Chapter 4 Outline: Designing Distribution Networks and Applications to e-Business

- The Role of Distribution in the Supply Chain
- Factors Influencing Distribution Network Design
- Design Options for a Distribution Network
- E-Business and the Distribution Network
The Role of Distribution in the Supply Chain

- Distribution: the steps taken to move and store a product from the supplier stage to the customer stage in a supply chain
  - Distribution directly affects cost and the customer experience and therefore drives profitability

- Factors Influencing Distribution Network Design: As choice of distribution network can achieve supply chain objectives from low cost to high responsiveness:
  - Distribution network performance evaluated along two dimensions at the highest level (and when sustainability is explicitly considered, three):
    » Customer needs that are met
    » Cost of meeting customer needs
    » Affect on sustainability
  - Distribution network design options must therefore be compared according to their impact on customer service and the cost to provide this level of service as well as any significant sustainability impacts
Distribution Networks in Practice

◆ DC = Distribution Center (effectively synonymous w/ Wholesaler)
  – DCs can be operated by a manufacturer, retailer or completely separate player
  – Types of DCs
    1. Break-bulk
    2. Transport optimizers, especially Cross-Dock
    3. Fast response -aggregate inventory (risk-pooling) yet still quick delivery to customer, e.g. MRO

◆ Product, price, commoditization, and criticality (item’s importance) have an impact on the type of distribution system

◆ The choice of a distribution network has very long-term consequences
  – Consider whether an exclusive distribution strategy is advantageous
  – The ownership structure of the distribution network can have as big as an impact as the type of distribution network (ex. Naya water/CCE distribution)
A Professorial Aside: Value of Distributors in the Supply Chain

Are distributors an unnecessary link?

- Consolidate small or varied replenishment orders (breaking bulk orders and centralizing safety stocks)
  - Consumer Packaged Goods in India
  - Pharmaceuticals: 5-6 distributors in U.S. handle thousands of retailers who order from hundreds of manufacturers

- Sometimes mandated by regulation: For alcohol sales in the US, the 2\textsuperscript{nd} tier is mandated in 48 states, serves as a tax collection point

- Distributors typically have low margins (1\%-2\%), so are motivated to be efficient
Factors Influencing Distribution Network Design

◆ Elements of customer service (responsiveness) that are influenced by network structure:
  – Response time
  – Product variety & availability
  – Customer experience
  – Order visibility
  – Returnability (for both customer service and sustainability reasons)

◆ Supply chain costs affected by network structure (4 of 6 drivers from Chapter 3):
  – Facilities and handling (At the moment, focus is on warehousing facilities)
  – Inventories
  – Transportation
  – Information

  » Let’s graph the interactions of these with costs
Transportation Costs and Number of Facilities
Inventory Costs and Number of Facilities

Inventory Costs

Number of facilities
Total Costs Related to Number of Facilities

- Total Costs
- Facilities
- Inventory
- Transportation

Number of Facilities

Total Costs
Service and Number of Facilities

Number of Facilities

Response Time
Variation in Logistics Costs and Response Time with Number of Facilities

- Response Time
- Total Logistics Costs

Number of Facilities
Design Options for a Distribution Network

- We consider some various network options that move beyond the traditional model. (Many of these non-traditional networks have been made more viable by the internet revolution)
  
  Shown in graphic format in next few slides:
  - Manufacturer Storage with Direct Shipping
  - Manufacturer Storage with Direct Shipping and In-Transit Merge
  - Distributor Storage with Carrier Delivery
  - Distributor Storage with Last Mile Delivery

Also not explicitly graphed:

- Retail Storage with Customer Pickup- often integrated with traditional model (Bevmo.com, for example. REI.com and Gap.com also allow used this model in the US).
- Not discussed: Manufacturing/Distributor storage w/Customer Pickup
Manufacturer Storage with Direct Shipping via Parcel Delivery (Fig. 4.6)

This is also called *drop shipping*
In-Transit Merge Network (Fig. 4.7)

Factories

In-Transit Merge by Carrier

Retailer

Customers

Product Flow

Information Flow
Distributor Storage with Parcel Delivery (fig 4.8)

