
The Structure of Global Supply Chains

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Panos Kouvelis

*Washington University in St. Louis
USA
kouvelis@wustl.edu*

Ping Su

*SUNY New Paltz
USA
sup@newpaltz.edu*

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Foundations and Trends[®] in Technology, Information and Operations Management

Published, sold and distributed by:

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PO Box 1024
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www.nowpublishers.com
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Outside North America:

now Publishers Inc.
PO Box 179
2600 AD Delft
The Netherlands
Tel. +31-6-51115274

The preferred citation for this publication is P. Kouvelis and P. Su, The Structure of Global Supply Chains: The Design and Location of Sourcing, Production, and Distribution Facility Networks for Global Markets, *Foundations and Trends[®] in Technology, Information and Operations Management*, vol 1, no 4, pp 233-374, 2005

ISBN: 978-1-60198-098-4
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Foundations and Trends[®] in Technology, Information and Operations Management, 2005, Volume 1, 4 issues. ISSN paper version 1571-9545. ISSN online version 1571-9553. Also available as a combined paper and online subscription.

Foundations and Trends[®] in
Technology, Information and Operations Management
Vol. 1, No. 4 (2005) 233–374
© 2007 P. Kouvelis and P. Su
DOI: 10.1561/0200000003



The Structure of Global Supply Chains: The Design and Location of Sourcing, Production, and Distribution Facility Networks for Global Markets

Panos Kouvelis¹ and Ping Su²

¹ *Olin School of Business, Washington University in St. Louis, St. Louis, MO 63130, USA, kouvelis@wustl.edu*

² *School of Business, SUNY New Paltz, New Paltz, NY 12561, USA, sup@newpaltz.edu*

Abstract

In today's marketplace, most companies realize that it is essential to be aware of and participate in international markets. Furthermore, it becomes transparent that the footprint of the firm's global facilities for sourcing, R+D, production, distribution and sales, and the effective coordination of all flows between them become the major determinants of competitive success. In other words, global supply chain management is a core business process of the utmost strategic importance and all firms have to manage it as such. The authors provide a better understanding of the development of the right "footprint" of a global firm in its effort to supply its markets in environments of fast paced competition and tremendous uncertainty. The authors focus on the structure of global supply chains and the detailed choices involving the network of facilities at all stages of the supply chain in order to successfully execute the global business strategy.

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1

Introduction — Issues to Consider

Over the past two decades, a new global business environment has evolved. World exports of goods and services reached \$13.7 trillion in 2006, which was close to 30% of world gross domestic product, up from a mere 10% two years ago. The vast majority of businesses now has some form of global presence through exports, strategic alliances, joint ventures, or as part of a committed strategy to sell in foreign markets or locate production plants or business process services abroad. American manufacturers have 8000 units overseas employing almost 5 million workers, equal to nearly 25% of US manufacturing employment. Previously, large multinational corporations dominated the international marketplace, which domestic firms generally ignored. However, according to the 2001 census, 97% of manufacturers who exported were considered small- or medium-sized. In today's marketplace, most companies realize that it is essential to be aware of and participate in international markets. Furthermore, it becomes transparent that the footprint of the firm's global facilities (fully or partially owned, or simply accessed through joint ventures and strategic alliances, or just simply as part of outsourcing deals) for sourcing, research and development, production, distribution and retail sales, and the effective coordination and

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management of all flows between them (information, physical/product, and financial flows) become the major determinants of competitive success. In other words, global supply chain management is a core business process of the utmost strategic importance, and all firms have to manage it as such. The focus of this paper is on better understanding the development of the right “footprint” of a global firm in its effort to supply its markets in environments of fast paced competition and tremendous uncertainty (from political, macroeconomic, demand, and technological factors contributing to it). We are concerned with the structure of global supply chains and the detailed choices involving the network of facilities at all stages of the supply chain (sourcing, production, distribution, and sales) in order to successfully execute the global business strategy.

