all supplier or customer requirements such as pickup and delivery windows. This TMS functionality also enables shipment visibility throughout the delivery process and handles any order changes that might be requested by customers, such as altering the delivery date or adding a new item to the order.

Audit and payment is the third core functionality. The freight payment environment is very complex. The number of freight bills is generally large with different carriers and prices offered over many transportation lanes. In addition, freight billing and payment can take many forms: EDI, Internet, fax, or mail.

The audit functionality of a TMS keeps track of charges and discounts provided by carriers. It also checks for errors such as double billing to avoid overcharges. Once bills have been audited, the system authorizes and keeps track of payments.

One example of a TMS application is by Steelcase. This company, headquartered in Grand Rapids, Michigan, is the world's largest furniture manufacturer in the world, with 800 dealer locations throughout world. Prior to implementation finalized in 2017 it used a wide variety of planning software tools. Steelcase wanted to insource transportation planning to make better transportation decisions and better serve its customers. For instance, some customers wanted trucks loaded so that the office panels are unloaded first, followed by desks, and then chairs. Some buildings require elevator appointments to move the materials into the offices.[37] Steelcase uses SAP's

[37] "Steelcase, Nancy Hill, Presenting about Their TM Implementation with Novigo," https://www.youtube.com/watch?v=X5iyrUGisq0.

Transportation Management program for inbound, outbound, and interplant moves. The software allows Steelcase to see and know the exact cost of delivering an order to a customer. One of the biggest benefits it has received is increased visibility of where each of its shipments is at any time, as well as reduced costs, improved transportation processes, improved carrier selection, and global integration with the three other ERPs used by Steelcase.[38]

Yard management systems (YMSs) are designed primarily to manage containers and trailers in yards adjacent to manufacturing plants, warehouses, or other distribution facilities. Their goal is to improve asset utilization and visibility in order to reduce cost and improve customer service. YMSs are available either as stand-alone software or as part of WMS or TMS packages.

Similarly to WMSs and TMSs, the basic functionalities of YMSs are to automate control and to optimize execution. The control functionality of a YMS typically tracks the number, contents, location, and ownership of each container and trailer in the yard. It also keeps the corresponding documentation information about carriers, loads, and drivers. Finally, YMSs automate related communication tasks such as e-mail notifications of pickup and delivery to plant and warehouse managers, carriers, and shippers.

On the optimization side, YMSs assign trailers to drivers based on priority of movement, driver availability, and minimization of travel distance. Finally, YMSs also generate performance reports that serve as input to decision makers and to related systems such as WMS and TMS. For example, a YMS tracks the average time spent by a container or trailer in the yard or the average time spent on a warehouse dock.

Supply Chain Collaboration Support

Information technology tools are also needed to support supply chain collaboration. Some of these tools enable firms in the supply chain to collaborate in areas such as financial transactions, procurement, product design, or promotions. In each of these cases, data is exchanged among firms in the supply chain to improve operational efficiency and customer service. The data exchange is made possible by bar codes, EDI, and some of the other data capture and data transmission tools described earlier in the chapter. Two important areas of supply chain collaboration are coordinated inventory deployment and e-commerce, the buying and selling of products through electronic networks.

In coordinated inventory deployment, firms in the supply chain share demand, inventory, and promotional data to decide on the appropriate level of inventory to maintain throughout the supply chain. Vendor-managed inventory (VMI) is a form of supply chain collaboration whereby a supplier manages its customer's inventory using data supplied by the customer. It is important that the data is shared in a timely manner.[39] The level of inventory in the supply chain typically decreases because a single firm, the supplier, is able to coordinate inventory decisions for both firms. For instance, Ferrell Gas takes into account the location of all of its customers, as well as inventory, when scheduling deliveries, to maximize productivity and profits.[40]

[38] Ibid.; "Case Study: Steelcase," https://www.sap.com/about/customer-testimonials/finder.html?url_id=ctabutton-us-customer-finder&tag=solution:supply-chain/transportation-management.
[39] Andres Angulo, Heather Nachtmann, and Mathew A. Waller, "Supply Chain Information Sharing in a Vendor Managed Inventory Partnership," *Journal of Business Logistics*, Vol. 25, No. 1 (2004), pp. 101–120.
[40] Chris Jones, "A Different Approach to VMI," *DC Velocity*, August 12, 2013, http://blogs.dcvelocity.com/bestpractices/2013/08/a-different-approach-to-vmi.html.

