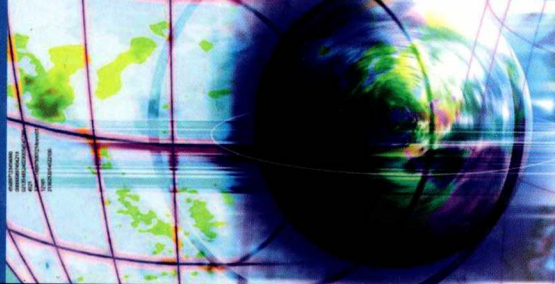


WILEY HANDBOOKS IN
OPERATIONS RESEARCH
AND MANAGEMENT SCIENCE



HANDBOOK OF INTEGRATED RISK MANAGEMENT — IN — GLOBAL SUPPLY CHAINS

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THE HANDBOOK OF

Integrated Risk Management in Global Supply Chains

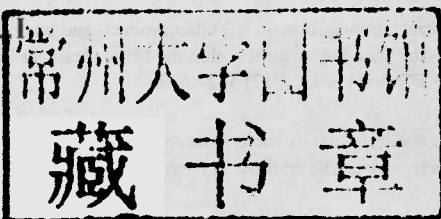
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Published by John Wiley & Sons, Inc., Hoboken, New Jersey
Published simultaneously in Canada

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Library of Congress Cataloging-in-Publication Data

Handbook of integrated risk management in global supply chains / Panos Kouvelis... [et al.].

p. cm. — (Wiley handbooks in operations research and management science)

Includes bibliographical references and index.

ISBN 978-0-470-53512-7

1. Business logistics. 2. Delivery of goods—Management. 3. Risk management. 4. Globalization. I. Kouvelis, Panos.

HD38.5 .H354 658.5—dc22

2011015212

Printed in the United States of America

oBook ISBN: 978-1-118-11580-0

ePDF ISBN: 978-1-118-11577-0

ePub ISBN: 978-1-118-11579-4

eMobi ISBN: 978-1-118-11578-7

10 9 8 7 6 5 4 3 2 1

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Wiley Handbooks in

OPERATIONS RESEARCH AND MANAGEMENT SCIENCE

The *Wiley Handbooks in Operations Research and Management Science* is a series of books that present both established techniques and cutting-edge developments in the field of operations research and management science. The goal of each handbook is to supply a practical, one-stop reference that treats the theory, formulae, and applications that, together, make up the cornerstones of a particular topic in the field. A self-contained presentation allows each volume to serve as a quick reference on ideas and methods for practitioners, while providing an accessible introduction to key concepts for students. The result is a high-quality, comprehensive collection that serves as a mainstay for novices and professionals alike.

Kouvelis, Dong, Boyalati, and Li · *Handbook of Integrated Risk Management in Global Supply Chains*

Forthcoming Wiley Handbooks in Operations Research and Management Science

Sokolowski and Banks · *Handbook of Real-World Applications of Modeling and Simulation*

Foreword

Globalization and the unbundling of value chains have been the major factors in the growth of global supply chains in the past two decades. These reflect the two fundamental factors driving economic growth identified over two centuries ago by Adam Smith in *The Wealth of Nations*: namely specialization (to achieve economies of scale) and trade (to link the most cost-effective sources of product design and manufacturing to end markets). Coupled with trade liberalization and the benefits of Internet-based IT, unbundling and globalization of trade have driven a veritable explosion of economic growth in the 1990s to the present. This has included the developments in market-based and financial institutions of the European Union and the increasing salience of the BRIC countries (Brazil, Russia, India, and China). In particular, China and India began their ascent to global leadership in low-cost manufacturing and services, including information-based technology support. All of this has been reflected in the huge increases in outsourcing and offshoring evident in the past decade for low-cost sources of goods and services and the unbundling of global supply chains.

While business and entrepreneurship, and rational trade policy, are the natural vehicles for realizing the power of globalization, operations and global fulfillment architectures have become the primary “glue” for integrating multitiered, global networks. The “new operations” that have emerged in the past decade reflects a strategic view of the supply chain and greater emphasis on information and financial flows across the network. Starting with Michael Porter’s work on the value chain in the 1980s, and motivated by the huge success of the supply-chain rationalizations of the 1990s, many of the most successful and innovative companies have come to formulate their strategies and business models in operational terms. These have come in the guise of innovative approaches to supply chain design based on operational flexibility and the network reconfiguration and sourcing strategies. In this evolution, companies have moved from a narrow focus on cost and leanness to an appreciation of the customer’s willingness to pay for reliability and tailored logistics solutions and to a closer scrutiny of the total financial costs and risks of supply relationships. Against this background, this text is a timely contribution to the critical and developing theme of integrated risk management for supply strategy. With the noted increasing organizational and geographic complexity of supply operations, business leaders face a complex fabric of risks from extreme weather events to major accidents to financial crises, in addition to the normal business risks of coordinating supply and demand through effective supply operations. Understanding and mitigating these risks by all supply chain participants

is now recognized as an essential accompaniment to profitability and long-term value creation.

