David Simchi-Levi, S. David Wu, and Z. Max Shen (Eds.)
Handbook of Quantitative Supply Chain Analysis:
Modeling in the E-Business Era

Chapter 1

SUPPLY CHAIN ANALYSIS AND E-BUSINESS

An Overview

David Simchi-Levi
Department of Civil and Environmental Engineering
Massachusetts Institute of Technology
dslevi@mit.edu

S. David Wu*
Department of Industrial and Systems Engineering
Lehigh University
david.wu@lehigh.edu

Z. Max Shen
Department of Industrial and Systems Engineering
University of Florida
shen@ise.ufl.edu

1. Introduction

Supply chain analysis is the study of quantitative models that characterize various economic tradeoffs in the supply chain. The field has made significant strides in both theoretical and practical fronts. On the theoretical front, supply chain analysis inspires new research ventures that blend operations research, game theory, and microeconomics. These ventures result in an unprecedented amalgamation of prescriptive, descriptive, and predictive models characteristic of each subfield. On the practical front, supply chain analysis offers solid foundations for strategic positioning, policy setting, and decision making. Over the past two decades, not only has supply chain analysis become a strategic fo-

*S. David Wu is supported by NSF Grants DMI-0075391 and DMI-0121395

cus of leading firms, it has also spawned an impressive array of research that brings together diverse research communities. Adding to this diversity and intellectual energy is the emergence of E-Business. E-Business creates new competitive dimensions that are fast-paced, ever-changing, and risk-prone, dimensions where innovation, speed, and technological savvy often define success. Most importantly, E-Business challenges the premises and expands the scope of supply chain analysis.

The research community has responded to the E-Business challenge. Despite the infamous dot-com bust in the early 2000's, scores of research initiatives, workshops, technical papers, and special journal issues have been devoted to the subject. E-Business remains a critical subject not only in the research community, but also in corporate boardrooms. Instead of the revolution that would replace every facet of business, the rise of E-Business might be viewed as the emergence of new economic intermediaries that offer opportunities for innovation. These new intermediaries offer different means to respond to market demands (e.g., Internet vs. traditional channels), to facilitate sourcing, procurement, and price discovery (e.g., electronic auctions), and to develop new mechanisms for coordination and execution (e.g., dynamic pricing, revenue management, and collaborative forecasting).

The area intersecting supply chain analysis and E-Business is in its infancy; it is still taking shape and emerging. Indeed, there are still debates and contentions as to whether E-Business offers any fundamentally new research dimensions. We thought that this might be the right moment to put together a book that takes a close look at what has been done in the field of supply chain analysis that may be relevant to the emerging environment of E-Business. We set out to edit a research handbook that pays as much attention to looking back as to looking forward. The handbook is intended as reference material for researchers, graduate students, and practitioners alike who are interested in pursuing research and development in this area, and who need both a comprehensive view of the existing literature, and a multitude of ideas for future directions. The handbook should serve quite nicely as supplementary material for advanced graduate level courses in operations research, industrial engineering, operations management, supply chain management, or applied economics.

The handbook contains 18 chapters organized in five main parts as follows:

1. Emerging Paradigms for Supply Chain Analysis,
2. Auctions and Bidding,
3. Supply Chain Coordinations in E-Business,
4. Multi-Channel Coordination, and
5. Network Design, IT, and Financial Services.

Each chapter was written by one or more leading researchers in the area. These authors were invited on the basis of their scholarly expertise and unique insights in each particular subarea. An outline of the chapter was first submitted to us; we tried to coordinate the contents and foci of the chapters for better overall coverage. Since this is a handbook rather than a collection of research papers, we encouraged the authors to position their chapters broadly so as to provide a comprehensive overview or survey of an area of interest. On the other hand, we also encouraged the authors to focus on quantitative models and analytical insights provided by these models. Individual authors ultimately determined the emphasis and perspectives of each chapter. All chapters were reviewed by us and at least one outside referee.

We acknowledge that supply chain management and E-Business are represented by a wide variety of disciplines and research communities. The categorization and coverage of this handbook is neither complete nor exhaustive. However, we do believe that the 18 chapters represent an excellent sample of research topics on the intersection of quantitative supply chain analysis and E-Business. Through these topics, we are able to touch and connect a key body of literature that forms the basic ingredients and theoretical underpinnings for future developments; we hope this provides a foundation that helps to perpetuate next generation research in quantitative supply chain analysis and E-Business.