Another form of coordinated inventory deployment is collaborative planning, forecasting, and replenishment (CPFR). CPFR works across organizational boundaries to develop a single forecast. In these cases their trading partners can use this forecast to effectively manage their supply chain activities, such as manufacturing, transportation, inventory, and labor utilization, to name a few. Inventory levels can be reduced, as well as the costs of transportation and manufacturing. For example, Sony (Canada) increased its in-stock levels from 87 percent to at least 95 percent while at the same time reducing overall supply chain inventory by 20 percent.

One of the first adopters of CPFR was Nabisco, which partnered with Wegman's, a grocery chain. Nabisco and Wegman's focused on improving the forecast of 22 Planter's peanut items. As a result, inventory levels decreased by 18 percent, while Nabisco's sales went up 31 percent and Wegman's dollar sales of nuts increased by 16 percent.[41] This points to the efficiencies of using information correctly: It is possible to increase sales, increase customer service, and reduce the cost of inventory.

Information technology tools are needed to enable e-commerce. E-commerce networks support either business to consumer (B2C) or business to business (B2B) settings. In a B2B setting, businesses exchange information through one or more computer networks, including the Internet. In a B2C setting, consumers may buy products from home using the Internet or use a kiosk in a store.

For instance, over the past several years personalized shopping assistants have increased on the Internet. Stitch Fix, Shop It To Me, Stylist, and M.M. LaFleur, to name a few, offer fashion consultants—and apps—to help select apparel choices for busy customers. Customers fill out a style profile and meet online with a stylist to determine preferences and the customer's budget. Items are selected and shipped to the customer, who keeps what he or she wants and sends the rest back.

Other B2C tools focus on apps developed by retailers and manufacturers, providing customers news about product updates, specials, or new arrivals. Almost everyone is getting in on the act. As of January 2017, over 2.2 million apps were available for download in Apple's iTunes App Store, with over 140 billion downloads worldwide! While shopping apps make up just over 1 percent of the available apps, they have one of the largest mobile audiences.[42]

What could possibly compare to Apple's iTunes App Store, or Google's Google Play? Businesses such as CDW and General Electric are developing their own enterprise app stores where employees can safely upload apps to communicate with vendors.[43]

Order Management

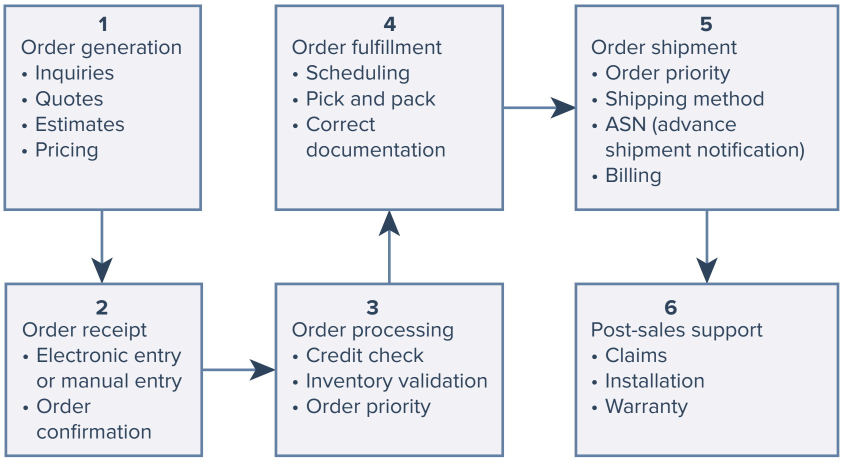
One of the key supply chain processes described in the SCOR Model is order management. It is important because orders are the triggers that set the supply chain in motion. The order management process starts with the initial contact between customer and supplier. It ends with the delivery of the order and subsequent after-sales service. While supply chain managers must manage both inbound and outbound orders, we focus on the customer, or outbound, side.

Steps in the Order Management Process

As indicated in Figure 3.6, the order management process might be separated into six steps: order generation, order receipt, order processing, order fulfillment, order shipment, and

[41] "Roadmap to CPFR: The Case Studies," Voluntary Interindustry Commerce Standards Association, 1999, pp. 33–44, https://www.scribd.com/document/41327891/04-1-4046-Nabisco-Wegmans-Pilot.
[42] "Number of Available Apps in the Apple App Store from July 2008 to January 2017," *Statista*, https://www.statista.com/statistics/263795/number-of-available-apps-in-the-apple-app-store/.
[43] Shane O'Neill, "The Enterprise App Store: 10 Must-Have Features," *CIO*, April 25, 2012, https://www.cio.com/article/2396723/mobile/the-enterprise-app-store--10-must-have-features.html.