The editors have brought together here the front line of the management science research community dealing with these issues. They have confronted them with a double challenge: first, to summarize the frontiers of research on integrated risk management for supply chain design and operations, and second, to draw the implications of this research for practice. The result is a splendid synthesis and contribution to our knowledge of how global supply chains are evolving and the fundamental role of risk management in assuring their robustness and resilience. In the process, the papers here also indicate the importance of integrating operations and finance in assuring profitability in the networked environment, which is now the essential frame for companies and economies across the globe. It is a distinct pleasure to see this set of essays appear, mapping both our current state of knowledge and the challenges ahead for business and research.

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Preface

Risks have always been a part of business reality. However, the extraordinary growth of global trade in the past several decades have taken the multitude and magnitude of risks to a new level of significance. The trend of globalization has put virtually every company in the massive, complex global trade network. On the one hand, the interconnection introduces to supply chains tremendous opportunity of cost reduction, access to labor/talent pools, capitals, and markets. On the other hand, the increase in supply chain scope presents new challenges that go beyond the typical supply chain concern of demand and supply uncertainties. Companies that were traditionally local or national oriented are now affected by the world commodity price shocks, currency fluctuations, and even by trade policy and law changes in other countries. Conversely, glitches at a supplier in one country may cause significant business disruptions downstream in another country. Added to the complexity in supply chain paradigm and convoluted dependence among supply chain members is the increasing frequency of natural disasters (hurricane, earthquake, volcano eruption, etc.) and political instability in parts of the world, which consequently superimpose another layer of change to companies' risk profiles. Local catastrophic events more often than not have impacts on businesses around the world, and collectively they are no longer rare events that companies can afford to merely react to on an ad hoc basis.

Companies have come under growing pressure to develop risk management schemes that identify the risks they are facing, measure the likelihood of occurrence and the scope and magnitude of the impact, and mitigate the detrimental impact. The urgency of seeking comprehensive risk management tools has motivated academicians to expand the supply chain management research in the direction of incorporating various aforementioned risks into the scope of study. Recognizing the multifunctional nature of the challenges faced by business, this growing area of research, appropriately titled as "integrated risk management," fully embraces a multidisciplinary approach that exploits recent development in finance, decision theory, operations research, and supply chain management to manage the complex, highly interacting, and diverse global supply chain risks.

The main objectives of this handbook are

1. To provide a collection of original ideas on the integrated risk management in operations and global supply chain to help academicians and practitioners develop a multifunctional perspective on these issues.

2. To offer managerial insights and outline challenges in identifying, measuring, and controlling risks in practice.
3. To raise important questions that remain unanswered, so as to set the agenda for future research that fully reflects the interdisciplinary nature of the risk management, measurement, and control challenges in operations and global supply chains.

We have organized 20 chapters of the handbook in five Parts. Part I, Foundation and Overview, provides general frameworks in supply chain risk management and overviews of some theoretical methodology. Parts II, III, IV, are devoted to the three themes of research on risk mitigation strategies, respectively, Integrated Risk Management, Supply Chain Finance, and Operational Risk Management Strategies. Lastly, Part V, Industrial Applications, showcases supply chain risk management in practice.

Foundation and Overview

Part I consists of five chapters. In Chapter 1, Integrated Risk Management: A Conceptual Framework with Research Overview and Applications in Practice, Kouvelis, Dong, Boyabatlı, and Li present an action-based supply chain risk management framework with insightful discussions on categorizations of risks and on actions should be taken in the planning and execution stages of risk management. Mapping the growing research field of integrated risk management within the context of the proposed conceptual framework, they identify a number of interesting directions for future research.

In Chapter 2, Risk Management and Operational Hedging: An Overview, Jan Van Mieghem provides an introduction and overview of risk management and broad operational hedging techniques, offers a view of treating risk management as an integral part of operations strategy, and describes in detail a four-step risk management process including risk identification, risk assessment, tactical risk decisions, and operational hedging implementation. The author also briefly discusses the financial hedging of operational risks.

