



# **SUPPLY CHAIN NETWORK ANALYSIS AND DESIGN**

# Learning Objectives

After reading this chapter, you should be able to do the following:

- Understand the need to evaluate the structure and functions of logistics/supply chain networks, and to make changes and improvements as appropriate.
- Identify factors that may lead to redesign of a logistics/supply chain network.
- Develop an effective process for logistics/supply chain network design.
- Understand key locational determinants, both national / regional / global and site specific, and the impact they may have on prospective locational alternatives.

- Appreciate different types of modeling approaches that may be used to gain insight into logistics/supply chain network design and facility location decision making.
- Apply the simple “grid” or center-of-gravity approach to facility location.
- Appreciate various ways in which transportation alternatives and transportation costs may affect the location decision.

# Introduction

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- As firms continue their searches for new ways to lower costs and improve service to their customers, the issue of where to locate logistics and manufacturing facilities has become critical and complex.
- In addition to enhancing the efficiency and effectiveness of a logistics/supply chain operation, the redesign of a firm's overall network can help to differentiate a firm in the marketplace.

# The Need for Long-Range Planning

In the short run, a firm's logistics/supply chain network and the locations of its key facilities are fixed. Site availability, leases, contracts, and investments make changing facility locations impractical in the short run. In the long run, however, the design of the overall network must be thought of as variable.

- Strategic Importance of Logistics/Supply Chain Network Design
  - All businesses operate in a very dynamic environment in which change is the only constant.
  - Each company needs to constantly review whether any existing logistics/supply chain network is up to date.

## ● Changing Customer Service Requirements

- Logistical requirements of customers are changing in numerous ways.
- Some customers have intensified their demands for more efficient and more effective logistics services.
- Others are seeking relationships with suppliers who can take logistical capabilities and performance to new, unprecedented levels.
- As a result, the need to reevaluate and redesign logistics/supply chain networks is of great contemporary interest.
- While customer service requirements may experience change, the types of customers served may also evolve over time.

- Shifting Locations of Customer and/or Supply Markets
  - Population shifts.
  - Service and cost requirements moves to JIT-based manufacturing.
  - Constant search for lower-cost manufacturing.
  - Growing economic importance of China and the Asia-Pacific.
  - Sourcing of raw materials from offshore suppliers.

- **Change in Corporate Ownership**

- Mergers, acquisitions, and divestitures are changing the landscape and providing opportunities to integrate and improve logistics activities.

- **Cost Pressures**

- Removing costs from key processes is a major priority for firms today.
- Low labor rates have driven internationalism of production and increased the importance of logistics.

