Supply Chain Network Optimization: Low Volume Industrial Chemical Product

Authors: Fred Dacha and Li Jin
Advisor: Dr. Tony Craig
Sponsor: TopChem Inc.

MIT SCM ResearchFest
May 22-23, 2013
Agenda

• Background
• Problem Statement
• Research Objectives
• Methodology
• Key Findings
• Conclusion
• Q&A
Background

- **TopChem Inc.**
  - Trades in petrochemicals including solvents
  - Ranked in Chemical Week’s Billion Dollar Club in 2012 & ICIS Top 100 Chemical Companies in 2012

- **SKU-1**
  - Hydrocarbon solvent
  - Wide industrial and household applications
  - Price sensitive, in a competitive market
  - Handling and transportation costs can take up to 20% of final product cost
    - Transportation; Terminal; Inventory holding; Railcar; Berth
    - Manufacturing
Background - continued

• Current global supply chain network of SKU-1
  • 3 Manufacturing Facilities – Two in North America, One in Europe
  • 5 Distribution Terminals
  • 100% manufactured in North America
  • 73% sales in North America and 27% in Argentina
  • 24 customers spread in 50 locations in North America; 1 distributor in Argentina

• Supply chain challenges
  • Illinois supply discontinued
  • Growing demand in Argentina - 2X in the next few years
  • Higher lead time and cost for Netherlands supply
Current and Future Network

- Illinois
- Louisiana
- Ontario
- New Jersey
- California
- Texas
- Argentina
- Louisiana Customers
- Illinois Customers
- Ontario Customers
- New Jersey Customers
- California Customers
- Argentina Customers
- Louisiana Customers

LEGEND:
- Manufacturing
- Terminal
- Transloading
- Customer
- Potential to include in network

- Texas
- Argentina
- Netherlands
- Ontario
- New Jersey
- California
- U.S. Customer 1
- U.S. Customer n
- Argentina Customers

May 22-23, 2013 MIT SCM Research Fest
Problem Statement

Optimize the global supply chain for SKU-1 so that customer demand is fulfilled with the least cost to serve (C2S)?
Research Objectives

• Build an optimization model to minimize total C2S while satisfying demand and supply constraints

• Conduct scenario analysis

• Analyze changes in C2S with increased demand from Argentina
Results

• Total C2S increases by:
  • 2% without Illinois capacity
  • 13 % without Illinois or Louisiana capacities

• Customer C2S increases by:
  • 2% to 20% for 38% of customers - without Illinois
  • 4% to 34% for 100% of customers - without Illinois or Louisiana
  • Customer Definition: Customer Name| Location| Delivery Mode

• Argentina C2S
  • Demand increase from 27% of total demand to 36%
  • C2S as proportion of total C2S increases from 29% to 47% if demand doubles in 4 years
Methodology

- Field trip and interview
- Analysis of Data provided by TopChem Inc.
- Regression of truck and rail rates
- Excel-based network optimization model
  - Deterministic model
  - Objective function
  - Parameters
  - Constraints
- Scenario analysis
  - Baseline scenario-Three refineries in Illinois, Louisiana, and Netherlands
  - Scenario 2-Two refineries in Louisiana and Netherlands
  - Scenario 3- One refinery in Netherlands
  - Demand Increase in Argentina
## Scenario Setup

Total Cost-to-serve and scenario analysis

<table>
<thead>
<tr>
<th>Scenario Description</th>
<th>Baseline Scenario</th>
<th>Scenario 1</th>
<th>Scenario 2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>All Available</td>
<td>No Illinois</td>
<td>No Illinois or Louisiana</td>
</tr>
<tr>
<td><strong>Manufacturing (MT)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Louisiana</td>
<td>11,000</td>
<td>11,000</td>
<td>0</td>
</tr>
<tr>
<td>Netherlands</td>
<td>11,000</td>
<td>11,000</td>
<td>11,000</td>
</tr>
<tr>
<td>Illinois</td>
<td>11,000</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

| **Total Supply (MT)**       | 10,434            | 10,434     | 10,434     |

| **Manufacturing Facility (MT)** |                   |            |            |
| Louisiana                      | 6,118             | 10,434     | 0          |
| Netherlands                    | 0                 | 0          | 10,434     |
| Illinois                       | 4,316             | 0          | 0          |

| **% of Total Supply**        |                   |            |            |
| Louisiana                     | 59%               | 100%       | 0%         |
| Netherlands                   | 0%                | 0%         | 100%       |
| Illinois                      | 41%               | 0%         | 0%         |
Results and Cost Drivers

<table>
<thead>
<tr>
<th></th>
<th>Baseline Scenario</th>
<th>Scenario 1</th>
<th>Scenario 2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>All Available</td>
<td>No Illinois</td>
<td>No Illinois or Louisiana</td>
</tr>
<tr>
<td>Total Cost-to-Serve</td>
<td>$12,215,201</td>
<td>$12,519,841</td>
<td>$13,861,737</td>
</tr>
<tr>
<td>Demand</td>
<td>10,434</td>
<td>10,434</td>
<td>10,434</td>
</tr>
<tr>
<td>Cost-to-Serve/MT</td>
<td>$1,171</td>
<td>$1,200</td>
<td>$1,329</td>
</tr>
<tr>
<td>% Change from Baseline</td>
<td>0%</td>
<td>2%</td>
<td>13%</td>
</tr>
</tbody>
</table>