1.1 Globalization of Operations and Supply Chains

Let us elaborate on documenting the globalization of firms’ operations and supply chain strategies. The following trends among US businesses illustrate the growing size and importance of global operations:

- According to the US Census, from 2003 to October 2005, the value of goods imported rose nearly 45% while the value of goods exported rose only 31.3%. Overall the trade deficit for goods rose 62% in that time.
- When other characteristics of companies are held constant, exporting firms perform much better than non-exporters. Worker productivity in exporting firms is 20% higher than that of non-exporting firms. Export jobs are better jobs: production workers in exporting firms earn 6.5% more. They are also more stable jobs: exporting firms are 9% less likely to go out of business than comparable non-exporting firms (Bergsten [3]).
- According to US Census information from 2001 to 2002, nearly 20% of US manufacturers participate in exporting, accounting for over 71% of the total known value for exports.
- Manufacturing assets held by multinational enterprises in foreign countries are substantial and rapidly increasing.

- Much of the US trade deficit represents what US corporations buy from their overseas units. In the late 1990's such foreign affiliates of US corporations generated close to \$3 trillion in sales, with 65% of that sold to local markets and the remaining 35% brought back to United States.
- In 2004 about 8% of administrative office work had been outsourced, much of it to India. In IT services, 16% of all IT work is done by an outsourced party. Much like manufacturing in the 1980's and 1990's, Business Process Outsourcing (BPO) is a growing trend, estimated to grow from \$3.6 billion in 2003 to \$21–\$24 billion by 2008.

Two factors underlie the dramatic rise in globalization. First, global reach is important to a firm's survival. Second, multinational firms are more profitable and grow faster. Among twenty major US manufacturing industries, multinational firms grew faster than domestics in 19 of the cases and were more profitable in 17 cases (Bergsten [3]).

1.2 Driving Forces of Globalization of Operations Strategies

As clearly explained in the recent work of Kouvelis and Niederhoff [24], the motivating factors, or often stated as the driving forces, for globalization of operations can be grouped into four:

Category 1: Global Market Forces. Market forces for globalization include the need to establish a presence in foreign markets to capitalize on foreign demand and recoup domestic demand lost to foreign imports, as well as to build a global presence to minimize foreign threats into the domestic market through a competitive balance. As the existence of secondary markets for end-of-life products begins to fade, speed to market sometimes dictates a global production and distribution network. Finally, as state-of-the-art niche markets develop in specific countries, companies must consider establishing a presence in these markets to stay competitive and abreast of the latest technology developments and demands.

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Category 2: Technological Forces. Many companies seek a global market in order to achieve economies of scale as they simultaneously narrow the scope of their product to a niche market by differentiating themselves in a commodity market. This, in effect, is the mass customization of a good at a global-level.

As technological production skills develop globally, multinational firms need to tap into the technological knowledge of various countries and integrate the new technology into their own product as necessary to stay competitive. In order to stay current and access these new developments in real time, global companies may benefit by forming close relationships with dominant foreign suppliers instead of investing in an in-house capability. Additionally, by placing production facilities close to the state-of-the-art suppliers and competitors, costly delays due to breakdowns are minimized. Globally located firms can also engage in technology sharing and interfirm collaborations, and take advantage of state-of-the-art or lower priced R&D workers in countries such as Taiwan, China, and India.

Category 3: Global Cost Forces. Perhaps the most commonly recognized force for globalization, experiences from previous global expansion projects, and some of their failures, indicates that costs to consider for offshore sourcing should go beyond just direct labor and definitely include quality, differential productivity, and design costs, and carefully account for added logistical and transportation costs. Often, direct labor is such a small component of total product cost that it is misleading to offshore solely on the basis reduced labor costs. In industries with capital-intense production facilities, globalization can be a natural result of multiple firms seeking a joint production facility or a single firm seeking economies-of-scale through high utilization of a private production facility.

Category 4: Political or Macro-economical Forces. Currency rate fluctuations can help or hurt global operations and require careful analysis and, preferably, a portfolio of options to balance unfavorable fluctuations. Regional trade agreements, such as NAFTA, also influence the decision to globalize operations. Finally, the imposition of trade

protection mechanisms, such as tariffs, trigger price mechanisms, local content requirements, technical standards, health regulations, and procurement policies, influence where a company may choose to locate global operations in order to make the most of its supply chain.