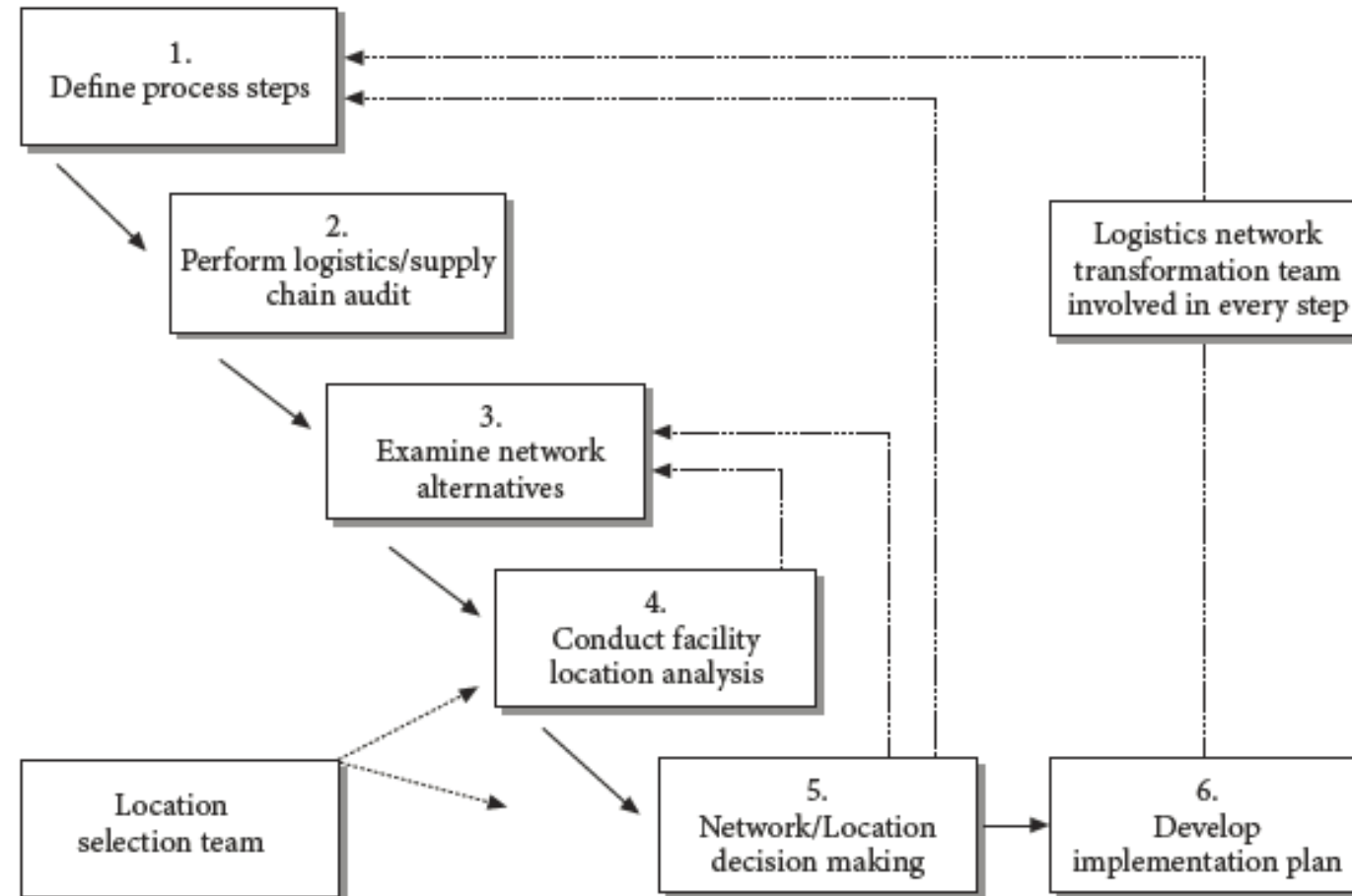
- **Competitive Capabilities**

- To remain competitive or establish a competitive advantage, firms should examine facility locations.



Figure 12.1

# Key Steps in Network Design Process



Source: C. John Langley Jr., Ph.D.

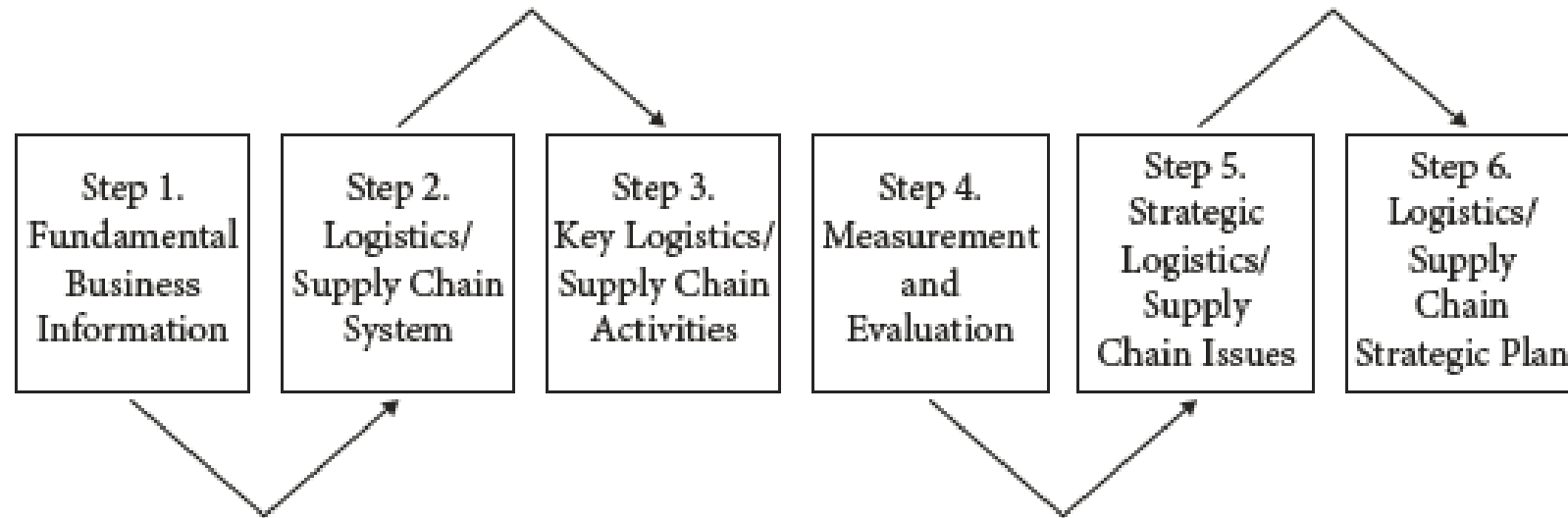
# Logistics/Supply Chain Network Design

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- Step 1: Define the logistics / supply chain design process.
- Step 2: Perform a logistics / supply chain audit.
- Step 3: Examine the logistics / supply chain network alternatives.
- Step 4: Conduct a facility location analysis.
- Step 5: Make decisions regarding network and facility location.
- Step 6: Develop an implementation plan.

**Figure 12.2**

## **Key Steps in Logistics/Supply Chain Audit**



Source: C. John Langley Jr., Ph.D.