2. Main Components of the Handbook

In the following sections, we provide an overview for each of the five parts of the handbook.

2.1 Emerging Paradigms for Supply Chain Analysis

The chapters in this part explore three emerging paradigms that are of increasing importance in quantitative supply chain analysis: game theory, bargaining theory, and agency theory. In **Chapter 2**, Cachon and Netessine provide a comprehensive survey of game theory in supply chain analysis. Game theory has become an essential tool in the analysis of supply chains, which often involves multiple agents with conflicting objectives. This chapter surveys the applications of game theory to supply chain analysis and outlines game-theoretic concepts that have potential for future application. They discuss both non-cooperative and cooperative game theory in static and dynamic settings. Careful attention is given to techniques for demonstrating the existence and uniqueness of equilibrium in non-cooperative games. A newsvendor game is employed throughout to demonstrate the application of various tools. In **Chapter 3**, Wu provides an overview of supply chain intermediation using the framework of bargaining theory. Supply chain intermediaries

are those economic agents who coordinate and arbitrate transactions between suppliers and customers. For any set of agents in the supply chain who desire to form supplier-buyer relationships, they may choose to do so through direct bargaining or through some form of intermediation. Thus, the merit of an intermediary must be justified by the outcome of its competing bargaining game. In this context, he examines bilateral and multilateral bargaining games under complete and incomplete information. In **Chapter 4**, Zenios introduces the principal-agent (or agency) paradigm for supply chain analysis. A principal has a primary stake in the performance of a system but delegates operational control to one or more agents. The agency theory has been adopted in various fields such as investment management, personnel economics, and managerial accounting. He first introduces the classical static principal-agent model, and he then introduces the dynamic principal-agent model and presents a solution methodology based on dynamic programming. Next, he presents an extension of the basic dynamic model in a setting where the decision processes are controlled by multiple agents with potentially conflicting objectives. Following this, he presents applications in a decentralized inventory system and a service delivery system.

2.2 Auctions and Bidding

The game-theoretic and bargaining-theoretic discussions extend naturally to auctions theory, the subject of the second part of the handbook. Auction is among the oldest and most widely used market mechanisms. There is an extensive literature on auctions theory that is both theoretically rich and practically significant. It is not our intent to survey the massive literature in auctions theory; the handbook focuses on the emergence of auctions as an intermediary in E-Business transactions, serving functions such as price discovering, revenue management, resource allocation, multilateral negotiations, and sourcing/procurement. We start out with **Chapter 5**, where Kalagnanam and Parkes provide a comprehensive survey of auctions from the perspective of decentralized resource allocation. This perspective is important because it brings in the dimensions of optimization and computing that have been previously overlooked in the auctions literature but that have critical importance for E-Business applications, such as procurement auctions. Procurement auctions motivate the study of theoretical and computational roadblocks involved in multi-unit, multi-attribute, sequential, and combinatorial auctions. Kalagnanam and Parkes provide details for some of the most interesting designs from the literature, establish state-of-the-art results, and identify emerging research directions. In **Chapter 6**, Elmaghraby focuses on the roles of auctions and precision pricing in B2B e-marketplaces. Using in-depth case studies of FreeMarkets' customized auction services and Manugistics' Network Target

Pricing (NTP) system, she explores the design dimensions and implementation challenges associated with the use of auctions in B2B markets. She discusses the decisions that FreeMarkets faces when designing a procurement auction, and then discusses the design and use of NTP, a bidding support software developed by Manugistics to aid suppliers in submitting bids. She then turns her attention to an alternative pricing mechanism in B2B e-marketplaces, precision pricing. She presents a detailed case study of Manugistics' Precision Pricing (P2) system, discussing the challenges in properly implementing precision pricing in B2B contexts. In **Chapter 7**, de Vries and Vohra survey the state of knowledge on the design of combinatorial auctions. Combinatorial auctions involve the sale of assets that demonstrate complementarities, e.g., radio spectrums, where the bidders are allowed to bid on combinations or bundles of different assets that reflect their preferences. The authors focus on the revenue maximization and economic efficiency of such auctions. They present various integer programming formulations of the winner determination problem, and give an in-depth discussion of efficient mechanisms such as the VCG auction and its variations.