FIGURE 3.6
The Order Management Process



post-sales support. We first briefly describe each step. In the next section we discuss issues in the order management process.

Order generation encompasses the supply chain activities performed to obtain a customer order. These include responding to customer inquiries, preparing cost estimates, and pricing products. The second step is order receipt. An order may be received via a number of different methods, including EDI, which we covered earlier in this chapter. Alternatively, orders may be handed in by a salesperson, phoned in, or faxed. Usually the customer receives back an acknowledgment of the order, which may also be done via one of the methods listed above.

The order processing step is next. This refers to the preparation of an order to be filled. In this step, the customer's credit status is checked, as is the inventory availability of the ordered items. One additional preparatory activity is to prioritize orders to decide which ones will be filled first. This may be done according to a number of criteria. For example, orders may be filled on a first-come, first-served basis, by importance of customer; or to minimize production cost. In one such approach, customers are ranked by volume purchased. Orders are then allocated accordingly.[44]

The fourth step is order fulfillment, which starts by scheduling the picking of individual items and orders. The next activity is to produce a "pick list." The list triggers the warehouse activities of picking items, aggregating them by individual orders and customers, and then packing. The preparation of the related documentation for shipping occurs simultaneously. This step is described further in Chapter 6, *Warehouse Management*. Order shipment begins when deliveries are scheduled and the order is loaded in a vehicle for transportation to the customer's facility. Lastly, the customer also receives billing documentation, after the shipper receives a proof-of-delivery, or POD, that the order has been delivered. Chapter 5, *Transportation: Overview, Infrastructure, Measures, and Management*, covers additional information related to this step. The order management process does not end with the delivery of the product and the customer's payment. There is one more important step, post-sale support. This includes activities such as handling claims related to the order, for example, an unmatching weight or price. Post-sale support additionally includes warranty-related work, when an ordered product fails to match a performance requirement.

[44] For additional information on this approach, please see Walter Zinn, John T. Mentzer, and Keely L. Croxton, "Customer Based Measures of Inventory Availability," *Journal of Business Logistics*, Vol. 23, No. 2 (2002), pp. 19–44.

The Order Management Process

The role of a supply chain manager goes beyond understanding the steps in the order management process. The process needs to be actively managed to reduce cost and support customer service. An order is a key contact point between customer and supplier. It has been suggested that "every time an order is handled, the customer is handled. Every time an order sits unattended, the customer sits unattended."[45]

In order to reduce the cost of processing orders and managing the related level of customer service, managers need to first map the order process and then look for ways to reduce cost. Costs in the order management process often originate from one or more of the following causes:

- Gaps
- Bottlenecks
- Errors
- Duplication of activities

A process map is a visual representation of a process. In varying degrees of sophistication, it represents the path of the information throughout the supply chain, decisions and activities that occur at each point in the process, as well as the related timeline. If the process involves more than one function, as is the case with the order management process, the map should also represent the role of each function. Process maps may be paper-based or, as is often the case, be constructed with the help of specialized software.

There are many reasons for constructing a process map.[46] While they refer more generally to supply chain maps, some of the reasons also apply to mapping the order management process. First, mapping is crucial to redesign the order management process. It documents the current state of the process and provides a platform to examine potential improvements. Second, a process map facilitates a common understanding of the order management process. This is because the different people and functions involved in the order management process may develop different views of it. A process map promotes a common understanding because all involved base their views on the same information. Finally, a process map is an effective communication tool among all involved in the order management process.

Furthermore, to provide customer service, managers should work to reduce the time and uncertainty that it takes to move an order through the management process, especially the order cycle time. The order cycle time is the critical time period between a customer placing an order and its delivery. It is represented by steps 2 to 5 in Figure 3.6.

Customers value short order cycle times and low uncertainty about the time of delivery because this improves their ability to plan. Think, for instance, of a customer awaiting an express package. Knowing when the package will arrive is often as important as receiving it quickly. This is because the customer can make plans based on the arrival of the package. The customer could plan to be home to receive the package or to bring it on a trip and so on.