# Major Locational Determinants

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- Key Factors for Consideration
  - Labor market/climate.
  - Transportation services and infrastructure.
  - Proximity to markets and customers.
  - Quality of life.
  - Taxes and industrial development incentives.
  - Supplier networks.
  - Land costs and utilities.
  - Company preference.

## ● Current Trends Governing Site Selection

- Positioning of inventories located at “market-facing” logistics facilities.
- General trend toward “disintermediation” of many wholesaler-distributor operations, greater use of “customer direct” delivery.
- Growing use of and need for strategically located “cross-docking”.
- Due diligence for location and site selection decisions is placing great emphasis on access to major airports and/or ocean ports for import and export shipments.
- Greater use of providers of third-party-logistics services.

# Modeling Approaches

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- Optimization Models

- Precise mathematical procedures that are guaranteed to find the “best,” or optimum, solution.
- Optimization approaches essentially select an optimal course of action from a number of feasible alternatives.

- Simulation Models

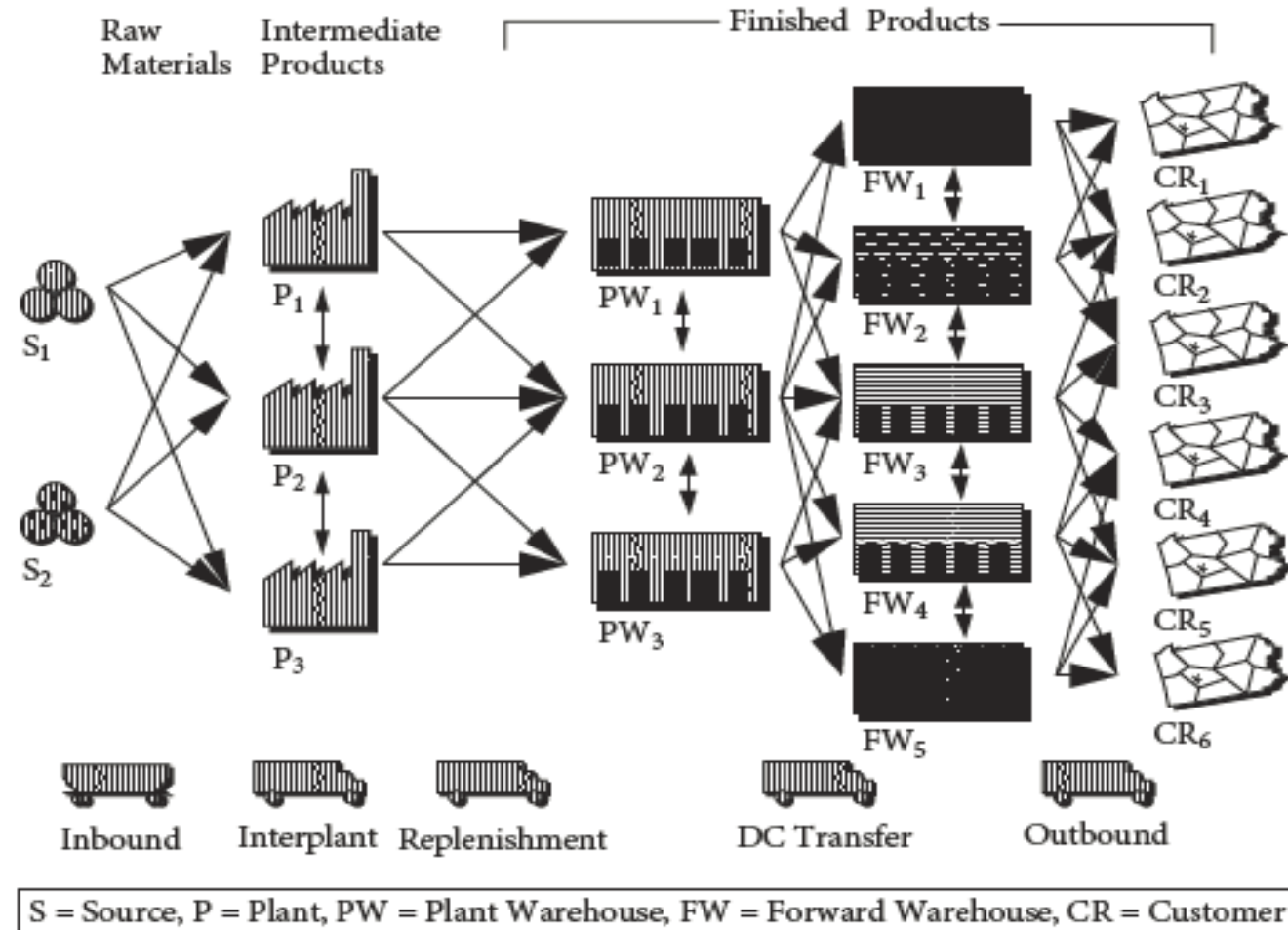
- Simulation – “the process of designing a model of a real system and conducting experiments with it for the purpose of understanding system behavior or evaluating various strategies within the limits imposed by a set of criteria governing system operation.