2.3 Supply Chain Coordinations in E-Business

In the new environment of E-Business, the mechanisms by which firms coordinate different stages in the supply chain are undergoing profound changes. New technologies have emerged to acquire instantaneous feedback from customers and markets, to enable information-sharing with suppliers, and to collaborate decision-making throughout the supply chain. This enhanced level of coordination significantly increases the dependencies among retailers, suppliers, manufacturers, and intermediaries, posing significant challenges in strategic positioning, planning, and execution. This part of the handbook is dedicated to different aspects of supply chain coordinations that attempt to address the emerging needs of E-Business. In **Chapter 8**, Chayet, Hopp, and Xu focus on the marketing-operations interface. In specific, they address the changing customer contact mechanisms and information flows due to the Internet. They examine the stages of the "customer contact chain" to identify areas in which the Internet presents new management issues. By reviewing the literatures traditionally related to Marketing and Operations Management, they suggest new research avenues for addressing the marketing-operations challenges posed by E-Business. In **Chapter 9**, Chan, Shen, Simchi-Levi, and Swann address the coordination of pricing and inventory decisions in the supply chain. Pricing is among the most significant issues in E-Business, especially when it is integrated with production/inventory decisions. The authors provide an in-depth survey of the literature where price is a decision variable, where customer demand depends on the price chosen, and where production/inventory decisions

can be coordinated with pricing. They consider a variety of pricing strategies, including dynamic pricing, simultaneous pricing of multiple products, and pricing across customer segments; they also consider different forms of price coordination, including price-coordination across multiple channels and price-coordination with production lead time decisions and capacity investment decisions. They devise a taxonomy which classifies the literature in terms of nine key elements. Collaborative forecasting is another significant issue in supply chain coordination. In **Chapter 10**, Aviv provides an in-depth examination of collaborative forecasting models and their impact on supply chain performance. He describes models using the *linear state-space framework* that integrates the demand process with forecasting, inventory control, and collaboration processes. He surveys demand models that can be used in an integrative collaborative forecasting model. He then discusses the dynamic inventory control problem for each of the demand models. An integrative model in a two-stage supply chain is presented in detail, and the author describes the evolution of information and replenishment policies along with the value of information sharing in the context of this model. The author further examines the benefits of collaborative forecasting processes in a certain auto-regressive demand environment and their impact to the inventory cost performance. In **Chapter 11**, Ball, Chen, and Zhao give an overview on the Available to Promise (ATP) business process. ATP is the set of capabilities that supports the response to customer order requests. Traditionally ATP refers to a simple database lookup into the Master Production Schedule. As the variety and complexity of product offerings increase, ATP has become a key E-Business function that requires sophisticated modelling and IT support. The authors provide an overview of ATP-related research as well as of business practices. They classify ATP research into two main categories: push-based models that allocate resources and prepare responses based on forecasted demand and pull-based models that generate responses based on actual customer orders. Directly related to ATP is the issue of lead-time quotation, or more generally, due date management. In **Chapter 12**, Keskinocak and Tayur provide an extensive survey of the due date management (DDM) literature. Due date management decisions typically include order acceptance (demand management), due date quotation, and sequencing and scheduling. The authors survey a wide variety of DDM models, including off-line models that assume the demand is known *a priori*, on-line models that consider dynamic arrival of orders, models that consider service level constraints, and models that consider order acceptance and pricing decisions. They point to several important research directions directly relevant to the E-Business environment.

