Global Supply Chain Design Review

Marc Goetschalckx

School of Industrial and Systems Engineering
Georgia Institute of Technology

MHRC Portland, 2002

Overview

- Definitions and problem statement
- Literature review
- Characteristics of (global) strategic supply models
- Computational tools
- Research opportunities and conclusions
Supply Chain Definition

“A supply chain is a network of organizations that are involved through upstream and downstream linkages in the different processes and activities that produce value in the form of products and services in the hands of the ultimate customer,” Christopher (1998).

Single Period, Single Echelon, Multicommodity Example
Inherently Stochastic Design Yields Profit Distributions

Supply Chain Design Objectives

- Cost minimization
- Return on investment maximization
- Profit maximization
- Robustness
- Responsiveness
- Flexibility
- Usually conflicting
Supply Chains Design: Holistic, Integrated and Comprehensive

Matrix Organization of (APS) Planning Modules

<table>
<thead>
<tr>
<th>Strategic</th>
<th>Strategic Enterprise Planning</th>
<th>Strategic Demand Planning</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tactical</td>
<td>Master Production and Distribution Planning</td>
<td>Tactical Demand Planning</td>
</tr>
<tr>
<td>Operational</td>
<td>Material Requirement Planning</td>
<td>Production Planning</td>
</tr>
<tr>
<td>Execution</td>
<td>Purchasing</td>
<td>Scheduling</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Vehicle Dispatching</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Demand Monitoring</td>
</tr>
</tbody>
</table>

Copyright © 2000-2002 Marc Goetschalckx, All rights reserved
Strategic Logistics

Examples:

- Build a manufacturing plant
- Select third-party logistics
- Select customer-product groups

Long range permanence of decisions

Heterogeneous forecasted data, if available at all

Company vision and survival

Supply Chain Strategic Design Problem

Multicommodity, multiperiod, multi-echelon, capacitated network flow design problem (planes, nodes, arcs)

Decision variables

- Binary status variables for facility location status, technology and size, and machines
- Continuous material flow variables (production, transportation, storage, and sales)
Supply Chain Strategic Design Problem Continued

- **Objectives**
  - Cost minimization, profit maximization, risk minimization, flexibility
- **Objective function, constraint matrix, RHS parameters all are stochastic**

Overview

- **Definitions and problem statement**
- **Literature review**
- **Characteristics of (global) strategic supply models**
- **Computational tools**
- **Research opportunities and conclusions**
Supply Chain Research Publication Statistics

<table>
<thead>
<tr>
<th>Category</th>
<th>Modeling</th>
<th>Design</th>
<th>Descriptive</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supply Chain</td>
<td>326</td>
<td>1215</td>
<td>14638</td>
</tr>
<tr>
<td>Global Supply Chain</td>
<td>188</td>
<td>698</td>
<td>972</td>
</tr>
<tr>
<td>Supply Chain Management</td>
<td></td>
<td></td>
<td>692</td>
</tr>
<tr>
<td>Logistics</td>
<td></td>
<td></td>
<td>6045</td>
</tr>
<tr>
<td>Global Logistics</td>
<td>12</td>
<td>35</td>
<td>35</td>
</tr>
<tr>
<td>Material Handling</td>
<td>208</td>
<td>852</td>
<td>1239</td>
</tr>
<tr>
<td>Facilities Planning</td>
<td>15</td>
<td>62</td>
<td>162</td>
</tr>
<tr>
<td>Warehousing</td>
<td>15</td>
<td>91</td>
<td>191</td>
</tr>
</tbody>
</table>

Initial Research Paper Counts
**Subset of Research Paper Counts**

![Graph showing research paper counts for different categories of research: Modeling, Design, Descriptive. Categories include Global Supply Chain, Global Logistics, Material Handling, Facilities Planning, and Warehousing.]

**Recent Reviews**

- **Global models**
  - Vidal and Goetschalckx (1997)
  - Cohen and Huchzermeir (1999)
  - Ganeshan et al. (1999)
  - Schmidt and Wilhelm (2000)

- **Location models**
  - Owen and Daskin (1998)
Recent Reviews Continued

- Historic Perspective

- Software Tools

Recent Books

- Ballou (1998) (UG)
- Wood et al. (1999) (UG)
- Tayur (1999) (Academic)
- Simchi-Levi et al. (1999) (MBA)
- Chopra and Meindl (2001) (UG, IIE*)
- Stadtler (2000, 2002) (Practitioner)
- Shapiro (2001) (Grad)
**Supply Chain Research Summary**

- Much more papers as compared to material handling
- For all categories, mostly descriptive or analysis, fewer design, very few normative modeling

**Design Research Review Summary**

- Extensive literature on deterministic or scenario-based supply chain design
- Few papers on multinational supply chains
- Stochastic optimization for small problems
- Some stochastic optimization for exchange rates in global systems
Overview

- Definitions and problem statement
- Literature review
- Characteristics of (global) strategic supply models
- Computational tools
- Research opportunities and conclusions