## ● Heuristic Models

- Heuristic models are able to accommodate broad problem definitions, but they do not provide an optimum solution.
- The use of a heuristic approach can help to reduce a problem to a manageable size and search automatically through various alternatives in an attempt to find a better solution.
- To reduce the number of location alternatives, the decision maker should incorporate into the heuristic program site characteristics considered to be optimal.

# Figure 12.4

## Supply Chain Complexity

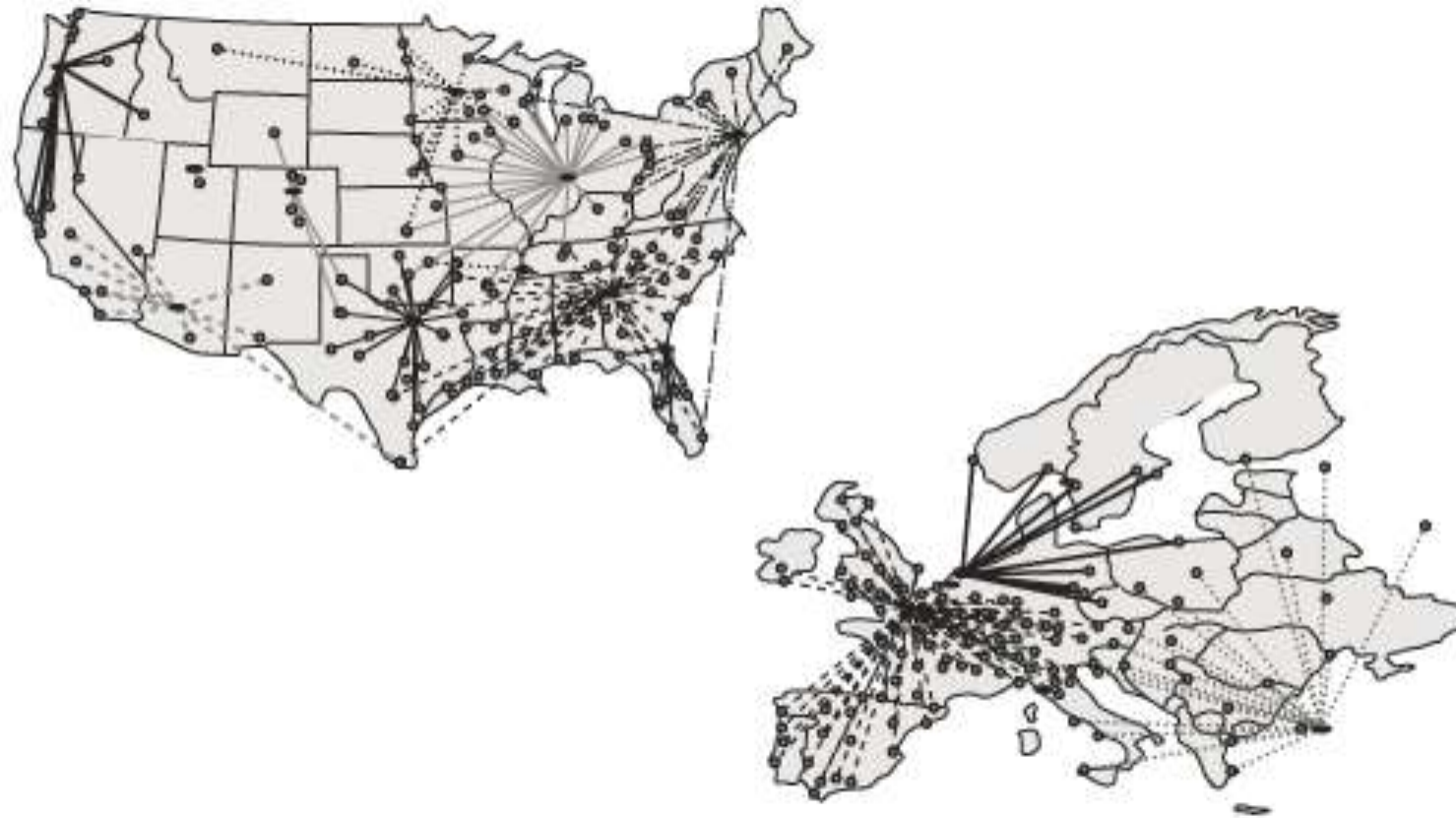


Source: Strategic Analysis of Integrated Logistics Systems (2006) 5



## Figure 12.5

# Graphical Mapping Example



Source: Insight, Inc.(2006)

- Potential Supply Chain Modeling Pitfalls to Avoid
  - Short-term horizon.
  - Too little or too much detail.
  - Thinking in two-dimensional maps (demand vs. supply, and distance vs. cost).
  - Using published costs.
  - Inaccurate or incomplete costs.
  - Use of erroneous analytical techniques.
  - Lack of appropriate robustness analysis.