2.4 Multi-Channel Coordination

Integrating traditional and Internet channels is among the most significant E-Business developments that have a direct impact on supply chain management. For instance, an emerging retail structure known as "bricks-and-clicks" allows retailers such as Best Buy and Circuit City to maintain market presence through the Internet and the physical stores. However, the retailers must face significant operational challenges in effectively coordinating the dual channels. After all, the Internet stores require no physical inventory, and it is common for the wholesalers to stock and own the inventory and ship directly to the customers at the retailers' request. In **Chapter 13**, Tsay and Agrawal provide a review of quantitative models for multi-channel coordination. They focus on the issue of channel conflict where one channel may object to the actions taken by another (e.g., pricing, tax, shipping charges). They note that the fear of alienating incumbent channel intermediaries is among the most cited reasons why many manufacturers choose to avoid direct (Internet or otherwise) sales. The authors emphasize the implications of Internet sales for supply chain distribution strategies and suggest potential research opportunities. In **Chapter 14**, Netessine and Rudi present an in-depth analysis of drop-shipping Internet channel, in which the retailer handles customer acquisition, but the wholesaler takes inventory risk and performs fulfillment. They conduct a game-theoretic analysis aiming to compare three distinct supply chain settings: (1) a vertically integrated supply chain, (2) a traditionally structured supply chain where the retailer assumes the inventory risk, and (3) a drop-shipping supply chain. They consider three different power structures for the drop-shipping supply chain: a powerful wholesaler, a powerful retailer, and an equally powerful wholesaler and retailer. They demonstrate how decision power affects the decision variables and profits, and they show that both the traditional and drop-shipping supply chains are system sub-optimal. They further show that inefficiencies arising in the drop-shipping channel are different from these in the traditional channel and propose a new mechanism that coordinates the former. In **Chapter 15**, Cattani, Gilland, and Swaminathan provide a literature survey on multi-channel coordination. They construct the survey based on three channel coordination opportunities along the supply chain: procurement, pricing, and distribution. In this order, they consider research in e-procurement and electronic marketplaces, pricing coordination between traditional and Internet channels, and distribution/fullfillment strategies. The survey focuses on quantitative models based on four basic settings: independent competition, bricks-and-clicks, forward integration, and full integration.

2.5 Network Design, IT, and Financial Services.

Fundamental to the operations and execution in a supply chain are the issues of network design and information technology. E-Business potentially increases the complexity of and changes the design criteria for these systems. In this part of the handbook, we devote three chapters to the state-of-the-art concerning supply chain network design, production/distribution integration, and ERP systems. While significant supply chain infrastructures have been put into place in the retail and manufacturing sectors, the use of supply chain and E-Business concepts is only beginning to penetrate service sectors such as health care and financial services. We will devote the final chapter to the impact of supply chain and E-Business on financial institutions. In **Chapter 16**, Kouvelis and Munson describe a conceptual framework for analyzing strategic international facility network structures. They suggest ways to operationalize the conceptual framework as a managerial tool for the design and monitoring of a facility network. Three main dimensions are being considered: market focus, plant focus, and network dispersion. The authors use global sensitivity analysis to develop a structural equations model based on a mixed integer program that captures essential design tradeoffs of global networks and explicitly incorporates government subsidies, trade tariffs, and taxation issues. The resulting structural equations model classifies a firm's network structure according to the authors' conceptual framework via the calculation of a few key independent variables. The chapter exemplifies current research efforts in building comprehensive models that capture the complex facets of global supply networks, taking into consideration factors such as tariffs, transportation costs, and subsidized financing opportunities. Focusing on a similar modeling paradigm, Chen provides in **Chapter 17** a comprehensive survey of integrated production and distribution models in the supply chain literature; his survey focuses on mathematical programming models. He suggests a taxonomy that classifies existing models into five classes based on the level of decisions, the structure of production-distribution integration, and problem parameters such as infinite/finite horizon, single/multiple period, and constant/dynamic demands. He reviews each class of problems and suggests important directions for future research. In **Chapter 18**, Griffin and Scherrer provide a survey of next generation Enterprise Resource Planning (ERP) systems. They suggest that current ERP systems have not lived up to their initial promise, particularly in the E-Business environments. They explore some of the reasons for this unsatisfactory performance and discuss new development trends in next generation ERP systems. The authors focus their discussion on the issues of scalability and decentralization and discuss research needs in these areas. In **Chapter 19**, Soteriou and Zenios offer their unique perspectives on the impact of supply chain and E-Business concepts to financial services. Specifically, they build on

previous literature in this area by discussing e-banking services; they present a new business model that focuses on the market potentials of e-banking and explore factors for a successful e-banking strategy. The authors review some major changes in the world of financial services in the E-Business era, and examine both supply and demand forces that shape Internet-based financial services. They present a case study base on a personal financial planning system deployed by several Italian banks, and analyze some of its components in light of their business model.

3. Conclusions

The area of quantitative supply chain analysis is undergoing profound changes due to the fast emergence of E-Business practices in the industry. This handbook is an attempt to gauge the broader impact of E-Business on supply chain research. We hope that this is not the end but the beginning of an era where new ideas and innovation opportunities brought by E-Business provide the catalyst for next generation development of supply chain strategies. We believe that the body of fundamental research summarized in this handbook will play a pivotal role in shaping the future of this development.

Acknowledgments

We are grateful to Lian Qi and Jia Ren who completed the typesetting of this handbook. We acknowledge the supports from Kluwer Academic Publishers throughout the preparation of the manuscript.