This same logic applies to business customers. The relevance of the order cycle time is straightforward: The longer the order cycle time, the longer customers must wait for ordered products. As a result, customers must either hold more inventory or anticipate their purchases. The earlier course of action results in a higher inventory carrying cost. A consequence of the latter course of action is that the customer works with a longer

[45] Benson P. Shapiro, V. Kasturi Rangan, and John J. Sviokla, "Staple Yourself to an Order," *Harvard Business Review*, July–August 1992, pp. 113–121.
[46] John T. Gardner and Martha C. Cooper, "Strategic Supply Chain Mapping Approaches," *Journal of Business Logistics*, Vol. 24, No. 2 (2003), pp. 37–64.

forecast horizon and thus a larger forecast error. Reducing order cycle time uncertainty is also an important factor in customer service. The greater the uncertainty about the time of delivery, the larger the investment in safety stock that the customer must make to ensure a smooth continuity to its operations.

The Future Role of Information

As we noted at the beginning of the chapter, the digital world has made time and space obsolete. Consumers can shop online, at any time, virtually anywhere in the world, and, in some cases, get what they ordered delivered to them within a few short hours. Amazon has even filed a patent for delivery trucks equipped with 3-D printers. When a customer orders a printable product, the order will begin printing as the truck drives to the final destination.[47] Where these and other technologies are headed—and the speed by which they will impact the market—are hard to determine. Two of the more impactful applications—blockchain and the Internet of Things (IoT)—are noted below.

Blockchain

More than at any other time in history do we care where products come from, and at the same time wish to have the ability to verify their pedigree. For instance, do you care where your coffee comes from? Do you care if it is Fair Trade? How do you know if the fish in your sandwich was certified by the Marine Stewardship Council? How do you know if the shoes on your feet really are from Nike? After all, one study estimates that counterfeit and pirated goods are worth nearly $500 billion each year.[48]

In part, labels, bar codes, and RFID tags have been used to verify where a product was produced, but these tags have limitations. Information about the product is not instantaneous or online. What is needed is a network available to everyone, and difficult or impossible to edit or alter.

Enter the world of blockchain. Suppose you want to buy a watch over the Internet. Usually there would be a middle person (or several!) involved in the transaction. A bank would record cash going from one account into another.

With blockchain, there are not middle persons. When the transaction is made, it is recorded on a ledger, or a block. These blocks are all joined together to form a chain, hence the name blockchain. Each of these blocks is shared across the network, making counterfeits or theft nearly impossible. It is assumed that consensus creates truth.

How would this apply to supply chains? It will differ by industry, but the impact could be significant. For instance, think about pharmaceuticals, where the chain of custody is critical and where ingredients for the medication may pass through several countries.[49] One study found the value of the counterfeit drug market to be around $200 billion.[50] In this case, a firm can create a block when the drug is made, another block when it passes quality assurance, and yet another when put in the DC. Other blocks would be added as the drug moves from the DC to a distributor, transportation provider, retailer, and finally to the hospital or patient. Information about the drug from its creation can be validated and verified by permissioned users.

[47] Brian Krassenstein, "Amazon Files Patent for Mobile 3D Printing Delivery Trucks," 3Dprint.com, February 25, 2015, https://3dprint.com/46934/amazon-3d-printing-patent/.
[48] "Global Trade in Fake Goods Worth Nearly Half a Trillion Dollars a Year—OECD & EUIPO," OECD, April 18, 2016, https://www.oecd.org/industry/global-trade-in-fake-goods-worth-nearly-half-a-trillion-dollars-a-year.htm.
[49] Alexandra Ossola, "The Fake Drug Industry Is Exploding, and We Can't Do Anything About It," *Newsweek*, September 17, 2015, accessed March 12, 2018, http://www.newsweek.com/2015/09/25/fake-drug-industry-exploding-and-we-cant-do-anything-about-it-373088.html.
[50] "20 Shocking Counterfeit Drugs Statistics," HealthResearchFunding.org, https://healthresearchfunding.org/20-shocking-counterfeit-drugs-statistics/.

FIGURE 3.7
Types of Blockchains

Source: Timothy Leonard, "Blockchain for Transportation: Where the Future Starts," TMW Systems, Inc., *White Paper*, 2017.