The sense of urgency that the need for disruption risk management tools is universal across industries is clearly communicated in Chapter 3, The Effect of Supply Chain Disruptions on Corporate Performance, by Kevin Hendricks and Vinod Singhal. They investigate the impact of supply chain disruptions on the corporate performance. The evidence indicates that firms continue to operate at a lower performance level for at least two years after experiencing disruptions. Given the significant economic losses, firms cannot afford such disruptions even if they occur infrequently. A key managerial insight is that overemphasis on efficiency and removing slack from the system can make supply chains vulnerable, unreliable, and nonresponsive: While efficient and lean supply chains are desirable objectives, they should not come at the expense of reliability and responsiveness.

Different operational strategies have different strengths and limitations in managing supply chain disruption risks. In Chapter 4, *Operational Strategies for Managing Supply Chain Disruption Risk*, Brian Tomlin and Yimin Wang provide a roadmap to supply chain managers in designing and implementing their disruption mitigation strategy, including stockpiling inventory, supply diversification, backup supply, demand management, and supply chain strengthening. The key managerial insight is that a one-size-fits-all approach of employing the same strategy for all product lines may not be appropriate if different products exhibit different supply chain and market characteristics. The disruption management strategy should be tailored to the needs of each product.

When firms do not have sufficient data to characterize the probability distribution of risks they are facing, they are exposed to decision making under ambiguity. Using traditional performance measures such as expected value or mean-variance utility becomes problematic, and there is a need for defining appropriate performance measures under ambiguity. Karthik Natarajan, Melvyn Sim, Chung-Piaw Teo, in Chapter 5, *Beyond Risk: Ambiguity in Supply Chains*, address this issue. They review the notion of ambiguity (origination, evidence, and models) from different academic fields and link it to supply chain management practice. They discuss one of the most popular approaches to account for aversion to ambiguity, the maximin expected utility (MEU) theory, and demonstrate the implications of this theory in making operational decisions in a supply chain framework.

Integrated Risk Management

Part II, *Integrated Risk Management*, consists of four chapters, all exploring the joint use of operational and financial hedging of commodity price uncertainties.

In Chapter 6, *Managing Storable Commodity Risks: Role of Inventories and Financial Hedges*, Panos Kouvelis, Rong Li, and Qing Ding consider a risk-averse buyer who dynamically maximizes the mean-variance utility of the cash flows in a multiperiod setting. The commodity buyer procures from a long-term supply contract and from the commodity market, and hedges the price and demand uncertainties dynamically, using all financial derivatives written on the commodity price, such as futures contracts, call and put options, and so on. They derive an optimal time-consistent integrated policy of inventory and financial hedging. They find, contrary to results in the existing literature, that myopic hedging is not optimal; financial hedging may lead to inventory reduction in multiperiod problems. Finally, insights are offered on the impact of the physical inventory and financial hedging on the profitability, variance control, and service level to the customer.

In Chapter 7, *Integrated Production and Risk Hedging with Financial Instruments*, Çağrı Haksöz and Sridhar Seshadri provide a review of the existing literature on integrated operational hedging and financial hedging decisions for a risk-averse firm that produces a commodity and maximizes the expected utility (general utility or mean-variance objective), in single-period and multiperiod

settings. They investigate the effectiveness of the optimal use of a fixed-price long-term contract and spot market trading for a risk neutral commodity producer in a continuous-time model.

Contingency planning is a powerful risk-mitigating tool and is widely used in industry. Bardia Kamrad, in Chapter 8, *Capacity Expansion as A Contingent Claim: Flexibility and Real Options in Operations*, provides a review of the real options framework for evaluating contingency claims. In this methodological chapter, he discusses the no-arbitrage financial pricing model for contingent claims (e.g., options) and introduces how to apply this model to value real options in the context of a capacity investment problem. Advantages and disadvantages, rising from the difference between financial options and real options, are also discussed.

In Chapter 9, *Financial Valuation of Supply Chain Contracts*, Mustafa Pinar, AlperŞen, and A. Gökay Erön apply the no-arbitrage financial pricing model for contingent claims to value multiperiod supply contracts. They consider a setting where the demand is perfectly positively correlated with a risky security, and both the financial and the demand markets evolve as discrete scenario trees. The buyer is committed at the beginning of the planning horizon to purchase a fixed quantity of inventory each period and a multiperiod option contract, which allows the buyer to determine how much to buy (or how many options to exercise) each period after observing real demand. An experimental study is presented to illustrate the sensitivity analysis.