# Example of a Heuristic Modeling Approach: The Grid Technique

Compute this concept mathematically, finding the ton-mile center, or center of mass, as follows

$$C = \frac{\sum_{i=1}^m d_i S_i + \sum_{i=1}^n D_i M_i}{\sum_{i=1}^m S_i + \sum_{i=1}^n M_i}$$

where

$C$  = Center of mass, or ton – mile center

$D_i$  = Distance from 0 point on grid to the grid location of finished good  $i$

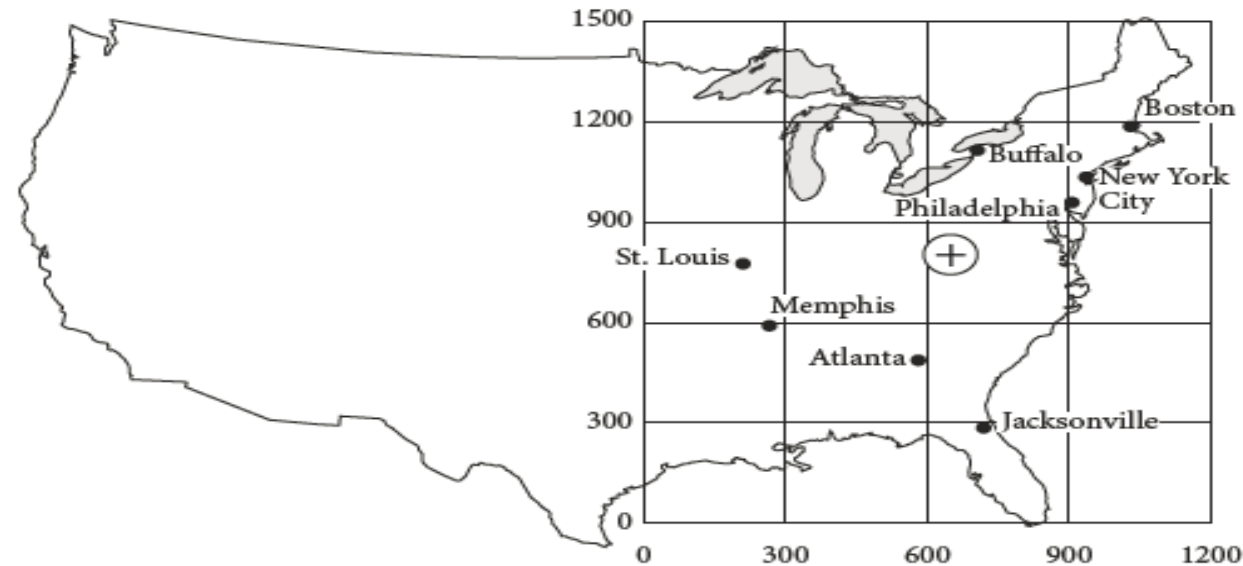
$d_i$  = Distance from 0 point on grid to the grid location of raw material  $i$

$M_i$  = Weight (volume) of finished goods sold in market  $i$

$S_i$  = Weight (volume) of raw materials purchased at source  $i$

Figure 12.6

## Grid Locations and Sources of Markets



Sources	Grid Coordinates	
	Horizontal	Vertical
Buffalo ( $S_1$ )	700	1,125
Memphis ( $S_2$ )	250	600
St. Louis ( $S_3$ )	225	825
Markets		
Atlanta ( $M_1$ )	600	500
Boston ( $M_2$ )	1,050	1,200
Jacksonville ( $M_3$ )	800	300
Philadelphia ( $M_4$ )	925	975
New York ( $M_5$ )	1,000	1,080

Source: Edward J. Bardi, Ph.D.

## *Example of a Heuristic Modeling Approach: The Grid Technique, continued*

Incorporate the transportation rates of different products, using this modification as follows:

$$C = \frac{\sum_{i=1}^m r_i d_i s_i + \sum_{i=1}^n R_i D_i M_i}{\sum_{i=1}^m r_i s_i + \sum_{i=1}^n R_i M_i}$$

where

$r_i$  = Raw materials rate/distance unit for raw material  $i$

$R_i$  = Finished goods transportation rate/distance unit for finished good  $i$

$r_i$  and  $R_i$  are the transportation rates per distance unit, and we assume them to be linear with respect to distance. This assumption does not correspond to the tapering principle of rates (to be discussed later in this chapter), but it does simplify the analysis.