Manufacturing Cost

<table>
<thead>
<tr>
<th>Cost Category</th>
<th>Baseline Scenario</th>
<th>Scenario 1</th>
<th>Scenario 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Terminal Handling</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inventory Holding</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stock Movement</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Freight to Customer</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rail Car to Terminals</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rail Car to Customer</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

% Change from Baseline

- Manufacturing: 0%
- Other Costs: 2%
## Product Flow

<table>
<thead>
<tr>
<th>Terminal Product Handled (MT)</th>
<th>Baseline Scenario</th>
<th>Scenario 1</th>
<th>Scenario 2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>All Available</td>
<td>No Illinois</td>
<td>No Illinois or Louisiana</td>
</tr>
<tr>
<td>Ontario</td>
<td>231</td>
<td>322</td>
<td>366</td>
</tr>
<tr>
<td>New Jersey</td>
<td>1,143</td>
<td>1,783</td>
<td>1,779</td>
</tr>
<tr>
<td>California</td>
<td>1,440</td>
<td>1,440</td>
<td>1,440</td>
</tr>
<tr>
<td>Texas</td>
<td>2,858</td>
<td>2,858</td>
<td>10,434</td>
</tr>
<tr>
<td>Argentina</td>
<td>2,858</td>
<td>2,858</td>
<td>2,858</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>% Change from Baseline</th>
<th>Baseline Scenario</th>
<th>Scenario 1</th>
<th>Scenario 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ontario</td>
<td>0%</td>
<td>39%</td>
<td>58%</td>
</tr>
<tr>
<td>New Jersey</td>
<td>0%</td>
<td>56%</td>
<td>56%</td>
</tr>
<tr>
<td>California</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>Texas</td>
<td>0%</td>
<td>0%</td>
<td>265%</td>
</tr>
<tr>
<td>Argentina</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
</tr>
</tbody>
</table>
# Customer C2S

<table>
<thead>
<tr>
<th>Sold to Customer</th>
<th>Scenario 1</th>
<th>Scenario 2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No Illinois</td>
<td>No Illinois or Louisiana</td>
</tr>
<tr>
<td>Customer A</td>
<td>LEESPORT</td>
<td>Road Tank Truck</td>
</tr>
<tr>
<td>Customer A</td>
<td>READING</td>
<td>Road Tank Truck</td>
</tr>
<tr>
<td>Customer B</td>
<td>BEDFORD PARK</td>
<td>Road Tank Truck</td>
</tr>
<tr>
<td>Customer C</td>
<td>SAINT PAUL</td>
<td>Road Tank Truck</td>
</tr>
<tr>
<td>Customer D</td>
<td>MISSISSAUGA</td>
<td>Road Tank Truck</td>
</tr>
<tr>
<td>Customer I</td>
<td>CHANDLER</td>
<td>Road Tank Truck</td>
</tr>
<tr>
<td>Customer I</td>
<td>FAIRFIELD</td>
<td>Road Tank Truck</td>
</tr>
<tr>
<td>Customer P</td>
<td>PORTLAND</td>
<td>Road Tank Truck</td>
</tr>
<tr>
<td>Customer I</td>
<td>FAIRFIELD</td>
<td>Rail Tank Car</td>
</tr>
<tr>
<td>Customer AD</td>
<td>Argentina</td>
<td>Bulk tanker</td>
</tr>
</tbody>
</table>
Argentina Demand and C2S

<table>
<thead>
<tr>
<th></th>
<th>YR 0</th>
<th>YR 1</th>
<th>YR 2</th>
<th>YR 3</th>
<th>YR 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Demand (MT)</td>
<td>10434</td>
<td>13863</td>
<td>14549</td>
<td>15372</td>
<td>16360</td>
</tr>
<tr>
<td>Argentina Demand (MT)</td>
<td>2858</td>
<td>3429</td>
<td>4115</td>
<td>4938</td>
<td>5926</td>
</tr>
</tbody>
</table>

Total Demand (MT)

- **YR 0**: 10434 MT
- **YR 1**: 13863 MT
- **YR 2**: 14549 MT
- **YR 3**: 15372 MT
- **YR 4**: 16360 MT

Argentina Demand (MT)

- **YR 0**: 2858 MT
- **YR 1**: 3429 MT
- **YR 2**: 4115 MT
- **YR 3**: 4938 MT
- **YR 4**: 5926 MT

---

**Cost to Serve, $**

- **YR 0**: $10,000,000
- **YR 1**: $12,000,000
- **YR 2**: $14,000,000
- **YR 3**: $16,000,000
- **YR 4**: $18,000,000

**Total and Argentina C2S**

- **Argentine C2S**: 29%, 27%, 36%, 47%
- **Total C2S**: 50%, 45%, 40%, 35%

---

**Total and Argentina C2S as % of Total C2S**

- **Total C2S**: 50%, 45%, 40%, 35%
- **Argentina C2S**: 29%, 27%, 36%, 47%
Conclusion

- Total C2S increases by:
  - 2% without Illinois capacity
  - 13% without Illinois or Louisiana capacities

- Customer C2S increases by:
  - 2% to 20% for 38% of customers - without Illinois
  - 4% to 34% for 100% of customers - without Illinois or Louisiana

- Argentina C2S
  - Demand increase from 27% of total demand to 36%
  - C2S as proportion of total C2S increases from 29% to 47% if demand doubles in 4 years

- Can these costs be transferred to customers?

- Further work to enrich the project
  - Transportation lead time and demand variability
  - Inventory policy
Q&A?