1.3 Structure of Global Supply Chains: Issues to Consider

Strategic planning for global facilities networks is complex, involving decisions of where to locate factories, how to allocate production to the various facilities, how to develop suppliers for the plants, how to manage the distribution of products, and how to organize the interfaces along the global supply chain. The “givens” that frame these decisions are the company’s particular set of markets; products to produce and sell; demand projections for the different markets; and information about future macroeconomic conditions, transportation costs, and production economics (e.g., cost curves as a function of production volumes for each individual process step or component that goes into the product).

The very first issue typically addressed in global operations textbooks in an effort to capture, at least at a conceptual level, the issues associated with the structure of global supply chains is the so called “orientation of facility networks” concept (refer to Dornier et al. [10]). The “facility orientation” concepts are struggling to capture the concerns in global supply chain structure in an effort to create supply chains that meet the competitive priorities of the various products at the different markets. These priorities include cost, quality, service, and flexibility criteria, and in a dynamic global environment the added criterion of ability to react to environmental changes (i.e., hedge against uncertainties of the global environment) plays an important role. In general, current textbook theories orient facility networks by market, by product, and by process.

- (1) *Market Focus*: In this approach, the firm locates entire supply chains in different markets. The driving force behind location decisions is proximity to markets where products are sold. In such a scenario, the “supply” (supplier network and production) organization is decentralized and each supply

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chain produces the entire product line for its respective market. The “demand” chain (distribution and retail) is also decentralized and each market is treated separately.

- (2) *Product Family Focus*: Under this scheme, the firm locates segments of its supply chain (various facilities) in different parts of the world driven by economies of scale. Typically facilities specialize in a specific product family, with products in a product family sharing technical traits, components, setups and production lines, and often “business” similarities (competitive priorities, order profiles etc.). The “supply” organization is mainly centralized because the company has to manage the allocation of the different products to the different markets from the same set of facilities. Sometimes the organization might be decentralized if some product families belong in specific markets because of structural constraints such as import barriers. The “demand” chain organization may also be either centralized (with distribution and sales offices placing orders to the various facilities in the supply network to meet the needs of their markets) or decentralized (by operating distribution and sales networks at the various markets).
- (3) *Process Focus*: Using a process focus, a company locates facilities in different parts of the world, but each facility specializes in specific steps of the supply/production/logistic process (e.g., metal components, assembly facilities, plastic molding, large container transportation, high volume distribution facilities etc.). The driving force behind this strategy is economies of scale in particular processing and logistic steps. Therefore, the supply organization is centralized to coordinate the “bringing together” (e.g., assembly) of the different activities involved. The “demand” chain is also centralized to coordinate the “bringing together” of the logistic and sales activities for the different markets.

In reality, it is difficult to find a company that follows any of the above presented approaches exactly. However, by analyzing these different

approaches it is possible to understand some of the trade-offs inherent in structuring global supply chains. The textbook of Dornier et al. [10] does a great job in capturing these trade-offs at an introductory level, and we refer the interested readers to it.

To further elaborate at the abstract level on the issues of global supply chain structure, we use a simple two dimensional construct to map the various approaches for “facility orientation” we discussed above. The two dimensions we use reflect essential product characteristics: supply system complexity (abbreviated from now on as “supply” complexity) needed to produce them, and market demand requirements complexity (abbreviated from now on as market complexity). *Supply complexity* refers to the difficulty of the production processes of the various components and assemblies. For example, if we compare the hand tools industry with the computer industry, we see that the complexity for the first is lower than the second. Processing activity complexity can be based on a variety of factors, such as the number of processing steps, physical characteristics of the product, and environmental requirements. *Market complexity* captures the specifications and complexities the distribution and sales functions face in executing the delivery and customization requirements for the various customers and markets. The apparel industry, where fashion is the critical driver, has significantly higher “market” complexity than the electronic components industry, where customers are less fashion and more functionality and efficiency driven.