Factories

Warehouse Storage by Distributor/Retailer

Customers

Product Flow

Information Flow
Distributor Storage with Last Mile Delivery (Fig. 4.9)
Table 4-7 in the text shows that each of these distribution networks has different characteristics with respect to:

- Costs - facilities, inventory, transport, information
- Service/Responsiveness:
  - Response time
  - Product variety
  - Product availability
  - Customer experience
  - Order visibility
  - Return-ability

Performance will change depending on attributes of
- Products: demand level, variety, multiple sources? high value
- Customers: do they desire quick response times? Effort level?
E-Business and the Distribution Network

Depending on the firm, the product and core customer base, e-Business will have different impacts on:

- **Customer Service** (i.e. Responsiveness of Supply Chain):
  - Response time (non downloadable products), Product variety, Product availability, Customer experience, Time to market, Order visibility, Returnability, Direct Sales to Customers, Efficient Funds Transfer,

- **Costs** Facilities, Inventory, Transportation, Information

- In general, E-Business provides an easier way to adjust Pricing: Flexible Pricing, Product Portfolio, and Promotions

- Example: Table 4-10 in the text summarizes Dell’s online business with respect to two different products:
  - customized, high-value PCs verses standardized, commodity PCs
Chapter 5 Outline: Network Design in the Supply Chain

- The Role of Network Design in the Supply Chain
- Factors Influencing Network Design Decisions
- Framework for Network Design Decisions
- Models for Facility Location and Capacity Allocation
Network Design Decisions

- Facility role
  - What role should each facility play?

- Facility number and location
  - How many facilities do we need?
  - Where should facilities be located?

- Capacity allocation
  - How much capacity should be allocated to each facility?

- Market and supply allocation
  - What supply sources should feed each facility?
  - What markets should each facility serve?
Facility Role-Classifications of Facilities

In order from lowest cost to highest value, and their strategic roles:

1. **Offshore** (Low cost facility for export production)
2. **Source** (Low-cost facility for global production)
3. **Server** (Regional production facility)
4. **Contributor** (Regional production facility with development skills)
5. **Outpost** (Regional production facility used by the firm to gain expertise from the locals)
6. **Lead** (Model facility that leads the firm in development of new products or technologies)
Factors Influencing Network Design Decisions

◆ **Strategic**
  – Evaluate tradeoffs: place manufacturing close to market -vs.- low cost?
  – Should we co-locate facilities with vendors/suppliers?

◆ **Technological:** Do production technologies have significant economies of scale?

◆ **Macroeconomic**
  – Tariffs and tax incentives (i.e. free trade zones), Exchange rate and demand risk

◆ **Political:** Stability, clear legal system and regulations important for corporations

◆ **Infrastructure**
  – Will local infrastructure support a facility? Labor (especially skilled) available?

◆ **Competitive:** Locate near or far from rivals?

◆ **Customer Response time / Local Presence**
  – How important is convenience –vs.- lower cost centralized facilities
  – Is “local knowledge” crucial to the business model?

◆ **Logistics & facility COSTS**
  – Crucial to consider in setting up or redesigning the supply chain

◆ **Sustainability:** Are local environmental and ethical practices consistent with corporate need?
The Cost-Response Time Frontier

High

Cost

Low

Quick

Response Time

Sloooow

FG - finished goods.
WIP - Work in Progress
How Many Facilities?
Service given Number of Facilities

Response Time

Number of Facilities
Costs and Number of Facilities

Costs

Number of facilities

Inventory

Facility costs

Transportation
Cost Buildup as a Function of Facilities

- Transportation
- Total Costs
- Inventory
- Facilities
- Percent Service Level Within Promised Time