Continuous Location Example: Varignon Frame, Weber (1904)
### Discrete Location: Geoffrion and Graves Model

\[
\begin{align*}
\text{min} & \quad \sum_{ijkp} c_{ijkp} x_{ijkp} + \sum_j \left( f_j z_j + h_j \sum_{kp} r_{kp} y_{jk} \right) \\
\text{s.t.} & \quad \sum_{jk} x_{ijkp} \leq s_{ip} \quad \forall ip \\
& \quad \sum_i x_{ijkp} = r_{kp} y_{jk} \quad \forall jk \\
& \quad \sum_j y_{jk} = 1 \quad \forall k \\
& \quad TL_j z_j \leq \sum_{pk} r_{kp} y_{jk} \leq TU_j z_j \quad \forall j
\end{align*}
\]

### Supply Chain Models: Single-country Costs

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Single-Country (Domestic) Characteristics</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Objective</td>
<td>Cost minimization</td>
<td>Profit maximization</td>
<td>Inventory minimization</td>
<td>Cost Variance Minimization</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Costs</td>
<td>Materials Production Distribution Internal Transportation External Transportation (Suppliers and Customers) Inventory Sales Revenue (Negative Cost) Fixed Transformation Facility Fixed Distribution Facility Fixed Machine Fixed Product-Mix Fixed Vendor Use</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

5-Jun-02  Global Supply Chain Design Review, MHRC Portland 2002  Marc Goetschalckx
Supply Chain Models: Components and Decisions

Decisions
- Supplier-Facility (Purchasing)
- Product-Transformer (Production)
- Product-Machine (Production)
- Product-Mix-Machine (Production)
- Transformer-Customers (Distribution)
- Machine-Customers (Distribution)
- Tactical Inventory Levels
- Dynamic Facility Status (more than one change)

Components
- Countries
- Products
- Suppliers
- Machines & Technologies
- Transformation Facilities
- Distribution Facilities
- Customers
- Transportation Modes
- Echelons

Constraints
- Production Capacities
- Supply Capacities
- Sales Upper Bound by Demand
- Demand Satisfaction
- Transportation Capacities

Multiple-Country (Global) Characteristics

Objectives
- Global After-Tax Profit Maximization

International Costs
- Country-Specific Tax Rates
- Tariffs
- Duties
- Export Incentives (Negative Cost)
- Transfer Prices or Markups

Decisions
- Transfer Prices or Markups
- Transportation Cost Allocation

International Constraints
- Local Content / Manufacturing Offset
- Minimum Taxes per Country

International Factors
- Exchange Rates
Global Supply Chain Models

Summary

- Unified comprehensive model does not exist
  - Dynamic, stochastic, MIP
  - Economies of scale and scope explode number of binary variables
  - Non-linear effects (transfer prices, overhead, markups)
  - Path-based formulations (duty relief)

Global Supply Chain Solution Algorithms

- Large majority use commercial MIP solvers (B&B + LP)
- Stochastic (operational) simulation
- Decomposition (Benders), factorization, bilinear programming are very rarely used
- Stochastic solutions obtained using limited number of scenarios
- Heuristics
Overview

- Definitions and problem statement
- Literature review
- Characteristics of (global) strategic supply models
- Computational tools
- Research opportunities and conclusions

Enterprise Resource Planning (ERP) Software

- Logistics systems status
- “Bookkeeping”
  - Transactional
  - Data warehouse
- Advantages
  - Enterprise standardization
  - Data integration
  - Up-to-date data
  - Multinational
ERP Vendors

- Growing importance
- Major vendors
  - SAP (financial),
    - New enterprise module: Network Design
  - Baan (manufacturing, transportation),
    - CAPS Logistics Toolkit
  - PeopleSoft (human resources)
  - ...

Supply Chain Management (SCM) Software

- Logistics systems configuration and planning
- “Optimizing”
  - Operations research
  - Constraint based logic
- Interface with ERP
- Also called advanced planning systems (APS)
SCM Vendors

- **Strong consolidation**
- **Major vendors**
  - I2 – InterTrans
    - I2 Rhythm Supply Chain Strategist
  - Manugistics
  - J.D. Edwards – Numetrix
    - Enterprise Planning
Logistics Software Reference


Design Tools for the Third Millennium
Supply Chain Modeling Challenges

- Multiple periods, combined with tactical
  - Periodic and seasonal demand
  - Dynamic strategic systems
- Global
  - Taxes and profit realization
  - Local contents, duty drawback
- Stochastic and multi-objective
  - Flexibility, responsiveness, robustness, risk, scenarios

Integrated models are large and complex and expensive

Multi-objective performance measures are complex

Strategic design as a continuous effort

Technology transfer to logistics professionals and students
Research Needs and Opportunities - Modeling

- Data aggregation and synthesis tools
  - Middleware between ERP and models
- Rapid-prototyping design tools
  - Procurement-manufacturing-distribution-markets mission configuration
- Multi-objective design models
  - Explicit tradeoffs between economics, risk, flexibility, and responsiveness

Research Needs and Opportunities - Algorithms

- Robust optimization algorithms (w.r.t. data perturbations)
- Large-scale multi-objective stochastic optimization algorithms
Thank You
Questions and Discussion