	Public	Private	Consortium
Structure	Decentralized	Centralized	Partially decentralized
Access	Open read/write	Permissioned	Permissioned
Speed	Slower (~10 minutes)	Faster (same as a transactional system)	Varies by the number of nodes
Consensus	Proof of work Proof of stake	Pre-approved	Pre-approved
Identity	Anonymous	Known identities	Known identities
Use cases	Cryptoeconomy	Reference data management	Secure data sharing
Examples	Bitcoin, ethereum, dash	MONAX, multichain	R3, EWF

There are three basic types or platforms for blockchains, as noted in Figure 3.7. Public blockchain is what we typically think of when it comes to blockchains. It is a decentralized network open to all; users read transactions, add themselves to the network, and transfer assets. Security is based on consensus; everyone has the same data, counterfeiting becomes incredibly difficult. Achieving this consensus can take time, ranging from 2 to 10 minutes.[51]

A private blockchain is centralized and users are preapproved, or permissioned, to be a member of the network. Because private blockchains are permissioned, speed to verify a block is much faster. Private blockchains are typical for internal functions within a firm.

A consortium blockchain is a hybrid of the previous two types. It is decentralized and permissioned. All of the rules and policies governing the blockchain are defined by the members.[52] For instance, Maersk is partnering with IBM to create a new company that "intends to help shippers, ports, customs offices, banks, and other stakeholders in global supply chains track freight as well as replace related paperwork with tamper-resistant digital records."[53] This will greatly increase efficiency and timeliness in transportation. IBM has also partnered with Walmart, Unilever, Nestle, and others in blockchains focused on supply chains and food safety.

Blockchains are not without limitations. One of the most mundane roadblocks is the current infrastructure between shippers and carriers. EDI has been around since before the 1950s, and getting everyone to change will be a daunting effort.

Another issue will be speed. In a public blockchain, security is based on consensus; everyone in the blockchain gets the same information. Achieving consensus takes time—and speed is needed for the digital supply chain to flourish.

Along with speed, there are few global standards. This situation of lacking standards is common in logistics and transportation. EDI formats vary, as do RFID standards.

Finally, blockchains are not an environmentally friendly solution. Blockchains require consensus; this means multitudes of computers are involved in this process. Bitcoin's blockchain is estimated to consume more energy than what 159 countries consume in a single year.[54]

[51] Timothy Leonard, "Blockchain for Transportation: Where the Future Starts," TMW Systems, Inc., *White Paper*, 2017.
[52] Ibid.
[53] Robert Hackett, "IBM and Maersk Are Creating a New Blockchain Company," *Fortune*, January 16, 2018, http://fortune.com/2018/01/16/ibm-blockchain-maersk-company/.
[54] Dom Galeon, "Mining Bitcoin Costs More Energy Than What 159 Countries Consume in a Year," *Futurism*, November 27, 2017, https://futurism.com/mining-bitcoin-costs-more-energy-159-countries-consume-year/.

Internet of Things (IoT)

Some of us started to learn about connectivity back in kindergarten, where we sang that the toe bone is connected to the foot bone, the foot bone is connected to the heel bone, and the heel bone is connected to the leg bone. In many ways, the sensors in our clothes are connected to our phone, and our phone is connected to our Mac or PC, which is connected to our garage door, oven, toaster, refrigerator, car, and dog, just to name a few. It is not just an Internet for people, but an Internet of Things (IoT) as well.

Conceptually, it is easy to understand the IoT. It allows our devices to connect to us, each other, and our applications over the Internet. Your clothes can tell us how effective your workout was and track the calories you burned. If you are on a diet, an app can recommend what you should eat today based on your workout, your diet, and what food you have in your smart refrigerator. Perhaps one day the refrigerator will send the car to the supermarket to pick up food you need for dinner—all without your prompting.

In fact, there are probably more things on the Internet than people. In 2016 it was estimated that there were anywhere from 6.4 billion devices (not including computers, phones, or tablets) to 17.4 billion devices (including everything).[55] World population? Less than 8 billion!

Information is critical to the effective and efficient operations of a supply chain, and for this reason the IoT could have dramatic impacts on how supply chain activities are completed. Internally, production efficiencies can increase and errors be reduced by using better technology. Prior to using RFID tags, Whirlpool used a manual process to track washing machines being made at the factory. Paper tags on the lid would fall off, resulting in lost and excess inventory. Now, using RFID tags, managers have real-time information about production and the location of the inventory. Items are assembled and painted based on real demand. Quality went up, and inventory levels went down.[56]

It is difficult to determine exactly when and how IoT (and blockchain) will impact logistics, transportation, and supply chain management. Both are merging technologies, still being tested in the field. Greater visibility of both can only benefit manufacturers, distributors, and retailers, especially as consumer's appetite for real-time visibility continues to grow. Both technologies play a critical role in the digital world that stands before us.