Supply Chain Finance

Part III, *Supply Chain Finance*, consists of four chapters. The first two chapters study financing alternatives available to budget-constrained supply chain members in a linear supply chain of a newsvendor retailer and a supplier, as well as the presence of a financial institution (e.g., a bank). In Chapter 10, *Supply Chain Finance*, Panos Kouvelis and Wenhui Zhao consider supply contracts that could effectively serve as trade credit contracts that the supplier offers to the retailer. A key managerial insight is that when both the supplier and the retailer have access to competitively priced short-term bank loans, it is in the best interest of the risk neutral supplier to offer trade credit to the retailer with an interest rate lower than or equal to the risk free rate; and if optimally parameterized, the retailer always prefer such trade credit. Contrasting to the known result that buyback contracts, revenue sharing contracts, and all-unit discount contracts all coordinate a supply chain without budget constraints, the authors demonstrate that none of these contracts coordinate a budget-constrained supply chain though yield different levels of supply chain efficiency.

In Chapter 11, *The Role of Financial Services in Procurement Contracts*, René Caldentey and Xiangfeng Chen consider a model that is similar to the previous chapter except a difference in the assumption of when the retailer's budget constraint limits his ordering quantity. The authors reach similar conclusions regarding the benefit of trade credit over bank loans. A key managerial insight

is that the value of trade-credit for the retailer is non-monotonic in his internal budget, and there is an intermediate budget level at which his expected payoff is maximized.

Within the context of a single firm, “When is the separation of operations and finance a good enough approximation of reality, and when should these functions be coordinated because the interactions are too important to ignore?” are the fundamental questions that Qiaohai (Joice) Hu, Lode Li, and Matthew Sobel address in Chapter 12, Production/Inventory Management and Capital Structure. They consider a setting where bankruptcy is costly, and hence the Modigliani-Miller Theorem no longer holds. Specifically, they study the integration of operational and financial decisions for a public firm that maximizes the expected present value of the dividends issued each period. In each period, the firm makes short-term decisions, including inventory (operational) and loan and dividend (financial), as well as long-term decisions, including long-term debt level. In a multiperiod framework, the chapter analyzes the optimal level of operational and financial decisions, the value of integrating the operational and financial decisions, and the relationship between the short-term and long-term decisions.

When the retailer does not have access to a perfectly competitive banking industry, the interaction between the retailer and the bank becomes strategic, with the bank turning into a profit maximizing lender. This is the scenario considered in Chapter 13, Bank Financing of Newsvendor Inventory: Coordinating Loan Schedules, by Qiaohai (Joice) Hu and Maqbool Dada. A key managerial insight is that the bank’s profit tends to increase when the retailer’s demand distribution becomes less skewed, and a nonlinear profit splitting loan mechanism can coordinate the financial supply chain of the bank and the retailer.

Operational Risk Management Strategies

Part IV, Operational Risk Management Strategies, consists of three chapters. In Chapter 14, Decentralized Supply Chain Risk Management, Göker Aydın, Volodymyr Babich, Damian Beil, and Zhibin Yang provide a taxonomy of supply risks and discuss challenges to manage those risks in decentralized supply chains where self-interested firms are interacting. Four key challenges are emphasized in managing supply risk in decentralized supply chains: misalignment of incentives between buyers and suppliers, competition among suppliers, competition among buyers, and asymmetric information. Through an in-depth review of literature they discuss the tools and trade-offs involved in the use of various operational risk management tools.

Focusing on the effectiveness of using supplier portfolios to cope with demand uncertainty, Victor Martínez-de-Albeniz studies the optimal sourcing decisions and investigates the trade-off between cost and flexibility in procurement in Chapter 15, Using Supplier Portfolios to Manage Demand Risk. A buyer contracts with two suppliers, a low-cost supplier offers a contract with no adjustment flexibility, and a high-cost supplier offers the flexibility that allows the buyer to adjust

quantities after receiving demand forecast updates. The key managerial insight is that the firm should use the low-cost contract to fulfill the demand that materializes with high likelihood, and use the high-cost, but more flexible, contract to fulfill the fraction of demand that has higher uncertainty. The author also investigates the value of using portfolio of contracts over using a single contract and the impact of demand uncertainty on this value.

Inventory buffering is another effective tool to cope with demand uncertainty. In Chapter 16, An Opportunity Cost View of Basestock Optimality for the Warehouse Problem, Nicola Secomandi shows an easy-to-understand derivation of the optimality of the two-level basestock policy, a common trading practice in the commodity industries. The author illustrates that the results based on a simple modeling setting provides insights on the policies that should be adopted in more complex environments, the development of computational algorithms, and financial hedging policies.