Figure 1.1 captures the different approaches as a function of the dimensions discussed. For low supply and market complexity, the market focus fits better. In this environment it is easier to serve customers when one facility or the whole regional chain is responsible for the entire product and the main drivers for customers are service and quality (as opposed to cost). As supply complexity increases, firms must specialize their supply and production facilities into specific activities (tasks), because quality becomes a critical element (i.e., shift to process focus). When combined with economies of scale, quality differentiation is adequate to give the firm a competitive advantage. If market requirements complexity is high, then the driver for going from a product family focus into the process focus is increased importance of economies of

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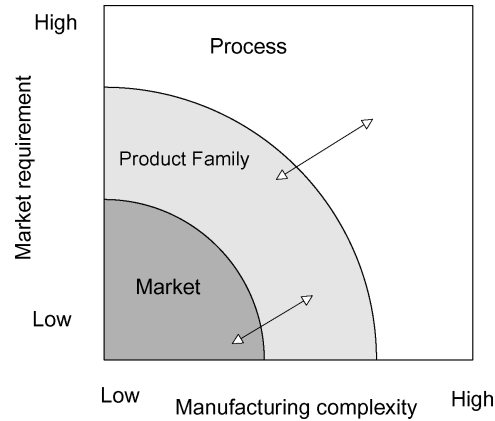


Fig. 1.1 Orientation of facility networks.

scale. When the market requirements complexity is low, such as in the apparel industry for some models of jeans with long product lifecycles, firms may decide to automate the supply process and through reduced supply complexity (via standardization and automation) move back from product family to market focus. In other words, the product family focus occupies the middle ground between market and process focus.

For an abstract and introductory discussion, global facilities network design issues are captured in such concepts of “facility orientation” and different global supply chain designs can be explained through simple two dimensional constructs along dimensions of “supply complexity” and “market complexity.” However, the main purpose of this research review is to go beyond such elementary exposition of global supply chain network design issues, and using the latest research on the subject to find ways to identify the multiplicity of factors that contribute to designing these networks for competitive advantage of the global firm, while at the same time exposing both the successful features but also the challenges faced by decision support systems developed to address such decisions. Our emphasis is on presenting approaches, which are built on the richness of operations and supply chain modeling research and support tools, going beyond abstract

discussion of trade-offs and into careful quantification of them. And then, such approaches, through systematic evaluation and selection processes often of an algorithmic nature, result in profit maximizing and risk controlling strategies for developing effective global supply chains. All presented approaches are based on rigorously documented academic and industrial research, most of it spanning seminal developments of the last 15–20 years, but with a heavier emphasis on tools and approaches of the last decade. Hopefully, the reader will find in adequate detail a comprehensive answer to the questions on how a global firm should configure its network of facilities (supply, production, and distribution), and what dynamic approaches to use to effectively reconfigure it in an effort to meet demand in global markets in a profit maximizing way of sustainable profitability and of enduring nature competitive advantage. We conclude this introductory section by describing the structure of our research review in answering these questions.

1.4 Structure of Our Review

In Section 2, we introduce the most important and practice relevant concepts in the literature on the issue of “facility orientation” of global supply chain networks. The first of these concepts is based on the recent research of Kouvelis and Munson [23], and classifies global facility network structures along three main dimensions: market focus, plant focus, and network dispersion. The authors argue in a rigorous manner via the use of a structural equations modeling approach that a few key independent variables, which are relatively easy to calculate, capture all essential trade-offs and allow us to classify a firm’s network structure along one of the above three dimensions. Specifically, economies of scale, complexity costs of the production system, transportation costs, and tariffs are the primary levers in determining a global firm’s network structure. The work of Kouvelis and Munson, effectively summarized in our section, develops aggregate ways to measure “economies of scale,” “complexity costs,” and relevant “transportation” and “tariff” costs, and then explicitly describe via empirically derived equations the casual relationship of these measures with appropriately defined measures of “market focus,” “plant focus,” and “network dispersion.”