## ● The Grid Technique

- Advantages

- *The grid technique's strengths are in its simplicity and its ability to provide a starting point for location analysis.*
- *The grid technique also provides a starting point for making a location decision.*

- Limitations

- *It is a static approach, and the solution is optimum for only one point in time.*
- *The technique assumes linear transportation rates, whereas actual transportation rates increase with distance but less than proportionally.*
- *The technique does not consider the topographic conditions.*

# Table 12.2

## Grid Technique Analysis of Plant Location Example

SOURCES/ MARKETS	RATE \$/TON-MILE (A)	TONS (B)	GRID COORDINATES		CALCULATIONS	
			HORIZONTAL	VERTICAL	(A) × (B) × HORIZONTAL	(A) × (B) × VERTICAL
Buffalo ( $S_1$ )	\$0.90	500	700	1,125	315,000	506,250
Memphis ( $S_2$ )	\$0.95	300	250	600	71,250	171,000
St. Louis ( $S_3$ )	\$0.85	<u>700</u>	225	825	<u>133,875</u>	<u>490,875</u>
		1,500			520,125	1,168,125
Atlanta ( $M_1$ )	\$1.50	225	600	500	202,500	168,750
Boston ( $M_2$ )	\$1.50	150	1,050	1,200	236,250	270,000
Jacksonville ( $M_3$ )	\$1.50	250	800	300	300,000	112,500
Philadelphia ( $M_4$ )	\$1.50	175	925	975	242,813	255,938
New York ( $M_5$ )	\$1.50	<u>300</u>	1,000	1,080	<u>450,000</u>	<u>486,000</u>
	TOTALS	<u>1,100</u>			<u>1,431,563</u>	<u>1,293,188</u>
			HORIZONTAL		VERTICAL	
			Numerator: $\sum (r \times d \times S) =$		520,125	1,168,125
			$+ \sum (R \times D \times M) =$		<u>1,431,563</u>	<u>1,293,188</u>
			Sum		1,951,688	2,461,313
			Denominator: $\sum (r \times S) =$		1,330	1,330
			$+ \sum (R \times M) =$		<u>1,650</u>	<u>1,650</u>
			Sum		2,980	2,980
			Grid Center		655	826

Source: Edward J. Bardi, Ph.D.

# Table 12.3

## Impact of Transportation Rate Change

SOURCES/ MARKETS	RATE \$/TON-MILE (A)	TONS (B)	GRID COORDINATES		CALCULATIONS	
			HORIZONTAL	VERTICAL	(A) × (B) × HORIZONTAL	(A) × (B) × VERTICAL
Buffalo ( $S_1$ )	\$0.90	500	700	1,125	315,000	506,250
Memphis ( $S_2$ )	\$0.95	300	250	600	71,250	171,000
St. Louis ( $S_3$ )	\$0.85	<u>700</u>	225	825	<u>133,875</u>	<u>490,875</u>
		1,500			520,125	1,168,125
Atlanta ( $M_1$ )	\$1.50	225	600	500	202,500	168,750
Boston ( $M_2$ )	\$1.50	150	1,050	1,200	236,250	270,000
Jacksonville ( $M_3$ )	\$2.25	250	800	300	450,000	168,750
Philadelphia ( $M_4$ )	\$1.50	175	925	975	242,813	255,938
New York ( $M_5$ )	\$1.50	<u>300</u>	1,000	1,080	<u>450,000</u>	<u>486,000</u>
	TOTALS	<u>1,100</u>			<u>1,581,563</u>	<u>1,349,438</u>
			HORIZONTAL		VERTICAL	
			Numerator: $\sum (r \times d \times S) =$		520,125	1,168,125
			$+ \sum (R \times D \times M) =$		<u>1,581,563</u>	<u>1,349,438</u>
			Sum		2,101,688	2,517,563
			Denominator: $\sum (r \times S) =$		1,330	1,330
			$+ \sum (R \times M) =$		<u>1,838</u>	<u>1,838</u>
			Sum		3,168	3,168
			Grid Center		664	795

Source: Edward J. Bardi, Ph.D.