Number of Facilities

Cost of Operations

Level of Service

High
Low

Number of Facilities
A Framework for Global Site Location

PHASE I
Supply Chain Strategy

PHASE II
Regional Facility Configuration

PHASE III
Desirable Sites

PHASE IV
Location Choices

Competitive STRATEGY

INTERNAL CONSTRAINTS
Capital, growth strategy, existing network

PRODUCTION TECHNOLOGIES
Cost, Scale/Scope impact, support required, flexibility

COMPETITIVE ENVIRONMENT

PRODUCTION METHODS
Skill needs, response time

FACTOR COSTS
Labor, materials, site specific

GLOBAL COMPETITION

TARIFFS AND TAX INCENTIVES

REGIONAL DEMAND
Size, growth, homogeneity, local specifications

POLITICAL, EXCHANGE RATE AND DEMAND RISK

AVAILABLE INFRASTRUCTURE

LOGISTICS COSTS
Transport, inventory, coordination
Network Optimization Models

- Useful tools for both Phase II and Phase IV

- Question for Phase II: “In what regions should we source demand in and how do we configure our network?” given:
  - Regional demand, tariffs, economics of scale, aggregate factor costs
  - Not necessary to go to detail of specific plant locations as we do in later phases
  - Need to also consider less quantifiable factors such as political and regulatory climate, competition

- Phase IV involves selecting specific existing facilities and allocating capacity within those selected given:
  - Fixed facility cost, Transportation cost, Production cost, Inventory cost, Coordination cost
SunOil, a global energy company, needs to determine
1. where to locate facilities to service their demand
2. what size to build in the region (small or large), should they locate a facility there

- They divide the world into 5 different regions: N.America, S.America, Europe, Asia, Africa
- SunOil knows regional demands, transport costs, and facility costs and capacities for each size (and region)
- We will ignore tariffs and exchange rate fluctuations for now, and assume all demand must be met (so we can focus on minimizing costs)

**What analytic tool are we likely to use?**
**What is the “twist” that we need to consider?**
Excel Example: SUNOIL

- I’ll email the following document: network-MIP.xls
- Turn to the SunOil sheet
- The data is shown below

<table>
<thead>
<tr>
<th>Supply Region</th>
<th>N. America</th>
<th>S. America</th>
<th>Europe</th>
<th>Asia</th>
<th>Africa</th>
</tr>
</thead>
<tbody>
<tr>
<td>N. America</td>
<td>$81</td>
<td>$92</td>
<td>$101</td>
<td>$130</td>
<td>$115</td>
</tr>
<tr>
<td>S. America</td>
<td>$117</td>
<td>$77</td>
<td>$108</td>
<td>$98</td>
<td>$100</td>
</tr>
<tr>
<td>Europe</td>
<td>$102</td>
<td>$105</td>
<td>$95</td>
<td>$119</td>
<td>$111</td>
</tr>
<tr>
<td>Asia</td>
<td>$115</td>
<td>$125</td>
<td>$90</td>
<td>$59</td>
<td>$74</td>
</tr>
<tr>
<td>Africa</td>
<td>$142</td>
<td>$100</td>
<td>$103</td>
<td>$105</td>
<td>$71</td>
</tr>
<tr>
<td>Demand total</td>
<td>12</td>
<td>8</td>
<td>14</td>
<td>16</td>
<td>7</td>
</tr>
</tbody>
</table>
Capacitated Plant Location Model

- **n**: the number of potential sites
  - As we are considering two different type plants (small, large) for each region, \( n = 10 \)
- **m**: regions with demand
- **\( D_j \)**: demand in region \( j \)
- **\( K_i \)**: capacity at plant \( i \)
- **\( f_i \)**: fixed cost of keeping plant \( i \) open
- **\( c_{ij} \)**: variable cost of sourcing region \( j \) from plant \( i \)
- **\( y_i \)**: 1 if plant is located at site \( i \), 0 otherwise
- **\( x_{ij} \)**: Quantity shipped from site \( i \) to region \( j \)

\[
\begin{align*}
\text{Min} & \quad \sum_{i=1}^{n} f_i y_i + \sum_{i=1}^{n} \sum_{j=1}^{m} c_{ij} x_{ij} \\
\text{s.t.} & \quad \sum_{i=1}^{n} x_{ij} = D_j \\
& \quad \sum_{j=1}^{n} x_{ij} \leq K_i y_i \\
& \quad y_i \in \{0,1\}
\end{align*}
\]

- **Can we do this with a pure LP?**
- **When would a simple LP be acceptable?**

While the equations may look complex, go to the spreadsheet and look at the underlying relationships.
Before solving, we can experiment with some configurations. What are the tradeoffs?