Section 2 also contains discussion of the “popular” MBA classroom framework of Kasra Ferdows [12] of “six types of foreign factories.” The framework classifies foreign factories based on the three primary strategic reasons for the factory’s location (low cost production, access to skills and knowledge, and proximity to market), and the level of the site’s competence (low versus high). The third framework we present in this section is recently proposed by Vereecke et al. [37]. They focus on the intangible characteristics of plants. Along the lines of Ferdows’s work, they focus on the intangible characteristics of plants. This empirically derived typology is based on the knowledge flows between the plants. The fourth framework presented is the one by Cohen and Lee [7]. This is a broad framework addressing the various components of the supply chain and discussing various sourcing, plant charter, and distribution strategies.

In Section 3, we present the modeling details and the decision support tools for designing global supply chains. We first start with the global facility network model of Kouvelis and Munson [23], which is used both in the derivation of their conceptual framework and as a decision support tool for global supply chain design. Section 3 also includes the modeling framework proposed by Tsiakis et al. [33] on multi-echelon supply chain network design under scenario-based demand uncertainty. We then spend significant effort in describing an important approach, the “robustness approach,” in making global supply chain designs under significant uncertainty. The designed supply chain is robust in the sense that it hedges the firm’s performance against the worst contingencies in terms of uncertain factors (demand, exchange rates, commodity prices etc.) over a planning horizon. The work of Gutierrez and Kouvelis [14] formally introduced many of those early concepts and presented effective algorithmic procedures for the solution of the resulting difficult mixed-integer programs. The wide applicability of the approach is further illustrated in the work of Lowe et al. [27] in designing the global supply chain of the company illustrated in the popular case study of Applichem (Flaherty [13]), and thus making this material easy to transfer into MBA and executive classrooms. A by-product of this work is an easy quantification of the value of excess capacity in global supply chain networks, by illustrating that it is an essential feature of global supply

chain designs (see discussion in Lowe et al. [27]). We also present one of the better known decision support tools for global supply chain design, which originated from its application in the design of global supply chains for Digital Equipment Company and its early documentation appeared in the work of Arntzen et al. [2]. Finally, we conclude the section with an overview of the recent research that uses the news vendor network approach to design global facility networks, Lu and Van Mieghem [28] and Biller and Xiang [4].

In Section 4, we devote our attention to modeling and decision support approaches that explicitly deal with some added complexities and uncertainties often dominating and substantially complicating the supply chain design of global firms versus national or regional supply chains. These factors are: fluctuating exchange rates, price uncertainties (both of inputs and outputs), investment financing decisions of global facilities, regional trade agreement complexities and local content rules, international taxation complexities and transfer pricing schemes. We also include the stream of research of applying option valuation approach to value the operational flexibility under exchange rate uncertainty. Among the research works explicitly discussed are seminal work of Hodder and his coauthors (in [15], [16], and [18]), Daskin et al. [8], Huchzermeier and Cohen [19], Kogut [21], Kogut and Kulatilaka [22], Munson and Rosenblatt [29], Villegas and Quenniche [41], and Kouvelis et al. [25].

Finally, our Section 5 concludes with an extensive discussion of previous research survey works in the area of global supply chain design, thus allowing the reader to see the extensive literature from many different perspectives, and in the process we highlight different viewpoints and methodological and managerial insights. At the end we present a comprehensive classification scheme of the most important papers in the area of global supply chain network design.