# Table 12.4

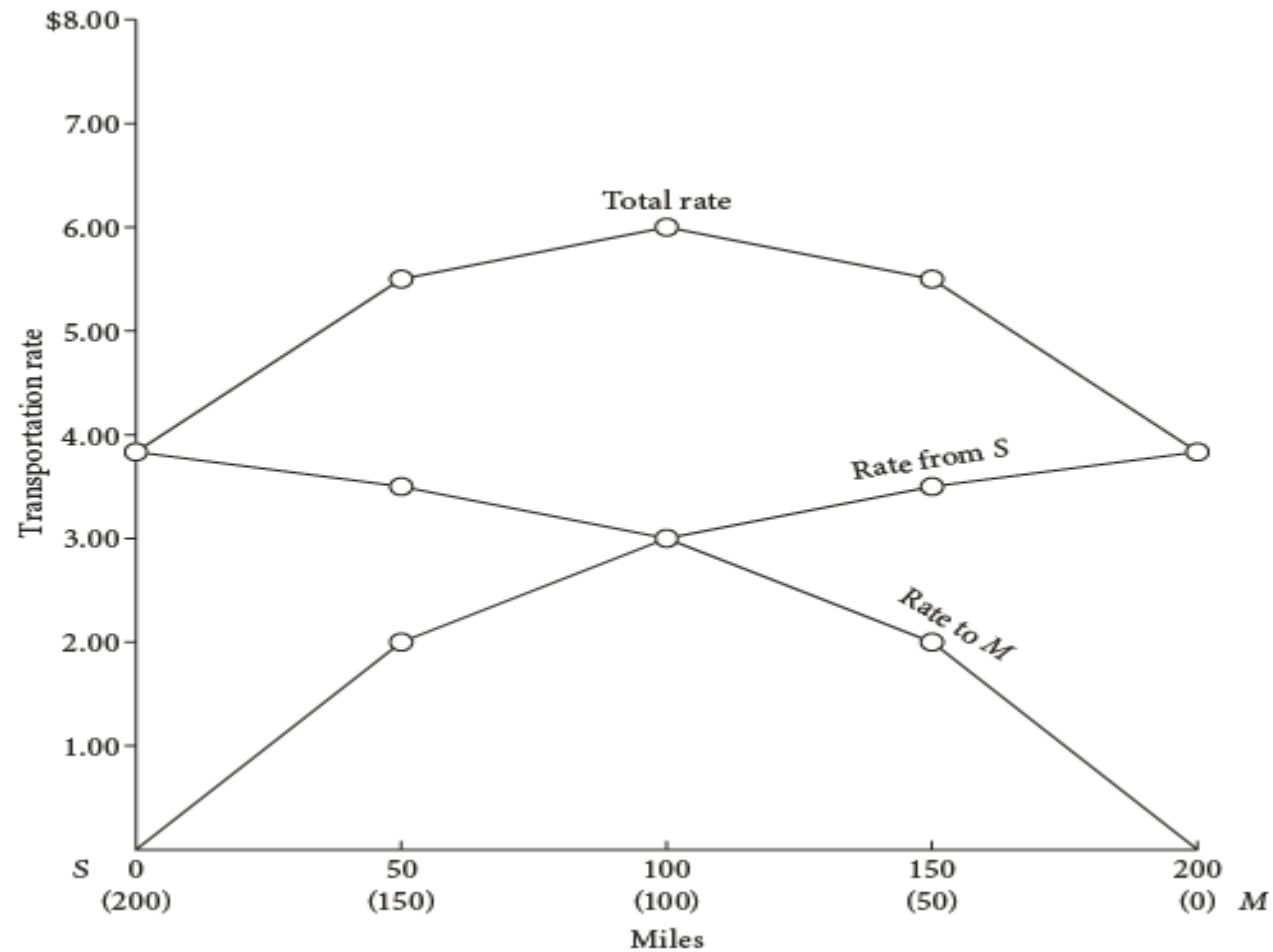
## Impact of Supply Source Change

SOURCES/ MARKETS	RATE \$/TON-MILE (A)	TONS (B)	GRID COORDINATES		CALCULATIONS	
			HORIZONTAL	VERTICAL	(A) × (B) × HORIZONTAL	(A) × (B) × VERTICAL
Buffalo ( $S_1$ )	\$0.90	0	700	1,125	0	0
Memphis ( $S_2$ )	\$0.95	800	250	600	190,000	456,000
St. Louis ( $S_3$ )	\$0.85	<u>700</u>	225	825	<u>133,875</u>	<u>490,875</u>
		1,500			323,875	946,875
Atlanta ( $M_1$ )	\$1.50	225	600	500	202,500	168,750
Boston ( $M_2$ )	\$1.50	150	1,050	1,200	236,250	270,000
Jacksonville ( $M_3$ )	\$2.25	250	800	300	450,000	168,750
Philadelphia ( $M_4$ )	\$1.50	175	925	975	242,813	255,938
New York ( $M_5$ )	\$1.50	<u>300</u>	1,000	1,080	<u>450,000</u>	<u>486,000</u>
	TOTALS	<u>1,100</u>			<u>1,581,563</u>	<u>1,349,438</u>
			HORIZONTAL		VERTICAL	
			Numerator: $\sum (r \times d \times S) =$		323,875	946,875
			$+ \sum (R \times D \times M) =$		<u>1,581,563</u>	<u>1,349,438</u>
			Sum		1,905,438	2,296,313
			Denominator: $\sum (r \times S) =$		1,355	1,355
			$+ \sum (R \times M) =$		<u>1,838</u>	<u>1,838</u>
			Sum		3,193	3,193
			Grid Center		597	719

Source: Edward J. Bardi, Ph.D.