- Often a good idea to experiment to help understand the network model and the solution

Consider the optimal solution- what are some characteristics?

Food for Thought: what happens if we want to change the model?

- Force a plant to be located in Europe?
- Avoid locating more than one facility in the same region?
- Force worldwide capacity to be able to accommodate more than current demand by 5 M…
What the book has for Phase III: Gravity Methods for Location

◆ Ton Mile-Center Solution

- $x, y$: Warehouse Coordinates
- $x_n, y_n$: Coordinates of delivery location $n$
- $d_n$: Distance to delivery location $n$
- $F_n$: Annual tonnage to delivery location $n$

\[
\begin{align*}
    d_n &= \sqrt{(x - x_n)^2 + (y - y_n)^2} \\
    x &= \frac{\sum_{n=1}^{k} D_n x_n F_n}{\sum_{n=1}^{k} D_n F_n} \\
    y &= \frac{\sum_{n=1}^{k} D_n y_n F_n}{\sum_{n=1}^{k} D_n F_n} \\
\end{align*}
\]

Min $\sum d_n D_n F_n$

Before you pull out your calculator....
Gravity Location Models: Limitations

Professor Opinion, not in Textbook

◆ Assumes that all distances have identical per-mile costs
  – Assumes homogenous topography
  – Ignores limitations of existing ground/water transport network, inter-state/country transit taxes and regulations

◆ Costs of setting up a new facility is often prohibitive compared to revamping an existing facility (even if in a less desirable location)
  – Especially pertinent given economic and less-quantifiable costs of shutting down facilities
  – The problems I have encountered personally have been to consolidate or revamp facilities, never to set up a completely new installation

◆ For this class, you can assume that you will be provided with a finite number of site locations, and that you will be given all cost parameters $c_{i,j}$ for transit between location $i$ and $j$
Phase IV: Network Optimization Models- Allocating Demand

- Allocating demand to production facilities
- Locating facilities and allocating capacity

**Key Costs:**

- Fixed facility cost
- Transportation cost
- Production cost
- Inventory cost
- Coordination cost

*Which plants to establish/keep? How to configure the network?*
Example- Modeling a Phase IV Decision

TelecomOne has merged with High Optic. They have plants in different cities and service several regions. They would like to figure out how to service all demand while keeping costs low:

- The supply cities are Baltimore (capacity 18K), Cheyenne (24K), Salt Lake City (27K), Memphis (22K) and Wichita (31K)
- They have the following monthly regional demands:
  - 10K in Atlanta
  - 6K in Boston
  - 14K* in Chicago * per table 5.3, Book uses 12 K, not 14K for Chicago,
  - 6K in Denver although their spreadsheet inserts are okay
  - 7K in Omaha
- They will consider consolidating facilities

What sort of tool are we likely to use?
Demand Allocation Model

Answers the questions of...

- Which market is served by which plant?
- Which supply sources are used by a plant?

Decision variables:

\[ x_{ij} = \text{Quantity shipped from plant site } i \text{ to customer } j \]

- Can solve as a simple LP, see sheet “Telecom-all-plants” under network-MIP.xls

- But what if we also have the option of not using all facilities....

\[
\begin{align*}
\text{Min } & \sum_{i=1}^{n} \sum_{j=1}^{m} c_{ij} x_{ij} \\
\text{s.t. } & \sum_{i=1}^{n} x_{ij} = D_j \\
& \sum_{j=1}^{m} x_{ij} \leq K_i \\
& x_{ij} \geq 0
\end{align*}
\]
Allocating Demand to Production Facilities

Decision variables

- $y_i = 1$ if plant is located/left open at site $i$, 0 otherwise
- $x_{ij} =$ Quantity shipped from plant site $i$ to customer $j$

See Sheet “Telecom-close-plants” of network-MIP.xls

Look familiar?

$$Min \sum_{i=1}^{n} f_i y_i + \sum_{i=1}^{n} \sum_{j=1}^{m} c_{ij} x_{ij}$$

s.t.

$$\sum_{i=1}^{n} x_{ij} = D_j$$

$$\sum_{j=1}^{n} x_{ij} \leq K_i y_i$$

$y_i \in \{0,1\}$
Demand Allocation Model
Example Results

Before we solve the problem, what can we say about TelecomOptic’s situation?