Industrial Applications

Part V, Industrial Applications consists of four chapters. In Chapter 17, Procurement Risk Management in Beef Supply Chains, Onur Boyabatlı, Paul Kleindorfer, and Stephen Koontz study the commodity price risk management of a meatpacker in beef supply chains. In particular, they consider the optimal mix of contract and spot purchases in providing input (fed cattle) to a meatpacker from upstream feedlots and spot markets, when the meatpacker acts as a wholesaler into beef-product markets. They describe the background of the U.S. beef industry and provide computational results based on data for the U.S. beef industry described in the GIPSA Report (2007), and complemented the analysis by industry demand and supply studies. The analysis is focused on determining the impact on the optimal procurement portfolio, the expected profit, the value of spot and contract market and the expected plant utilization of spot price and demand uncertainty, the degree of substitution between products in final markets, as well as the cost characteristics of the meatpacker and the nature of quality and cost differences in the contract and spot markets. The chapter provides a foundation for understanding the complementary roles of contract and spot markets in U.S. beef markets.

In Chapter 18, Risk Management in Electric Utilities, Stein-Erik Fleten, Jussi Keppo, and Erkka Näsäkkälä review two main risks in electricity markets: volume risk and price risk. The authors provide a discussion on how to model and hedge these risks. They introduce a continuous stochastic process to model both types of risk. The optimal timing of a single trade of forward contracts is determined to minimize the variance of the cash-flow at the end of the planning horizon. Other practical risks in electricity markets, including liquidity risk and operational and political risk, are also discussed.

The final two chapters provide a holistic view of supply chain risk management from the perspective of industry practitioners. In Chapter 19, Supply Chain Risk Management: A Perspective from Practice, Colin Kessinger and Joe McMorrow

offer a practical approach for assessing risk and resiliency in the supply chain: what is supply chain risk management (SCRM), how to develop SCRM capabilities, and what is SCRM process approach, and so on. They illustrate a case study of Cisco Systems' response to the 2008 Sichuan Earthquake.

Focusing on how to enable quick response after the occurrence of risk events, in Chapter 20, A Bayesian Framework for Supply Chain Risk Management Using Business Process Standards, Changhe Yuan, Feng Cheng, Henry Dao, Markus Ettl, Grace Lin, and Karthik Sourirajan develop a Bayesian graphical model to identify, quantify, mitigate, and respond to the risks affecting global supply chains. Based on the risk categorization network, which maps risk factors to business processes, this Bayesian model enables automatic learning using information such as business process standards, heterogeneous operational data, and expert knowledge. This methodology is further illustrated using a case study based on global logistics process performance data.

Acknowledgments

First and foremost, we sincerely thank all the authors who contributed to this handbook: Jan Van Mieghem, Vinod Singhal (Kevin Hendricks), Brian Tomlin (Yimin Wang), Melvyn Sim (Karthik Natarajan, Chung-Piaw Teo), Qing Ding, Sridhar Seshadri (Çağrı Haksöz), Bardia Kamrad, Mustafa Pınar (Alper Şen, A. Gökay Erön), Wenhui Zhao, René Caldenteu (Xiangfeng Chen), Lode Li (Qiaohai (Joice) Hu, Matthew Sobel), Maqbool Dada, Volodymyr Babich (Göker Aydın, Damian Beil, Zhibin Yang), Victor Martínez-de-Albeníz, Nicola Secomandi, Paul R. Kleindorfer (Stephen Koontz), Jussi Keppo (Stein-Erik Fleten, Erkka Näsäkkälä), Colin Kessinger (Joe McMorrow), Grace Lin (Changhe Yuan, Feng Cheng, Henry Dao, Markus Ettl, Karthik Sourirajan). Their enthusiastic support to this project has made the process a great experience for us.

We want to thank our doctoral students at Olin Business School, Washington University: Ehsan Bolandifar, Xingxing Chen, Junghee Lee, Zhili Tian, Mike Mingcheng Wei, Xiaole Wu, Yixuan Xiao, Yueshan Yu, who read the earlier draft of the manuscripts and offered many insightful suggestions for improvement.

We are indebted to Paul R. Kleindorfer for encouraging and supporting this book project, and generously agreeing to write a foreword to this book.

We are grateful to the organizers and participants of the Mini-conferences on Integrated Risk Management in Operations and Global Supply Chain Management held at Washington University in St. Louis in 2004, 2005, 2007 (sponsored by The Boeing Center on Technology, Information and Manufacturing), at the University of Michigan in 2006, and at Lee Kong Chian School of Business, Singapore Management University in 2008. Those conferences promoted the early research in integrated risk management and helped shape this emerging field of research.

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