## Figure 12.7

### Locational Effects of Tapering Rates\*

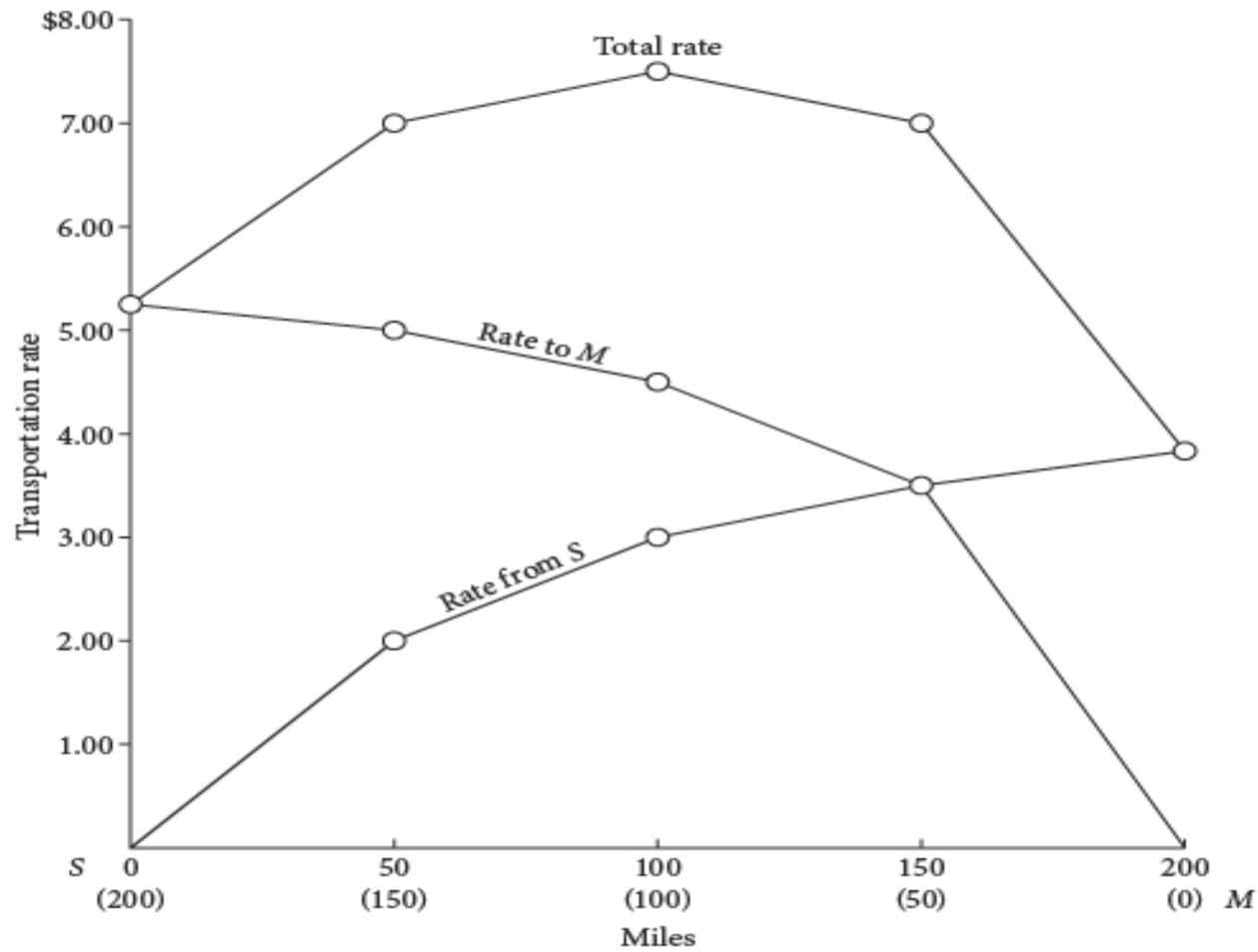


Source: Edward J. Bardi, Ph.D.

\* Constant rate assumption

## Figure 12.8

### Locational Effects of Tapering Rates\*



Source: Edward J. Bardi, Ph.D.

\* No constant rate assumption

## ● Transportation Pragmatics

- Commercial Zone is a specific blanket area, the transportation definition of a particular city or town.
- Foreign Trade Zone (FTZ) is a geographic area into which importers can enter a product and hold it without paying duties—and only paying duties or customs when it is shipped into U.S. customs territory.
- Transit Privilege permits the shipper to stop a shipment in transit and to perform some function that physically changes the product's characteristic.

# Summary

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- The logistics/supply chain network design decision is of great strategic importance to logistics, the firm as a whole, and the supply chain. This decision is becoming increasingly important due to trends related to globalization of manufacturing, marketing, sourcing, and procurement.
- A number of factors may suggest the need to redesign the logistics/supply chain network.
- A formal, structured process for network design is preferable; the potential impacts on cost and service justify a significant effort toward following a sound process.

## *Summary, continued*

- Numerous factors may affect the design of a logistics network and the location of specific facilities within the context of the network.
- Principal modeling approaches to gain insight into the topic of logistics/supply chain network design include optimization, simulation, and heuristic models.
- The “grid” method represents a useful way to obtain a good, but not necessarily optimal solution to a logistics facility location problem.
- The availability and cost of transportation affect the location decision in a number of significant and unique ways.