What does the Excel model indicate should happen with plant configuration? Demand allocation?

What are the ramifications from this solution?

What are some what-if scenarios we might consider?
Considering Additional Layers: Simultaneously Locating Plants and DCs

- Now add cost to transport from suppliers, as well as the plant and DC/Warehouse costs

\[
\text{Min } \sum_{i=1}^{n} f_i y_i + \sum_{e=1}^{t} f_e y_e + \sum_{h=1}^{l} \sum_{i=1}^{n} c_{hi} x_{hi} + \sum_{i=1}^{n} \sum_{e=1}^{t} c_{ie} x_{ie} + \sum_{e=1}^{t} \sum_{j=1}^{m} c_{ej} x_{ej}
\]

s.t.

\[
\sum_{i=1}^{n} x_{ij} = D_j
\]

\[
\sum_{j=1}^{n} x_{ij} \leq K_i y_i
\]

Etc… (Don’t worry- that’s beyond the scope of this class)
Making Network Design Decisions

In Practice

◆ Do not underestimate the life span of facilities
  – Production facilities harder to retool than storage facilities
  – Consider ethical issues with respect to closing plants

◆ Do not gloss over the cultural implications
  – Should Eichbaum (who has a single brewery in Mannheim) produce beer for the growing Chinese in Shanghai?

◆ Do not ignore quality of life issues

◆ Consider tariffs and tax incentives when locating facilities
Due to time limitations, we do not delve into Decision Tree theory and other analytical models in this chapter, and we consider only the introductory material in this chapter.

- The Impact of Globalization on Supply Chain Networks
- The Offshoring Decision: Total Cost
- Risk Management in Global Supply Chains
The Impact of Globalization on Supply Chain Networks

- Globalization offers companies opportunities to simultaneously grow revenues and decrease costs.

- The opportunities from globalization are often accompanied by significant additional risk.

- There will be a good deal of uncertainty in demand, prices, exchange rates, and the competitive market over the lifetime of a supply chain network.

- Therefore, building flexibility into supply chain operations allows the supply chain to deal with uncertainty in a manner that will maximize profits.
The Offshoring Decision: Total Cost

- Total cost can be identified by focusing on the complete sourcing process, not just per-unit cost.
- Offshoring to low-cost countries is likely to be most attractive for products with:
  - High labor content
  - Large production volumes
  - Relatively low variety
  - Low transportation costs
- Perform a careful review of the production process
  - Consider use of auditors (verifying workplace conditions) and quality testing services.
Risk Management in Global Supply Chains

- Disruptions
  - Topical Example: Honda, Nissan and Toyota have effectively shut down factories for weeks following the 2011 Tsunami
    » Nissan estimates lost profits of over $25 million/day

- Delays
- Systems risk
- Forecast risk
- Intellectual property risk
- Procurement risk
- Inventory risk
- Capacity risk
Tailored Risk Mitigation Strategies

- Increase capacity
- Get redundant suppliers
- Increase responsiveness
- Increase inventory
- Increase flexibility
- Pool or aggregate demand
- Increase source capability
Summary of Chapter 4’s Learning Objectives

◆ What roles do distributors play in the supply chain?
◆ What are the key factors to be considered when designing the distribution network?
◆ What are the strengths and weaknesses of various distribution options, including e-Business enabled ones?
Summary of Chapter 5’s Learning Objectives

- What is the role of network design decisions in the supply chain?
- What are the factors influencing supply chain network design decisions?
- Describe a strategic framework for facility location
- How can network optimization methods be used for facility location and capacity allocation decisions?