Summary

Recall that we began this chapter by referring to information as the lifeline of supply chains. This is because managers need information to support all activities and decisions in supply chain management. In particular, information is needed to maintain visibility of supply chain assets, to manage daily operations, and to support supply chain planning and strategy.

In addition to describing the uses of information in supply chains, there were three additional learning objectives for this chapter. First was to describe how information is used to capture and transmit data in supply chains. We reviewed tools available to support supply chain managers in each of those areas. Bar codes and radio frequency identification (RFID) are data capture tools. Supply chain managers may select Electronic Data Interchange (EDI), Extensible Markup Language (XML), and/or Value Added Networks (VANs) as data transmission tools.

[55] Amy Nordrum, "Popular Internet of Things Forecast of 50 Billion Devices by 2020 Is Outdated," *IEEE*, August 18, 2016, https://spectrum.ieee.org/tech-talk/telecom/internet/popular-internet-of-things-forecast-of-50-billion-devices-by-2020-is-outdated.

[56] Joe Mariani, Evan Quasney, and Michael Raynor, "Forging Links into Loops: The Internet of Things' Potential to Recast Supply Chain Management," *Deloitte Review*, Issue 17, July 27, 2015, https://www2.deloitte.com/insights/us/en/deloitte-review/issue-17/internet-of-things-supply-chain-management.html.

In support of the second objective, understanding how information is used, we reviewed enterprise resource planning (ERP) as a software tool available to support transactions in supply chains. In the area of supply chain planning, there are tools available to support integrated operations, such as application programming interfaces (APIs), as well as tools to support specific functions. These tools support inventory management, warehouse management system (WMS), transportation management system (TMS), and yard management system (YMS). Information is also crucial to support supply chain collaboration in areas such as vendor-managed inventory (VMI); collaborative planning, forecasting, and replenishment (CPFR); and e-commerce.

The final objective of this chapter was to review the order management process, which is critical to both cost management and customer service. We discussed the steps in order management, the importance of process maps to manage the order management process, and the importance of the order cycle time and its related uncertainty.

In the next chapter, we will examine the role of inventory in the management of supply chains.

Suggested Readings

Ames, Ben, "IT Firm Rolls out Platform to Expedite Data Exchange among Carriers, 3PLs, Shippers," DC Velocity, December 9, 2015, available at http://www.dcvelocity.com/articles/12051209-it-firm-rolls-out-platform-to-expedite-data-exchange-among-carriers-3pls-shippers/.

Angulo, Andres, Heather Nachtmann, and Mathew A. Waller, "Supply Chain Information Sharing in a Vendor Managed Inventory Partnership," *Journal of Business Logistics*, Vol. 25, No. 1 (2004), pp. 101–120.

Grackin, Ann, "Thinking Anew—Transform Your Supply Chain Using Multi-Echelon Inventory Optimization" ChainLink Research whitepaper, 2018, http://www.clresearch.com/media/docs/original/ME-Inventory-Optimization.pdf.

Jacobs, Robert F., and F.C. 'Ted' Weston Jr., "Enterprise Resource Planning—A Brief History," *Journal of Operations Management*, Vol. 24, No. 2 (2007), pp. 357–363.

Jones, Chris, "A Different Approach to VMI," DC Velocity, August 12, 2013, http://blogs.dcvelocity.com/bestpractices/2013/08/a-different-approach-to-vmi.html.

Sanders, Nada, *Big Data Driven Supply Chain Management: A Framework for Implementing Analytics and Turning Information into Intelligence*, Pearson Education, 2014. (Upper Saddle River, NJ: /)

Tillman, Joe, Karl B. Manrodt, and Donnie Williams, "DC Measures 2017," WERCWatch, Spring 2017, Warehouse Education Research Council, Chicago, IL.

Questions and Problems

LO 3-1 1. Describe the role information plays in managing the supply chain. How important is it?

LO 3-2 2. What are the three basic reasons supply chain managers need information?

LO 3-3 3. Briefly describe any three tools used to support planning and collaboration in the supply chain. How would not having these tools impact supply chain performance?

LO 3-4 4. Briefly describe the order management process.