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Biographies

Panos Kouvelis is the *Emerson Distinguished Professor of Operations and Manufacturing Management* at the Olin School of Business at Washington University in St. Louis, and he currently serves as the *Area Chair* of the Operations and Manufacturing Management (OMM) group at Olin. He also serves as the *Director of the Boeing Center on Technology, Information and Manufacturing at Washington University*. He has held visiting appointments with the Graduate School of Business, University of Chicago, where he taught in the executive programs in Barcelona, Chicago and Singapore, and Koblenz School of Management, Germany. He received his PhD in Industrial Engineering and Engineering Management at Stanford University, MBA and MS in Industrial and Systems Engineering at the University of Southern California, and a diploma in Mechanical Engineering at the National Technical University of Athens. He has previously taught at the *Fuqua School of Business, Duke University* and the Management Department of the *University of Texas at Austin*. He teaches courses in Information Technology and Supply Chain Management, Global Operations and Logistics, Global Business Process Outsourcing, Managing Technological Innovation, Operations Strategy and Operations

Management. He has received *numerous teaching awards*, with the most recent ones being the EMBA Reid Teaching Award 2003, Executive Masters in Manufacturing Management (*EM³*) Teaching Awards, 1998, 1999, 2000, and 2002; the MBA Reid Teaching Awards, 1998 and 2000 at Olin, and Faculty of the Term MBA Teaching Award, 1996 at Fuqua, Duke. He has been frequently mentioned as a top operations management professor in surveys of top MBA programs by Business Week (quoted as the most popular” business professor at Olin in the 1998 Business Week Survey). He often teaches in executive management programs and offers short customized courses to interested companies. He currently teaches in the EMBA program at the Olin School of Business and the joint Olin-Fudan EMBA program in Shanghai, China. He also recently developed an e-learning course on “Global Supply Chain Management” (currently sold by the Chicago based Learning Insights company). He is an accomplished and *prolific researcher*, ranked in the top ten operations management researchers in terms of research productivity and quality (recent survey in Journal of Operations Management). He received the 2000 *IIE Transactions Award* for the *Best Paper in Operations Engineering Issue* (awarded by the Institute of Industrial Engineers for the best research paper in the flagship journal of the field). His research interests include global supply chain management, implications of e-business for supply chain strategies, business process outsourcing and purchasing management, manufacturing strategy, technology management, the study of marketing/manufacturing interfaces, project management, e-procurement and other B2B applications, scheduling of operations, process management and reengineering, facilities location and layout design. He has *published over 70 articles* in *Management Science*, *Operations Research*, *Manufacturing and Service Operations Management (M&SOM)*, *Naval Research Logistics*, *IIE Transactions*, *Production and Operations Management (POM)*, *Journal of Operations Management*, *European Journal of Operations Research*, *Operations Research Letters*, *Journal of Operational Research Society*, and other high quality academic journals. He also frequently contributes chapters in edited books on global supply chain management and optimization issues. He currently serves as Department Editor of *Supply Chains/Production-Inventory Systems*

of *IIE Transactions* (and in the past he served as Department Editor of *Project Selection, Coordination and Management* of the same journal), as senior editor of *M&SOM*, as Department Editor of *POM* in the area of *Manufacturing Operations*, and as associate editor of *Operations Research and Decision Sciences*. In the past he served as associate editor of *Interdisciplinary Management Research and Applications of Management Science* (and before that he was associate editor for *Supply Chain Management* in the same journal), and has been for many years on the editorial review board of *POMS* and *MSOM*. He has also edited special issues for the *Journal of Global Optimization* and the *Journal of Intelligent Manufacturing*. Kouvelis' book on *Robust Discrete Optimization* was published in 1997 by Kluwer and his co-authored textbook on *Global Operations and Logistics: Text and Cases* was published by Wiley in 1998 (and has been translated in Chinese and Portuguese). He has served as *President-Elect* and *President of the MSOM Society* for 2002–2004. He has consulted with and/or taught executive programs for Emerson, IBM, Dell Computers, Boeing, Hanes, Duke Hospital, Solutia, Express Scripts, Spartech, MEMC, Ingram Micro, Smurt Stone, Reckitt & Colman, and Bunge on supply chain, inventory management, lean manufacturing, operations scheduling, and manufacturing system design issues.

Ping Su is currently an assistant professor in Operations Management and Technology at SUNY New Paltz. She received her PhD in Operations Management at Washington University. She received her Bachelor in MIS from the School of Economics and Management, Tsinghua University, China. Her research interests include global supply chain management and the interface between Operations Management and Finance/Industrial Organization.